UDC 575:630
DOI: 10.2298/GENSR1501063M
Original scientific paper

CORRELATION AND PATH COEFFICIENT ANALYSIS IN *Jatropha curcas* L.

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Maurya R., U. Kumar, R. Katiyar, and H. Kumar Yadav (2015): *Correlation and path coefficient analysis in Jatropha curcas L.*. - Genetika, Vol 47, No. 1, 63-70.

Correlation and path analysis on 80 diverse accessions of *J. curcas* showed that seed weight/plant was significantly and positively associated with female flower/plant, male flower/plant, number of flower/plant, number of seed/plant, fruit weight/plant, seed width and negatively associated with oil content. Oil content was negatively and significantly correlated with all the traits studied with strong negative association with female flower/plant followed by male flower/plant, number of seed/plant, fruit weight/plant and seed weight/plant. Male flower per plant had the maximum direct effect on seed yield, followed by number of seeds/plant, seed width, number of fruits/plant and oil content. The results of the present investigations suggests that selection in *J. curcas* based on male flower/plant, number of fruit/plant, number of seeds/plant, seed width and oil content would be advantageous to achieve the desirable goals. The indirect selection through other component traits would also be rewarding to improve the seed yield.

Key words: breeding, correlation, *Jatropha curcas*, path coefficient analysis, selection

INTRODUCTION

Jatropha curcas L. is a perennial oil seed plant belonging to the family Euphorbiaceae which is native of Tropical America (FAIRLESS, 2007). It is a diploid plant species having chromosome 2n=22 (DEHGAN, 1984) with relatively smaller genome size of 416 Mb (CARVALHO *et al*., 2008; SATO *et al.,* 2011). It has wide distribution across the world mainly in tropical and subtropical area especially in Africa, India and Southeast Asia (OPENSHAW, 2000; SUJATHA and PRABHAKARAN, 1997). *J. curcas* is a multipurpose shrub with significant economic importance and having the capabilities to rehabilitate the degraded lands. In recent past peoples across the world projected *J. curcas* as an alternative and renewable source of biodiesel due to its wider

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adaptability (HELLER, 1996) and it can grow well in different kinds of soils, tolerate drought conditions and animals do not browse its leaves (PATIL, 2004) and high quality oil suitable for energetic use (GMUNDER *et al.,* 2012). However, the presently available genetic materials of *J. curcas* are reported to be still under domestication and had various negative/undesirable traits which needs to be improved through various tools including conventional and modern breeding approaches (YADAV *et al.,* 2011). Few reports are available where some efforts have been made to characterize the genetic materials and tried to understand the various genetic parameters such as genetic variability, heritability, correlation among various traits etc (DAS *et al*., 2010; RAO *et al*., 2008; KAUSHIK *et al*., 2007; SINGH *et al*., 2013; MAURYA *et al*., 2013). The understanding of genetic behavior and association among various agronomically important traits are very crucial step to design and implement breeding strategies to improve the traits under consideration.

Genetic improvement of crop plants relies on various parameters such as level of genetic variability available in gene pool, inheritance pattern and heritability of traits, association behavior of various agronomically important traits etc. The analysis of correlation coefficient provides information about the degree of relationship between important plant traits and also a good index to predict the yield response in relation to the change of a particular character. However, a study of correlation alone is not enough to provide an exact picture of relative importance of direct and indirect influences of each of the component traits on dependent trait such as yield. In this context, path coefficient analysis is an important tools in which partition the total correlation coefficients into direct and indirect effects of independent variables. Path co-efficient analysis measures the direct and indirect effect of one variable upon another and permits the separation of the correlation co-efficient into components of direct and indirect effect (DEWEY and LU, 1959). According to BOARD *et al*. (1997), path coefficient is a standardized partial regression coefficient that measures the direct influence of one trait upon another and permits the separation of a correlation coefficient in to components of direct and indirect effects. As it is shown in several previous studies that yield is a complex character and is associated with number of component characters which are themselves interrelated. Such interdependence often affects their relationship, thereby making correlation coefficient ineffective to get the information on actual contribution of each character to yield. Thus, correlation in conjunction with path analysis could give a better insight into cause and effect relationship between different pair of characters. Therefore, the present investigation was undertaken to study the association of different characters of *Jatropha curcas* to identify important yield attributing characters which would be helpful in development of high yielding *Jatropha* genotypes.

MATERIALS AND METHODS

The plant materials used in the present investigation include a total of 80 accessions of *J. curcas* collected from different eco-geographical and agro-climatic zone of India. These accessions are being maintained in the germplasm bank maintained at National Botanical Research Institute, Lucknow India. For conducting field experimental trials fifteen cuttings of each accession were first raised in polybags filled with soil, cowdung manure and sand in equal proportion. The six rooted cuttings of each accession were then transplanted in experimental plot in Randomized Block Design (RBD) with 3 replications and two plants/replications. The experimental plot is situated between 26^0 40'N latitude and 80^0 45' E longitude and at an altitude of 129 m above sea level. The distances between rows and plants were kept 2 meter. The field was irrigated as and when required. First and second pruning of plants was practiced 2 feet above the ground after 9 and 21 month from the date of transplantation. Data on different morphometric traits were recorded during 29^{th} – 31^{st} month old plant. Following traits were considered for data recording: *Female flower/plant*: Number of female flower counted during flowering period (November – January), *male flower/plant*: Number of male flower counted per plant, *male/female ratio*: ratio between female and male flower per plant, *Number of fruits/plant*: total number of fruits counted per plant at harvesting time, *Number of seeds/plant*: Total number of seeds counted per plant, *Fruit weight/plant*: total fruit weight measured in gram per plant, *Seed weight/plant*: total seed weight measured in gram per plant, *Seed length and width*: twenty seeds per plant randomly selected and length and width measured in middle with vernier caliper (mm), *Oil content*: twenty five to thirty seeds randomly selected per plant and used to measure oil content in percent through Nuclear Magnetic Resonance (NMR) spectrometer.

The mean values for each trait were subjected to statistical analysis using WINDOSTAT software (www.indostat.org) following SINGH and CHAUDHARY (1985).

RESULTS AND DISCUSSION

Correlation coefficient analysis

Majority of the agronomic traits are complex in their genetic behavior and are the result of interaction of a number of component factors. The understanding of the relationship between yield and its component traits is of paramount importance for making the best use of these relationships in selection of the promising plant types. Therefore, the genotypic and phenotypic correlations among various traits are of value to indicate the degree to which various traits of the plant are associated with economic productivity. Correlation study thus provides information on correlated response of important plant traits and therefore leads to a directional model for yield response. So, in the present study genotypic and phenotypic correlation between the yield and its various contributing traits had been calculated in 80 diverse accessions of *J. curcas* over pooled data of two years and are presented in Table 1. The values of phenotypic and genotypic correlations were of the same sign except in female flower/plant vs male flower/plant, male female ratio vs fruit weight/plant. In general genotypic correlations were slightly higher than the corresponding phenotypic correlation, which might be due to modifying effect of environment (SINGH *et al*., 2003, 2004; YADAV *et al*., 2006). In some cases where the magnitude of genotypic and phenotypic correlations were nearly the same, the environmental covariance was very small, which indicates that the influence of environment on these correlations was minimal (FALCONER 1989). The seed weight/plant (SWP) was significantly and positively associated with female flower/plant (0.99; 0.44), male flower/plant (0.64; 0.36), Number of flower/plant (0.99; 0.39), Number of seed/plant (0.99; 0.52), fruit weight/plant (0.98; 0.40), seed width (0.23; 0.16) and negatively associated with oil content (-0.30; -0.18). Positive and significant correlation of seed yield with male female ratio and flower number was also reported earlier by RAO *et al*. (2008). Negative association of seed length with oil content was also reported by KAUSHIK *et al*. (2007) and RAO *et al*. (2008). On contrary to present investigation positive and significant association of seed yield with oil content was reported by KAUSHIK *et al*. (2007). The oil content was found to be negatively and significantly correlated with all the traits studied with strong negative association with female flower/plant followed by male flower/plant, number of seed/plant, fruit weight/plant and seed weight/plant. Positive association of seed yield/plant with fruit/plant was also reported by DAS *et al*. (2010). Among component traits female flower/plants was significantly and positively correlated with male flower/plant (0.77; 0.44), number of fruits/plants (0.99; 0.57), number of seeds/plants (0.98; 0.41), fruit weight/plants (0.99; 0.63) and seed length (0.32; 0.14) and negative association with oil content (-.039; -0.22).

Table 1. Estimates of genotypic (r_G) and Phenotypic (r_P) correlation coefficients between the traits determined in 80 accessions of J. curcas

		MFP	MFR	NFP	NSP	FWP	SWP	SL	SW	OC
FFP	rg	0.77	0.10	0.99	0.98	0.99	0.95	0.32	0.10	-0.39
	rp	0.44**	-0.38**	0.57**	0.41**	0.63**	0.36**	0.14*	0.09	-0.22**
MFP	rg		0.71	0.73	0.66	0.72	0.64	0.22	0.20	-0.32
	rp		0.65**	0.39**	0.37**	0.39**	0.36**	0.11	0.11	-0.20**
MFR	rg			-0.04	-0.05	0.03	-0.04	0.00	0.24	-0.07
	rp			-0.09	0.04	-0.13*	0.05	-0.00	0.05	-0.03
NFP	rg				0.99	0.99	0.99	0.37	0.24	-0.29
	rp				0.42**	0.81**	0.39**	0.17**	0.14*	-0.19
NSP	rg					0.99	0.99	0.11	0.14	-0.31
	rp					0.47**	0.52**	0.06	0.09	-0.20**
FWP	rg						0.98	0.35	0.17	-0.30
	rp						0.40**	0.14*	0.14*	-0.20**
SWP	rg							0.19	0.23**	-0.30**
	rp							0.11	0.16	-0.18
SL	rg								0.74	-0.05
	rp								0.65**	-0.05
SW	rg									-0.03
	rp									-0.04
OC										

*, ** = significant at 5% and 1% respectively.FFP: female flowers/plant; MFP: male flowers/plant; MFR: male female ratio; NFP: number of flowers/plant; NSP: number of seeds/plant; FWP: fruit weight/plant; SWP: seed weight/plant; SL: seed length; SW: seed width; OC: oil content; rg: genotypic correlation coefficient; rp: phenotypic correlation coefficient

Male flower/plant had significant and positive correlation with male female ratio (0.71; 0.65), number of fruits/plant (0.73; 0.39) and fruit weight/plant (0.72; 0.39). Male female ratio had significant and negative correlation with fruit weight/plant (0.03; -0.13). The negative association of male female ratio with seed yield was also reported earlier by SINGH *et al.* (2013). Number of fruits/plant had significant and positive correlation with number of seeds/plant (0.99; 0.42), fruit weight/plant (0.99; 0.81), seed length (0.37; 0.17) and seed width (0.24; 0.14). Number of seeds/plant had significant and positive correlation with fruit weight/plant (0.99; 0.47) and negatively correlated with oil content (-0.31; -0.20). Fruit weight/plant had significant and positive correlation with seed length (0.35; 0.14) and seed width (0.17; 0.14) while negatively correlated with oil content (-0.30; -0.20). Seed length had significant and positive correlation with seed width (0.74; 0.65) which was also previously reported by KAUSHIK *et al.* (2007) and GUAN *et al.* (2013). The positive and significant association of major component among themselves in general and with seed weight/plant in particular suggests that selection of component traits jointly or individually may enhance the seed yield however oil yield yield could be compromised upto some extent as it showed negative association with most of the component traits. Therefore, precaution should be taken while selecting plant type based on component traits so that both seed yield and oil yield could be optimized to its maximum potential.

Path coefficient analysis

Correlation analysis reveals over all relationship between among different traits which may be negative or positive in nature and it is the net result of direct effect of a particular trait and indirect effects *via* other traits. In order to predict the direct and indirect effect of traits on correlation among various traits the path analysis studies are being carried out. The path analysis is a statistical technique used primarily to examine the comparative strength of direct and indirect relationship among variables and thus permits a critical examination of components that influence a given correlation and can be helpful in formulating an efficient selection strategy (SHIPLEY, 1997; SCHEINER *et al*., 2000). This approach quantifies the relationship among variables based on a priori assumptions, which traits are to be included in analysis. Such assumptions are somewhat subjective but path coefficient may allow a better understanding of the interrelationships between traits than correlation tables with all possible combinations between all the traits. The path diagram specifies the causal and non-causal paths between independent and dependent variables. The path coefficient analysis for seed yield in *J. curcas* germplasm was performed and results are presented in Table 2.

Table 2. Path coefficient analyses for seed yield/plant in J. curcas germplasm

Traits	Direct Effect	Indirect effect via										
		FFP	MFP	MFR	NFP	NSP	FWP	SL	SW	OC	r2	Total Indirect effect
FFP	**-2.19**	-	3.78	-0.33	0.31	0.7	-1.18	-0.13	0.05	-0.06	**0.95**	3.14
MFP	**4.87**	-1.67	-	-2.36	0.2	0.46	-0.83	-0.09	0.11	-0.05	**0.64**	-4.23
MFR	**-3.32**	-0.22	3.46	-	-0.01	-0.04	-0.04	0	0.14	-0.01	**-0.04**	3.28
NFP	**0.28**	-2.42	3.5	0.14	-	0.8	-1.25	-0.15	0.14	-0.05	**0.99**	0.71
NSP	**0.71**	-2.17	3.2	0.16	0.32	-	-1.2	-0.05	0.08	-0.06	**0.99**	0.28
FWP	**-1.14**	-2.26	3.54	-0.12	0.3	0.75	_	-0.14	0.09	-0.04	**0.98**	2.12
SL	**-0.4**	-0.7	1.1	0	0.1	0.08	-0.4	-	0.41	0	**0.19**	0.59
SW	**0.57**	-0.2	0.99	-0.8	0.07	0.1	-0.2	-0.3	-	0	**0.23**	-0.34
OC	**0.15**	0.85	-1.57	0.23	-0.08	-0.22	0.34	0.02	-0.02	-	**-0.30**	-0.45

FFP: female flowers/plant; MFP: male flowers/plant; MFR: male female ratio; NFP: number of flowers/plant; NSP: number of seeds/plant; FWP: fruit weight/plant; SWP: seed weight/plant; SL: seed length; SW: seed width; OC: oil content

The male flower per plant had the maximum direct effect on seed yield (4.87), followed by number of seeds/plant (0.71), seed width (0.57), number of fruits/plant (0.28) and oil content (0.15). On the other hand female flower/plant (-2.19), male female ratio (-3.32), fruit weight/plant (-1.14), seed length (-0.4) exhibited negative direct path effect on seed yield but showed positive and significant correlation on seed yield except male female ratio. Similarly, SINGH *et al*. (2013) also reported negative direct effect of path coefficient and negative correlation of male female ratio on seed yield/plant in *Jatropha.* The negative direct effect of female flower/plant, fruit weight/plant, seed length on seed yield/plant was counterbalanced by indirect positive effect via male flower/plant, number of fruit/plant, number of seeds/plant, and seed width. The apparent contradiction was probably due to the fact that the total correlation simply measures mutual association without considering the causation, whereas the path analysis specifies the causes and measures their relative importance (BHATT, 1973). Male flower/plant (3.78), number of fruits/plant (0.31), number of seeds/plant (0.70), seed width (0.05) had indirect positive effect and influenced female flower which indirectly affect yield. Male female ratio showed negative indirect effect and negative correlation with yield. Oil content had positive direct effect on seed yield/plant though it had negative association which was due to negative indirect effect via male flower/plant, number of seeds/plant, number of fruit/plant and seed width. The positive direct effect of male flower/plant, number of fruit/plant, number of seeds/plant, seed width and oil content for seed yield/plant indicated that plant types with larger seeds, higher number of male flower, fruit and seeds would be desirable trait for improving seed yield in *J. curcas.* The results of the present investigations suggests that selection in *J. curcas* based on male flower/plant, number of fruit/plant, number of seeds/plant, seed width and oil content would be advantageous to achieve the desirable goals. The indirect selection through other component traits would also be rewarding to improve the seed yield.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, CSIR-National Botanical Research Institute, Lucknow for providing facilities for the conduction of experiment.

Received May 21th, 2014
Accepted October 05th, 2014

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ANALIZA KOEFICIJENTA KORELACIJE I PATH KOEFICIJENTA KOD *Jatropha curcas* L.

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Izvod

Korelacije i path analiza 80 različitih genotipova *J. curcas* su pokazale da su težina semena/biljci značajno i pozitivno vezane za biljke sa ženskim cvetovima, biljke sa muškim cvetovima , broj semena/biljci, težinu ploda/biljci, i negativno vezane sa sadržajem ulja. Rezultati istraživanja pokazuju da selekcija *J. curcas* zasnovana na ovim osobinama ima prednosti u postizanju željenog cilja u oplemenjivanju.

Primljeno21. V. 2014.
Odobreno 05. X. 2014.