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Variation in seed morphology, germination characteristics and seedling growth in different provenances of *Acacia mangium* wild

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Abstract
Variability studies in sixteen provenances of *Acacia mangium* Wild for seed morphology, germination behaviour and seedling growth traits were undertaken at the Institute of Forest Genetics and Tree Breeding, Coimbatore, India. The provenances were collected from natural distribution ranges in PNG, Queensland, Philippines, Vietnam, first and second-generation seed orchards in India. Significant differences were observed between the seed lots with respect to seed morphology, germination characters and growth parameters of seedlings. Significant strong positive correlation exists between the seed morphological parameters with germination attributes and seedlings growth attributes such as seedling height, shoot length, root length, basal diameter and number of leaves have recorded strong positive correlation with vigor index. The study concludes that provenance variation contributes largely to seed morphological variations and seedling growth attributes in *Acacia mangium*.

Keywords: *Acacia mangium*, seed morphology, germination, growth attributes and vigor indices

Introduction
Acacia mangium is a fast growing, evergreen multi purposes tropical tree species belonging to the family of leguminosae. It grows up to 35 m in height and 50 cm diameter under good growing condition (Macdicken and Brewbaker, 1984; Pinyopusarerk *et al.*, 1993) [29, 35]. It is native to Papua New Guinea, north-eastern Queensland in Australia Papua, Western Irian, Java and the Maluku islands in Indonesia. The species was introduced into Asian, African and western hemisphere countries for establishing large scale commercial plantation. In India, it is largely cultivated by paper mills, forest department and Forest Corporation as a pulp crop (6 – 7 years rotation) in states of Kerala, Karnataka, Maharashtra, Orissa and North Eastern Region. It is a nitrogen fixing tree used for reclamation of waste and degraded sites (Awang and Taylor, 1993) [2]. The wood of this species is used mainly for making paper and pulp, laminate, furniture, plywood, electric poles, tool handles and agricultural tools (Logan and Balodis, 1982, Hamdan, 2011) [27, 16]. Wood possess high calorific value of 800 kcal kg^{-1} to 900 kcal kg^{-1} and used for the production of good quality charcoal, wood pellets and activated carbons (Sein and Mitlohner, 2011) [39].

The success of any tree breeding program mainly depends on the extent of variability present in the base breeding population which is quantified by different population parameters including genotypic and phenotypic variations and genotypic and phenotypic coefficients of variation (Subramanian *et al*., 1995). Genetic, physiological, and environmental factors play an important role in determining the variability and quality of the seeds. The strong genetic control was registered in seed and seedlings' characters (Roy *et al*., 2004) [38]. The variation in germination ability of the seeds is depending on the seed source origin, edaphic factors, soil moisture, nutrient temperature plant density, and habitat disturbance. The success of large-scale afforestation programmes depends on the seed source and quality of planting materials. Screening of good seed sources provides a great opportunity to the tree breeder to capture natural variation. It also provides information about the nature and magnitude of variability present in the planting material for breeding and developing genetically improved planting stock within a seed source.

The quality of seed is an important factor in forest tree species and is found to play a vital role in germination, survival seedlings in nursery and field conditions. Many authors have already reported that the nature and magnitude of variability in seed characteristics is widely used for tree improvement programme of different tree species (Uniyal 2000; Kumar and Toky 1993; Milberg *et al.*, 1996) [44, 25, 30]. The variation in seed morphology and seedlings characteristics have been reported earlier in many trees species such as *Acacia auriculiformis* and *A. mangium* (Ramakrishna Hegde *et al*., 2000), *A nilotica* (Vanangamudi *et al*., 1998; Venkatesh, 2000) [45, 46], *Albizia lebbeck* (Radhakrishnan, 2001) [36], *Azadirachta indicia* (Kumaran, 1997) [26], *Madhucalatifolia* (George Jenner, 2003; Umesh Kanna, 2001) [13, 43], *Tectona grandis* (Parthiban, 2001) [33] and *Tamarindus indicia* (Divakara, 2002) [12]. Knowledge of variation in seed morphology, germination and seedling characters is lacking in this species at seed lot leveling spite of its multipurpose utility. Hence, the main objective of the present investigation was to understand the nature, extent, and pattern of variation existing in different seed lots of *A. mangium* with respect to seed morphology, germination and seedling growth.

Materials and Methods

The present investigation was carried out to study the seed morphometric variation, germination and seedling parameters in 16 selected provenances of *Acacia mangium*. The CSIRO had initiated an International Provenance Trial program for widening the genetic base in Acacia growing countries. Sixteen seed lots included provenances of PNG (10), Vietnam (2), Queensland (1) Philippines (1) and India (2). The details of seed lots and geographical position are given in Table -1 and Fig1. Selected seed sources ranged from 29º37" N to 32º12" N latitude and 76º53" E to 79º38" E longitude and altitude from 550 m to 1980 m above MSL (Figure 1, Table 1).

Table 1: Location details of 16 different provenance of *Acacia mangium* selected for the study

SL. No	State	Location	CSIRO Seed lot Number	Latitude	Longitude	Altitude (m)
1	Papua New Guinea	PNG- Bensbach Area WP	18212	8° 53'	141° 17'	25
2	Papua New Guinea	PNG- Oriomo WP	19678	8° 49'	143° 0'	10
3	Papua New Guinea	PNG- Bituri WP	19679	8° 40'	142° 43'	45
4	Papua New Guinea	PNG- Aiambak Fly River WP	19863	7° 20'	141° 15'	30
5	Papua New Guinea	PNG- Lake Murray	20127	7° 0'	141° 33'	50
6	Papua New Guinea	PNG- Balimo	20128	8° 5'	142° 58'	15
7	Papua New Guinea	PNG- Upper Aramia	20130	7° 56'	142° 35'	15
8	Papua New Guinea	PNG- Lower Fly	20131	8° 19'	143° 2'	10
9	Papua New Guinea	PNG- Binaturi	20134	8° 0'	141° 54'	10
10	Papua New Guinea	PNG-Pohaturi	20135	8° 52'	142° 53'	40
11	Queensland	QSL- Pascoe River	20045	12° 34'	143° 9'	20
12	Vietnam - SPA	VIE- Dong Ha	21300	0° 0'	0° 0'	0
13	Vietnam – CSO	VIE- VIAM	21215	0° 0'	0° 0'	0
14	Philippines – SSO	PHI- Siloo	20935	8°25'	124° 57'	600
15	Kerala, India - FGS	IFGTB- FGAM, Nilambur	IFGTB I	11° 16'	76° 14'	40
16	Kerala, India - SGS	IFGTB- FGAM, Palode	IFGTB II	8° 43'	77° 1'	60

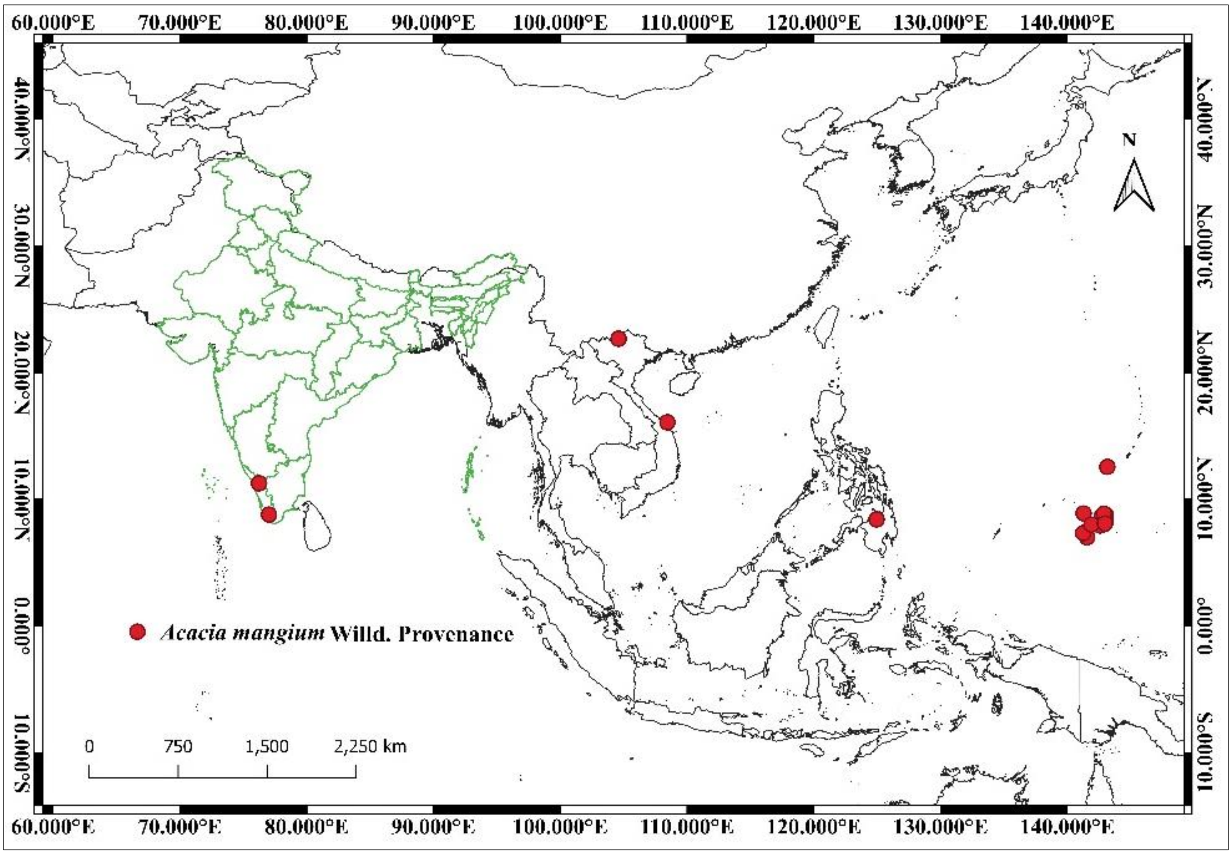

Fig 1: Geographical positions of the selected 16 provenances of *Acacia mangium*

The laboratory and nursery experiments were under taken at Microscopic Laboratory and Silviculture Nursery at the Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu, India during the year 2019-2020. Study site is located at 11°09'N latitude and 76°84'E longitude at an altitude of 350 m above MSL. The average annual rainfall is 945 mm, most of which is received between June to September and temperature varies from 15 ºC to 34.9 ºC.

The seed morphology parameters were studied in a random sample of 100 seeds from each seed source with four replications. The morphological characters *viz.*, seed length (mm), seed breadth (mm), seed perimeter (mm), seed roundness (mm), seed aspect ratio and fullness ratio were measured using image analyzer (Leica Q win 500 MC*).* Seed weight was determined as per standard rules (ISTA 1993) [17] using an electronic top pan balance (Sartorius-MA 4).

The seeds were subjected to hot water pre-treatment (dipping in boiling water for 30 seconds followed by soaking in cold water for 24 hours) before sowing. A total of 100 seeds were selected randomly from each seed lot for germination studies. The germination experiments were conducted in Completely Randomized Design (CRD) with four replications at IFGTB-Silviculture Nursery, Coimbatore. The raised mother bed with a size of 1 m x 10 m was formed with sterilized river sand mixed with red earth (1:1) (32±2°C; RH: 65±2%). Seeds were sown in 1 x 1 cm^2 spacing at a depth of 2 cm. Watering was done twice a day until the completion of germination. Seeds were considered germinated when the sprouted plumule had emerged about 1 cm above the soil and germination was recorded accordingly. Germination count was made every day and percentage of germination was determined (ISTA 1995) [48]. The germinated seedlings at the age of 25 days were transplanted in to the polythene bags (20×10 cm) containing soil + FYM + sand (2:1:1) as potting media. The germination percent (%), germination value (*GV*) (Czabator, 1962) [10], Mean Germination Time (*MGT*) (Bonner, 1984) [6], germination energy and germination energy index (Grouse & Zimmer, 1958) [15] were calculated.

The seedling height, collar diameter and number of phyllodes were measured 90 days after sowing. The data on height of seedling was recorded from the soil level to the terminal portion and collar diameter was measured using a vernier caliper at 1 cm above the soil surface. The number of phyllodes was measured by directly counting the number of phyllodes in the seedlings.

Analysis of variance for seed morphometric, germination and seedling traits was determined to study variation in different provenances of *A. mangium*. Data was subjected to analysis of variance (ANOVA) using SPSS version 25. A simple (Pearson) correlation was worked out to correlate the different traits of morphology of seed, germination characters with germination percentage and vigour index respectively.

Results and Discussion

Significant variations of seed area were recorded among the 16 provenances of *Acacia mangium* (Table 2). The mean seed area was 0.11 cm^2 with higher seed area was recorded in PNG-Upper Aramia provenance (0.18 cm^2) followed by PHI-Siloo provenance (0.17cm^2). The lower seed area values were registered in PNG- Pituri provenance (0.08 cm^2). The maximum seed lengthof 0.61 cm was recorded in PNG-Upper Aramia provenance followed by 0.58 cm in PHI- Siloo provenance and minimum valueof 0.40 cm was registered in provenance PNG- Pituri provenance. The highest seed breadth of0.39 cm registered in PHI- Siloo provenance followed by 0.38 cm in PNG-Upper Aramia provenance. The lowest value in seed breadth of 0.26 cm was recorded in PNG- Balimo provenance. The seed perimeter and seed weight recorded no significant difference among the provenances. This variation in seed morphology among provenances is probably due to influence of geographical isolation, cross pollination nature of the species and prevailing environmental condition of the seed sources. Similarly, variation in seed and seedlings characteristics have been reported earlier in many tree species such as *Acacia auriculiformis* and *A. mangium* (Ramakrishna Hegde *et al*., 2000) [18], *A. nilotica* (Venkatesh, 2000) [47], *Albizialebbeck* (Radhakrishnan, 2001) [36], *Azadirachta indica* (Kumaran, 1997) [26], *Madhuca latifolia* (Umesh Kanna, 2001) [43], *Tectona grandis* (Parthiban, 2001) [33] and *Tamarindus indica* (Divakara, 2002) [12].

Significant variation in seed germination was recorded among the 16 provenances of *Acacia mangium* (Table 3). The germination percentage of the different provenance varied from 38.75 % to 87.25 %. The provenance IFGTB- SGAM recorded the highest germination percentage of 87.25 followed by77.50 percentage in VIE- Dong- HA provenance. The lowest germination percentage of 38.75 was recorded in PNG- Fly River provenance. Among the provenances, the first day of germination had significant variation and it varied from 3.75days to 6.25 days. The provenance PNG- Fly River provenance recorded the maximum delayed germination of 6.25 days and earliest initiation of germination of 3.75 days was recorded in PNG- Bensbach provenance and VIE- Dong-HA provenance. The longest period of germination of 17 days was recorded in PHI- Siloo, PNG- Lake Murray, PNG-Balimo, PNG- Upper Aramaia, PNG- Lower Fly and PNG-Bohaturi provenances. The shortest germination period of 15 days was recorded by IFGTB- SGAM provenance. Seeds of IFGTB- SGAM provenance registered the maximum mean daily germination of 8.17 seeds per day and the minimum mean daily germination of 3.98 seeds per day was reported in PNG- Fly River provenance. *Acacia mangium* usually has higher germination percentage. It was reported to be much higher than *A. auriculiformis*, *A. aurlacocarpa* and *A. crassicarpa*and *A. oerfota* (Indira, 1999; Abari*et al.*, 2012) [20]. Ginwal *et al*., (2005) [14] have observed the seed source variation in morphology, germination and seedling growth of *J. Curcas*in central India.The present finding is in conformity with the earlier results of Sridhar (2006) [42] in *Jatropha curcus,* Kaushik *et al*., (2015) [24] in *Pongamia pinnata.*

Seedling growth attributes recorded significant differences among the 16 provenances. The mean seedling height was 24.49 cm with maximum height of 29.23 cm in IFGTB-FGAM provenance and the minimum height of 17.98 cm was recorded in PNG- Lake Murray provenance. Significant variation was recorded in the shoot length of the seedlings of 16 provenances and it varied from 15.50 cm to 22.73 cm. The highest shoot length of 22.73 cm was recorded in IFGTB-FGAM provenance and the lowest shoot length of 15.5 cm was registered in PNG- Lake Murray provenance. The higher value of root length of 6.5 cm was recorded in IFGTB-FGAM provenance and the lower value of root length of 2.48 cm was recorded in PNG- Lake Murray provenance. The maximum basal diameter of 2.50 mm was recorded in PNG-Pohaturi provenance and the minimum basal diameter of 1.84 mm was recorded in PNG- Lake Murray provenance. The highest number of phyllodes of 5.25 was recorded in IFGTB-FGAM provenance and the lowest number of phyllodes of 3.4

was recorded in PNG- Balimo provenance. Variations in growth characteristics of different seed sources may be attributed to adaptation because the seedlings from all the sources were raised under identical conditions (Singh and Pokhriyal, 2005) [41].

The highest shoot vigour index of 1982.99 was recorded in IFGTB- FGAM provenance with and the lowest shoot vigour index of 632.25 was recorded in PNG- Lake Murray provenance. Similarly, the maximum root vigour index of 567.25 was recorded in IFGTB- FGAM provenance and the minimum root vigour index of 101.36 was recorded in PNG- Lake Murray provenance. The highest vigour index of 2550.24 was registered in IFGTB- SGAM provenance an-d the lowest vigour index of 733.61 was recorded in PNG- Lake Murray provenance.

Table 5 presents the correlation between seed morphometric characteristics and germination attributes of seeds of *Acacia mangium* from different provenances. It is evident from the results that significant strong positive correlation exists between the seed morphological parameters as well as seed morphology and germination attributes. Seed area was found to be correlated strongly and positively with seed length (r = 0.99), seed breadth (r = 0.98) and seed perimeter (r = 0.94). Similarly seed length recorded significant positive correlation with seed breadth and seed perimeter. Seed breadth also recorded positive correlation with seed perimeter. Seed perimeter has recorded positive correlation with the speed of germination. Hundred seed weight did not exhibit any significant correlation. Similarly mean daily germination recorded non-significant correlation with the seed parameters, however, the result implies that mean daily germination of *Acacia mangium* is inversely related to seed morphometric characteristics. Interestingly, all the seed morphometric characters except hundred seed weight have recorded significant positive correlation with the speed of germination of seeds indicating that the germination velocity of *Acacia mangium* seeds are negatively impacted by an increase in the seed weight. Mean daily germination was found to have a strong negative correlation with mean germination (r = -0.75) time which further reveals that a lower the daily germination rate higher will be the average time required for the completion of germination. On the contrary, mean daily germination was found to record strong positive correlation (r = 0.91) with the germination percentage of the seeds. The strong negative correlation between mean germination time and germination percentage (r = -0.81) concluded that an increase in the time required to complete germination results in a decrease in the germination percentage of the *Acacia mangium* seeds. Significant positive correlation of seed characters were also observed in *D. sissoo* (Singh & Pokhriyal, 2002) [40], *Cordia africana* (Loha *et al*., 2006) [28], *Santalum album* (Chitra & Jijeesh, 2021) [9] and *Leucaena leucocephala* (Hooda & Bahadur, 1993) [19].

Correlation between seedling growths attributes and growth indices of seedlings of *Acacia mangium* from different provenances recorded significant results (Table 6). Perusal of data revealed that growth attributes of the seedlings such as seedling height, shoot length, root length, basal diameter and number of leaves have recorded significant strong positive correlation with growth indices such as shoot vigor index, root vigor index and vigor index. Similarly, significant and positive correlation was observed between volume index and plant height followed by collar diameter in teak (Parthiban, 2001) [33] and in *Albizia lebbeck* (Radhakrishnan, 2001) [36]. A positive and significant correlation between volume index and growth parameters was reported in several tree species like *Acacia nilotica* (Jayaprakash, 2000) [22], *Eucalyptus tereticornis* (Paramathma, 2000) [32] *Dalbergia sissoo* (Dhillon *et al*., 1992) [11], *Terminalia arjuna* (Srivastava *et al*., 1993b). Chauhan *et al*., (2019) [8] reported positive and significant correlation for the growth traits among 23 provenances of *Azadirachta indica*.

Table 2: Variation in seed morphometric characteristics in selected provenances of *Acacia mangium*

Sl. No.	Name of the Provenance	Seed Area (cm^2)	Length (cm)	Breadth (cm)	Perimeter (cm)	Aspect Ratio	Seed Weight (g)
1	PNG-Bensbach	0.14	0.53	0.36	1.61	1.48	1.23
2	PNG- Oriomo	0.09	0.43	0.28	1.21	1.50	1.20
3	PNG-Bituri	0.08	0.40	0.27	1.15	1.04	1.25
4	PNG-Fly River	0.09	0.44	0.27	1.22	1.63	1.18
5	PNG-Lake Murray	0.14	0.52	0.34	1.67	1.52	1.38
6	PNG- Balimo	0.08	0.42	0.26	1.16	1.58	1.26
7	PNG-Upper Aramia	0.18	0.61	0.38	1.70	1.60	1.16
8	PNG-Lower Fly	0.09	0.43	0.28	1.38	1.53	1.24
9	PNG-Binaturi	0.09	0.43	0.27	1.21	1.57	1.18
10	PNG- Pohaturi	0.09	0.43	0.28	1.21	1.54	1.30
11	QSL-Pascoe River	0.09	0.42	0.29	1.23	1.47	1.35
12	VIE-Dong Ha	0.09	0.43	0.28	1.21	1.50	1.15
13	VIE-VIAM	0.09	0.44	0.28	1.23	1.58	1.28
14	PHI- Siloo	0.17	0.58	0.39	1.63	1.50	1.21
15	IFGTB-FGAM	0.08	0.41	0.26	1.17	1.58	1.06
16	IFGTB-SGAM	0.09	0.42	0.28	1.24	1.49	1.14
Mean		0.11	0.46	0.30	1.33	1.51	1.22
SE (m)		0.01	0.02	0.01	0.07	0.04	0.02
CD		0.02	0.03	0.02	0.12	0.08	0.05
p- value		0.03	0.89	0.56	0.67	0.73	0.84

Table 3: Variation in seed germination attributes in selected provenances of *Acacia mangium*

SL No.	Name of the Provenance	Germination Percentage	First Day of Germination	Last Day of Germination	Mean Daily Germination	Peak Value	Total Speed of Germination
1	PNG-Bensbach	68.50	3	17	5.18	1.10	13.25
2	PNG- Oriomo	62.25	5	17	5.48	1.40	11.50
3	PNG-Bituri	57.75	5	17	4.90	1.24	11.75
4	PNG-Fly River	38.75	6	16	3.98	0.88	9.75
5	PNG-Lake Murray	67.50	5	17	5.78	1.27	11.75
6	PNG- Balimo	68.75	5	17	5.61	1.25	12.25
7	PNG-Upper Aramia	70.00	4	17	5.38	1.31	13.00
8	PNG-Lower Fly	73.25	5	17	5.88	1.28	12.50
9	PNG-Binaturi	72.75	4	16	6.06	1.59	12.00
10	PNG- Pohaturi	47.50	6	17	4.15	1.01	11.50
11	QSL-Pascoe River	73.25	4	16	6.42	1.58	11.50
12	VIE-Dong Ha	77.50	5	16	6.92	1.81	11.50
13	VIE-VIAM	73.75	4	16	6.57	1.74	11.75
14	PHI- Siloo	68.75	4	17	5.29	1.48	13.00
15	IFGTB-FGAM	75.50	5	17	6.16	1.47	12.25
16	IFGTB-SGAM	87.25	4	15	8.17	2.14	11.00
Mean		67.69	4.58	16.47	5.74	1.41	11.89
SE (m)		2.92	0.17	0.16	0.26	0.08	0.21
CD		7.24	0.43	0.40	0.64	0.20	0.53
p- value		0.264	0.77	0.04	0.01	0.01	0.22

Table 4: Variation in seedling growth attributes in selected provenances *Acacia mangium*

SL No.	Name of the Provenance	Total Seedling Height (cm)	Shoot Length (cm)	Root Length (cm)	Basal Diameter (mm)	Number of Phyllodes	Shoot Vigour Index	Root Vigour Index	Vigour Index
1	PNG-Bensbach	28.86	22.61	6.25	2.39	5.42	1753.05	484.50	2237.55
2	PNG- Oriomo	20.64	17.73	2.91	2.21	4.34	841.58	137.88	979.45
3	PNG-Bituri	26.80	21.38	5.43	2.14	4.18	1571.63	398.93	1970.55
4	PNG-Fly River	22.98	19.00	3.98	2.21	4.64	1283.00	268.70	1551.70
5	PNG-Lake Murray	17.98	15.50	2.48	1.84	4.75	632.25	101.36	733.61
6	PNG- Balimo	24.85	20.20	4.65	2.19	3.67	1388.63	319.69	1708.31
7	PNG-Upper Aramia	21.69	18.31	3.38	2.31	4.28	1258.44	231.88	1490.31
8	PNG-Lower Fly	26.79	21.44	5.35	2.24	4.19	1570.56	392.05	1962.61
9	PNG-Binaturi	27.50	21.75	5.75	2.08	5.54	1604.38	424.38	2028.75
10	PNG-Pohaturi	25.19	20.38	4.81	2.50	5.26	1493.13	353.06	1846.19
11	QSL-Pascoe River	24.25	19.81	4.44	2.05	4.34	1385.75	310.00	1695.75
12	VIE-Dong Ha	21.19	17.94	3.25	2.09	4.18	1116.81	202.38	1319.19
13	VIE-VIAM	21.96	18.43	3.54	1.94	4.29	1064.61	205.29	1269.90
14	PHI- Siloo	23.88	19.50	4.38	1.97	4.27	1336.25	299.88	1636.13
15	IFGTB-FGAM	28.09	22.25	5.84	2.25	5.34	1679.31	440.50	2119.81
16	IFGTB-SGAM	29.23	22.73	6.50	2.48	5.64	1982.99	567.25	2550.24
Mean		24.49	19.93	4.56	2.18	4.64	1372.65	321.11	1693.75
SE (m)		0.82	0.51	0.31	0.04	0.14	85.92	31.95	117.48
CD		2.02	1.27	0.76	0.11	0.35	213.00	79.20	291.24
p-value		0.01	0.03	0.02	0.04	0.04	0.01	0.01	0.01

Table 5: Correlation between seed morphometric characters and germination attributes of seeds of *Acacia mangium* from different provenances

	Seed Area	Seed Length	Seed Breadth	Seed Perimeter	Hundred Seed Weight	Mean Daily Germination	Total Speed of Germination	Germination Percentage
Seed Area	1							
Seed Length	0.99^{**}	1						
Seed Breadth	0.98^{**}	0.97^{**}	1					
Seed Perimeter	0.94^{**}	0.94^{**}	0.94^{**}	1				
Hundred Seed Weight	0.06	0.04	0.11	0.20	1			
Mean Daily Germination	-0.17	-0.22	-0.14	-0.14	-0.20	1		
Total Speed of Germination	0.59^{*}	0.56^{*}	0.59^{*}	0.58^{*}	-0.03	0.01	1	
Germination Percentage	0.06	0.01	0.09	0.09	-0.22	0.91^{**}	0.40	1

Table 6: Correlation between seedling growth attributes and growth indices of *Acacia mangium* from different provenances

	Total Height	Shoot Length	Root Length	Basal Diameter	Number of Leaves	Shoot Vigor Index	Root Vigor Index	Vigor Index
Total Height	1							
Shoot Length	0.99**	1						
Root Length	0.99**	0.98**	1					
Basal Diameter	0.58*	0.59*	0.55*	1				
Number of Leaves	0.57*	0.55*	0.61*	0.55*	1			
Shoot Vigor Index	0.97**	0.96**	0.96**	0.65**	0.62**	1		
Root Vigor Index	0.98**	0.97**	0.99**	0.61*	0.66**	0.98**	1	
Vigor Index	0.97**	0.97**	0.97**	0.64**	0.63**	0.99**	0.99**	1

Conclusion

The present study was conducted to understand the provenance variation in the seed morphological, germination and seedling growth attributes among the selected 16 provenances of *Acacia mangium*. The study concludes that the seed morphology did not influence the seed germination pattern in *Acacia mangium*. However, the total speed of germination recorded positive correlation with the seed morphological characteristics such as seed length, seed breadth, seed area and seed perimeter. Provenances such as IFGTB- FGAM, IFGTB-SGAM, PNG- Binaturi, PNG-Bensbach and PNG- Pituri were found to be the best in seedling growth attributes and germination attributes. Hence, these provenances can be further recommended for large scale multiplication and plating in the field.

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References

1. Abari AK, Nasr MH, Hodjati M, Bayat D, Radmehr M. Maximizing seed germination in two Acacia species. Journal of Forestry Research. 2012;23(2):241-244.
2. Awang K, Taylor D. Acacia mangium Growing and Utilization. Winrock International and the Food and Agriculture Organization of the United Nations, Bangkok, Thailand; c1993, p. 278.
3. Bagchi SK, Dobriyal ND. Provenance variation in seed parameters of *Acacia nilotica.* Indian Forester, 1990;116(12):958-961.
4. Bahuguna VK, Lal P. Studies on comparative growth performance of *Albizzia procera*, *Albizzia lebbek*, Eucalyptus FR1-4, *Dendrocalamus strictus* and *Acacia nilotica* at nursery stage; c1989, p. 631-618.
5. Baldwin HI. Forest tree seed of the north temperate regions with special reference to North America; c1942.
6. Bonner FT. New forests from better seeds: the role of seed physiology. In seedling physiology and reforestation success. Springer, Dordrecht; c1984, p. 37-59.
7. Carleton AE, Cooper CS. Seed size effects upon seedling vigor of three forage legumes 1. Crop Science. 1972;12(2):183-186.
8. Chauhan RS, Thakur NS, Gunaga RP, Bhuva DC, Jadeja DB. Assessment of germination attributes in candidate plus trees (CPTs) of Malabar Neem (Melia dubia cav.). Indian Journal of Ecology. 2019;46(2):335-339.
9. Chitra P, Jijeesh CM. Biopriming of seeds with plant growth promoting bacteria Pseudomonas fluorescens for better germination and seedling vigour of the East Indian sandalwood. New Forests. 2021;52(5):829-841.
10. Czabator FJ. Germination value: an index combining speed and completeness of pine seed germination. Forest Science. 1962;8(4):386-396.
11. Dhillon GPS, Gill RSI, Kaur N, Balajit Singh. Variation in seed parameters, germination behaviour and seedling traits among different seed sources of *Jatropha curcas* Linn. Annals of Forestry. 2008;16(1):1-7.
12. Divakara BN. Clonal evaluation and genetic diversity studies using biometric and isozyme approaches in *Tamarindus indica* L. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, 2002.
13. George Jenner V, Dasthagir MG, Parthiban KT, Jude Sudhagar R. Variability studies on seed and seedling attributes in Mahua *(Madhuca latifolia).*Indian Forester. 2003;129(4):509-516.
14. Ginwal HS, Phartyal SS, Rawat PS, Srivastava RL. Seed source variation in morphology, germination and seedling growth *of Jatropha curcas* Linn, in Central India. Silvae Genetica. 2005;54(2):76-80.
15. Grouse RJ, Zimmer WJ. Some laboratory germination responses of the seeds of river red gum *Eucaluptuscamaldulensis* Dehn. Australian Journal of Botany. 1958;6(2):129-153.
16. Hamdan H. Veneer recovery and quality. In: Lim SC, Gan KS, Tan K. (Eds), Recent Developments in Acacia Planting. Proceedings of international workshop, Hanoi, Vietnam. Australian Centre for International Agricultural Research, Canberra; c2011, p. 128-135.
17. Hampton, JG. The ISTA perspective of seed vigor testing. Journal of seed Technology. 1993;17(2):105-109.
18. Hegde R, Varghese M, Padmini S, Jayaraj RGS. Variation in seed and seedling characteristics of *Acacia mangium* Wild and *A. auriculiformis* A. Cunn. Ex. Benth. Indian Forester. 2000;126(4):382-387.
19. Hooda MS, Bahadur R. Variability, Correlation and Path-Coefficients Analyses for Some Seed Traits in Subabul (*Leucaena leucocephala* L.). Seed Research. 1993;21:49-51.
20. Indira EP. *Provenance Trial in Acacia*. KFRI Research Report 171, Kerala Forest Research Institute, Thrissur; c1999, p. 21.
21. Isik K. Altitudinal variation in *Pinus brutia* Ten.: seed and seedling characteristics. Silvaegenetica. 1986;35(2-3):58-66.
22. Jayaprakash J. Studies on genetic analysis among sources of *Acacia nilotica* (Linn.) wild ex. del. using biometric and biochemical approaches; c2000.

23. Kandya AK. Relationships among seed weight and various growth factors in *Pinus oocarpa*Schiede seedlings. Indian Forester; c1978, p. 561-567
24. Kaushik N, Mann S, Kumar K. Pongamiapinnata: A candidate tree for biodiesel feedstock. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. 2015;37(14):1526-1533.
25. Kumar N, Toky OP. Variation in pod and seed size among *Albizialebbeck*provenances. Nitrogen Fixing Tree Research Report. 1993;11(2):64-67.
26. Kumaran K. Selection of one-parent families for higher growth, oil and Azadirachtin content in neem *(Azadirachta indica A. Juss.)*, 1997.
27. Logan AF, Balodis V. Pulping and papermaking characteristics of plantation-grown *Acacia mangium* from Sabah. Malaysian Forester. 1982;45(2):217-236.
28. Loha A, Tigabu M, Teketay D, Lundkvist K, Fries A. Provenance variation in seed morphometric traits, germination, and seedling growth of *Cordia africana* Lam. New forests. 2006;32(1):71-86.
29. MacDicken KG, Brewbaker JL. Descriptive summaries of economically important nitrogen fixing trees. Nitrogen fixing tree research reports; c1984.
30. Milberg P, Andersson L, Noronha A. Seed germination after short-duration light exposure: implications for the photo-control of weeds. Journal of Applied Ecology. 1996 Dec 1, 1469-1478.
31. Palanisamy K, Subramanian K. Vegetative propagation of mature teak trees (*Tectona grandis* L.). Silvae Genetica. 2001;50(5-6):188-190.
32. Paramathma M, Amal JA, Rajkumar M. Tree allelopathy in agroforestry. In Allelopathy in ecological agriculture and forestry, Springer, Dordrecht; c2000, p. 229-235.
33. Parthiban KT. Seed source variations, molecular characterization and clonal propagation in teak (*Tectona grandis* Linn F.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore; c2001.
34. Patil PVM, Shivanna H, Surendra P, Manjunatha GO, Krishna A, Dasar GV. Study of variability for seed traits, seedling traits and seed oil content of Pongamiapinnata (L.) Pierre of Agro climatic zones of Northern Karnataka. My Forester. 2008;44(3):243-249.
35. Pinyopusarerk K. Genetic resources of fifteen tropical acacias. In: Awang, K. and Taylor, D. A. (eds.), Acacias for Rural, Industrial and Environmental Development. Proceeding of the second meeting of the consultative group for research and development of *Acacias*, Udorn Thani, Thailand; c1993, p. 94-112.
36. Radhakrishnan S. Genetic divergence and DNA based molecular characterization in Albizialebbeck (L.) Benth (Doctoral dissertation, Ph.D. (For.) Thesis, Tamil Nadu Agricultural University, Coimbatore); c2001.
37. Rawat K, Bakshi M. Provenance variation in cone, seed and seedling characteristics in natural populations of Pinus wallichiana AB Jacks (Blue Pine) in India. Annals of Forest Research. 2011;54(1):39-55.
38. Roy SM, Thapliyal RC, Phartyal SS. Seed source variation in cone, seed and seedling characteristic across the natural distribution of Himalayan low-level pine *Pinus roxburghii*sarg. Silvae Genetica. 2004;53(3):116-123.
39. Sein CC, Mitlohner R. *Acacia mangium* Willd. Ecology and silviculture in Vietnam. Center for International Forestry Research, Bogor Barat, Indonesia; c2011, p. 16.
40. Singh N, Pokhriyal TC. Nitrogen fixation and nodulation behavior in relation to seed source variations in *Dalbergia sissoo* seedlings. Journal of Tropical Forest Science, 2002 Apr 1, p. 198-206.
41. Singh N, Pokhriyal TC. Nitrate reeducates activity and nitrogen content in relation to seed source variation in Dalbergia sissoo seedlings. Journal of Tropical Forest Science. c2005 Jan 1, p. 127-140.
42. Sridhar KB. Provenance variation of *Jatropha curcus*for their seed and seedling attributes; c2006.
43. Umesh Kanna S. Genetic analysis, biochemical and molecular characterization of *Madhuca latifolia* Macb. Ph.D. (For.) Thesis, Tamil Nadu Agricultural University, Coimbatore; c2001.
44. Uniyal AK, Bhatt BP, Todaria NP. Provenance characteristics and pretreatment effects on seed germination of *Grewia oppositifolia* Roxb. – A promising agroforestry tree-crop of Garhwal Himalaya, India. International Tree Crops Journal. 2000;10(3):203-213.
45. Vanangamudi K, Umarani R, Bharathi A, Venkatesh A. Effect of seed source on physical and physiological qualities of *Acacia nilotica* seeds. Seed Research. 1998;26(2):114-116.
46. Venkatesh, A. Studies on seed source variations, standardization of seed testing procedures and nursery techniques in *Acacia nilotica* (L.) Wild Subsp indica Benth. Ph.D. (For.) Thesis, Tamil Nadu Agricultural University, Coimbatore; c2000.
47. Venkatesh A, Vanagamudi K, Umarani R. Standardization of germination medium for seeds of *Acacia nilotica* (L.) Wild. Journal of Tree Science. 2000;19:19-24.
48. Turner J. Prospero's Floating Island: ISTA 1995. Asian Theatre Journal. 1997 Apr 1:120-5.