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Genetic Variability on Growth, Phenological and Seed Characteristics of *Jatropha curcas* L.

Sagar MOHAPATRA, Prasanna Kumar PANDA

Institute of Minerals and Materials Technology, Natural Products Department (Council of Scientific and Industrial Research) Bhubaneswar-751 013, Orissa, India; Sagar.phdhfc@gmail.com (corresponding author)

Abstract

Twenty randomly selected seeds of *Jatropha curcas* collected from different agroclimatic zones of India were studied for variability on growth, phenology and seed characteristics in a progeny trial under tropical monsoon climatic conditions of Bhubaneswar (20^0 14'N/85^0 50' E), India. Correlation studies revealed that length and number of branches were positively correlated with the number of inflorescence (P<1%) and number of fruits per plant (P<5%). A positive correlation between fruit diameter and oil content and also, between seed length and test weight was observed. Number of fruits per plant showed almost 100% heritability followed by the number of inflorescence (88.79%). Non hierarchical Euclidean cluster analysis resulted in six clusters with highest number of six accessions namely, 'Chandaka', 'PKVJ-AKT-1', 'TNMC-4', 'PKVJ-MKU-1', 'TFRI-1' and Indore falling under cluster II. Maximum and minimum intra-cluster distances were observed for cluster II (2.929) and cluster III (0.000), respectively. Maximum inter-cluster distance (7.195) was found between cluster III and VI followed by Cluster III and IV (7.074). Analysis of the results of the present study clearly indicate that crossing between the accessions of cluster III and VI would be useful in developing variable genotypes in the subsequent generations.

Keywords: heritability, correlation, Euclidean cluster analysis, divergence studies

Introduction

On the backdrop of increased prices of petroleum products coupled with depletion of fossil fuel reserves and compelling environmental reasons to reduce green-house gas emission, there has been a world-wide interest for searching alternate sources of raw-material for fuels. In recent years *Jatropha curcas* L., a perennial plant belonging to family *Euphorbiaceae* has received considerable attention from researchers as a potential source of non-edible vegetable oil which is eminently suitable for production of liquid bio fuel, meeting international standards (Azam *et al.,* 2005; Tiwari *et al.,* 2007). The plant is reported to grow in diverse habitat and eco-physiological regions with minimum cultural practices (Behera *et al.,* 2010; Jongschaap *et al.,* 2007). In spite of its large-scale cultivation that has been undertaken in recent years in many countries, *Jatropha* is still considered a wild plant and there exists considerable amount of genetic variability to be exploited for realization of a potential economic yield (Rao *et al.,* 2008). Kaushik *et al.* (2007) reported divergence in seed oil traits of *Jatropha curcas* from a limited number of locally collected accessions. Ginwal *et al.* (2005) reported seed source variability of *Jatropha curcas* in central India. Ranade *et al.* (2008) assessed 12 germplasms of *Jatropha curcas* through molecular markers and reported a wide diversity among them. One of the important limitations for selection regarding crop improvement is the lack of adequate information on the extent of diversity present in the germplasms. Since genetic variation on growth and seed oil content at variety or progeny level can be expected in an out crossing species like *Jatropha*, the evaluation of such variation would be beneficial for future genetic selection when the desired ideotypes for agroforestry systems are clearly defined (Burley *et al.,* 1984; Canel, 1982). Considering the potential economic importance of Jatropha, progeny trials for genetic variation in branching pattern, male to female flower ratio, fruiting ability, disease and pest resistance, drought hardiness and yield attributes assumes great significance in crop improvement programmes and for developing standard agro-techniques (Von Carlowitz, 1986). Therefore the present study was undertaken with the objective to evaluate the variation in vegetative, flowering, fruiting, seed and oil traits for 20 accessions collected from various places from India under the agro-climatic conditions of eastern India (20^{0}14′N/85^{0}50′E).

Materials and methods

Seeds from dry matured fruits were collected from twenty morphologically superior candidate plus trees (CPTs) occurring in wild conditions as well as from designated research farms of India during June 2004 from latitude ranging 11°00'-23°50'N and Longitude 74°38'-86-°25'E. The seeds were sown in polythene bags filled with compost during July 2004 at the Medicinal Plants Research Garden, IMMT, Bhubaneswar. The soil of IMMT is classified as an Aeric Tropaquept with soil order Inceptisol. The

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soil is sandy loam (83.2% sand, 6.6% silt and 10.2% clay) with pH-5.52 and EC-0.076 mS cm^{-1}. Seedlings after attaining 30 cm height were transplanted to the field during monsoon season (August, 2004) with 3m×3m spacing. Randomized block design was followed with 3 replications for each set of accession. The plots in each replication comprised of 25 plants. The selection was based upon phenotypic characters of economic potential (Rao *et al.,* 2008). After attaining 4 years of age, when the economic yield starts, field experiment was conducted under rainfed conditions and repeated twice (2008-2009). Biometrical observations from five randomly selected plants were recorded, leaving the border ones.

The plant height, collar diameter, and length of branches were measured (in cm) and numbers of newly formed branches and inflorescence were counted on each of the selected plants in three replications. Similarly total number of flowers and female flowers per inflorescence were counted daily up to complete opening. Days required for fruiting were recorded when the petals were shed down and ovary had swollen. Seeds were harvested from fully ripened fruits by carefully removing the shell manually. The seeds were sun dried for 10 days, winnowed and stored in muslin cloth bags. Single seed weight and test weight (expressed in grams) of seeds was taken separately by weighing five random samples of undamaged seeds and from each lot comprising 100 seeds, respectively.

Oil content of seeds was estimated by solvent extraction method with soxhlet apparatus using three replicates for each seed lot. Petroleum ether (boiling point 60°C-80°C) was used as solvent. Data thus obtained were subjected to statistical analysis. Analysis of variance was carried out following the procedure given by Panse and Sukhatme (1976). The variability, heritability in broad sense, genetic advance as percent of mean, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were worked out for all the parameters.

Results

Variability in growth, flowering, fruiting, seed and oil characteristics

Significant variation was observed in branch growth during the active growth period (Tab. 1). Maximum branch length of 25.25 cm was observed in 'Baramunda' followed by 'Raipur' which recorded 22.37 cm. Accessions 'Kalyanpur', 'Mancheswar', 'Ambikapur' and 'PKVJ-MKU-1'recorded at par branch lengths *viz*; 22.10 cm, 21.38 cm, 20.99 cm and 20.82 cm respectively. Other accessions attained branch lengths less than 20 cm. Significant variation was recorded with regards to number of branches among the accessions. Maximum number of branches 43.77 was recorded in 'Baramunda' followed by 41.57 in 'TNMC-3'. Accession 'RJ 117' and 'PKVJ-

Tab. 1. Mean values of growth, flowering, fruiting, seed and oil characteristics of *Jatropha* accessions (Pooled data 08-09)

Accessions	LB	NB	NI	NF	NFF	MF/FF	DFr	DFrR	NFrPP	FrDia	SL	SB	SSW	TW	OIL
'RJ-117'	19.87	34.66	40.40	96.39	7.27	12.72	34.86	30.52	122.05	2.41	1.58	1.18	0.40	33.43	31.10
'TNMC-3'	16.03	41.57	27.20	97.08	9.90	9.57	31.72	31.13	94.62	2.50	1.68	1.14	0.38	33.28	33.03
'PKVJ-DHW-1'	16.78	25.80	29.97	110.15	6.82	16.45	16.73	32.55	79.49	2.42	1.64	1.12	0.34	35.20	31.33
'Raipur'	22.37	27.50	40.80	110.97	9.23	12.24	29.10	31.68	113.95	2.49	1.62	1.15	0.27	33.77	33.50
'PKVJ-SJ-1'	13.50	25.66	13.82	131.65	8.23	14.98	34.18	31.28	90.81	2.52	1.83	1.12	0.30	35.22	31.67
'Sagar'	18.71	26.58	24.57	137.47	8.08	16.45	32.32	32.28	58.10	2.44	1.65	1.13	0.32	34.54	33.57
'Chandaka'	16.94	21.04	17.12	126.17	8.03	15.57	25.47	32.62	66.46	2.58	1.73	1.15	0.36	35.32	30.03
'PKVJ-AKT-1'	19.15	32.47	17.65	134.90	12.31	12.18	25.45	29.62	39.00	2.52	1.57	1.12	0.30	29.35	32.67
'TNMC-2'	13.06	18.19	11.00	119.83	11.88	11.18	10.57	31.02	99.04	2.61	1.87	1.15	0.35	38.11	31.77
'TNMC-4'	16.53	21.80	36.60	92.46	10.05	10.21	22.65	29.36	40.86	2.45	1.72	1.15	0.38	32.60	30.45
'Mancheswar'	21.38	21.52	23.65	100.49	9.16	11.35	29.76	30.73	107.46	2.52	1.79	1.12	0.38	35.82	35.13
'Kendrapada'	17.96	24.13	26.43	117.22	7.27	16.46	33.52	27.99	47.64	2.42	1.78	1.14	0.36	37.83	31.33
'Ambikapur'	20.99	23.06	25.52	129.60	7.33	17.46	29.77	37.73	81.07	2.45	1.85	1.15	0.36	36.39	33.33
'PKVJ-MKU-1'	20.82	16.94	22.41	104.01	10.07	9.87	26.00	31.44	106.75	2.60	1.69	1.15	0.26	35.79	30.83
'Pendraroad'	16.43	14.24	20.95	125.56	8.08	15.15	28.64	34.80	46.26	2.54	1.64	1.12	0.33	36.52	31.00
'Kalyanpur'	22.10	26.87	23.22	139.20	7.01	19.82	27.66	28.53	60.76	2.60	1.77	1.31	0.44	37.04	31.50
'TFRI-2'	18.70	24.15	18.30	141.22	8.47	16.30	31.26	28.82	49.49	2.56	1.79	1.12	0.40	37.36	32.67
'TFRI-1'	17.48	20.73	13.55	110.72	8.94	11.97	27.69	30.07	51.99	2.52	1.76	1.12	0.35	32.36	32.67
'Indore'	17.07	17.75	17.27	115.85	12.14	9.90	18.56	31.89	34.12	2.63	1.76	1.10	0.34	30.32	30.67
'Baramunda'	25.25	43.77	45.78	132.36	12.00	12.49	23.45	32.44	162.34	2.71	1.79	1.17	0.40	33.97	36.33
Mean	18.56	25.42	24.81	118.67	9.11	13.62	26.97	31.32	77.61	2.52	1.72	1.14	0.35	34.71	32.22
C.D.	2.498**	4.814**	3.650**	8.522**	1.354**	3.366**	3.104**	2.732**	4.88**	0.094**	0.154**	0.078**	0.050**	3.046**	1.654**
SEm (±)	1.249	2.407	1.825	4.261	0.677	1.683	1.552	1.366	2.44	0.047	0.077	0.039	0.025	1.523	0.827

** Significant at 1%**;** LB- Length of branch (cm), NB-Number of branches, NI-Number of inflorescence per plant, NF- Number of flowers per inflorescence, NFF- Number of female flowers per inflorescence, MF/FF-Male to female flower ratio, DFr- Days to fruiting, DFrR- Days to fruit ripening, NFrPP- Number of fruits per plant, FrDia- Fruit diameter (cm), SL= Seed length (cm), SB= Seed breadth (cm), SSW- Single seed weight (g), TW- Test weight (g), OIL- Oil content

AKT-1' were having branches of more than 30 numbers i.e., 34.66 and 32.47 respectively. The recorded data pertaining to flowering parameters showed significant variation among the accessions. The number of inflorescence per plant showed a high degree of variability. Maximum number of inflorescence (45.78) was observed in 'Baramunda' followed 'Raipur' by (40.80). Six accessions namely 'PKVJ-SJ-1', 'Sagar', 'PKVJ-AKT-1', 'Kalyanpur', 'TFRI-2' and 'Baramunda'were having more than 130 numbers of flowers per inflorescence. Among these, maximum flowers (141.22) were observed in 'TFRI-2'. In rest of the accessions flower numbers ranged between 92.46 and 139.20. Maximum number of female flowers per inflorescence (12.31) was recorded in 'PKVJ-AKT-1'. The male to female flower ratio was highest in 'Kalyanpur' (19.82) followed by 'Ambikapur' (17.46). The lowest ratio (9.57) was observed in 'TNMC-3'. Days taken from flowering to fruiting varied between a minimum of 10.57 to a maximum of 34.86 days. The mean number of days required to reach fruiting stage after flowering was 26.97 days, where as the mean value for fruiting to ripening was 31.32 days for all accessions. 'Baramunda' yielded the maximum number of fruits (162.34) per plant followed by (122.05) in 'RJ-117'. Fruit diameter of the studied materials ranged between a minimum value of 2.41 cm in 'RJ-117' to a maximum value of 2.71 cm in 'Baramunda'.

All the accessions showed significant variability for seed length, seed breadth, single seed weight, test weight and oil content (Tab. 1). Seed length was maximum (1.87 cm) in 'TNMC-2', whereas maximum seed breadth (1.31 cm) was observed in 'Kalyanpur'. Maximum single seed weight (0.44 g) was observed in 'Kalyanpur' followed by 0.40 g each in 'RJ-117', 'TFRI-2' and 'Baramunda'. For 100 seed test weight the top ranking (38.11 g) accession was 'TNMC-2' closely followed by 'Kendrapada' and 'TFRI-2'. Minimum 100 seed weight (29.35 g) was observed in 'PKVJ-AKT-1'. Seed Oil content varied significantly among different accessions, from the maximum of 36.33% in 'Baramunda'to the minimum of 30.03% in 'Chandaka'.

Genetic association for growth, flowering, fruiting, seed and oil characteristics

The amount of genetic variations and association was evident from the study of GCV, PCV and correlation analysis. Significant correlation was observed between the length of branch, number of inflorescence plant^{-1} and number of fruits plant^{-1} (Tab. 2). Positive *r* values were found with other characters like number of flowers, male to female flower ratio, days to fruiting and days to fruit ripening. Correlation of number of branches with characters like number of flowers, number of female flowers and days to fruiting however exhibited positive values, but it was significantly correlated with the number of inflorescence and number of fruits plant^{-1}. Similarly number of inflorescence per plant was significantly correlated with the number of fruits plant^{-1} at both genotypic and phenotypic levels. Number of flowers per inflorescence was significantly correlated with male to female flower ratio. Other characters were not significantly correlated with each other.

Seed and oil traits recorded significant variation. Fruit diameter was significantly correlated with seed length, breadth and oil content from the genotypic point of view (Tab. 3). Similarly seed length was genotypically signifi-

Tab. 2. Genotypic (G) and Phenotypic (P) correlation between plant physical and phenological attributes (Pooled data 08-09)

Characters	G/P	NB	NI	NF	NFF	MF/FF	DFr	DFrR	NFrPP
LB	G	0.382	0.611**	0.134	-0.159	0.213	0.267	0.062	0.454*
	P	0.382	0.512*	0.138	-0.078	0.189	0.234	0.020	0.352
NB	G		0.632**	0.004	0.200	-0.073	0.272	-0.057	0.553*
	P		0.555*	0.040	0.115	0.006	0.220	-0.097	0.488*
NI	G			-0.506*	-0.244	-0.083	0.181	0.072	0.559*
	P			-0.383	-0.112	-0.024	0.164	0.012	0.521*
NF	G				-0.483*	0.829**	0.048	0.272	-0.394
	P				-0.224	0.515*	0.098	0.082	-0.332
NFF	G					-0.943**	-1.062**	-0.295	-0.005
	P					-0.620**	-0.604	0.123	0.006
MF/FF	G						0.356	0.248	-0.265
	P						0.191	0.010	-0.158
DFr	G							-0.107	0.028
	P							-0.132	0.024
DFrR	G								0.247
	P								0.165

**Significant at 1%, *Significant at 5%; LB- Length of branch (cm), NB-Number of branches, NI- Number of inflorescence per plant, NF- Number of flowers per inflorescence, NFF- Number of female flowers per inflorescence, MF/FF-Male to female flower ratio, DFr- Days to fruiting, DFrR- Days to fruit ripening, NFrPP-Number of fruits per plant

Tab. 3. Genotypic (G) and phenotypic (P) correlation coefficients between seed and oil traits in *Jatropha curcas* (Pooled data 08-09)

Characters	G/P	SL	SB	SSW	TW	OIL
FrDia	G	0.917**	0.595**	0.086	0.023	0.459*
	P	0.100	0.135	-0.113	-0.064	0.108
SL	G		-0.030	0.300	0.516*	0.172-
	P		-0.050	-0.045	0.118	0.082
SB	G			0.672**	0.346	-0.085
	P			0.266	0.095	-0.033
SSW	G				0.226	0.122
	P				0.152	0.211
TW	G					-0.035
	P					0.083

** Significant at 1%, * Significant at 5% and Oil content in %; FrDia- Fruit diameter (cm), SL= Seed length (cm), SB= Seed breadth (cm), SSW- Single seed weight (g), TW- Test weight (g), OIL- Oil content

cantly correlated ($P<0.05$) with test weight, but the *r* value of seed breadth was high with single seed weight. Single seed weight was positively correlated with test weight and oil content but with no significance.

Number of fruits per plant exhibited high GCV and PCV followed by number of inflorescence and the number of branches (Tab. 4). Broad sense heritability was generally higher than 50 .00% for all characters except for number of flowers, male to female flower ratio, days to fruiting, fruit diameter, seed length and breadth and test weight. Number of fruits per plant showed near to 100% heritability (98.18%) followed by number of inflorescence per plant (88.79%). Fruit diameter showed significantly less heritability near 15%. Similarly genetic advance for number of fruits plant^{-1} was the highest (82.46%). Other characters registered gain from 1% to 54 % with the lowest one being 1.19 for fruit diameter.

Divergence studies

On the basis of non-hierarchical Euclidian cluster analysis, 20 accessions were grouped into 6 clusters (Tab. 5). A maximum of 6 accessions were included in cluster II followed by 5 accessions in cluster V, where as cluster III and VI included only 1 accession. The cluster pattern exhibited that geographical diversity need not to necessarily be correlated with genetic diversity. The inter and intra-cluster distances are presented in (Tab. 6). The intra-cluster distances ranged from 0.000 to 2.929 with a maximum value in cluster II followed by cluster IV and cluster V. Minimum intra-cluster distance was found in cluster III. The highest inter cluster distance was found between cluster III and VI (7.195) followed by cluster III and IV (7.074). The minimum inter-cluster distance was found between clusters I and V (2.868).

Discussion

The present study has conclusively established significant variations in the progeny trial of the crop for growth, flowering, fruiting and seed characters. Branch length and number of branches are important characters for the selection of this crop when the objective is to include *Jatropha* in an agroforestry system. On the other hand the variation observed in flowering, fruiting and seed characters can be useful in selecting plants for block plantation with the primary objective to have higher yield of seeds.

Tab. 4. Estimates of genetic variables for growth, phenological, seed and oil traits of *Jatropha* germplasms (Pooled data 08-09)

Traits	Mean	Range		Coefficient of variation		Heritability (broad sense)	Genetic advance as % of mean
		Min.	Max.	Genotypic	Phenotypic		
LB	18.56	13.50	25.25	15.74	19.59	64.58	26.08
NB	25.42	14.24	43.77	29.95	34.15	76.86	54.13
NI	24.81	11.00	45.78	35.92	38.11	88.79	69.73
NF	118.67	92.46	141.22	10.34	12.07	73.37	18.25
NFF	09.11	6.82	12.31	11.14	17.03	42.77	15.04
MF/FF	13.62	9.57	19.82	18.30	28.17	42.18	24.45
DFr	26.97	10.57	34.86	22.48	24.59	83.58	42.34
DFrR	31.32	27.99	37.73	06.60	10.03	43.29	08.97
NFrPP	77.61	34.12	162.34	40.39	40.76	98.18	82.46
FrDia	02.52	2.41	2.71	01.41	03.58	15.49	01.19
SL	01.72	1.57	1.87	04.97	09.27	28.76	05.23
SB	01.14	1.10	1.31	02.88	06.67	18.67	02.63
SSW	00.35	0.26	0.44	12.56	17.74	50.16	17.14
TW	34.71	38.11	29.35	06.75	10.16	44.08	09.22
OIL	32.22	30.03	36.33	04.96	06.66	55.39	07.60

LB- Length of branch (cm), NB-Number of branches, NI- Number of inflorescence, NFPI- Number of flowers per inflorescence, NFF- Number of female flowers per inflorescence, MF/FF-Male to female flower ratio, DFr- Days to fruiting, DFrR- Days to fruit ripening, NFrPP- Number of fruits per plant, FrDia- Fruit diameter (cm), SL= Seed length (cm), SB- Seed breadth (cm), SSW- Single seed weight (g), TW- Test weight (g), OIL- Oil content

Tab. 5. Composition of Euclidean clusters for growth, flowering, fruiting, seed and oil traits in *Jatropha curcas*

Cluster	Number of accessions	Accessions
I	3	'PKVJ-SJ-1', 'Kendrapada', 'TFRI-2'
II	6	'Chandaka', 'PKVJ-AKT-1', 'TNMC-4', 'PKVJ-MKU-1', 'TFRI-1', 'Indore'
III	1	'Kalyanpur'
IV	4	'RJ-117', 'TNMC-3', Raipur, 'Baramunda'
V	5	'PKVJ-DHW-1', 'Sagar', 'Mancheswar', 'Ambikapur', 'Pendra Road'
VI	1	'TNMC-2'

Tab. 6. Estimates of inter and intra-cluster distances for growth, flowering, fruiting, seed and oil traits in *Jatropha curcas*

Clusters	I	II	III	IV	V	VI
I	1.825					
II	3.907	2.929				
III	5.486	6.875	0.000			
IV	4.807	4.187	7.074	2.790		
V	2.868	3.224	6.224	3.642	2.618	
VI	4.995	4.920	7.195	6.536	4.966	0.002

The study of seed characters of tree born oilseed (TBO) crops of natural population is often considered to be useful in evaluation of the genetic variability. Variation in the morphological characters could be due to the fact that the species grow over a wide range of rainfall, temperature and soil types. Such variations in relation with the habitat in *Jatropha* have also been reported by Ginwal *et al.* (2005); Kaushik *et al.* (2003), and Kumar *et al.* (2003). Therefore the present set of accessions having more seed weight and oil content could be used for crop improvement programmes. High estimates of heritability (broad sense) for these characters, as observed in the present study (Tab. 4) revealed the heritable nature of variability present in the collected accessions.

Studies of branch length, number of branches, number of inflorescence, number of flowers, days to fruiting and number of fruits per plant have a distinctly higher heritability in broad sense than other characters. High heritability of these phenological traits is reported to be an important factor in tree breeding programmes as it provides an index of the relative role of heredity and the environment in the expression of various traits (Dorman, 1976). High heritability accompanied by high genetic advance for growth parameters have been reported by Solanki *et al.* (1984) in *Prosopis cineraria*. Hence these characters can be treated as best gain characteristics for *Jatropha* improvement programme because of its strong genetic control and the wide variability. It should be noted that estimation of heritability is of little significance in selection based breeding programme unless accompanied by sufficient genetic gain (Tefera *et al.,* 2003). Except for the number of fruits and number of inflorescence all characters showed low to moderate genetic gain indicating that improvement could be made for these characters. This may be due to extreme variation in the materials studied.

On the other hand characters like number of female flowers, male to female flower ratio, days to fruiting, days to fruit ripening, fruit diameter, seed length, seed breadth and test weight may not be taken as selection indices for *Jatropha* improvement because of the low heritability for these traits, as observed in the present set of experiments (Tab. 4). This is contrary to earlier findings of Rao *et al.,* (2008) who reported that seed test weight could be one of the selection indices for *Jatropha*.

The correlation matrix revealed that statistically significant correlation (P<1% and P<5%) exists between the number of branches, number of inflorescence and number of fruits per plant. This can be explained that during growth period the appearance of morphological determinants viz., the number of branches contributed to a higher number of inflorescence *vis-à-vis* female flowers, which contributed to more fruit and net oil yield. Similar results have been reported for other tree borne oil seeds (Kaura *et al.,* 1998). Therefore on the basis of the data from these analyses, higher number of branches, inflorescence and fruit diameter can be considered as important traits for early selection with the objective to have more yield of seed *vis-à-vis* oil. Such early selection on the basis of these traits is of great relevance in a crop like Jatropha, where the potential yield of the crop comes only after four to five years of growth after planting.

Tab. 7. Cluster mean values for growth, flowering, fruiting, seed and oil traits

Cluster	LB	NB	NI	NF	NFF	MF/FF	DFr	DFrR	NFrPP	FrDia	SL	SB	SSW	TW	OIL
I	16.72	24.65	19.52	130.03	7.99	15.91	32.99	29.36	62.65	2.50	1.80	1.13	0.35	36.80	31.89
II	18.00	21.79	20.77	114.02	10.26	11.62	24.30	30.83	56.53	2.55	1.71	1.13	0.33	32.62	31.22
III	22.10	26.87	23.22	139.20	7.01	19.82	27.66	28.53	60.76	2.60	1.77	1.31	0.44	37.04	31.50
IV	18.66	36.42	31.80	114.37	9.35	12.44	31.05	31.34	117.46	2.54	1.72	1.15	0.37	33.98	33.03
V	18.86	22.24	24.93	120.65	7.97	15.37	27.44	33.62	74.48	2.47	1.71	1.13	0.35	35.69	32.87
VI	13.06	18.19	11.00	119.83	11.88	11.18	10.57	31.02	99.04	2.61	1.87	1.15	0.35	38.11	31.77

LB- Length of branch (cm), NB-Number of branches, NI- Number of inflorescence, NFPI- Number of flowers per inflorescence, NFF- Number of female flowers per inflorescence, MF/FF-Male to female flower ratio, DFr- Days to fruiting, DFrR- Days to fruit ripening, NFrPP- Number of fruits per plant, FrDia- Fruit diameter (cm), SL= Seed length (cm), SB- Seed breadth (cm), SSW- Single seed weight (g), TW- Test weight (g), OIL- Oil content

Maximum intra-cluster distance (2.929) in cluster II indicates the chances of selection of parents for hybridization within the cluster. The maximum inter-cluster distance (7.195) between cluster III and VI followed by cluster III and IV (7.074) indicates wider genetic diversity between the trees in these groups. Selection of parent materials from such clusters for hybridization programme will develop elite plants with desirable characters. The minimum inter-cluster distance between clusters I and V indicate that trees in these groups are closely related. Therefore the selection of parent trees from these clusters should be avoided. Theoretically the clusters that are having more inter-cluster distance and high mean will produce divergent candidates. Hens trees from cluster III and VI should be selected as parents for *Jatropha* improvement programme.

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