



Intra-Population Variation in Mahua (*Madhuca longifolia* var. *latifolia* Roxb. A. Chev.) for Fruit, Seed and Germination Traits

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Abstract: Experiment was designed to understand the intra-population variation for fruit, seed and germination attributes of *Madhuca longifolia* var. *latifolia* (mahua) - a high value tropical tree species. Study was carried out in two years (2015 and 2016). Seed lots of identified open pollinated mother trees (10) were segregated and used for study. Fruit and seed traits like length, thickness and weight showed significant variation among open pollinated mother trees. Trees coded as MLLMG-3, MLLMG-4 and MLLMG-9 comparatively recorded with large seeds. Germination percentage, germination rate index, mean daily germination, peak value of germination, germination value mean germination time showed significant variation. Pooled analysis showed that there was no significant effect of collection period (year to year) on fruit, seed and germination traits except fruit length. Further, there was an auto correlation among various fruit and seed traits. Strong correlation observed for fruit traits (weight and thickness) with germination attributes. Experimental outcomes revealed a strong intra-population variation for studied attributes in mahua. Therefore, further selection and improvement work can be done on this species for production of quality seeds in large quantity.

Keywords: Correlation, Germination, Intra-population, Mahua, Selection, Tropical tree

Non-Timber Forest Products (NTFPs) play an important role in sustainable livelihood of the tribes as well as other forest dwellers living in and fringe forest areas. NTFPs are the backbone to the Indian forest economy contributing over 50 per cent to the forest revenues (Patel and Naik 2010). These products also serve as an important source of food, nutrition, medicine etc. *Madhuca longifolia* var. *latifolia* (mahua) is one of such resource that contributes greatly to the forest revenue. Mahua is one of the ecologically and economically important species having wide distribution in South Asian countries including India, Nepal, Burma, Myanmar and Sri Lanka. In India, this species is distributed in northern, central and southern part of peninsular India (Mishra and Pradhan 2013, Akshatha et al 2013). Tree has great value for its flowers and seeds in Gujarat state, India. Products of mahua play an important role in income and livelihood of tribal areas of the country and considerable part of their total income is obtained from sale of forest products. At local, the forest dwellers and tribal people use products from mahua regularly and use full of its extent. There is a great demand for seeds and flowers of mahua for commercial purpose and required raw materials come from natural sources. Large scale plantation of this species is required to fulfill the sustainable utilization of mahua resources. On other hand, genetic variation helps to identify individuals as well as species to withstand against the extreme environmental conditions and biotic pressures. Intra specific variation leads trees to show better phenotypic characters, resistance against the harsh conditions and biological agents (Anonymous 2013). These

characters would help to screen the best genotypes for the specific purpose. The basis for any breeding programme is to understand the intra and inter-specific/population variation for traits of interest. Furthermore, scientific information regarding the variability and superiority of the individuals growing within the population are also important for the conservation of genetic diversity as well as improvement and multiplication of species. Moreover, genetic diversity is needed in order to ensure that forest trees can survive, adapt and evolve under changing environmental conditions (Whitham 2014). Review shows that there is a little work on tree improvement aspects of this species (George et al 2003, Wani and Ahmad 2013, Divakara and Das 2014). There is no report of intra-population variation for morphometric distinction in fruit, seed and germination attributes in mahua and their correlation. Therefore, to fulfill some of these gaps in intra-population, variability studies in this high value tropical tree species was undertaken.

MATERIAL AND METHODS

Site location: To study the intra-population variation, a mahua population was identified as a focal population and it is situated in Makadban forest of Valsad district, Gujarat state in India and between 20° 26' 38" N and 73° 13' 53" E with an altitude of 41 m above MSL. The study area located in the northern part of Western Ghats comprising the laterite and medium black soils and experiences the typical tropical climatic conditions. The maximum daily temperature during the year ranges from 32.2°C in August to 41.2°C in April,

while minimum temperature ranges from 9.9°C in January to 23.3°C in May. The average annual normal rainfall of the area is 2422 mm. Approximate extent of this population is 10 ha that consists of good number of mahua trees and well distributed in the study area. The fruit and seed characterization as well as germination experiment was undertaken during the year 2015 and 2016 at Navsari Agricultural University, Gujarat, India. Navsari Agricultural University, Navsari (20° 55' 38" N 72° 53' 54" E with an altitude of 9 m above MSL). The location experiences a typical tropical warm climate characterized by fairly hot summer, moderately cold winter and warm humid monsoon. Generally, monsoon in this region commences in the second week of June and ends in September. Most of the precipitation is received from South west monsoon, concentrating in the months of July and August. Average annual rainfall of this region generally ranges from 1200 to 1500 mm. April and May months recorded highest maximum temperature. December, January and February months recorded the lowest minimum temperature.

Fruit collection and germination study: Total ten healthy matured good fruit bearing open pollinated mother trees were selected randomly and marked for fruit collection. Growth observation such as tree height, GBH, commercial bole height and crown diameter of selected trees were recorded using standard procedure (Cheturvedi and Khanna 2011) (Table 1). Fruits were collected during June from selected Open Pollinated Mother Trees (OPMTs) and individual identity of OPMT was maintained. For each OPMT, total five hundred seeds *i.e.*, five samples containing 100 seeds each, were used to assess the variation for fruit and seed traits along with seed germination among different populations (ISTA 2017). Data on various quantitative traits of fruits and seeds like length, thickness and weight were recorded. Germination experiment was carried out in the nursery under shade-net. Daily

germination count was made up to 30 days. Emergence of the shoot just above the sand level was considered as germination. Germination per cent and its various parameters such as germination rate index, mean daily germination, peak value of germination, germination value and mean germination time were calculated as per standard procedure following Czabator (1962), Orchard (1977) and Esechie (1994).

RESULTS AND DISCUSSION

Fruit, seed and germination studies: Upshot of the study shows significant and strong intra-population variation for fruit traits like length, thickness, weight as well as seed traits like length, thickness, weight, dry biomass, volume and density (Table 2, 3 and 4). Pooled analysis showed non-significant influence of collection period on fruit, seed and germination parameters except fruit length. In the present study, significant intra-population variation was recorded in fruit length (36.60-51.90 mm & 31.70-49.70 mm), fruit thickness (32.08-41.47 mm & 27.20-38.07 mm) and fruit weight (18.19-37.54 g & 13.94-27.95 g), in 1st and 2nd year of study, respectively. Similarly, intra-population variation was also recorded in seed length (25.08-33.26 mm & 25.30-32.90 mm), seed thickness (14.70-18.95 mm & 11.35-15.49 mm) and seed weight (2.84-5.26 g & 2.96-5.09 g), in first and second year, respectively. OPMTs namely MLLMG-3, MLLMG-4 and MLLMG-9 recorded with heavier and bigger fruits and seeds than other individuals. Germination percentage, germination rate index, mean daily germination, peak value of germination, germination value mean germination time showed significant variation among OPMTs selected within a population (Table 5, 6). The germination per cent ranged from 56.2 to 93.0 in first year (2015) and 66.0 to 98.0 in second year. Interestingly, OPMTs *viz.*, MLLMG-1, MLLMG-9 and MLLMG-10 showed better germination per cent to the tune of 93.00 & 90.00 per cent, 84.00 and 96.00

Table 1. Growth attributes of open pollinated mother trees selected for intra-population variation study

Open pollinated mother trees	Tree height (m)	Girth at breast height (cm)	Commercial bole height (m)	Crown diameter (m)
MLLMG-1	21.50	280.00	8.00	14.05
MLLMG-2	19.00	178.00	7.20	13.95
MLLMG-3	21.00	232.00	8.50	13.85
MLLMG-4	24.50	309.00	7.50	16.50
MLLMG-5	18.00	232.00	6.50	15.35
MLLMG-6	19.50	261.00	6.00	13.45
MLLMG-7	17.50	130.00	4.50	13.85
MLLMG-8	18.50	172.00	6.50	11.95
MLLMG-9	20.50	270.00	7.00	14.40
MLLMG-10	22.50	340.00	7.50	16.90

percent and 85.00 and 98.00 respectively for 2015 & 2016.

Correlation studies: There was an auto correlation among fruit and seed traits (Table 7). The fruit length showed positive correlation with fruit thickness, fruit weight, seed thickness and seed dry biomass. Similarly, fruit thickness also showed positive correlation with fruit weight. Seed weight showed positive correlation with seed length and seed thickness. Such significant association was also observed between

seed dry biomass and seed thickness. Such strong and positive association was also observed among germination attributes. Seed germination showed significant and positive correlation with Germination rate index. However, none of the fruit and seed traits does not show significant correlation with germination. Further, GRI also showed positive correlation with MDG and GV. Moreover, fruit weight positively correlated with GRI, MDG and GV.

Table 2. Fruit traits variation in *Madhuca longifolia* var. *latifolia* (Roxb.) A. Chev.

Open pollinated mother trees	Fruit length (mm)			Fruit thickness (mm)			Fruit weight (g)		
	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled
MLLMG-1	40.52	39.60	40.06	33.49	34.10	33.80	21.61	21.45	21.53
MLLMG-2	36.60	40.00	38.30	36.41	27.20	31.81	22.89	13.94	18.42
MLLMG-3	46.56	46.70	46.63	41.47	32.36	36.92	37.54	19.32	28.43
MLLMG-4	43.14	37.20	40.17	36.58	32.48	34.53	26.31	17.78	22.05
MLLMG-5	48.20	48.90	48.55	40.68	38.07	39.38	33.78	27.95	30.87
MLLMG-6	38.32	35.50	36.91	32.08	29.64	30.86	18.19	14.08	16.14
MLLMG-7	40.26	31.70	35.98	37.11	30.77	33.94	25.97	14.14	20.06
MLLMG-8	46.78	39.70	43.24	34.54	34.07	34.31	23.57	19.52	21.55
MLLMG-9	51.88	49.70	50.79	34.30	33.11	33.71	27.23	24.98	26.11
MLLMG-10	43.66	43.50	43.58	36.30	33.25	34.78	26.90	24.07	25.49
Mean	43.60	41.20	42.40	36.30	32.50	34.40	26.40	19.72	23.06
CD @ 5%	1.10	1.20	6.67	1.00	1.36	NS	1.51	1.57	NS
CV (%)	1.97	2.24	2.10	2.15	3.25	2.70	4.47	6.18	5.20
CD @ 5% (YxT)	-	-	1.12	-	-	1.17	-	-	1.51

Table 3. Seed traits variation in *Madhuca longifolia* var. *latifolia* (Roxb.) A. Chev.

Open pollinated mother trees	Seed length (mm)			Seed thickness (mm)			Seed weight (g)		
	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled
MLLMG-1	30.56	29.50	30.03	17.06	12.19	14.63	4.60	3.44	4.02
MLLMG-2	26.42	32.60	29.51	14.70	15.18	14.94	2.84	5.05	3.95
MLLMG-3	33.26	32.90	33.08	18.95	14.03	16.49	5.26	5.09	5.18
MLLMG-4	29.64	31.70	30.67	17.87	14.37	16.12	5.14	4.91	5.03
MLLMG-5	25.08	29.30	27.19	16.65	13.48	15.07	3.74	3.72	3.73
MLLMG-6	26.00	31.60	28.80	16.25	11.35	13.80	3.69	3.56	3.63
MLLMG-7	25.66	25.30	25.48	17.93	11.40	14.67	4.55	2.99	3.77
MLLMG-8	28.10	31.40	29.75	15.22	13.02	14.12	3.59	3.79	3.69
MLLMG-9	29.92	25.40	27.66	16.46	15.27	15.87	3.98	2.96	3.47
MLLMG-10	28.30	29.60	28.95	16.06	15.49	15.78	3.95	3.28	3.62
Mean	28.29	29.93	29.11	16.72	13.58	15.15	4.13	3.88	4.01
CD @ 5%	0.86	1.24	NS	0.48	0.90	NS	0.20	0.51	NS
CV (%)	2.35	3.24	2.85	2.23	5.17	3.63	3.78	10.18	7.49
CD @ 5% (YxT)	-	-	1.06	-	-	0.70	-	-	0.38

Understanding intra-population variation for reproductive traits would be fundamental steps for domestication and conservation of species. Information generated through such studies help in selection and improvement of species. In the present study, significant intra-population variation was for fruit and seed traits. Among 10 OPMTs selected, MLLMG-3, MLLMG-4, MLLMG-5 and MLLMG-9 showed superiority for fruit and seed traits, which produces bigger and wider fruits

and heavy seeds than other mother trees. However, such tree to tree variation within a population recorded in *Dysoxylum binectariferum* (Gunaga et al 2015), *Mammea suriga* (Gunaga and Vasudeva 2009), *Nothapodytes nimmoniana* (Hareesh et al 2008), *Garcinia talbotii* (Bansude et al 2013) and *Sterculia urens* (Bhuva 2016).

Variations in the fruit and seed sizes could be due to genetic potential among the selected individuals or it may be

Table 4. Seed dry biomass and moisture content variation in *Madhuca longifolia* var. *latifolia* (Roxb.) A. Chev.

Open pollinated mother trees	Dry biomass of seed (g)			Moisture content (%)		
	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled
MLLMG-1	2.02	0.88	1.45	55.62	74.44	65.03
MLLMG-2	1.33	1.43	1.38	53.24	71.79	62.52
MLLMG-3	2.10	1.06	1.58	60.18	78.98	69.58
MLLMG-4	1.80	1.81	1.81	64.92	62.61	63.77
MLLMG-5	1.40	1.14	1.27	62.64	69.28	65.96
MLLMG-6	1.68	1.17	1.43	54.25	66.71	60.48
MLLMG-7	1.94	0.44	1.19	57.21	85.17	71.19
MLLMG-8	1.58	1.18	1.38	56.00	68.45	62.23
MLLMG-9	2.37	1.81	2.09	40.41	37.80	39.11
MLLMG-10	1.90	1.36	1.63	51.93	58.55	55.24
Mean	1.81	1.23	1.52	55.64	67.38	61.51
CD @ 5%	0.32	0.14	NS	8.17	6.26	NS
CV (%)	13.72	8.54	9.77	11.45	7.24	7.09
CD @ 5% (YxT)	-	-	0.18	-	-	5.62

Table 5. Seed germination, GRI and MDG variation in *M. longifolia* var. *latifolia*

Open pollinated mother trees	Seed Germination (%)			GRI			MDG		
	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled
MLLMG-1	93.00 (79.25)	90.00 (78.47)	91.50	5.74	6.10	5.92	4.43	3.82	4.13
MLLMG-2	73.00 (59.12)	94.00 (81.00)	83.50	4.59	6.13	5.36	3.20	4.11	3.66
MLLMG-3	79.00 (62.84)	66.00 (54.61)	72.50	4.66	3.87	4.27	2.83	2.70	2.77
MLLMG-4	81.67 (64.88)	84.00 (72.00)	82.84	5.28	5.54	5.41	3.73	3.69	3.71
MLLMG-5	87.50 (72.48)	80.00 (66.51)	83.75	5.77	5.58	5.68	3.63	3.72	3.68
MLLMG-6	56.25 (48.89)	88.00 (74.36)	72.13	3.07	5.08	4.08	2.14	3.72	2.93
MLLMG-7	90.00 (71.86)	84.00 (69.04)	87.00	5.38	5.33	5.36	3.79	3.37	3.58
MLLMG-8	87.50 (75.06)	90.00 (75.69)	88.75	5.87	5.84	5.86	4.73	4.11	4.42
MLLMG-9	84.00 (66.94)	96.00 (82.63)	90.00	4.85	6.67	5.76	3.23	4.64	3.94
MLLMG-10	85.00 (67.54)	98.00 (86.31)	91.50	5.54	5.93	5.74	3.75	4.36	4.06
Mean	81.69 (66.88)	87.00 (74.06)	84.35	5.08	5.61	5.34	3.54	3.82	3.69
CD @ 5%	10.71	17.63	NS	0.85	1.11	NS	0.86	0.76	NS
CV (%)	12.48	18.55	16.13	13.00	15.46	14.43	18.96	15.49	17.19
CD @ 5% (YxT)	-	-	14.53	-	-	0.97	-	-	0.79

GRI =Germination Rate Index; MDG= Mean Daily Germination; : Figures in the parenthesis are arc-sine transformed values

due to the differences in microsite environmental as well as edaphic factors in which the mother trees grow (Xu et al 2015, Zang et al 2016, Kołodziejek 2017). On other hand, the character of maternal and paternal parent also influences fruit and seed traits due to the nature of cross pollination in forest species (Kahn et al 2003, Lim and Lauders 2009). The

mahua is highly cross-pollinated species and many pollinating agents are involved in pollination. It could be one reason of wide variability occurrence in fruit and seed characters in mahua. Forest tree species are typically long-lived, highly heterozygous organisms that have developed natural mechanisms to maintain high levels of intraspecific

Table 6. PV, GV and MGT variation in *M. longifolia* var. *latifolia*

Open pollinated mother trees	Seed Germination (%)			GRI			MDG		
	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled	Year -1 (2015)	Year-2 (2016)	Pooled
MLLMG-1	2.22	2.40	2.31	9.74	9.16	9.45	16.50	15.35	15.93
MLLMG-2	1.51	2.08	1.80	4.96	8.52	6.74	16.46	16.04	16.25
MLLMG-3	1.43	1.33	1.38	4.04	3.60	3.82	17.73	17.88	17.81
MLLMG-4	2.37	1.85	2.11	9.40	7.31	8.36	16.22	16.02	16.12
MLLMG-5	2.27	2.78	2.53	8.26	10.37	9.32	15.77	15.00	15.39
MLLMG-6	0.84	1.83	1.34	1.79	6.84	4.32	18.95	17.85	18.40
MLLMG-7	2.27	1.96	2.12	8.84	6.60	7.72	17.14	16.68	16.91
MLLMG-8	2.50	2.12	2.31	12.56	8.68	10.62	15.33	15.97	15.65
MLLMG-9	1.88	2.45	2.17	6.06	11.20	8.63	17.86	14.81	16.34
MLLMG-10	1.48	1.27	1.38	5.54	5.59	5.57	15.69	17.30	16.50
Mean	1.87	2.01	1.94	7.11	7.79	7.45	16.75	16.29	16.53
CD @ 5%	0.59	0.82	0.52	3.75	3.67	NS	1.20	1.74	NS
CV (%)	24.30	32.01	28.69	41.05	36.78	38.82	5.54	8.34	7.40
CD @ 5% (YxT)	-	-	NS	-	-	3.64	-	-	1.48

PV= Peak Value; GV= Germination Value and MGT = Mean Germination Time

Table 7. Influence of fruit and seed traits on seed germination parameters in *M. longifolia* var. *latifolia*

Traits	FL (mm)	FT (mm)	FW (g)	SL (mm)	ST (mm)	SW (g)	SDW (g)	MC (%)	GRI	MDG	PV	GV	MGT
FL: Fruit length	-												
FT: Fruit thickness	0.534**												
FW: Fruit weight	0.809**	0.863**											
SL: Seed length	-0.038	-0.165	-0.235										
ST: Seed thickness	0.562**	-0.028	0.330	0.177									
SW: Seed weight	0.019	-0.225	-0.281	0.754**	0.363*								
SDW: Seed dry weight	0.432*	0.034	0.273	0.215	0.691**	0.273							
MC: Moisture Content	-0.511	-0.164	-0.467	0.250	-0.493	0.317	-0.806						
GRI	0.288	0.280	0.439*	-0.410	0.207	-0.267	0.239	-0.377					
MDG	0.331	0.278	0.437*	-0.189	0.228	-0.290	0.482**	-0.622	0.679**				
PV	0.236	0.337	0.298	-0.318	-0.107	-0.173	-0.095	0.009	0.572	0.215			
GV	0.330	0.397*	0.416*	-0.320	0.013	-0.212	0.117	-0.215	0.730**	0.545	0.925**		
MGT	-0.504	-0.469	-0.492	0.187	-0.181	0.026	-0.257	0.292	-0.597	-0.489	-0.598	-0.685	
Seed germination (%)	-0.047	-0.023	0.155	-0.306	0.106	-0.325	0.126	-0.275	0.741**	0.532	0.183	0.341	0.078

GRI =Germination Rate Index; MDG= Mean Daily Germination; PV= Peak Value; GV= Germination Value and MGT = Mean Germination Time

variation such as a high rate of out-crossing, and dispersal of pollen and seeds over wide areas (Anonymous 2013).

Variation in seed germination reflects adaptations to site conditions which strongly influence the seedling growth and survival. Seed germination capacity is one of the ecological important parameters and forest regeneration is highly depends upon seed germination, viability and seed set (Khurana and Singh 2001). Further, all these parameters along with ecological condition shape the forest structure and composition (Bhadouria et al 2016). Variability in the germination response of seeds from different provenances, populations, individuals of the same population, or from different locations in the crown of the same individual tree is well known (Mamo et al 2006). The seed source and individual trees have more influence on seed germination (Vasav et al 2011). Review shows that there are many studies pertaining to inter-population or provenance or seed source variation for seed germination attributes among forest tree species; however, intra-population variation for germination and its attributes is sparse. In fact, such studies are very important for a breeder to understand the genetic base of the population and information generated through this study would help in further selection and improvement of species.

In present study, year to year variation for seed germination and its attributes was not significant among mother plants within a population. In contrast, a significant intra-population variation was for seed germination parameter for each year of study among 10 OPMTs. Absolutely no report on intra-population variation for seed germination parameters in mahua, however, report on tree to tree variation for this trait has been recorded in mahua (Divakara et al 2011). Similar intra-population variation has been documented in other forest species (Gunaga & Vasudeva 2009, Gunaga et al 2015, Bansude et al 2013, Bhuva 2016, Smita et al 2015). Intra-population variability in germination is also a common occurrence in forest trees as a result of genetic factors (Van der Vegte 1978) and climate variability during seed ripening (Meyer and Allen 1999). Further, variability in seed germination may also be attributed owing to other maternal provisioning during seed development like hormones, proteins and nutrients.

Correlation study helps breeder to choose multiple traits for selection of superior individuals, especially during indirect selection. In many genetic studies, phenotypic and genotypic correlations are done for identifying suitable traits for tree selection. Study shows that bigger/heavier seeds speedup the germination and it may also produce higher seedling biomass (Gunaga et al 2010, Souza and Fagundes 2014). Therefore, selection of seedlot with heavier seeds may resulted in higher and speeder germination (Selvan and

Guleria 2012, Sofi and Singh 2013, Mishra et al 2014). In the present study, germination parameters such as GRI, MDG and GV is highly influenced by the fruit weight in mahua. Furthermore, dry weight of seeds also resulted in positive association with MDG, indicating bigger seeds speedup the germination. Therefore, fruit weight and seed biomass may be considered while selection of genotypes in mahua.

CONCLUSION

The study indicates strong intra-population variation for fruit and germination traits; however, no significant variation observed in most of the traits studied for the period of seed collection (year to year), which suggest that, fruit, seed and germination characters of mahua seed are sturdily controlled by genetic factors. Therefore, there is a lot of scope for selection of genotypes within a population. Perhaps, this would be the first report on intra-population variation in mahua. Traits such as fruit weight and thickness resulted in strong correlations with germination attributes; therefore, one should consider such fruit parameters while selecting better genotype as well as further breeding programme. The screening of superior genotypes within a population would help foresters and tree breeders to identify climate resilient individuals to grow without disturbance in the era of climate variation and recognize the reliable source of viable seeds for further programmes.

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AUTHOR'S CONTRIBUTION

Dr. H.T. Hegde - Conceptualization, investigation, original draft preparation; Dr. R.P. Gunaga-Methodology, formal analysis and supervision of the study; Dr. N. S. Thakur-Validation of data,review & editing; Dr. J.B. Bhusara, Dr. R.L. Soundarva & amp; D.C. Bhuva – Assistance in data collection, compilation & amp; field management activities.

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