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Genetic Variability, Character Association and Path Analysis in *Jatropha curcas*

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Abstract : Sixteen *Jatropha curcas* genotypes collected from four states were grown in randomized block design and evaluated for 12 characters. The genotypes showed significant differences in most component traits and seed yield, excepting primary branches/plant, fruits/bunch and seeds/fruit. The genotypes Utkal nursery, Phule1, IST 1, Jodhpur1 and Chhatrapati had above average (>84.7 g) seed yield/plant. Phenotypic coefficient of variation (PCV) & genotypic coefficient of variation (GCV) estimates were high for seed yield/plant followed by flowering bunches/plant, fruits/plant and secondary branches/plant. Heritability was high (>80%) for plant height, fruits/plant and 100 seed weight. Genetic advance (GA) was high (>50%) for seed yield/plant, fruits/plant and flowering bunches/plant. Moderate to high heritability accompanied with high genetic advance for seed yield/plant, fruits/plant and flowering bunches/plant indicated additive gene action and selection for these characters would be effective. Fruits/plant, flowering branches and bunches/plant, collar diameter and secondary branches/plant had high positive correlation with seed yield/plant. Flowering bunches/plant and fruits/plant had high positive direct effect on yield and indirect positive effect via these two traits greatly influenced positive association of other traits with yield. Seeds/fruit and 100 seed weight had moderate positive direct effect on yield. The remaining seven component traits had very low direct effect on yield. The character association and path analysis study revealed that selection for flowering bunches/plant and fruits/plant would be highly effective in bringing out improvement in yield. Selection for seeds/fruit and 100 seed weight would result in some improvement in yield. Thus, the ideotype to achieve high yield in *Jatropha* should have more number of flowering bunches/plant and fruits per plant and moderate to high value for seeds/fruit and 100- seed weight.

Key words: Jatropha curcas · Genetic parameter · Character association · Path analysis

INTRODUCTION

Jatropha curcas Linn. (Physic nut or Ratanjot) is a tree-borne oil seed crop. It is native to Tropical America and belongs to family Euphorbiaceae. It can grow well in different kinds of soils, tolerate drought conditions and animals do not browse its leaves [1, 2]. It is a versatile plant with multiple uses and it has gained more popularity due to its biofuel property. *Jatropha* has evoked interest all over the world in comparison to other tree-borne oil seed crops because of its better adaptation to a wide range of environmental conditions, low cost of seeds, high oil content, small gestation period and smaller plant size that makes the seed collection easier [3]. Jatropha helps in increasing rural economy and self sustainability for agro industries [4]. Nevertheless, until now this crop has not been fully domesticated. Success of commercial cultivation of Jatropha is much dependent on use of high-yielding genotypes instead of low-yielding local genotypes, therefore genetic improvement of this crop is quite indispensable to develop high-yielding genotypes. Selection/development of high yielding genotypes depends on the genetic variability present in the gene pool. Sakaguchi and Somabi [5] studied forty genotypes of *J. curcas* from different places of Thiland but did not find much variation in morphological traits.

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Ginwal *et al*. [6] reported significant variation in seed morphology and seedling growth parameters like seedling height, collar diameter, and leaves/plant in 10 accessions of *J. curcas.* Kaushik *et al*. [7] studied variability in seed traits of 24 *J. curcas* accessions and observed significant differences in seed size and 100 seed weight. Rao *et al.* [8] studied genetic variability and diversity in seed and growth characters of thirty-two candidate plus trees.Gohil and Pandya [9] evaluated nine *J. curcas* genotypes to study genetic variability and heritability.The objective of the present investigation was to quantify the magnitude of genetic variability present in the existing base population, study the association among characters and to identify important yield attributing characters, selection for which would help in development of high yielding *Jatropha* genotypes.

MATERIALS AND METHODS

Plant materials comprised of 16 genotypes, collected from four different regions of India. The seeds were sown directly in polythene bags (one seed per bag) before planting in the main field. Three-month-old seedlings were planted in the main field at a spacing of 2 m x 2 m on 1st week of August 2005 (East and South-East Coastal Plain Zone, 20°15' N latitude and 85°52' E longitude). The experiment was conducted in a randomized block design with two replications under India coordinated research project on agroforestry at Central Research Station, OUAT, Bhubaneswar. The plot size was 10 x 6 m, fertilizers were applied @ 20:40:20 kg of N: P: K / hectare each year. This study is on the 3rd year (2007-8). Observations on plant height (cm), collar diameter (cm), number of primary branches/plant, number of secondary branches/plant, number of flowering branches/plant, number of flowering bunches/plant, number of female flowers/bunch, number of fruits/bunch, number of fruits/plant, number of seeds/fruit, 100 seed weight and seed yield/plant were recorded on 5 random competitive plants/plot. The data on the 12 traits was analyzed in RBD. Genetic variability parameters, heritability and genetic advance of the traits were estimated following Al-Jibouri *et al.* [10]. The phenotypic correlation between pairs of characters were computed according to formulae suggested by Robinson *et al.* [11] and the correlations of the component traits with yield was partitioned into direct and indirect effects by path co-efficient analysis following Dewey and Lu [12].

RESULTS

Mean performance of 16 *Jatropha curcas* genotypes in respect of 12 characters is presented in Table 1. Seed yield of the genotypes varied from 40.5 to 196.4 g/plant with an average of 84.7 g/plant. The genotypes Utkal nursery, Phule1, IST 1, Jodhpur1 and Chhatrapati had above average (>84.7 g) seed yield/plant. Phule1 and IST 1 recorded high value in respect of all the characters studied. Utkal nursery, the highest yielder, had fewer fruits/bunch but its high yield is mainly due to very high flowering branches/plant (22.3) and fruits/plant and moderate values for other traits. Jodhpur1 showed low performance for flowering bunches/plant and above average performance for rest of the characters. Chhatrapati showed low performance for plant height and 100 seed weight and high performance for other characters. The genotypes JSK 2-1, JSK 2-2, JSK 2-3, JH 1 and Urlikanchan showed very low yield performance of less than 50 g/plant.

The 16 Jatropha genotypes showed variation in the traits (Table 2) and analysis of variance indicated significant differences among the genotypes for all traits studied except primary branches/plant, fruits/bunch and seeds/fruit. Phenotypic & genotypic coefficient of variations (PCV & GCV) were highest for seed yield/plant (66.24% & 58.38%) followed by flowering bunches/plant, fruits/plant and secondary branches/plant. Plant height, collar diameter, seeds/fruit and 100-seed weight showed low value percentage <20 for both PCV & GCV. Heritability estimates in broad sense were found to be high (>80%) for 100-seed weight, fruits/plant and plant height, moderate (60-80%) for collar diameter, secondary branches/plant, flowering branches/plant, flowering bunches/plant, female flowers/bunch and seed yield/plant and low for other traits. Genetic advance (at 20% selection intensity) as percentage of mean was high (>50%) for seed yield/plant (71.6%) followed by fruits/plant and flowering bunches/plant, moderate (30-50 %) for flowering branches/plant and secondary branches/plant and low for other traits.

The phenotypic correlation (r_p) estimates among the 12 traits ranged from 0.097 to 0.897 and 35 of the r_p estimates were significant (Table 3). All the 11 component traits showed positive correlation with yield and among themselves but the magnitude of association varied. Fruits/plant, flowering bunches/plant, collar diameter and flowering branches/plant showed highly significant positive correlation (0.839-0.678) with seed yield/plant.

Table 1: Mean performance of 16 *Jatropha curcas* genotypes

Genotype	Plant Height (cm)	Collar Diameter (cm)	Primary Branches/plant	Secondary Branches/plant	Flowering Branches/plant	Flowering Bunches/plant	Female Flowers/bunch	Fruits /bunch	Fruits /plant	Seeds /fruit	100 seed wt. (g)	Seed yield /plant (g)
ND	176.9	5.90	5.40	9.70	6.35	7.15	8.75	6.05	31.9	1.95	79.3	51.9
Jodhpur 1	196.5	7.85	6.20	12.3	9.05	9.05	12.0	8.10	56.5	2.60	98.3	133.5
JSK 2-3	120.5	4.90	3.10	8.10	5.75	5.95	5.15	5.80	25.5	1.80	48.9	40.5
SKNJ 4	170.5	6.20	3.15	7.85	5.75	7.70	10.9	6.95	33.0	2.20	81.8	51.1
JSK-2-1	154.5	5.75	4.85	8.20	5.35	6.45	9.50	5.65	31.0	2.10	51.9	37.8
Phule 1	169.8	7.90	5.40	12.4	10.3	16.9	10.3	8.20	72.0	2.50	92.1	181.5
IST 1	185.2	7.75	5.00	11.7	9.00	12.8	12.0	7.40	71.4	2.30	89.4	140.4
JH 1	146.3	5.85	4.55	7.75	7.90	8.40	5.30	5.40	25.6	1.70	75.8	34.8
Jodhpur 2	192.4	6.55	6.65	13.4	12.1	15.4	11.5	7.85	75.4	1.60	60.1	69.9
JSK 2-2	117.4	4.65	3.15	6.25	5.25	6.75	8.90	6.50	34.7	1.60	75.3	48.9
Chhatrapati	153.3	6.85	5.95	12.4	10.8	14.1	10.7	8.05	78.5	2.30	70.1	123.3
Jodhpur 3	136.5	5.40	3.20	7.95	6.85	10.4	7.15	5.20	43.0	2.20	76.8	64.2
Hansaraj	136.9	6.40	4.25	8.05	6.60	9.90	8.25	7.30	44.2	2.15	70.1	70.2
SKN (big)	151.1	5.95	6.00	7.65	4.35	6.20	9.20	5.90	33.0	2.45	75.0	71.8
Urlikanchan	143.4	5.45	2.70	3.70	4.90	7.35	8.10	6.30	32.3	1.90	66.5	39.8
Utkal nursery	225.4	7.70	4.95	14.9	12.7	22.3	11.5	6.50	87.7	2.45	77.10	196.4
Grand mean	161.0	6.32	4.66	9.51	7.66	10.4	9.32	6.70	48.5	2.11	74.3	84.7
CD (5%)	21.2	1.35	NS	3.96	3.45	5.28	2.26	NS	13.9	NS	5.88	56.5

Table 2: Genetic parameter of yield and component traits in *J. curcas*

Character	Mean	Range	PCV (%)	GCV (%)	Heritability (broad sense)	GA (20%)	GA (% mean)	F-value
Plant height (cm)	161.0	117.4-225.4	18.7	17.7	89.0	37.6	23.3	17.24**
Collar diameter (cm)	6.32	4.65-7.85	18.0	15.0	68.9	1.10	17.4	5.45*
Primary branches/plant	4.66	2.70-6.65	31.7	22.1	48.5	1.00	21.5	2.88
Secondary branches/plant	9.51	3.70-14.9	34.4	28.3	67.7	3.11	32.7	5.19*
Flowering branches/plant	7.66	4.35-12.7	37.8	31.3	68.6	2.78	36.3	5.36*
Flowering bunches/plant	10.4	5.95-22.3	47.8	41.5	75.2	5.25	50.5	7.08*
Female flowers/bunch	9.32	5.15-12.0	24.6	21.8	78.6	2.52	27.0	8.38*
Fruits/bunch	6.70	5.20-8.10	18.2	11.3	38.5	0.66	9.90	2.25
Fruits/plant	48.4	25.5-87.7	45.3	43.3	91.1	28.0	57.9	21.49**
Seeds/fruit	2.11	1.60-2.60	18.8	10.6	31.9	0.18	8.53	1.94
100 seed wt. (g)	74.5	48.9-98.3	18.1	17.8	95.8	18.1	24.2	46.68**
Seed yield/plant (g)	85.3	40.5-196.4	66.2	58.4	77.7	61.1	71.6	7.96*

Table 3: Phenotypic correlation among yield components traits in *Jatropha curcas*

Characters	Collar Diameter (cm)	Primary Branches /plant	Secondary Branches /plant	Flowering Branches /plant	Flowering Bunches /plant	Female Flowers /bunch	Fruits /bunch	Fruits /plant	Seeds /fruit	100 seed wt. (g)	Seed yield /plant (g)
1. Plant height (cm)	0.688**	0.524*	0.683**	0.607*	0.569*	0.666**	0.361	0.609*	0.419	0.432	0.619*
2. Collar diameter (cm)		0.454	0.725**	0.679**	0.654**	0.625**	0.643**	0.670**	0.463	0.556*	0.704**
3. Primary branches/plant			0.495	0.467	0.284	0.518*	0.420	0.458	0.268	0.311	0.385
4. Secondary branches/plant				0.794**	0.726**	0.576*	0.464	0.791**	0.251	0.284	0.678**
5. Flowering branches/plant					0.897**	0.494	0.518*	0.864**	0.067	0.233	0.681**
6. Flowering bunches/plant						0.468	0.383	0.863**	0.189	0.234	0.782**
7. Female flowers/bunch							0.573*	0.627**	0.390	0.439	0.574*
8. Fruits/bunch								0.568*	0.170	0.338	0.449
9. Fruits/plant									0.337	0.271	0.839**
10. Seeds/fruit										0.459	0.612*
11. 100 seed wt. (g)											0.545*

* and ** indicate correlation estimate significant at 5% and 1% level, respectively.

Table 4: Direct and indirect effect of different characters on seed yield/plant in *J. curcas*

character	Plant Height (cm)	Collar Diameter (cm)	Primary Branches/plant	Secondary Branches/plant	Flowering Branches/plant	Flowering Bunches/plant	Female Flowers/bunch	Fruits /bunch	Fruits /plant	Seeds /fruit	100 seed wt. (g)	Seed yield /plant (g)
Plant Height (cm)	-0.005	-0.079	0.027	0.049	-0.148	0.302	-0.062	0.017	0.271	0.127	0.120	0.619
Collar diameter (cm)	-0.004	-0.115	0.024	0.052	-0.165	0.347	-0.058	0.031	0.298	0.145	0.155	0.704
Primary Branches/plant	-0.003	-0.053	0.052	0.037	-0.117	0.151	-0.048	0.020	0.204	0.081	0.059	0.385
Secondary Branches /plant	-0.004	-0.083	0.026	0.072	-0193	0.385	-0.054.	0.022	0.352	0.076	0.079	0.678
Flowering Branches /plant	-0.003	-0.078	0.024	0.057	-0.243	0.476	-0.046	0.025	0.384	0.020	0.065	0.681
Flowering Bunches /plant	-0.003	-0.075	0.015	0.052	-0.218	0.530	-0.044	0.018	0.384	0.057	0.065	0.782
Female Flowers /bunch	-0.004	-0.072	0.027	0.041	-0.120	0.248	-0.094	0.027	0.279	0.118	0.122	0.574
Fruits/bunch	-0.002	-0.074	0.022	0.033	-0.126	0.203	-0.054	0.048	0.253	0.051	0.094	0.449
Fruits/plant	-0.003	-0.077	0.024	0.057	-0.210	0.458	-0059	0.027	0.445	0.102	0.075	0.839
Seeds/fruit	-0.002	-0.053	0.014	0.018	-0.016	0.100	-0.037	0.008	0.150	0.302	0.128	0.612
100 Seed wt.(g)	-0.002	-0.064	0.011	0.020	-0.057	0.124	-0.041	0.016	0.121	0.139	0.278	0.545

R^2 = 91.2%, Residual effect =0.30

Correlation of plant height, female flowers/plant, seeds/fruit and 100-seed weight with yield/plant was positive and significant at 5% level. Considering r_p estimates among 11 component traits, the characters plant height, collar diameter, primary and secondary branches/plant, flowering branches and bunches/plant, female flowers/bunch, fruits/bunch and fruits/plant showed strong positive association among themselves and 25 of the 36 r_p estimates were significant. Seeds/fruit and 100 seed weight did not show significant correlation with other component traits.

Path coefficient estimates partitioned the association (Phenotypic correlation) of traits with yield/plant into direct and indirect effect on yield (Table 4). High R^2 (91.2%) and low residual effect (0.30) indicated that most of the important characters contributing to yield are included in the study. Flowering bunches/plant and fruits/plant had high positive direct effects of 0.530 and 0.443 on yield, respectively. These two traits also influenced positive association of other traits with yield through indirect positive effects. Seeds/fruit and 100 seed weight had moderate positive direct effect of 0.300 and 0.278 on yield. The remaining seven component traits had very low direct effect on yield and their positive association with yield was greatly influenced by indirect effects *via* other traits.

DISCUSSION

The relative values of PCV, GCV and range give an idea about the magnitude of variability present in a genetic population. Estimates of GCV were much less than PCV for many traits indicating the role of environment in the expression of the traits. The variability parameter estimates in the study are in close approximation with the findings of genetic parameters in *Azadirachta indica* [13] and in *Pongamia pinnata* [14]. Heritability estimates were found to be high (>80%) for plant height, fruits/plant and 100 seed weight and moderate for seed yield/ plant. Dorman [15] had observed estimation of heritability of traits is important in tree improvement program. Studies on 32 CPTs of *J. curcas* revealed that the traits female: male flower ratio, seed yield and plant height had high broad sense heritability [8]. High heritability was also reported for plant height and collar diameter in *Tectona grandis* [16]. Genetic advance (at 20% selection intensity) as percentage of mean was high (>50%) for the traits seed yield/plant, fruits/plant and flowering bunches/plant. Estimates of heritability along with genetic advance have a crucial role in tree improvement, as it provides an index of the relative role of heredity and environment in the expression of various traits. In this study, moderate to high heritability accompanied with high GA for seed yield/plant, fruits/plant and flowering bunches/plant indicated that heritability was due to additive gene action and selection for these characters may be effective.

As long as the genes governing the characters are not combined at random characters may show some correlations. The immediate effect of pleiotropy and close linkage is generally similar though their effect on potential breeding value could be different [17]. If the observed correlation is due to multiple effects of same gene, the selection for one character will improve another. Hence, correlations among traits influence effectiveness of selection. In the present study, fruits/plant, flowering bunches and branches/plant, collar diameter and secondary branches/plant had high positive and significant correlation with seed yield/plant. Primary branches/plant and fruits/bunch showed lowest positive & non-significant correlation with yield. On the other hand, primary branches/plant and fruits/bunch showed low positive correlation with yield. The characters plant height, collar diameter, primary and secondary branches/plant, flowering branches and bunches/plant, female flowers/bunch, fruits/bunch and fruits/plant showed strong positive association among themselves indicating that some genes controlling these characters might be closely linked or might have pleitropic effects. Seeds/fruit and 100-seed weight did not show significant independent genetic governance.

Path analysis gives information on direct and indirect effects of component traits on yield and hence helps in selection for genetic improvement. In this study, flowering bunches/plant and fruits/plant had high positive direct effects on yield and these two traits influenced positive association of other traits with yield through indirect positive effects. Seeds/fruit and 100 seed weight had moderate positive direct effects on yield. The remaining seven component traits had very low direct effect on yield and their positive association with yield was mainly due to positive indirect effects via flowering branches/plant and fruits/plant. The findings of Rao *et al.* [8] revealed that female to male flower ratio, number of branches/plant and number of days from fruiting to maturity had direct positive effect on seed yield. This character association and path analysis study in *Jatropha* revealed that indirect selection for flowering bunches/plant, fruits/plant and seeds/fruit would be effective in bringing out improvement in yield. Selection for 100 seed weight would also result in some improvement in yield.

CONCLUSIONS

Results of the present study revealed that considerable genetic variability existed among the 16 genotypes for most of the characters. Heritability, character association and path analysis study in *Jatropha curcas* revealed that flowering bunches/plant and fruits/plant are the important yield attributing traits. Selection of these two traits may help in indirect selection of high yielding genotypes.

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