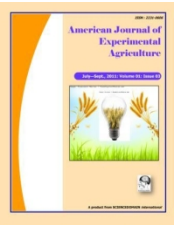

American Journal of Experimental Agriculture
3(2): 361-373, 2013

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Estimation of Field Environment Variability for Germination and Seedling Traits in *Madhuca indica* Gmel

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Authors' contributions

This work was carried out in collaboration between both authors. Author MSW designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author LA managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

Research Article

Received 18th December 2012
Accepted 9th February 2013
Published 17th March 2013

ABSTRACT

Objective: The study was conducted to estimate the pattern of field environment genetic variation for twenty genotypes of *Madhuca indica* Gmel distributed over different sites/locations of district Allahabad and adjoining areas of Uttar Pradesh, India.
Study Design: Study under Randomised Block Design (RBD).
Place and Duration of Study: The study was carried out in field environment in the nursery of the School of Forestry and Environment, Allahabad Agricultural Institute, Deemed-University, Allahabad, situated at 25.28ºN latitude and 81.55ºE longitude, located at an altitude of 98m amsl, during July, 2010.
Materials and Methods: Candidate plus trees of *Madhuca indica* were marked using the following criteria; Height (m), Diameter at breast height (m), Seed length (cm), Seed diameter (cm), free from disease and insect-pests and straight, non-forked cylindrical bole. Following the above criteria, fresh and fully ripened open pollinated seeds of 20 plus trees were collected from different geographical locations in district Allahabad and adjoining areas in Uttar Pradesh India, during July 2010. Germination tests were conducted under field (open) environment between 30-35ºC. Three replications of 40 seeds each were used for the test. 120 seeds of each plus tree were simultaneously sown under field environment

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in nursery in polythene bags, in three replicates used RBD design. The germination count was recorded on every alternate day for 30 days. Observations on morphological traits were taken after one growing season. The recorded observations were subjected to analysis of variance (ANOVA) to understand the significance of differences among 20 plus tree progenies. Various genetic parameters like genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), broad sense heritability, estimated genetic advance and genetic gain were determined by previously described methods.

Results: The results revealed, higher values for phenotype coefficient of variation as compared to genotypic coefficient of variation in corresponding germination and seedling growth characters, indicating that the characters are greatly influenced by the field environment. The heritability and expected genetic gain were also observed to be high to moderate for these characters. There is wide scope for early screening of the genotypes because of the positive and significant correlation at 5% level of significance among germination and seedling growth characters with each other except for few characters times with each other such as internodal length with number of leaves per seedling, number of leaves with dry weight of shoot, fresh weight of root and total biomass of seedling.

Conclusion: Respectively as such genotypes S_{20}, S_9, S_{12} and S_{19} showed better performance as compared to other genotypes and are recommended for further genetic improvement programme in this species.

Keywords: Madhuca indica; field environment; genetic variation; heritability.

1. INTRODUCTION

Madhuca indica Gmel commonly known as Mahua belongs to family “Sapotaceae”. It is a deciduous, medium sized tree, attaining a height of 12-18 m, usually with a short bole and a girth of 2-4 m. The colour of the seed varies from yellowish brown to dark brown [1]. The tree is essentially found in the dry tropical and sub-tropical climate, where the absolute maximum shade temperature varies from 28.5ºC to 48.5ºC and the absolute minimum varies from 1.7ºC to 11.7ºC. The normal rainfall in its natural habitat varies from 750 to 2000mm or more. Mahua occurs below 800 m amsl as the attitudinal range above sea level. It is widely grown in large parts of India from Indo-gangetic plains in the North to Tamil Nadu in South [1].

Used in agro-forestry systems (agri-silviculture, agri-silvi-pastoral and agri-horti-silviculture systems), *Madhuca indica* is economically important because of its multifarious uses. Almost all parts roots, bark, latex- juice, seed and seed oil are known to possess medicinal properties, the leaves are astringent; bark is used for rheumatism, ulcers and diabetics mellitus [2] Flowers are used in cough, cold and bronchitis. Mahua seed oil possesses biodiesel properties [3]. Madhua wood is durable and lasts well under water. The timber can be put to a variety of uses. Virtually being the lifeline of tribal belt in Central India. The tree is culturally most identified with Indian life in plains. The tree wins in fame due to liquor distilled from the flowers which are used to make vinegar [1].

In spite of multifarious and diversified uses of Mahua, the species is not getting due consideration from silvicultural and management point of view for the reason of other commercial crops, due to which the genetic resources of the species are depleting hard and fast. The species, therefore, is urgently required to be conserved. Large scale-artificial regeneration and tree improvement work is required to augment the economy, for its hard

and fast depleting genetic resources as the local people sweep the canopy floor of the plant for maximum seed collection for multiple uses. To begin with, it is important to study the variability existing in the species and to select superior genotypes for adoptability, fast growth, oil content and disease resistance. It is desirable to screen the naturally available genetic variation so as to ensure that only the best material is utilized for maximum productivity and for further breeding work [4].

In this research paper a successful attempt was made to find out the variation in germination, morphological and biomass traits of twenty (20) genotypes collected from different geographical sites/locations in Uttar Pradesh India.

2. MATERIALS AND METHODS

The study was conducted in the Forest Nursery of Allahabad Agricultural Institute-Deemed University, Allahabad, situated at 25.28ºN latitude and 81.55ºE longitude. The area is located at an altitude of 98 m above average mean sea level, and enjoys sub-tropical type of climate. Candidate plus trees of *Madhuca indica* were marked using the following criteria; Height (m), Diameter at breast height (m), Seed length (cm), Seed diameter (cm), free from disease and insect-pests and straight, non-forked cylindrical bole. Following the above criteria, fresh and fully ripened open pollinated seeds of 20 plus trees were collected from different geographical locations in district Allahabad and adjoining areas in Uttar Pradesh during July, 2010 (Table 1).

Four seed samples were randomly collected from each select plus tree from 20 different sites or locations for the measurement of seed parameters. The seed length and seed diameter were measured by using vernier caliper for four replications, 100 seed weight was also recorded for four replications of 100 seeds each randomly selected from seed samples collected. Germination tests were conducted under field (open) environment between 30-35ºC. Three replications of 40 seeds each were used for the test. 120 seeds of each plus tree were simultaneously sown under field environment in nursery, in polythene bags at a depth of 1.0 cm containing potted mixture of soil, sand and farm yard manure (1:1.1) in three replicates used Randomized Block Design (RBD) during last week of July, 2010. Plant to plant distance was kept at 15 cm and row to row distance at 30 cm. A uniform pre-treatment was given to the seeds by soaking in warm water, allowed to cool and kept soaked for 24 hours. Watering was done daily and polythene bags were placed on raised beds to avoid water logging, regular weeding was done as per requirement.

The germination count was recorded on every alternate day for 30 days. Various germination indices viz., germination percentage (GP), germination energy index (GEI), mean daily germination (MDG), peak value (PV), germination value (GV) and germination speed (GS) were calculated following [5]. Observations on seedling height, seedling collar diameter, internodal length, number of leaves per seedling, leaf area, shoot fresh and dry weight, root fresh and dry weight, shoot/root ratio and total biomass of seedlings were taken after one growing season, for the reason that *Madhuca indica* develop a strong root system during the whole growing season which could be unsound for laboratory morphological observations. 15 seedlings per replication i.e. 45 seedlings per plus tree progeny/family, randomly selected were taken for the purpose of observations.

The recorded observations were subjected to analysis of variance (ANOVA) to understand the significance of differences among 20 plus tree progenies. Least significant difference (LSD) was calculated and plus tree progenies were ranked for the variables studied using a

computer software program “SPSS”. Coefficient of variance (CV %) and linear correlation coefficients among studied traits were calculated as described by [6]. Various genetic parameters like genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), broad sense heritability, estimated genetic advance and genetic gain were determined following [7].

Procedure followed for variability parameters [7].

$$PCV\ (\%) = \sqrt{\frac{Vp}{\overline{X}}} \times 100$$

$$GCV\ (\%) = \sqrt{\frac{Vg}{\overline{X}}} \times 100$$

Where;

Vp = Phenotypic variance
Vg = Genotypic variance
PCV = Phenotypic coefficient of variability
GCV = Genotypic coefficient of variability
$\overline{X}$ = Population mean of the character

h^2 = Heritability (broad sense) was calculated as suggested by [7].

$$h^2 = \frac{Vg}{Vp} \times 100$$

Where;

h^2 = Broad sense heritability
Vg = Genotypic variance
Vp = Phenotypic variance

Genetic gain was worked out by the following method suggested by [7].

$$\text{Genetic gain } (\%) = \frac{\text{Genetic advance}}{\overline{X}} \times 100$$

$$\textbf{Genetic advance} = h^2 \times \sqrt{Vp \times K}$$

Where;

h^2 = Heritability (Broad sense)
Vp = Phenotypic variance
K = Selection differential at 5 per cent selection
Intensity K = 2.06 [8]
$\overline{X}$ = Population mean of the character

Table 1. Passport details and Morphological observations of 20 plus trees (S_1-S_{20}) of *Madhuca indica* Gmel in natural condition

Notation	PT/Site (Name)	Latitude	Longitude	Height (m)	Dbh (m)	Seed length (cm)	Seed diameter(cm)
S_1	Hanumanganj	25º 42'N	82º 04'E	14.5	2.8	3.5	1.7
S_2	Ghoorpur (Mankawar)	25º 18'N	81º 48'E	14.8	3.2	3.4	1.5
S_3	Phulpur (Munshikapur)	26º 08'N	82º 86'E	16.2	2.5	3.4	1.6
S_4	Jhansi (Sarianayat)	25º 25'N	81º 54'E	13.7	3.5	3.7	1.4
S_5	Naini (Kharkawni)	25º 21'N	81º 51'E	17.1	2.9	3.5	1.7
S_6	Naini (Chakka)	25º 27'N	81º 51'E	13.5	2.8	3.2	1.5
S_7	Sahsoo (Badrahikapur)	25º 29'N	81º 58'E	12.3	3.9	3.8	1.6
S_8	Dandi (Muhabatgaj)	25º 24'N	81º 50'E	17.5	2.3	3.1	1.5
S_9	Jhalwa (Peepal)	25º 25'N	82º 46'E	14.2	3.6	3.4	1.8
S_{10}	Mahewa (Agri-field)	25º 24'N	81º 51'E	15.6	3.2	3.9	1.7
S_{11}	Gousi (Aravikalla)	25º 26'N	82º 05'E	12.3	4.1	3.2	1.6
S_{12}	Phulpur (Malaka)	25º 33'N	81º 92'E	18.3	2.7	3.3	1.7
S_{13}	Sarila	25º46'N	´79° 43'E	13.9	3.7	3.0	1.6
S_{14}	Jalalpur (Khurd)	25º 36'N	81º 27'E	14.8	3.2	3.4	1.8
S_{15}	Dandi (Muradpur)	25º 22'N	81º 51'E	17.3	3.6	3.2	1.8
S_{16}	Naini (Tilakwar)	25º 19'N	81º 52'E	12.7	3.5	3.3	1.4
S_{17}	Gauhania (Govti)	25º 14'N	81º 41'E	16.8	2.9	3.1	1.5
S_{18}	Nawabganj	26º 56'N	82º12'E	16.5	4.2	3.9	1.9
S_{19}	Naini (Madhupur)	25º 43'N	82º 16'E	15.9	3.4	3.3	1.5
S_{20}	Karhedahm(The)	25º 26'N	81º 50'E	18.2	3.7	3.6	1.8

3. RESULTS AND DISCUSSION

3.1. Germination and Seedling Growth

An appraisal of the data presented in Table 2 pertains to germination traits of 20 different genotypes of *Madhuca indica* under field environment. Analysis of variance indicated highly significant differences (*P* =.05) among the 20 genotypes for all the traits studied. The maximum value for germination per cent (90.00) was recorded for S_{20} which was followed by S_{19} (71.67). The maximum value for germination energy index (37.50) per cent was recorded for S_{20} which was followed by S_9 (29.86) per cent. The maximum value (3.21) for mean daily germination was exhibited by S_{20} which was followed by S_9 (2.56). The maximum value (4.67) for peak value was revealed by S_{20} followed by S_9 (3.67). The maximum value for germination value was recorded for S_{20} (15.00) followed by S_9 (9.35). The maximum value for germination speed (1.37) was recorded for S_{20} followed by S_9 (1.06).

The differences among 20 genotypes of plus tree progenies were noticed to the significant (*P* = .05) for germination, morphological and biomass traits (Table 2 and 3). The maximum seedling height (24.02 cm) was recorded for S_8 followed by S_{13} (22.88 cm). The maximum collar diameter (6.73 mm) was revealed for S_{20} followed by S_{19} (6.33 mm). The maximum value for internodal length (3.25 cm) was observed for S_7 followed by S_8 (2.83 cm). Maximum number of leaves per seedling (9.73) was noticed in S_{15} proceeded by S_{13} (9.63). The maximum leaf area (43.20 cm^2) was recorded for S_{20} which was followed by S_{19} and S_{10} (40.00 cm^2). The maximum shoot fresh weight (8.77 g) was revealed for S_{20} followed by S_9 (8.04 g). The maximum shoot dry weight (2.14 g) was noticed for S_{20}, statistically at par with S_2, S_8 and S_{13} (1.73). The maximum root fresh and dry weight (15.23 g) and (3.93 g) both were recorded for S_{12}. The highest value (0.80) for shoot/root ratio was recorded for S_{10}, followed by S_{17} (0.64). The maximum value (23.00 g) registered for total biomass of seedling was revealed for S_{12} followed by S_{19} and S_5 (22.50 g).

Variations refer to the observable differences in individual for a particular trait. These differences may be partly due to genetic factors and partly due to environmental effect. The observed value of a trait is the phenotypic value of that individual. The related magnitude of these components determines the genetic properties of any particular species [9]. The extent of variation observed in germination value (CV–54.79%), germination speed (CV–43.39%) and germination per cent (CV–27.50%) (Table 2) was found to be high as compared to other germination traits studied. Whereas, the extent of variation observed in internodal length (CV–18.89%), root fresh weight (CV–18.59%) and seedling height (CV–18.51%) was found to be high as compared to other morphological and biomass traits studied (Table 3). The variation noticed among the 20 plus tree progenies/genotypes might have arisen due to the fact that such genotypes grew in different edaphic and micro-climatic (locality) conditions and must have experienced varying pressures of natural selection. The differences observed in morphological and biomass traits may be attributed to genetic in nature as a result of adaptation to diverse environmental conditions [10]. Similar significant variation in germination, morphological and biomass traits has earlier been reported in *Acacia mangium* [11], *Acacia. nilotica* [12], *Albizia chinensis* [13], *Cassia ariculata* [14], *Dalbergia sissoo* [15], and *Tecomella undulate* [16].

Table 2. Mean performance of 20 plus trees of *Madhuca indica* for germination characters under field environment during 2010

Sites	Germination (%)	Germination Energy Index	Mean daily Germination	Peak value	Germination value	Germination speed
S_1	48.33	20.25	1.73	2.00	3.45	0.50
S_2	35.00	14.58	1.25	2.33	2.98	0.38
S_3	45.00	18.75	1.61	2.33	3.93	0.44
S_4	68.33	26.25	2.32	2.67	6.25	1.00
S_5	58.33	24.31	2.08	2.00	4.17	0.88
S_6	51.00	20.14	1.65	3.00	5.18	0.45
S_7	42.00	16.67	1.48	2.67	3.95	0.52
S_8	41.33	15.97	1.37	2.33	3.15	0.36
S_9	71.67	29.86	2.56	3.67	9.35	1.06
S_{10}	60.33	24.46	2.08	3.33	7.02	0.86
S_{11}	38.33	15.97	1.32	2.00	2.64	0.39
S_{12}	40.00	16.67	1.43	2.33	3.33	0.46
S_{13}	51.67	21.53	1.85	3.33	6.25	0.58
S_{14}	70.00	29.17	2.50	2.33	5.77	0.89
S_{15}	39.67	17.84	1.49	2.00	2.66	0.48
S_{16}	65.00	27.08	2.12	2.67	6.65	0.89
S_{17}	53.33	22.22	1.90	3.33	6.43	0.55
S_{18}	66.67	27.78	2.38	3.00	7.14	0.90
S_{19}	37.00	17.58	1.49	2.00	2.71	0.36
S_{20}	90.00	37.50	3.21	4.67	15.00	1.37
Mean	53.65	22.23	1.89	2.70	5.35	0.67
Range Min	35.00	14.58	1.25	2.00	2.64	0.36
Max	90.00	37.50	3.21	4.67	15.00	1.37
Coefficient of Variance (CV)	27.50	26.91	27.15	25.93	54.79	43.39
F – test	S	S	S	S	S	S
S. Ed. (±)	6.13	2.57	0.22	0.62	1.56	0.10
C.D. at (5%)	12.42	5.19	0.44	1.25	3.16	0.20

Table 3. Mean performance of 20 sites for morphological and biomass characters of *Madhuca indica* in field environment during 2010

Sites		Seedling height (cm)	Collar diameter (mm)	Internodal length (cm)	No. of leaves per seedling	Leaf area (cm^2)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Fresh weight of root (g)	Dry weight of root(g)	Shoot/ Root ratio	Total biomass of seedling(g)
S_1		13.35	4.27	1.93	7.33	31.30	5.37	1.46	7.60	1.92	0.80	12.97
S_2		14.63	6.31	1.85	8.40	27.90	6.77	1.73	10.80	2.90	0.60	17.57
S_3		13.00	5.05	2.15	6.33	22.40	7.57	2.00	14.37	3.76	0.54	21.93
S_4		13.98	5.27	1.50	9.34	32.50	5.82	1.48	9.76	2.66	0.55	15.58
S_5		17.85	4.93	2.50	8.87	28.50	7.90	2.04	14.60	3.85	0.53	22.50
S_6		22.15	5.53	2.47	9.13	26.80	5.68	1.38	9.80	2.65	0.52	15.48
S_7		18.18	5.90	3.25	6.00	20.70	6.27	1.52	13.28	3.59	0.42	19.55
S_8		24.02	5.60	2.83	8.73	33.40	7.28	1.73	12.60	3.38	0.52	19.88
S_9		17.07	5.48	1.95	9.00	28.40	8.04	1.98	11.97	3.18	0.62	20.01
S_{10}		18.50	6.03	2.10	9.03	40.00	7.23	1.70	12.42	3.22	0.53	19.66
S_{11}		18.83	6.17	2.29	9.20	27.00	5.41	1.39	10.77	3.01	0.46	16.18
S_{12}		19.75	5.33	2.57	8.00	26.50	7.77	1.91	15.23	3.92	0.49	23.00
S_{13}		22.88	6.27	2.34	9.63	31.60	7.44	1.73	13.00	3.48	0.51	20.44
S_{14}		13.14	4.93	1.48	9.10	25.30	5.43	1.32	8.53	2.33	0.57	13.97
S_{15}		21.11	6.00	2.12	9.73	25.20	7.00	1.55	11.83	3.12	0.50	18.83
S_{16}		18.31	4.73	2.44	8.80	38.30	5.74	1.39	11.44	3.13	0.45	17.18
S_{17}		14.27	4.48	1.93	7.73	24.50	5.95	1.44	8.67	2.24	0.64	14.62
S_{18}		19.00	5.13	2.23	8.47	36.70	7.16	1.74	12.73	3.39	0.51	19.90
S_{19}		20.10	6.33	2.27	9.27	40.00	7.60	1.81	14.90	3.77	0.48	22.50
S_{20}		18.73	6.73	1.94	9.53	43.20	8.77	2.14	13.60	3.56	0.60	22.37
Mean		17.94	5.54	2.21	8.58	30.51	6.81	1.68	11.90	3.15	0.54	18.70
Range	**Min.**	13.00	4.27	1.48	6.00	20.70	5.37	1.32	7.60	1.92	0.42	12.97
	Max.	24.02	6.73	3.25	9.73	43.20	8.77	2.14	15.23	3.92	0.80	23.00
Coefficient of variance (CV)		18.51	11.81	18.89	12.03	12.03	15.05	15.03	18.59	17.84	15.54	16.57
F-test		S	S	S	S	S	S	S	S	S	S	S
S.Ed. (±)		1.59	0.53	0.20	0.62	0.40	0.70	0.19	1.30	0.34	0.05	1.92
C.D. at 5%		3.23	1.08	0.40	1.25	0.82	1.42	0.39	2.64	0.69	0.10	3.90

The extent of variability is also assessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation [17]. All the germination traits *viz*., germination per cent, germination energy index, mean daily germination peak value, germination value and germination speed, and morphological and biomass traits studied *viz*., seedling height, seedling collar diameter, internodal length, number of leaves per seedling, leaf area, fresh and dry shoot weight, fresh and dry root weight, shoot/root ratio and total biomass of seedling under field environment showed higher values for phenotypic coefficient of variation as compared to their corresponding genotypic coefficient of variation (Table 4). This indicated that all these traits are greatly influenced by environment. Similar findings were reported by [18] for seedling height, diameter and number of branches in *Cedrela* species, in *Pinus roxhurghii* [19,20] and in *Jatropha curcas* [21].

The heritability was maximum for leaf area (99.39%) respectively followed by germination speed (84.56%), germination per cent (77.90%), mean daily germination (76.70%), seedling height (73.89%) and internodal length (72.59%). The heritability values were ranging from very high to moderately high for almost all the traits study. The top ranking value was exhibited by leaf area (99.39%) and the bottom ranking value was recorded for peak value (34.34%). Although heritability in broad sense may give useful indication about the relative value of selection in the material at hand; to arrive at a more reliable conclusion, heritability and associated genetic gain should be considered jointly [7]. The expected genetic gain was ranging from quite high (85.59%) for germination value to moderate (12.67%) for seedling collar diameter. The traits germination value (85.59%), germination speed (79.80%), germination per cent (47.80%), mean daily germination (46.79%), germination energy index (46.26%), leaf area (42.60%), seedling height (30.40%) and fresh weight of shoot (27.25%) were found to be associated with higher amount of genetic gains indicating a wide scope of genetic improvement (Table 4). These findings are in line with those of *Acacia catechu* [22], *Heracleum candicans* [23] and *Euclyptus grandis* [17].

The correlation coefficient among the germination, morphological and biomass traits studied is presented in (Table 5 and 6). A perusal of data in Table 5 revealed that correlations between all the germination traits with each other showed positive and significant correlation at 5% level of significance. Scrutiny of data in Table 6 revealed that all the morphological and biomass traits with each other except for internodal length times with number of leaves per seedling, number of leaves per seedling times with dry weight of shoot, root fresh weight and total biomass of seedling showed positively non-significant correlation at 5% level of significance. Shoot/root ratio with all traits and shoot/root ratio with total biomass of seedling showed negatively non-significant correlation with each other at 5% level of significant. Similar results were earlier reported in *pinus elliottii* [24], *pinus oocarpa* [25], *Pinus dasycarpa* [26], *Pinus roxburghii* [20] and *Jatropha curcas* [21]. It can therefore be inferred that the positive correlation among all the germination, morphological and biomass traits can be used for early screening of the genotypes. The results are also useful for the further improvement of the species.

Table 4. Estimation of components of variance for germination, morphological and biomass characters of 20 plus tree progenies of *Madhuca indica* in field environment during 2010

Traits	Mean	(PCV)	(GCV)	Heritability (h^2) (%)	Genetic advance GA)	Genetic gain (%)
Germination (%)	53.65	29.78	19.29	77.90	25.64	47.80
Germination energy index	22.23	29.28	25.64	76.70	10.28	46.26
Mean daily	1.89	29.51	25.89	76.98	0.88	46.79
Peak value	2.70	34.58	20.26	34.34	0.66	24.46
Germination value	5.35	62.05	50.78	66.96	4.58	85.59
Germination speed	0.69	45.81	42.12	84.56	0.53	79.80
Seedling height (cm)	17.94	20.53	17.41	73.89	5.45	30.40
Collar diameter (mm)	5.54	15.22	9.67	40.42	0.70	12.67
Internodal length (cm)	2.21	20.90	17.80	72.59	0.69	31.25
No. of leaves per seedling	8.58	14.00	10.91	60.70	1.50	17.51
Leaf area (cm^2)	30.51	20.84	20.78	99.39	13.02	42.68
Fresh weight of shoot (g	6.81	18.22	13.91	52.40	1.34	19.67
Dry weight of shoot (g)	1.68	18.93	12.64	44.60	0.29	17.39
Fresh weight of root (g)	11.90	21.59	16.90	61.28	3.24	27.25
Dry weight of root (g)	3.15	20.89	16.10	59.38	0.81	25.55
Shoot/Root ratio	0.54	17.792	14.283	64.44	0.12	23.620
Total biomass of seedling (g)	18.70	19.50	14.88	58.28	4.38	23.41

Table 5. Correlation coefficient between different germination characterss of *Madhuca indica* in field environment during 2010

Traits	Germination (%)	Germination energy index	Mean daily germination	Peak value	Germination value	Germination speed
Germination (%)	1.000	0.999*	0.988*	0.716*	0.893*	0.966*
Germination Energy Index	-	1.000	0.994*	0.702*	0.893*	0.960*
Mean Daily Germination	-	-	1.000	0.708*	0.900*	0.964*
Peak Value	-	-	-	1.000	0.929*	0.666*
Germination Value	-	-	-	-	1.000	0.860*
Germination Speed	-	-	-	-	-	1.000

Table 6. Correlation coefficient between different morphological and biomass characters of *Madhuca indica* in field environment during 2010

Traits	Seedling height (cm)	Collar diameter (mm)	Internodal length (cm)	No. of leaves per seedling	Leaf area (cm^2)	Fresh weight of shoot(g)	Dry weight of shoot (g)	Fresh weight of root (g)	Dry weight of root (g)	Shoot/ Root ratio	Total biomass of seedling (g)
Seedling height (cm)	1.000	0.527*	0.769*	0.538	0.376*	0.459*	0.282	0.574*	0.601	-0.562	0.560*
Collar diameter (mm)	-	1.000	0.135*	0.614	0.330*	0.559	0.457*	0.503*	0.523	-0.379	0.542*
Internodal length (cm)	-	-	1.000	-0.065	0.173*	0.324*	0.276	0.596*	0.608*	-0.485	0.530
No. of leaves per seedling	-	-	-	1.000	0.424*	0.112	-0.099	0.059*	0.109	-0.391	0.079*
Leaf area (cm^2)	-	-	-	-	1.000	0.309*	0.238*	0.228	0.274*	-0.132	0.307
Fresh weight of shoot (g)	-	-	-	-	-	1.000	0.955*	0.821	0.790	-0.171	0.914*
Dry weight of shoot (g)	-	-	-	-	-	-	1.000	0.776*	0.744*	-0.031	0.867
Fresh weight of root (g)	-	-	-	-	-	-	-	1.000	0.990*	-0.594	0.982*
Dry weight of root (g)	-	-	-	-	-	-	-	-	1.000	-0.663	0.965*
Shoot/Root ratio	-	-	-	-	-	-	-	-	-	1.000	-0.478
Total biomass of seedling (g)	-	-	-	-	-	-	-	-	-	-	1.000

4. CONCLUSION

On the basis of mean performance of 20 genotypes of *Madhuca indica*, from the present investigation it is clear that considerable genetic differences exist in all the important characters of germination and seedling growth among the genotypes. Overall, the plus tree progenies of S_{20}, S_9, S_{12} and S_{19} accordingly have shown better germination and seedling growth performance for majority of the characters as compared to the rest of the genotypes as discussed above. They are also expected to do well in greenhouse environment as positive correlation between greenhouse and field performance in a number of tree species has been reported by many researchers [27,28] in *Acacia nilotica* and *Dalbergia sissoo*. Therefore, we recommend the genotypes S_{20}, S_9, S_{12} and S_{19} for further genetic improvement programme.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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