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# Genetic Variability in Growth and Seed Traits of *Jatropha curcas* L. Germplasm for Genetic Tree Improvement

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## Abstract

A 23 candidate plus trees of *Jatropha curcas* were selected from the states of Maharashtra, Chhattisgarh and Haryana in India. A total 14 seed traits and growth parameters were measured and their genetic values and correlation was calculated to serve as base information for further tree improvement and breeding program of *J. curcas.* Significantly treatment sum of squares were observed for all these traits under the study indicating an existence of a substantial variability revealed high PCV and GCV values for number of branches, number of primary branches, initial collar diameter of plant and seed yield per plant. The PCV values were higher than GCV values for all the traits, while the difference between PCV and GCV magnitude were minimum for number of seeds per fruit. High heritability was observed for number secondary branches and seed yield per plant with high genetic advance. These traits may be considered for selection and improvement of Jatropha accessions/genotypes. Positive and significant correlation exists between number of fruit per plant, number seed per fruit, 100 seed weight and seed yield. Accessions RJ-88, RJ-90, RJ-92, RJ-93, RJ- RJ-123, RJ-124 and RJ- 133 showed above average higher values for growth and seed traits attributes (viz. number of secondary branches, number of fruits per plant, 100 seed Test weight, shelling percentage, oil content and seed yield per plant. Identified promising genotype with favorable traits for future establishment of elite seedling seed orchard for varietal and hybridization programme of tree.

**Keywords:** Correlation; Genotypic; Growth; Heritability; Phenotypic; Yield

## Introduction

In recent years *Jatropha curcas* has drawn attention as a source of seed oil that can provide an economically viable substitute for motor fuel [1,2]. *J. curcas* has spread beyond its original distribution because of its hardiness, easy propagated by the seed and cuttings, Highly corss pollinated plant, drought endurance, high oil content, low seed cost, short gestation period, rapid vigorous growth, easy adoption to wide agro-climatic condition, bushy/shrubby deciduous in nature and multiple uses of different plant parts. Although Jatropha is well known for having wide adaptability and plethora of uses, the full potential of *J. curcas* is far from being realized because of several reasons. Apart from agronomic, socioeconomic and institutional constraints, planned for crop improvement programs are lacking globally. Hence, *J. curcas* can be improved through assessment of variability in wild sources and selection of superior genotypes in the desired traits. Worldwide introduction of *J. curcas* for varied purposes had met with limited success due to unreliable and low seed set as well as oil yields resulting in poor economic returns. *J. curcas* is a wild species and no varieties with desirable traits for specific growing conditions are available, which makes its cultivation a risky business [3]. The crop is also characterized by variable and unpredictable yield due to unidentified reasons [4]. The positive attributes of this plant are not fully understood in terms of breeding and utilization [5] which limits its large-scale cultivation and warrants the need for genetic improvement and breeding of superior genotypes of the species. Selection is the most important activity in all tree breeding programmes [6]. *J. curcas* being highly cross-pollinated species is anticipated to contain wide genetic variability offering significant scope for selecting superior genotypes which will help in the improvement of productivity. Knowledge of genetic relationship and variation in the species is a prerequisite in any tree breeding programme because it permits the organization of germplasm, including elite lines and provides for more efficient selection [7]. However, the major constraint in achieving higher quality oil yield of *J. curcas* is lack of information about its genetic variability, oil composition and absence of suitable ideo-types for different cropping systems. Plants, in general, might be expected to maintain high levels of genetic variation within their populations since their sessile nature often leads to the evolution of locally adapted ecotypes [8]. This variation may be utilized in selection and improvement of the species. However, information regarding the extent and pattern of genetic variation in *J. curcas* population is limited barring a few recent studies [9-11]. Therefore, genetic and correlation studies among the growth and seed traits were carried out in candidate plus trees of *J. curcas* selected from a wide geographical range in three Indian states aiming at utilization in identifying best genotypes for tree improvement.

## Material and Methods

An extensive wild germplasm exploration survey was conducted to identify the high yielding Candidate Plus Trees RJ (Rahuri Jatripha Tree) of *Jatropha curcas* at fruiting stage from different predominant naturalized locations from 3 Disricts Ahmednagar, Pune, and Aurangabad of Maharashtra and Ambikapur from Chattisgarh, Gurgaon district form Haryana state of India during March-May, 2005 (Table 1). Since *J. curcas* was grown as wild and had no definite geometry with neighboring trees for comparison, the selection was made by using single tree selection method based on phenotypic assessment of characters of economic importance viz. yield potential, crown spread, total height, girth at breast height, age of the tree, free from pest and diseases, seed size and seed weight. A total of 23 RJ accessions (Rahuri Jatropha morphologically superior trees) seeds were sown in polythene bag by using selected seeds. The bags were filled with FYM: sand: soil in 1:1:1: ratio. Seedling after attaining 30 cm height we transplanted to the field during mansoon season (July, 2005) planted with 3 × 3 m spacing in Random block design was followed by with three replication for each set of accession. A 23 RJ accession evaluated under the field experimental trial were conducted at Farm field of AICRP on Agroforestry, MPKV, Rahuri (latitude: 19°23' N, longitude: 74°42 'E, and altitude: 715 m, m.s.l. approx.) is a Semi-Arid Tropics of climate receiving mean annual rainfall of 561.6 mm with 44 annual rainy days for, Annual minimum and maximum temperature is 12.7°C and 40.2°C, respectively, with lowest temperature in December and highest temperature in May every year. Soils of the study area are Medium black soils. The plots in each replication comprised of 12 plants. Biometrical observations from six randomly selected plants were recorded, leaving the border ones, at periodical bimonthly intervals viz., Initial after planting, 2 months after planting (MAP), 4 MAP, 6 MAP, etc. The plant height (Initial), collar diameter (Initial), number of primary and secondary branches were counted on each of the selected plants in three replications. The plants starts fruiting (Initial harvest of fruits) seeds were harvested from fully ripened fruits by carefully removing the shell manually. The seeds were sun dried for 10 days, winnowed. 100 seed test weight (expressed in grams) of seeds was taken separately by weighing three random samples of undamaged seeds and from each lot comprising 100 seeds, respectively. The measurement of seed per fruit, shelling percentage, seeds diameter measurement at longitudinal and equatorial taken. Seed yield per plant measured. 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.

| Sr. No. | Genotype No. | Seed soruce location | District | State |
|---|---|---|---|---|
| 1 | RJ-87 | Pabal | Pune | Maharashtra |
| 2 | RJ-88 | Pur | Pune | Maharashtra |
| 3 | RJ-89 | Goasasi | Pune | Maharashtra |
| 4 | RJ-90 | Goasasi | Pune | Maharashtra |
| 5 | RJ-91 | Goasasi | Pune | Maharashtra |
| 6 | RJ-92 | Goasasi | Pune | Maharashtra |
| 7 | RJ-93 | Goasasi | Pune | Maharashtra |
| 8 | RJ-95 | Goasasi | Pune | Maharashtra |
| 9 | RJ-109 | Kanoli | Ahmednagar | Maharashtra |
| 10 | RJ-110 | Hangewadi | Ahmednagar | Maharashtra |
| 11 | RJ-115 | Taharabad | Ahmednagar | Maharashtra |
| 12 | RJ-117 | Gadakkwadi | Ahmednagar | Maharashtra |
| 13 | RJ-123 | Kolewadi | Ahmednagar | Maharashtra |
| 14 | RJ-124 | Kolewadi | Ahmednagar | Maharashtra |
| 15 | RJ-125 | Limbewadi | Ahmednagar | Maharashtra |
| 16 | RJ-130 | Warwandi | Ahmednagar | Maharashtra |
| 17 | RJ-3 | Sangavi | Aurangabad | Maharashtra |
| 18 | RJ-4 | Mumdabad | Aurangabad | Maharashtra |
| 19 | RJ-7 | Culambimala | Aurangabad | Maharashtra |
| 20 | RJ-8 | Naighawan | Aurangabad | Maharashtra |
| 21 | RJ-12 | Anavi | Aurangabad | Maharashtra |
| 22 | RJ-139 | Ambikapur | Ambikapur | Chattisgarh |
| 23 | RJ-133 | Gurgaon | Gurgaon | Harynana. |

**Table 1:** List of candidate plus trees of *Jatropha curcas* seed source.

## Data Analysis

The growth and seed traits were analyzed using Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) to understand the significant difference among growth and seed trait of RJ under consideration [12]. The phenotypic variation for each trait was partitioned into components due to genetic (hereditary) and non-genetic (environmental) factors and estimated using the following formula [13].

$Vp = MSG / r$ (1)

$Vg = (MSG-MSE) / r$ (2)

$Ve = MSE$ (3)

where, MSG, MSE and r are the mean squares of RJs, mean squares of error and number of replications, respectively. The phenotypic variance ($V_p$) is the total variance among phenotypes. The genotypic variance ($V_g$) is the part of the phenotypic variance that can be attributed to genotypic differences among the phenotypes, and the error variance ($V_e$) is part of the phenotypic variance due to environmental effects. To compare the variation among traits, phenotypic (PCV) and genotypic (GCV) coefficients of variation were computed according to the method suggested by Burton [14]:

$PCV = (\sqrt{Vp} / X) \times 100$ (3)

$GCV = (\sqrt{Vg} / X) \times 100$ (4)

where, $V_p$, Vg and X are the phenotypic variance, genotypic variance and grand mean for each pod and seed-related trait, respectively. Broad sense heritability ($h_2B$) was calculated according to Allard [15] as the ratio of the genotypic variance ($V_g$) to the phenotypic variance ($V_p$). Genetic advance (GA) was estimated in accordance with Johanson et al. [13] as follows:

$GA = K \times h2B \times \sqrt{Vp}$ (5)

$GA = (GA/X) \times 100$ (6)

where, K is the selection differential (2.06 for selecting 5 % of the genotypes); GA is as % of the mean. Phenotypic ($r_p$) and genotypic ($r_g$) correlations were further computed to examine inter-character relationships among seed and seedling traits following Goulden [16] as:

$rp = Covp\ (x1, x2)/[Vp(x1) \times Vp(x2)]$ ½ (7)

$rg = Covg\ (x1, x2)/[Vg(x1) \times Vg(x2)]$ ½ (8) where, $C_{ovp}$ and $C_{ovg}$ are phenotypic and genotypic covariances for any two traits $x_1$ and $x_2$, respectively, and $V_p$ and $V_g$ are the respective phenotypic and genotypic variances for those traits.

## Results

### Variability in growth and seed traits of Jatropha

Significant variation was observed in plant height at first harvest of fruit during growth period of progeny of 23 wild accession of *Jatropha curcas* (Table 2). Maximum plant height 176.75 cm was observed in RJ-87 fallowed by RJ-130 which recorded 172.25 cm. The lowest plant height was observed in the RJ-133 which 129.0 cm. Significant variation was recorded with regards to collar diameter highest found in R- 3 (5.33 cm) and lowest in RJ- (4.23 cm ) at first harvest stage of the plant. The number of primary branches is highest in RJ-110 (5.75) and lowest in the RJ-12 (2.0) . The number of secondary branches (12) higher in the both Jaropha accessions RJ-90 and RJ-93 respetively. The lower secondary branches found in RJ- 8 (2.75) which is a significantly found. The for the yield of fruit crop the number of the seed per fruits of plant is significantly higher in RJ-90 (3.00) fallowed by RJ-92 (3.00) and lowest in the RJ-3 (2.55) . The higher fruit diameter at longitudinal of the fruit is RJ-123 (3.15 cm) fallowed by RJ-90 (2.95) and lowest in RJ-117, RJ-8 and RJ-12. The fruit diameter at equatorial highest in RJ-133 (2.13 cm) and lowest in RJ- 4 (1.58). The highest 100 seed Test weight found in RJ- 90 (75.71gm) and lowest in RJ-3 (61.00 gm). The shelling percentage is highest in the RJ- 89 (42.03) and lowest in the RJ-109 (32.30). The oil content is significantly higher in the 39.10 % in RJ-91 and fallowed by the 38.50 % in RJ-93. The seed yield of all accession is significantly higher in RJ-RJ-90 (285.00 gm) per plant and lower in the RJ-3 (169.65). The mean analysis of variance for 14 growth and seed traits are significantly at 5 % and 1 % level showed in the (Table 3).

| Genotypes | Plant height (cm) | Plant height (at first harvest) cm | Collar diameter of plant initial (cm) | Collar diameter of plant (At first harvest) (cm) | No. of primary branches (At first harvest) | No. of secondary branches (At first harvest) | No. of fruits / plant (At first harvest) | No. of seed / fruit (At first harvest | Fruit diameter (longitudinal) (cm) | Fruit diameter (Equitorial) (cm) | 100 Seed Weight (g) | Shelling percentage (%) | Oil content (%) | Seed yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RJ-87 | 40.75 | 176.75 | 2.38 | 5.20 | 4.25 | 8.00 | 111.50 | 2.95 | 2.53 | 1.73 | 65.01 | 35.64 | 35.00 | 211.00 |
| RJ-88 | 39.38 | 159.50 | 2.15 | 5.30 | 5.25 | 9.25 | 117.75 | 2.85 | 2.60 | 1.90 | 67.48 | 36.04 | 36.80 | 227.00 |
| RJ-89 | 38.63 | 161.75 | 1.90 | 4.58 | 3.50 | 8.75 | 118.75 | 2.80 | 2.80 | 1.73 | 66.50 | 42.03 | 35.30 | 218.50 |
| RJ-90 | 44.75 | 160.25 | 1.98 | 5.28 | 4.75 | 12.00 | 126.25 | 3.00 | 2.95 | 1.93 | 75.71 | 35.98 | 37.90 | 285.00 |
| RJ-91 | 37.78 | 161.25 | 1.75 | 4.58 | 3.75 | 11.50 | 118.25 | 2.85 | 2.70 | 2.00 | 64.85 | 37.30 | 39.10 | 221.55 |
| RJ-92 | 42.75 | 146.00 | 1.73 | 4.23 | 4.75 | 10.00 | 125.75 | 3.00 | 2.68 | 2.10 | 71.49 | 32.17 | 38.10 | 263.85 |
| RJ-93 | 38.63 | 146.00 | 2.50 | 4.90 | 4.00 | 12.00 | 124.00 | 2.95 | 2.60 | 2.03 | 69.59 | 36.09 | 38.50 | 260.00 |
| RJ-95 | 37.88 | 171.75 | 3.35 | 4.95 | 4.75 | 10.50 | 109.75 | 2.70 | 2.55 | 1.93 | 66.38 | 39.06 | 38.00 | 204.75 |
| RJ-109 | 38.50 | 161.50 | 2.40 | 4.43 | 4.50 | 4.50 | 113.50 | 2.80 | 2.50 | 1.95 | 69.46 | 32.11 | 35.90 | 216.60 |
| RJ-110 | 39.25 | 155.75 | 2.23 | 5.15 | 5.75 | 9.00 | 114.25 | 2.75 | 2.60 | 2.05 | 70.00 | 34.01 | 37.80 | 224.67 |
| RJ-115 | 39.75 | 164.25 | 2.83 | 4.80 | 3.50 | 7.00 | 115.75 | 2.75 | 2.63 | 1.88 | 70.63 | 39.33 | 33.40 | 220.80 |
| RJ-117 | 37.00 | 155.25 | 2.18 | 4.60 | 2.50 | 9.50 | 112.50 | 2.70 | 2.40 | 1.63 | 61.46 | 36.20 | 34.10 | 188.00 |
| RJ-123 | 41.63 | 140.50 | 2.38 | 4.53 | 2.50 | 4.25 | 122.25 | 2.85 | 3.15 | 1.98 | 71.46 | 35.72 | 36.00 | 247.55 |
| RJ-124 | 42.13 | 150.75 | 2.10 | 4.33 | 2.25 | 8.25 | 123.75 | 2.90 | 2.65 | 2.03 | 70.75 | 34.20 | 36.30 | 255.00 |
| RJ-125 | 36.88 | 151.75 | 2.00 | 4.30 | 2.75 | 5.00 | 115.50 | 2.70 | 2.65 | 2.00 | 66.71 | 34.73 | 36.70 | 210.80 |
| RJ-130 | 40.38 | 172.25 | 1.78 | 4.15 | 3.50 | 3.50 | 119.50 | 2.85 | 2.78 | 2.08 | 69.51 | 41.34 | 34.60 | 233.95 |
| RJ-3 | 35.38 | 153.00 | 2.75 | 5.88 | 4.75 | 3.75 | 105.00 | 2.55 | 2.48 | 1.60 | 61.00 | 38.70 | 37.60 | 169.65 |
| RJ-4 | 35.63 | 152.50 | 2.38 | 5.23 | 3.75 | 3.00 | 110.50 | 2.60 | 2.55 | 1.58 | 64.75 | 38.12 | 35.50 | 189.35 |
| RJ-7 | 34.75 | 141.25 | 2.45 | 5.55 | 3.25 | 4.25 | 113.75 | 2.65 | 2.45 | 1.78 | 63.88 | 38.33 | 35.20 | 195.00 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RJ-8 | 35.75 | 132.75 | 1.75 | 5.50 | 3.00 | 2.75 | 106.75 | 2.75 | 2.40 | 1.73 | 65.17 | 40.30 | 38.25 | 194.80 |
| RJ-12 | 35.63 | 139.50 | 2.48 | 5.13 | 2.00 | 3.75 | 112.00 | 2.50 | 2.40 | 1.63 | 63.89 | 37.26 | 37.30 | 183.40 |
| RJ-139 | 36.63 | 139.75 | 2.38 | 4.65 | 3.00 | 3.25 | 117.25 | 2.80 | 2.43 | 2.05 | 66.92 | 36.62 | 36.60 | 224.56 |
| RJ-133 | 37.88 | 129.00 | 2.30 | 4.50 | 3.75 | 3.25 | 119.75 | 2.85 | 2.73 | 2.13 | 67.25 | 35.50 | 37.50 | 233.64 |
| Mean | 38.59 | 153.17 | 2.26 | 4.86 | 3.73 | 6.83 | 116.26 | 2.79 | 2.62 | 1.89 | 67.39 | 36.81 | 36.59 | 220.84 |
| SE | 1.47 | 6.90 | 0.17 | 0.27 | 0.62 | 1.21 | 3.15 | 0.07 | 0.10 | 0.09 | 2.03 | 1.58 | 1.05 | 9.67 |
| CD 5 % | 4.30 | 20.2 | 0.49 | 0.80 | 1.81 | 3.55 | 9.23 | 0.21 | 0.30 | 0.27 | 5.95 | 4.63 | 3.07 | 28.35 |

**Table 2:** Mean performance of 23 candidate plus trees of *Jatropha curcas* for 14 traits.

| Sr.No. | Character | Mean sum of squares | |
|---|---|---|---|
| | | Treatment (22) | Error (22) |
| 1. | Plant height (initial ) (cm) | $13.54^{**}$ | 4.30 |
| 2. | Plant height (at first harvest) (cm) | $316.31^{**}$ | 95.26 |
| 3. | Collar diameter of plant initial (cm) | $0.30^{**}$ | 0.06 |
| 4. | Collar diameter of plant (at first harvest) (cm) | $0.45^{**}$ | 0.15 |
| 5. | No. of primary branches (at first harvest) | $2.01^{*}$ | 0.76 |
| 6. | No. of secondary branches (at first harvest) | $21.15^{**}$ | 2.93 |
| 7. | No. of fruit /plant (at first harvest) | $67.66^{**}$ | 19.82 |
| 8. | No. of seeds/fruit plant (at first harvest) | $0.04^{**}$ | 0.01 |
| 9. | Fruit diameter (longitudinal) (cm) | $0.07^{**}$ | 0.02 |
| 10. | Fruit diameter (Equatorial ) (cm) | $0.06^{**}$ | 0.02 |
| 11. | 100 seed weight (g) | $24.85^{**}$ | 8.24 |
| 12. | Shelling percentage (%) | $13.49^{*}$ | 4.98 |
| 13. | Oil content (%) | $4.65^{*}$ | 2.19 |
| 14. | Seed yield / plant (g) | $1609.17^{**}$ | 186.84 |

**Table 3:** Analysis of variance for 14 traits in *Jatropha curcas* (L).
**Significant at 5 and 1 percent level of significance , respectively. Values in parenthesis indicate degree of freedom

## Genetic variability and correlation for growth and seed traits

The amount of genetic variation and association of growth and seed traits was evident from the study of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), environmental variance, heritability and genetic advance for growth and seed traits (Table 4). Wide difference has been observed for variance component of growth and seed traits. The GCV, PCV and ECV were highest at 711.17, 898.01 and 186.84 for the seed yield per plant. The lowest values of GCV (0.01), PCV (0.02) and ECV (0.01) for the number of seed per fruit of the plant. The phenotypic and environment coefficient of variability for all growth character higher than corresponding genetic coefficient of variability. Broad sense heritability values were above 50 % for all growth parameter and seed traits of the Jatropha plant. Genetic advance was recorded maximum (79.21 %) for number of secondary branches per plant while it was minimum (3.74 %) for oil content, correlation estimates among 14 traits ranged from -0.9614 to 1.3415. Out of the 196 values 56 were positively and 17 were negatively correlated (Table 5). The collar diameter, number of primary branches, number of secondary branches, number of fruits per plant, number of seeds per fruits , fruits diameter at both longitudinal and equatorial , 100 seed Test weight and seed yield per plant traits were positive and significantly correlation with plant height where these were negatively and non-significantly associated with oil content and shelling percentage . The seed yield traits ranged from 0.4623 to 1.0896 and 100 seed Test weight -0.4669 to 1.15595 respectively.

| Character | Range | Genotypic variance | Phenotypic variance | Environmental variance | Genotypic Coefficient of variation (%) | Phenotypic Coefficient of variation (%) | Heritability (%) | Genetic advance (GA) |
|---|---|---|---|---|---|---|---|---|
| Plant height (initial ) (cm) | 34.75-44.75 | 4.62 | 8.92 | 4.30 | 5.57 | 7.74 | 51.79 | 8.27 |
| Plant height (at first harvest) (cm) | 129.00-176.75 | 110.53 | 205.78 | 95.26 | 6.86 | 9.37 | 53.71 | 10.36 |
| Collar diameter of plant initial (cm) | 1.73-3.35 | 0.12 | 0.18 | 0.06 | 15.50 | 18.71 | 66.67 | 25.66 |
| Collar diameter of plant (at first harvest) (cm) | 4.15-5.88 | 0.15 | 0.30 | 0.15 | 7.92 | 11.25 | 50.00 | 11.52 |
| No. of primary branches (at first harvest) | 2.00-5.75 | 0.63 | 1.39 | 0.76 | 21.20 | 31.58 | 45.32 | 29.49 |
| No. of secondary branches (at first harvest) | 2.75-12.00 | 9.11 | 12.04 | 2.93 | 44.22 | 50.84 | 75.66 | 79.21 |
| No. of fruit /plant (at first harvest) | 105.00-126.25 | 23.92 | 43.74 | 19.82 | 4.21 | 5.69 | 54.69 | 6.41 |
| No. of seeds/fruit plant (at first harvest) | 2.50-3.00 | 0.01 | 0.02 | 0.01 | 4.02 | 5.49 | 50.00 | 5.38 |
| Fruit diameter (longitudinal) (cm) | 2.40-3.15 | 0.02 | 0.04 | 0.02 | 5.83 | 7.98 | 50.00 | 8.02 |
| Fruit diameter (Equatorial ) (cm) | 1.58-2.13 | 0.02 | 0.04 | 0.02 | 7.92 | 10.51 | 50.00 | 11.11 |
| 100 seed weight (g) | 61.00-75.71 | 8.31 | 16.55 | 8.24 | 4.28 | 6.04 | 50.21 | 6.25 |
| Shelling percentage (%) | 32.11-42.03 | 4.26 | 9.23 | 4.98 | 5.61 | 8.25 | 46.15 | 7.85 |
| Oil content (%) | 33.44-39.10 | 1.23 | 3.42 | 2.19 | 3.03 | 5.05 | 35.96 | 3.74 |
| Seed yield / plant (g) | 169.65-285.00 | 711.17 | 898.01 | 186.84 | 12.08 | 13.57 | 79.19 | 22.14 |

**Table 4:** Estimate of range, genotypic, phenotypic, environmental variance, genotypic and phenotypic coefficient of variation, heritability and genetic advance for various traits.

| Genotypes | | Plant height (initial) (cm) | Plant height (at first harvest) cm | Collar diameter of plant initial (cm) | Collar diameter of plant (At first harvest) (cm) | No. of primary branches (At first harvest) | No. of secondary branches (At first harvest) | No. of fruits / plant (At first harvest) | No. of seed / fruit (At first harvest | Fruit diameter (longitudinal) (cm) | Fruit diameter (Equitorial) (cm) | 100 Seed Weight (g) | Shelling percentage (%) | Oil content (%) | Seed yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (intial) (cm) | G | 1.000 | 0.4840* | -0.3156 | -0.5166** | 0.5849** | 0.6427** | 1.0662** | 1.3415** | 1.1189** | 0.5494** | 1.1595** | -0.3701 | 0.0243 | 1.0896** |
| | P | | 0.2546 | -0.2544 | -0.3185 | 0.0991 | 0.4461 | 0.5806** | 0.5589** | 0.4665* | 0.4832* | 0.6812** | -0.3551 | -0.0031 | 0.7171** |
| Plant height (at first harvest) cm | G | | 1.000 | 0.1106 | -0.2109 | 0.5599** | 0.6082** | 0.0455 | 0.3124 | 0.0955 | -0.0790 | 0.1376 | 0.2839 | -0.5440** | 0.0455 |
| | P | | | 0.1558 | -0.-0092 | 0.3333 | 0.3389 | -0.1410 | 0.1020 | 0.0994 | -0.0513 | 0.0622 | 0.1047 | -0.2329 | -0.0022 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Collar diameter of plant initial (cm | G | | | 1.0000 | 0.3386 | 0.1713 | -0.0781 | -0.4908* | -0.5641** | -0.4782* | -0.2862 | -0.3048 | 0.2087 | -0.2628 | -0.3654 |
| | P | | | | 0.3466 | 0.1066 | -0.047 | -0.3621 | -0.3406 | -01266 | -0.1751 | -0.1355 | 0.0220 | -0.0492 | -0.3202 |
| Collar diameter of plant (At first harvest) (cm) | G | | | | 1.0000 | 0.2996 | -0.1869 | -0.9614 | -0.5401** | -0.5803** | -0.7906** | -0.5658** | 0.5960** | 0.3426 | -0.5415** |
| | P | | | | | 0.3130 | -0.0297 | -0.3701 | -0.3566 | -0.2783 | -0.5319 | -0.2968 | 0.1349 | 0.1051 | -0.4016 |
| No. of primary branches (At first harvest) | G | | | | | 1.0000 | 0.5248** | -0.1087 | 0.4199* | -0.0394 | 0.3102 | 0.2729 | -0.2535 | 0.7608** | 0.2396 |
| | P | | | | | | 0.3467 | 0.0300 | 0.1875 | 0.0893 | 0.1375 | 0.2084 | -0.1727 | 0.1586 | 0.1595 |
| No. of secondary branches (At first harvest) | G | | | | | | 1.0000 | 0.4512* | 0.6201** | 0.2230 | 0.3293 | 0.3599 | -0.2107 | 0.5686** | 0.5388** |
| | P | | | | | | | 0.4497* | 0.4816* | 0.2201 | 0.1576 | 0.3059 | -0.2105 | 0.1494 | 0.4623* |
| No. of fruits /plant (At first harvest) | G | | | | | | | 1.0000 | 0.1298** | 0.9428** | 0.9222** | 1.0212** | -0.4046* | 0.2127 | 1.0612** |
| | P | | | | | | | | 0.5758** | 0.5366** | 0.5519** | 0.6425** | -0.3249 | 0.0817 | 0.8521** |
| No. of seed /fruit (At first harvest) | G | | | | | | | | 1.0000 | 0.7300** | 1.0522** | 1.0260** | -0.6141** | 0.3572 | 1.1878** |
| | P | | | | | | | | | 0.4161* | 0.4179* | 0.5281 | -0.2329 | 0.0705 | 0.6811** |
| Fruit diameter (longitudinal) (cm) | G | | | | | | | | | 1.0000 | 0.7736** | 1.0793** | -0.2261 | 0.0422 | 0.8422** |
| | P | | | | | | | | | | 0.2613 | 0.4669* | 0.0542 | 0.0276 | 0.5784** |
| Fruit diameter (Equatorial) (cm) | G | | | | | | | | | | 1.0000 | 0.8601** | -0.3658 | 0.3991 | 0.8775** |
| | P | | | | | | | | | | | 0.5719** | -0.4547 | 0.2666 | 0.6511** |
| 100 Seed Weight (g) | G | | | | | | | | | | | 1.000 | -0.2758 | 0.1781 | 1.1655** |
| | P | | | | | | | | | | | | -0.3857 | 0.0673 | 0.7430** |
| Shelling percentage (%) | G | | | | | | | | | | | | 1.0000 | -0.5134** | -0.4663* |
| | P | | | | | | | | | | | | | -0.1358 | -0.3502 |
| Oil content (%) | G | | | | | | | | | | | | | 1.0000 | 0.3373 |
| | P | | | | | | | | | | | | | | 0.1807 |
| Seed yield/ plant (g) | G | | | | | | | | | | | | | | 1.0000 |
| | P | | | | | | | | | | | | | | |

**Table 5:** Estimates of genotypic and phenotypic correlation coeffiencets of *Jatropha curcas* (L) traits. ***Significant at 5 and 1 percent level of significance, respectively. Values in parenthesis indicate degree of freedom

## Discussion

Various accessions of *J. curcas* exhibited considerable amount of variability in growth parameter and seed yield traits. Analysis of variance showed highly significant variations among the experimental accessions for plant height at first harvest, collar diameter, number of primary branches, number of secondary branches, number of fruits per plant, number of seeds per fruits, fruits diameter at both longitudinal and equatorial, 100 seed Test weight, shelling percentage, seed oil percentage and seed yield per plant traits (Table 2). The result revealed that the presence of considerable amount of variability in genotype, which can be used in improvement of traits including seed yield provided the accessions collected from wild is subjected to superior selection. Accession RJ- 90 had highest number of secondary branches, number of fruits per plant, number of seeds per fruits, fruits diameter at longitudinal, 100 seed Test weight, seed oil percentage at par with other high oil percentage accession and seed yield per plant and accession RJ-3 lowest number of fruits per plant, number of seeds per fruits, 100 seed test weight and seed yield per plant among all the experimental accessions (Table 2). The analysis of variance for 14 growth and seed traits in Jatropha significantly at 5 % and 1 % level (Table 3).

The data (Table 4) further revealed that genetic components of variance for different growth parameter and seed traits. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), environmental variance were highest at 711.17, 898.01 and 186.84 for the seed yield per plant. The lowest values of GCV (0.01), PCV (0.02) and ECV (0.01) for the number of seed per fruit of the plant. The phenotypic and environment coefficient of variability for all growth character higher than corresponding genetic coefficient of variability. Broad sense heritability values were above 50 % for all growth parameter and seed traits of the Jatropha plant.

Tree breeding strategy largely depends upon extent of variability in base population which may be measured by different parameters viz. 'genotypic, phenotypic variances' and 'genotypic, phenotypic coefficient of variation'. The GCV were comparatively lower than PCV for all traits. In the present study higher PCV than GCV for traits like plant height, collar diameter, fruit and seed per fruit per plant, 100 seed weight, oil percentage, shelling percentage, and seed yield per plant suggest that these characters were least influenced by the environment. Number of fruits per plant showed considerable differences between PCV (43.74) and GCV (23.92) (Table 4), which reflected considerable environmental effect on that traits. In the improvement of species, genetic component of variation is the only important factor to be transmitted to next generation. Heritability indicates the effectiveness with which genotypes selection would be based on phenotypic performance.

High heritability was observed for number of secondary branches and seed yield per plant (Table 4). Plant height, collar diameter, number of fruits per plant, number seeds per fruit, 100 seed Test weight, and oil content had moderate heritability values. Heritability in broader sense may also give useful indication about the relative values for selection of material in hand, but to arrive at more reliable conclusion, heritability should be considered with genetic relevance [17]. High heritability (75.66 %) with high genetic advance (79.21 %) was shown by number of secondary branches per plant. Highly heritable characters with high genetic advance could be further improved through individual plant selection. It is suggested that there is a definite scope for tree improvement in these characters through direct selection from the germplasm. Mohapatra and Panda [18] showed almost 100 % heritability for number of fruits per plant and 88.79 % for number of inflorescence in Jatropha; they further advocated that accessions having more seed weight and oil content could be used for tree improvement program. Moderate heritability with high genetic advance was coupled with plant height (H2 53.71 and GA = 10.36) and collar diameter (H2 66.67 and GA = 25.66). These traits should be considered as selection parameters for improvement program. Seed yield per plant exhibited good magnitude of heritability (79.19) but with lower genetic advance (22.14). Panse and Sukhatme [19] observed that high estimation of broad sense heritability and low genetic advance is due to the presence of non-additive gene effects and high genotypic and environment interaction. Estimation of broad sense heritability for growth traits indicated that a considerable portion of variance is additive. High additive genetic variance and variation between wild germplasm sources offer good scope for genetic improvement of this species. Moderate heritability with low genetic advance was exhibited by plant height perhaps due to non-additive gene action, i.e., dominance or epistatic. The traits like seed oil content percentage of plant recorded low heritability and low genetic advance indicating the predominance of non-additive gene effects. Hence, it could be suggested that improvement of these traits might be very difficult through selection, which ultimately suggests maintenance of heterozygosity in population. Correlations among traits influence effectiveness of selection [20]. Correlation study reveals that highly significant correlation exists between the collar diameter, number of primary branches, number of secondary branches, number of fruits per plant, number of seed per plant, number of seeds per fruits , fruits diameter at both longitudinal and equatorial , 100 seed Test weight and seed yield per plant traits were positive and significantly correlation with plant height. These characters show strong and positive association among themselves indicating some genes controlling these characters might be closely linked or might have pleiotropic effects. Positive and significant correlation exists between number of fruit per plant, number seed per fruit, 100 seed weight and seed yield. Rao et al. [20] discovered non-significant association of seed yield per plant with 100 seed weight and seed oil content (%). Similar results was made in the present study where oil content (%) showed no association with seed yield per plant suggesting independent genetic control of these traits. It is therefore possible to improve seed yield per plant without compromising oil content (%).

## Conclusion

High heritability was observed for number secondary branches and seed yield per plant with high genetic advance. These traits may be used for selection and tree improvement of Jatropha genotypes. Positive and significant correlation exists between number of fruit per plant, number seed per fruit, 100 seed weight and seed yield. Accessions RJ-88 ,RJ-90, RJ-92, RJ-93 , RJ- RJ-123, RJ-124 and RJ- 133 showed above average higher values for growth and seed traits attributes (viz. number of secondary branches, number of fruits per plant, 100 seed Test weight, shelling percentage, oil content and seed yield per plant Thus, these traits should be selected as parents materials for *Jatropha curcas* tree improvement program and identified superior accession with favorable traits for future establishment of elite seedling seed orchard and clonal seed orchard for varietal and hybridization program.

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