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Genetic variation and heritability estimation in 100 accessions of *Jatropha curcas* L. for fruit yield and vegetative traits in sub-tropical climate of Ranchi district of Jharkhand

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Abstract
The experiment was conducted employing Randomized Block Design (RBD) with four replications, 100 accessions per replication and 9 plants per accession at a spacing of 3 metre x 3 metre. The main aim of the experiment was to determine the fruit yield and vegetative traits of 100 accessions, to estimate the genetic variability and heritability and to study the relationship among these traits. The performance of all traits showed highly significant variations. Broad sense heritabilities for height, collar diameter, the diameter of the first branch, number of branches and survivability was 0.23, 0.17, 0.22, 0.25 and 0.20 with a genetic gain of 14.36, 8.08, 11.72, 15.74 and 13.37 respectively. The number of branches was most important traits with maximum genotypic and phenotypic coefficient of variations of 15.44% and 30.77%, respectively for yielding point of view. Accession IC 468907 maintained 1st ranks in height, collar diameter, number of branches and fruit production among all accessions. Accessions IC 468907, IC 468919, IC 471353, IC 468909, IC 568552, IC 566538 and IC 471343 were the best performers for all traits including fruit production. The assessment of different accessions indicated large genetic improvement possibilities in *Jatropha curcas*.

Keywords: *Jatropha curcas*, accessions, heritability, genetic advance, genetic gain, traits, and fruit yield

Introduction
Jatropha curcas L. is one of the important bio-diesel plants that belong to Euphorbiaceae family. It is being extensively studied for its oil yielding seeds to be used as bio-diesel (after transesterification of the oil) and thus providing an alternate source of decreasing fossil fuel. *Jatropha curcas* has tremendous potential to provide an environmentally safe, cost effective and renewable source of biodiesel. Jatropha can be adapted to wide range of environmental and ecological conditions with a tremendous ability to withstand diverse environmental conditions ranging from subtropical, tropical with humid and sub humid conditions along with resistant to pests and diseases suggesting that there exists a considerable amount of genetic diversity [1]. Rao [2] reported variability observed in *Jatropha curcas* in Central India which was mainly limited to seed source variation in morphology, germination and seedling growth. Kaushik [3] have reported divergence in seed oil traits of *Jatropha curcas* from a limited number of locally collected accessions.
Jatropha curcas L. is a diploid species with chromosome number 2n= 22 [4, 5]. The plant is monoecious with racemose inflorescence, can be propagated by seed, stem cutting, grafting,

budding, air layering or by clone techniques [6]. It is to be noted that favourable environmental conditions that affect its production are yet to be known [7]. So the main objective of the research project was to find out the site specific best germplasm on the basis of growth performance and variability in 100 accessions of *Jatropha curcas* L. in the sub-tropical, geo climatic region of Ranchi district of Jharkhand.

Materials and Methods

The Study Site

The experimental field was established at Nagri, 7 Km from the Institute of Forest Productivity, Ranchi (Latitude: $23^0$21.388' N, Longitude: $85^0$14.661' E). The area has a sub-humid, sub-tropical climate and medium elevation plateau nature with an altitude of 685 meters. Vegetation type is a dry-deciduous forest. The average annual rainfall at Ranchi is 1423.9 mm covering about two and a half months (73 days of a year) with 19 % coefficient of variation. The seasonal rainfall distribution indicates that Ranchi receives 82 % of annual rainfall within the four months of monsoon i.e. June to September. About 8% and 7% rain occurs in the season of summer and post monsoon respectively. Least rain is received in winter with 3% rainfall [8].

The temperature recorded during 2012 i.e. during the peak period of this experiment ranged from highs of 42.2 °C to lows of 4.7 °C [9]. However, its mean monthly temperature varies between 23ºC and 33ºC with the lowest in December and highest in May or June. The average humidity of the area remains higher during the rainy season from July to September (82.93, 84.50 and 81.66% respectively) [10].

The specific site condition of the experimental field was a wasteland in nature, having low fertile red lateritic acidic soil with the flat surface containing moram and gravels and medium natural drainage. The majority of replication was planted on the levelled surface while some part of replication was over a subtle slope. For soil characteristic analysis, the soil samples from the experimental site collected during June, 2012 were sent to NBRI, Lucknow. The soil testing was done on different parameters revealed following characteristics.

Range of different Soil parameters for the trial plot

Parameter	Range
pH	5.63-6.53
EC(µS)	9.18-22.17
Available Nitrogen (%)	0.03-0.04
Available Phosphorus(mg/g)	0.004
Available Potassium(mg/g)	0.03
TOC (%)	0.86-0.90

Experimental Design

One hundred accessions of *Jatropha curcus* L. (Table 1) were collected from different regions of India (54 accessions from Biotech park, Lucknow, Uttar Pradesh, 33 accessions from Ruchi, Indore, Madhya Pradesh and 13 accessions from Nandan, Hyderabad, then Andhra Pradesh now Telangana) and planted in the experimental field. The cuttings of *Jatropha curcas* were planted in manually dug 45 cm. deep pits refilled with soil and cow dung manure. The sub-plot and the treatment plots with replication were properly mapped and marked with metallic labels. Irrigation and weeding did whenever required. No any chemical or biofertilizer were applied.

The experimental plots were established in December, 2010 with four replications in Randomized Block Design (RBD) of the experiment. 100 accessions in a replication of Jatropha plants were planted at a rate of 9 plants per accession at a spacing of 3m×3m. Measurements were taken in every six months until three years.

Data Analysis

For evaluation of germplasm exploring genetic variability is the first step for plant improvement/breeding program [11]. The genetic parameters are one of the important and best useful tools to predict the amount of gain to expect from the accession (clonal) material. The variation between clones of different accessions is commonly used to estimate the total genetic variation and also to calculate the degree of genetic control for particular trait [12].

In this experiment, the parameters for data analysis were plant height, collar diameter, the diameter of the first branch, number of branches and survivability. Following analysis was carried out using statistical package for social studies (SPSS).

Analysis of variance

The observation taken in the month of December 2012 was analyzed for analysis of variance (ANOVA).

Variance

The genotypic and phenotypic components of variance were calculated from the ANOVA [13].

- Genotypic variance (σ^2_g) = (MSG - MSE)/r
- (Where MSG = mean square of accessions, MSE (σ^2_e) = mean square of error and r = number of replications)
- Phenotypic variance (σ^2_p) = $\sigma^2_g + \sigma^2_e$
- Genotypic Coefficient of variance (GCV) = ($\sqrt{\sigma^2_g}$ /mean) x 100
- Phenotypic coefficient of variance (PCV) = ($\sqrt{\sigma^2_p}$ /mean) x 100.

Heritability

Broad sense heritability was calculated [14].

$h^2 = \sigma^2_g / \sigma^2_p$.

Genetic Advance

The genetic advance was calculated [14].

Genetic advance (Gs) = K. h^2. σ_p (Where, K =2.06).

To predict the genetic advance, a selection intensity of 5% of the families was used. i.e., from the 100 evaluated accessions, the best 5 were selected.

Genetic gain

The expected genetic gain, in per cent of mean, was calculated following [14].

Genetic gain = (Gs/mean) x 100.

Results and Discussion

All the genetic parameters are described and calculated here initially at six months and finally at the stage of 2.5 years after the plantation. The present results, however, can serve as an indicator to compare with the results of fruit yield data to be obtained at later stages of the same year. The comparison between results of genetic parameters and fruits yielding data are important for the selection of best germplasm of Jatropha accessions. Assessment of fruit yield data would determine whether the genetic analysis is reliable or not. These results agreed with findings of Kaushika [3] who reported that the germplasm of *Jatropha curcas* collected in India showed a significant variation for the vegetative traits. This finding shows that there is a high correlation between the number of branches, plant height and yield.

After six months of the plantation, the results of height, collar diameter and number of branches are depicted in table-1. As seen from table 1, the height, collar diameter and a number of branches were ranging from 39.82 cm to 100.34 cm, 1.95 cm to 3.57 cm and 1.36 to 3.34 respectively. The overall average values of height, collar diameter and number of branches were 58.38 cm. 2.68 cm and 2.1 respectively. Significant differences were found in growth behavior for all three traits in different accessions.

In table-2, the analytical tools like variance (both genotypic and phenotypic), heritability and genetic gain were used and calculated for height, collar diameter and number of branches. After 2.5 years of the plantation, 100% mortality was observed in two accessions and hence, these two accessions were excluded from analysis. All 98 accessions were observed and the high levels of significant differences were found in all traits of height, collar diameter, the diameter of the first branch, number of branches and survivability.

The data presented in the analysis of variance table (Table 3) showed that values for all the traits were highly significant. The genotypic and phenotypic coefficient of variation provides the evidence for the existence of adequate genetic variations for all traits of *Jatropha curcas* plant. It is notable that each inflorescence of Jatropha plant is developed at the tip portion of branches. The accessions with more branches are able to produce more flowers part which result in higher number of fruits. The table 4 shows that the number of branches was a most important trait with best genotypic and phenotypic coefficient of variation of 15.44% and 30.77%, respectively for yielding point of view.

The height and survivability of plant were also the next important traits with better genotypic and phenotypic coefficient of variation of 14.52% & 30.26% and 14.40% & 31.98% respectively for fruits production. This result shows that accession variation exists for further genetic variation. After 2.5 years of the plantation, the genotypic coefficient of variation increased from 8.98% to 15.44% and phenotypic coefficient of variation slightly decreased from 39.06% to 30.77% in a number of branches while more or less similar trend in height and collar diameter. This investigation indicated that some environmental factors also played an important role than the genetic factor.

The next important analytical tool is heritability which expresses the degree in which a character is influenced by genes as compared to the environment. Estimation of broad sense heritabilities for various characters as shown in table 4 shows moderate heritabilities for height (0.23), collar diameter (0.17), the diameter of first branch (0.22), number of branches (0.25) and survivability (0.20), and are conformity with the results of Nelson and Tauer [15]. They were reported moderate to high broad sense heritabilities for juvenile traits such as height, diameter, growth and leaf size. The heritability values of each trait had a low value which ranged from 0.17 to 0.25. In this investigation, the greatest genetic advance was observed for height (12.69) followed by survivability (9.60), collar diameter (2.99), the diameter of the first branch (2.77) and a number of branches (0.62). However, the maximum genetic gain was in a number of branches (15.74%) followed by height (14.36%), survivability (13.37%), the diameter of the first branch (11.72%) and collar diameter (8.08%). The genetic gain for all the traits was found positive particularly for the most important trait i.e. a number of branches.

In this experiment, the superiority for the parameter considered had been tested over a period of time to make suitable recommendations. The top twenty accessions in terms of mean height, collar diameter, the diameter of the first branch, number of branches and survivability as shown in table 4 were assessed for their ranking. On the basis of fruit production, accessions IC 468907 (42.22 Fruits/plant) maintained 1st rank with the best height, collar diameter, number of branches followed by accession IC 468919 (38.89 Fruits/plant) with better survivability, accession IC 471353 (26.56 Fruits/plant) with satisfactory height and collar diameter. However, accession IC 471357 also maintained 4th rank in fruit production (26.56 Fruits/plant) but did not rank of traits in top twenty. The accessions IC 468909 (17.22 Fruits/plant) IC 568552 (14.22 Fruits/plant) IC 566538 (13.33 Fruits/plant) and IC 471343 (8.33 Fruits/plant) showed the satisfactory result in fruit production with more or less satisfactory traits. Three accessions IC 468907, IC 468919and IC 471353 were selected for best germplasm for the production of fruits. The Table 5&6 shows that the accessions IC 468907, IC 468919, IC 471353, IC 468909, IC 568552, IC 566538 and IC 471343 were the best performers for all traits including fruits production.

Table 1: Mean of 100 accessions on growth traits after six months

Acc. Code	Accessions	Height cm	Collar dia. cm	No. of branch	Acc. Code	Accessions	Height cm	Collar dia. cm	No. of branch
1	IC 471359	61.54	2.71	2.29	51	IC 528114	65.21	2.82	2.36
2	IC 471360	48.34	2.23	1.74	52	IC 561292	55.91	2.57	1.94
3	IC 471356	68.47	2.59	2.38	53	IC 569349	47.89	2.52	1.54
4	IC 468910	63.50	2.72	1.81	54	IC 568554	55.84	2.54	1.96
5	IC 471358	51.51	2.30	2.00	55	IC 561290	57.00	2.81	2.35
6	IC 471344	52.86	2.83	2.44	56	IC 569346	62.01	2.61	2.21
7	IC 471352	64.25	2.96	1.84	57	IC 561291	52.44	2.49	2.00
8	IC 468909	43.03	2.28	1.85	58	IC 568552	53.30	2.61	2.94
9	IC 471353	43.67	2.34	1.44	59	IC 561287	46.81	2.06	2.50
10	IC 471349	41.11	2.14	1.58	60	IC 569342	51.54	2.41	2.17
11	IC 471126	43.15	2.15	2.65	61	IC 569344	46.69	1.95	2.17
12	IC 468908	50.54	2.33	1.79	62	IC 569343	51.71	2.26	1.78
13	IC 471346	45.76	2.22	2.38	63	IC 560620	73.44	3.08	2.76
14	IC 468919	47.88	2.72	2.88	64	IC 560627	57.32	2.51	1.71
15	IC 471345	51.74	2.26	1.38	65	IC 560653	39.82	2.11	1.66
16	IC 471357	42.54	2.52	2.19	66	IC 560626	69.86	2.81	2.37
17	IC 471343	54.24	2.71	2.04	67	IC 566889	55.47	2.73	2.53
18	IC 468907	53.91	2.23	1.42	68	IC 566603	53.30	2.61	2.31
19	IC 540920	59.28	2.50	2.07	69	IC 566612	63.59	3.03	2.32
20	IC 468917	52.90	2.45	2.54	70	IC 566602	51.69	2.55	1.79

21	IC 471354	43.44	2.31	2.12	71	IC 566601	48.88	2.30	1.74
22	IC 471355	43.10	2.38	1.61	72	IC 565667	85.03	3.30	2.79
23	IC 471124	51.54	2.38	1.79	73	IC 564020	61.12	2.88	2.40
24	IC 540922	58.56	2.46	1.79	74	IC 564023	70.63	2.88	1.88
25	IC 553592	74.96	3.17	3.01	75	IC 565668	73.86	2.65	1.93
26	IC 553591	60.70	2.50	1.72	76	IC 565669	51.90	2.72	2.97
27	IC 561232	53.37	2.03	2.13	77	IC 564013	55.60	2.81	2.32
28	IC 561231	62.33	3.26	1.99	78	IC 566614	66.22	2.78	2.03
29	IC 561235	55.11	2.45	1.82	79	IC 566604	72.25	3.48	2.14
30	IC 569353	50.74	2.77	3.24	80	IC 566607	52.94	2.62	1.63
31	IC 561230	45.12	2.68	1.93	81	IC 569131	67.09	3.04	2.86
32	IC 569361	58.26	2.81	2.10	82	IC 558210	61.04	2.78	2.04
33	IC 569355	49.72	3.08	2.23	83	IC 558215	41.12	2.33	1.80
34	IC 561229	55.28	2.62	1.95	84	IC 558214	80.00	3.49	2.69
35	IC 569362	49.47	2.55	1.41	85	IC 566535	83.94	3.16	2.33
36	IC 569356	52.84	2.56	2.10	86	IC 566533	45.92	2.52	2.05
37	IC 550431	50.97	2.51	2.53	87	IC 558213	74.79	2.94	2.04
38	IC 550449	54.53	2.74	2.00	88	IC 558209	59.99	2.69	1.86
39	IC 555379	76.01	3.46	3.34	89	IC 558212	56.79	2.48	1.48
40	IC 555383	65.28	3.40	3.09	90	IC 558222	69.88	2.81	1.68
41	IC 555381	79.86	3.57	2.52	91	IC 569133	87.90	3.43	2.78
42	IC 560688	58.31	2.56	1.93	92	IC 558217	57.52	2.65	1.90
43	IC 560687	56.38	2.77	1.92	93	IC 566536	67.30	3.33	1.96
44	IC 555380	100.34	3.05	2.34	94	IC 566532	48.56	2.39	1.41
45	IC555382	67.54	2.91	1.93	95	IC 566538	56.61	2.50	2.00
46	IC 564010	71.87	2.95	1.83	96	IC 569142	44.62	2.30	1.36
47	IC 564011	76.42	3.05	1.94	97	IC 569134	49.68	2.61	1.65
48	IC 569122	60.10	2.41	1.58	98	IC 558221	81.58	3.19	2.33
49	IC 569129	60.15	2.92	2.00	99	IC 569130	62.70	3.25	2.83
50	IC 550790	61.08	2.63	1.90	100	IC 569135	47.94	2.15	1.48
						Mean	58.38	2.68	02.10
						STDEV	11.70	0.36	00.44

Table 2: Different genetic parameters estimated for different traits of 100 accessions of *Jatrophacurcas* after six months

Traits	Mean	Range	GCV	PCV	Heritability	Genetic gain (%)
Height	58.38	41.11 – 100.34	15.89	29.12	0.30	17.87
Collar Diameter	2.68	1.95 – 3.49	8.25	23.02	0.13	6.09
Number of Branch	2.10	1.36 – 3.34	8.98	39.06	0.05	4.25

Table 3: Analysis of variance for different traits

Source of variation	DF	Mean sum of square				
		plant height	collar diameter	diameter of first branch	number of branches	survivability
Replication	2	21836.23	2992.83	1532.34	16.64	3091.89
Accession	97	1044.74**	100.66**	52.44**	2.20**	741.28**
Error	194	550.51	62.85	28.17	1.10	420.38

*, ** Significant at the 0.05 and 0.01 probability levels, respectively

Table 4: Different genetic parameters estimated for different traits of 98 accessions of *Jatropha curcas* after 2.5 years of plantation

Genetic parameter	plant height	collar diameter	diameter of first branch	number of branches	survivability
Genotypic variance (σ^2_g)	164.74	12.60	8.09	0.37	106.97
Phenotypic variance (σ^2_p)	715.26	75.45	36.26	1.47	527.34
Heritability (h^2)	0.23	0.17	0.22	0.25	0.20
Genetic advance (Gs)	12.69	2.99	2.77	0.62	9.60
Genetic gain (%)	14.36	8.08	11.72	15.74	13.37
Genotypic Coefficient of variance (GCV)	14.52	9.59	12.03	15.44	14.40
Phenotypic coefficient of variance (PCV)	30.26	23.46	25.47	30.77	31.98

Table 5: Mean values for various quantitative traits of Top twenty Jatropha accessions after 2.5 years of plantation

Accession	Plant height (cm)	Accession	Collar diameter (mm)	Accession	Diameter of first branch (mm)	Accession	Number of branches	Accession	Survivability (%)
IC 468907	150.35	IC 468907	54.90	IC 569142	36.65	IC 468907	7.71	IC 569122	100.00
IC 569142	132.29	IC 569122	53.00	IC 566532	34.85	IC 569122	5.99	IC 555379	96.30
IC 569122	123.71	IC 569142	50.30	IC 564023	34.41	IC 566604	5.94	IC 528114	96.30
IC 566602	123.59	IC 560620	49.33	IC 468907	32.78	IC 566602	5.90	IC 468919	92.59
IC 560620	121.05	IC 468908	48.79	IC 468908	31.67	IC 555383	5.52	IC 555381	92.59
IC 564023	117.15	IC 566602	48.39	IC 569122	31.29	IC 560627	5.22	IC 560688	92.59
IC 468908	116.06	IC 564023	45.91	IC 558215	29.97	IC 555380	5.14	IC 555380	92.59

IC 560653	113.82	IC 471354	44.57	IC 468909	29.97	IC 566532	5.13	IC 560627	92.59
IC 471343	113.36	IC 558215	44.46	IC 558222	29.77	IC 555379	5.12	IC 564020	92.59
IC 558222	112.54	IC 566889	43.99	IC 566602	29.36	IC 569134	5.04	IC 565668	92.59
IC 471354	111.63	IC 471126	43.42	IC 564020	29.25	IC 471126	4.76	IC 561290	92.59
IC 555379	110.01	IC 566536	43.04	IC 560620	28.80	IC 471343	4.74	IC 558217	88.89
IC 566889	108.87	IC 564011	43.04	IC 565669	28.49	IC 565667	4.74	IC 560687	88.89
IC 540920	107.44	IC 569134	43.01	IC 566538	27.87	IC 471345	4.74	IC 558209	88.89
IC 471349	106.24	IC 471353	42.84	IC 566535	27.78	IC 555382	4.70	IC 558221	88.89
IC 566538	105.33	IC 471343	42.57	IC 555379	27.53	IC 540922	4.69	IC 568552	88.89
IC 566532	104.77	IC 560687	42.44	IC 558213	27.37	IC 569142	4.67	IC 569342	88.89
IC 564020	104.46	IC 471344	41.38	IC 561235	27.03	IC 561290	4.65	IC 560620	88.89
IC 471353	104.13	IC 569133	41.25	IC 471126	27.01	IC 566535	4.63	IC 555383	85.19
IC 558215	103.92	IC 565669	41.18	IC 566889	26.83	IC 564023	4.56	IC 564011	85.19
CD	37.80		12.77		8.55		1.69		33.03

Table 6: Ten good accessions based on fruit production after 2.5 years of plantation

Rank	Acc. Code	Accession	Fruits/ plant	Source of origin of the Germplasm
1	18	IC 468907	42.22	Biotech Park, Lucknow
2	14	IC 468919	38.89	Biotech Park, Lucknow
3	9	IC 471353	26.56	Biotech Park, Lucknow
4	16	IC 471357	26.33	Biotech Park, Lucknow
5	8	IC 468909	17.22	Biotech Park, Lucknow
6	58	IC 568552	14.22	Biotech Park, Lucknow
7	95	IC 566538	13.33	Ruchi, Indore
8	62	IC 569343	10.89	Biotech Park, Lucknow
9	61	IC 569344	8.33	Biotech Park, Lucknow
10	17	IC 471343	8.33	Biotech Park, Lucknow

Conclusions

The analytical tools like variance (both genotypic and phenotypic), heritability, genetic advance and genetic gain were used and calculated for height, collar diameter, the diameter of the first branch, number of branches and survivability to select the best germplasm. Broad sense heritabilities for height, collar diameter, the diameter of the first branch, number of branches and survivability was 0.23, 0.17, 0.22, 0.25 and 0.20 with a genetic gain of 14.36, 8.08, 11.72, 15.74 and 13.37 respectively. The number of branches was most important traits with maximum genotypic and phenotypic coefficient of variation of 15.44% and 30.77%, respectively for yielding point of view. On the basis of fruits/plant and morphological traits, the top three accessions were IC 468907 (42.22 Fruits/plant), IC 468919 (38.89 Fruits/plant) and IC 471353 (26.56 Fruits/plant) were selected for best germplasm in 100 accessions. Accessions IC 468907, IC 468919, IC 471353, IC 468909, IC 568552, IC 566538 and IC 471343 were the best performers for all traits including fruits production. The accession IC 468907 achieved the highest plant height (150.35 cm), highest collar diameter (5.49 cm), the maximum number of branches (7.71branches/plant) and produced the maximum number of fruits (42.22 fruits/plant) among 100 accessions. Accessions IC 468907 showed high potential for the future breeding program.

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