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Genetic variability and correlation studies for vegetative, reproductive and yield attributing traits in papaya

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ABSTRACT

An experiment was carried out with 5 parent and 3 hybrid papaya genotypes to study the genetic variability and correlation between different yield attributing traits by evaluating 16 vegetative, reproductive, and fruit yield contributing traits during 2016-2017. The findings indicate that the maximum fruiting zone (129.8 cm) was in PS 3 followed by PS 3 × P-7-9 (128 cm). The hybrid PS 3 × P-7-9 had maximum number of fruits per plant (44.67), minimum fruit weight (1020g) and maximum yield per plant (46.33 kg/plant) among the three hybrids evaluated. The phenotypic coefficient of variation (PCV) is higher than the genotypic coefficient of variation (GCV) for all the traits studied. The genotypic variance and phenotypic variance were high for traits like leaf width, stem diameter and fruit weight. Traits such as leaf length, petiole length, number of fruits per plant, fruit diameter and fruit yield exhibited higher value of GCV and PCV. Heritability for traits ranged from 53.83 to 99.49, of which majority of traits showed very high heritability, except some traits such as inflorescence size and fruit length which showed moderate heritability. Genetic advance (GA) was recorded highest for fruit length (179.13). Traits like fruit yield, petiole length and leaf length exhibited high heritability accompanied by high to moderate genetic advance indicating additive gene action, which suggest that selection may be effective for these traits. The trait, fruit yield was positively associated with plant height at flower initiation and maturity stage, stem diameter, days to flowering, fruiting zone, number of fruits per plant and fruit diameter.

Key words: *Carica papaya*, variability, interelationship genetic advance, heritability.

INTRODUCTION

Papaya (*Carica papaya* L.) belonging to the family Caricaceae, is considered as one of the most important fruit crop cultivated throughout tropical and subtropical parts of the world owing to its high production potential, nutritional and medicinal importance. For an efficient crop improvement programme the two very important steps are, the collection of germplasm and the determination of nature and magnitude of genetic variability and association of traits. High magnitude of variability along with heritability in a population provides the opportunity for selection to evolve a variety having desirable characters. The genotypic and phenotypic coefficient of variations (GCV and PCV), heritability, genetic advance (GA) and correlation coefficients are helpful in exposing and understanding the clear picture of existing variability in the populations and employment of suitable method for improvement. Yield is a complex trait, which is influenced by a number of vegetative, reproductive and yield attributing traits, and by environment. Thus, the variability for these traits is the sum total of heredity effects of the concerned genes and the influence of the environment. Hence, it is very important to partition the total variability into heritable and non-heritable components because only heritable portion of variation is exploitable through selection. GCV along with heritability estimates and GA provides a better picture for the expected amount of genetic gain to be obtained from phenotypic selection (Burton, 3). Heritability coupled with genetic gain proves to be more useful than the heritability values alone as it allows the prediction of the resultant effect for selecting the best individual genotypes (Johnson *et al.*, 8). For predicting the effect of selection, heritability along with genetic advance over means (GAM) is more effective (Ramanjinappa *et al.*, 11). Correlation studies help in finding out the degree of interrelationship among various traits and in evolving breeding method for improvement. The practical utility of selection of a given character as a measure of improving another character depends on the extent to which they are related and this relation depends not only on genotypic correlation but also on phenotypic correlation (Imtiyaz *et al.,* 7). Achieving a superior cultivar with improved yield and good fruit quality is an important objective for further improvement. Thus, the present study was conducted to evaluate genetic variation and correlation among 16 vegetative, reproductive and fruit yield attributing traits.

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MATERIALS AND METHODS

The present study was conducted at the Main Experimental Orchard, Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi during 2015 and 2017. The experimental site is situated at 77º12'E longitude, 28º40 N' latitude and an altitude of 228.6 m above mean sea level. The average maximum temperature ranges between 38.5º to 44.4ºC and the average minimum temperature ranges between 6.1º to 16.9ºC. The experiment was laid out in a randomized block design with four replications. The research material consisted of 5 parent and 3 hybrid papaya genotypes, namely, Red Lady (Selfed) (RL), Pusa Nanha (PN), P-9-5, Pune Sel. 3 (PS 3), P-7-9, Red Lady (selfed) × Pusa Nanha, Red Lady (selfed) × P-9-5 and Pune Sel. 3 × P-7-9, which are maintained at ICAR-IARI, New Delhi and ICAR-IARI, Regional Station, Pune, Maharashtra. Seedlings of parents and F_1 hybrids were planted under uniform field conditions and 12 uniform healthy plants were maintained for each genotype. The plants were raised as per the recommended package of practices for papaya cultivation under north Indian plains.

Each plant was tagged for recording the observations. A total of 8 vegetative and reproductive; and 8 yield attributing traits were recorded on female and hermaphrodite plants of the 8 genotypes. The data obtained for different traits were statistically analyzed to find out the significance of the difference among the papaya genotypes. The mean values of all the traits were evaluated and ANOVA was performed using 'F' test. The significance of the difference among the treatments means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 6). The data was submitted for online http://hau.ernet.in/about/opstat.php) analysis using OP Stat software (Sheoran *et al*., 12). Genotypic and phenotypic variances were derived according to the method suggested by Johnson *et al*. (8). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated as the method suggested by Burton (3). For estimation of the expected genetic advance for different characters under selection was done according to Allard (2). Phenotypic and genotypic correlation coefficients were calculated for the characters by working out the variance components of each character and the covariance components for each pair of characters using the standard procedure suggested by Al-Jibouri *et al*. (1).

RESULTS AND DISCUSSION

Any crop improvement programme for qualitative and quantitative traits demands broad information on level and nature of variation in the available genotypes. Due to predominance of cross pollination and exclusive seed multiplication, higher level of genetic variation was observed in papaya. Data presented in Table 1 revealed significant difference among the parents and hybrids for all 16 vegetative, reproductive and yield attributing traits. Interaction between parents in hybrids showed significant difference for several traits. These results indicated that parents and their hybrids possessed high genetic variation for most of the traits. Plant height at initiation of first flower was highest in P-7-9 and hybrid Red Lady (self) × P-9-5. Plant height at first fruit maturity was highest in hybrid PS 3 × P-7-9. Duration for initiation of first flower was minimum in P-7-9 followed by Pusa Nanha and hybrid Red Lady (self) × Pusa Nanha). Genotype P-7-9 recorded the maximum inflorescence size followed by PS 3 and hybrid P-7-9. Fruiting zone was maximum in PS 3 and hybrid PS 3 × P-7-9. Minimum days to fruit maturity was observed in genotype P-9-5 closely followed by the hybrids Red Lady (self) × P-9-5 and PS 3 × P-7-9. The highest number of fruits per plant, minimum fruit weight and fruit cavity index were recorded in the hybrid PS 3 × P-7-9.

The extent of variability among the genotypes was estimated in terms of genotypic variance, phenotypic variance, GCV, PCV, heritability, GA and GAM as indicated in Table 2. The estimates of phenotypic and genotypic variances were high for fruit weight, stem diameter and leaf width. Whereas, traits like plant height at flower initiation, plant height at first fruit maturity and fruiting zone showed moderate genotypic and phenotypic variances; while, they were low for the remaining traits though it was exceptionally low for traits like inflorescence size and leaf length. Genotypic variance was found highest for fruit weight (14045.08) followed by stem diameter (2303.08) and leaf width (2021.83). Phenotypic variance was recorded highest for fruit weight (26089.39) followed by stem diameter (2366.62) and leaf width (2032.34). The PCV for all the traits were slightly higher than the GCV. Leaf length, fruit yield and number of fruits per plant was recorded with high GCV and PCV. The highest estimate of heritability for vegetative traits was observed for leaf length (99.49), followed by petiole length (99.04) and leaf width (98.78), whereas in case of yield and yield attributing traits, fruit diameter (97.90) followed by fruit yield (95.22) showed highest heritability. GA was found maximum for fruit length (179.13), followed by plant height at first fruit maturity (49.12), petiole length (27.69) and fruiting zone (26.71) whereas GAM% was observed highest for leaf length (46.20) followed by fruit yield (40.50). Leaf length and fruit

Table 1. Performance of papaya parent and hybrid genotypes for vegetative and reproductive traits.

Genotype	Plant ht. at flower initiation (cm)	Plant ht. at first fruit maturity (cm)	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)	Stem dia. (cm)	Days to flowering	Inflorescence size (cm)	Fruiting zone (cm)	Days to fruit maturity	No. of fruits/ plant	Fruit wt. (g)	Fruit dia. (cm)	Fruit length (cm)	Fruit cavity index (%)	Fruit yield (kg/ plant)
R L (S)	86.5	205.9	83.2	76.1	73.1	12.5	95.8	6.5	117.8	141.8	33.5	1323.8	31.3	24.0	31.7	43.0
P N	63.8	154.0	59.3	48.2	53.9	9.3	82.3	6.5	85.6	138.0	20.6	1160.0	17.9	21.5	30.6	23.8
R L (S) × P N	73.8	179.3	83.2	58.0	64.8	11.0	84.0	6.3	98.0	133.0	34.5	1120.3	24.5	20.5	26.8	38.2
P-9-5	81.0	197.3	96.2	63.3	67.0	12.7	92.3	6.5	120.3	125.5	35.2	1247.0	30.1	25.1	32.4	45.2
R L (S) × P-9-5	93.3	209.5	56.0	35.2	53.5	13.1	95.5	6.5	112.3	126.5	34.7	1123.8	24.5	21.7	34.7	41.4
P S 3	84.0	224.3	70.7	54.0	49.9	13.2	99.5	8.0	129.8	137.0	36.6	1436.3	25.4	18.6	37.6	52.8
P-7-9	96.5	224.0	80.2	55.5	55.5	11.8	81.8	8.5	124.3	144.3	33.9	1199.8	30.1	24.3	34.4	40.4
P S 3 × P-7-9	81.8	227.3	68.7	45.4	56.6	12.5	98.8	7.8	128.0	130.8	44.7	1020.0	21.3	20.9	24.0	46.3
Mean	82.6	202.7	74.7	54.4	59.3	12.0	91.2	7.1	114.5	134.6	34.2	1203.8	25.6	22.1	31.5	41.4
$LSD_{(P=0.05)}$	4.8	11.8	2.0	1.3	1.3	0.9	5.5	1.0	12.3	5.8	2.8	162.5	1.0	1.3	1.5	2.8
CV (%)	3.3	4.3	1.8	1.6	1.4	5.2	4.1	10.0	7.3	3.0	5.4	9.1	2.7	3.8	3.2	4.5

yield exhibited higher heritability along with higher GAM. Higher heritability coupled with higher GA was recorded for petiole length and leaf length. While traits like fruit yield and leaf width exhibited higher heritability with moderate GA.

Traits like fruit weight, stem diameter and leaf width which showed high values of genotypic and phenotypic variance value indicate presence of inherent genetic variance for which selection can be effective. Whereas, traits like inflorescence size, leaf length and fruit length, which were observed with extremely low genotypic and phenotypic variance offers very little or no advantage of genetic improvement through selection. Results revealed that the estimated value of PCV was slightly higher than the value of GCV, which indicates less effect of environment over the traits. The traits like leaf length, fruit yield and number of fruits per plant exhibited high magnitude of GCV and PCV indicating the presence of wide range of genetic variability for these traits and chances for improvement of these traits to be fairly high. The high heritability of the traits like leaf length, petiole length, leaf width, fruit diameter and fruit yield may be due to additive gene effect, suggesting that these traits to likely to respond to direct selection. Similar results regarding fruit yield of papaya and strawberry with high GCV, PCV, heritability and GA was reported by Davamani *et al.* (4) and Mishra *et al.* (10) respectively. High GCV was accompanied with high heritability estimates for leaf length, fruit yield, number of fruits per plant and fruit diameter, which revealed the fact that selection could be more effective for the improvement of these traits. Genetic gain gives an indication of expected genetic progress for a particular trait under suitable selection pressure. Moderate or low heritability estimates with low to medium GA was observed for inflorescence size which might be due to presence of non-additive gene actions. Hence, these traits are not much reliable for effective selection (Deepthi *et al.*, 5). Traits like leaf length and fruit yield exhibited higher heritability along with higher GAM, which indicates the predominance of additive gene action in governing these traits and selection can be done for these traits for further improvement. Traits like fruit length and inflorescence size exhibited low heritability and low GAM, which indicates the predominance of additive and non-additive gene action in controlling these traits. Hence, direct selection for these traits may not be rewarding.

From the correlation matrix for phenotype (Table 3) and genotype (Table 4), significant positive correlations were observed for plant height at flower initiation and maturity stage with stem diameter, inflorescence size, fruiting zone, number of fruits per

Table 2. Genetic parameters of vegetative and reproductive traits of parent and hybrid papaya genotypes.

Trait	Genotypic variance (σ^2g)	Phenotypic variance (σ^2p)	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability (%)	Genetic advance	Genetic advance in % of mean
Plant ht. at flower initiation	182.38	184.15	12.50	13.00	92.38	20.43	24.75
Plant ht. at first fruit maturity	149.86	150.64	12.38	13.04	90.26	49.12	24.24
Petiole length	64.61	65.33	18.09	18.17	99.04	27.69	37.08
Leaf length	1.65	2.04	22.49	22.55	99.49	25.15	46.20
Leaf width	2021.83	2032.35	13.34	13.42	98.78	16.49	27.31
Stem dia.	2303.08	2366.62	10.60	11.91	79.28	2.33	19.45
Days to flowering	51.85	65.83	7.89	8.89	78.78	13.17	14.43
Inflorescence length	0.64	1.13	11.33	15.08	56.43	1.24	17.53
Fruiting zone	220.57	289.47	12.97	14.86	76.20	26.71	23.33
Days to fruit maturity	42.88	58.44	4.87	5.68	73.36	11.55	8.58
No. of fruits/ plant	42.41	45.88	19.05	19.81	92.45	12.90	37.73
Fruit wt.	14045.08	26089.39	9.86	10.58	86.98	4.18	18.95
Fruit dia.	21.59	22.06	18.14	18.33	97.90	9.47	36.97
Fruit length	4.74	5.45	9.84	13.42	53.83	179.13	14.88
Fruit cavity index	19.20	20.24	13.90	14.27	94.87	8.79	27.89
Fruit yield	69.48	72.96	20.15	20.65	95.22	16.76	40.50

plant, fruit diameter and fruit yield. At phenotypic and genotypic level, a positive and significant association of petiole length, leaf length and leaf width was observed with fruit weight and fruit diameter. In case of stem diameter, a positive significant phenotypic and genotypic correlation was found for traits like plant height at flower initiation and maturity, days to flowering, fruiting zone, number of fruits per plant, fruit diameter and fruit yield. From the phenotypic and genotypic correlation matrix it was revealed that plant height at maturity, stem diameter, fruiting zone, number of fruits per plant and fruit yield had positive significant association with days to flowering. Traits like fruiting zone, days to fruit maturity, number of fruits per plant and fruit yield exhibited positive significant genotypic correlation with inflorescence size. Phenotypic and genotypic correlation for the trait, fruiting zone was positive and significant with plant height at flower initiation and maturity stage, stem diameter, days to flowering, inflorescence size, number of fruits per plant, fruit diameter and fruit yield. In case of the trait, days to fruit maturity, leaf length and inflorescence size showed positive significant association, whereas, it showed negative association with days to flowering (-0.392). Traits such as, plant height at flower initiation and maturity stage, stem diameter, days to flowering, fruiting zone and fruit yield showed positive significant phenotypic and genotypic correlation with number of fruits per plant. Positive association of fruit weight, fruit length and fruit diameter was observed with leaf length both at phenotypic and genotypic level. A positive significant association was observed for fruit cavity index with fruit diameter and fruit length. Fruit yield was positively and significantly associated with majority of traits such as plant height at flower initiation stage (0.556), plant height at fruit maturity stage (0.790), stem diameter (0.827), days to flowering (0.701), fruiting zone (0.810), number of fruits per plant (0.817) and fruit diameter (0.478) had positive significant association with fruit yield at phenotypic level. Plant height at flower initiation stage (0.595), plant height at fruit maturity stage (0.866), stem diameter (0.955), days to flowering (0.785), inflorescence size (0.476), fruiting zone (0.943), number of fruits per plant (0.836), fruit diameter (0.508) and fruit length (0.457) had positive significant genotypic association with fruit yield.

The genotypic correlation coefficients of vegetative, reproductive, fruit yield and other yield attributing characters were higher as compared to the phenotypic correlation coefficients in almost all cases, indicating that the effects of environment suppressed the phenotypic relationship between these characters. Mir *et al.* (9) also recorded positive and significant correlations for pomegranate yield

Table 3. Phenotypic correlations matrix of vegetative, reproductive, fruit and yield attributing traits in papaya.

Parameter	Plant ht. at flower initiation	Plant ht. at first fruit maturity	Petiole length	Leaf length	Leaf width	Stem dia.	Days to flowering	Inflorescence length	Fruiting zone	Days to fruit maturity	No. of fruits/ plant	Fruit wt.	Fruit dia.	Fruit length	Fruit cavity index	Fruit yield
Plant ht. at flower initiation	1.000															
Plant ht. at first fruit maturity	0.758**	1.000														
Petiole length	0.087NS	0.085NS	1.000													
Leaf length	-0.035NS	-0.046NS	0.792**	1.000												
Leaf width	0.156NS	-0.050NS	0.786**	0.812**	1.000											
Stem dia.	0.669**	0.781**	0.151NS	0.024NS	-0.004NS	1.000										
Days to flowering	0.236NS	0.568**	-0.090NS	-0.027NS	-0.214NS	0.741**	1.000									
Inflorescence length	0.380*	0.548**	-0.030NS	-0.119NS	-0.222NS	0.206NS	-0.021NS	1.000								
Fruiting zone	0.662**	0.889**	0.251NS	0.111NS	0.024NS	0.784**	0.610**	0.421*	1.000							
Days to fruit maturity	0.106NS	0.039NS	0.009NS	0.372*	0.201NS	-0.288NS	-0.314NS	0.366*	0.047NS	1.000						
No. of fruits/ plant	0.496**	0.730**	0.228NS	-0.044NS	0.058NS	0.645**	0.562**	0.323NS	0.662**	-0.269NS	1.000					
Fruit wt.	0.287NS	0.034NS	0.532**	0.455**	0.710**	0.028NS	-0.187NS	-0.122NS	0.131NS	0.091NS	-0.125NS	1.000				
Fruit dia.	0.639**	0.432*	0.732**	0.668**	0.716**	0.495**	0.095NS	0.075NS	0.484**	0.162NS	0.247NS	0.615**	1.000			
Fruit length	0.135NS	0.135NS	0.240NS	0.446*	0.068NS	0.187NS	0.220NS	0.190NS	0.221NS	0.343NS	-0.107NS	0.036NS	0.389*	1.000		
Fruit cavity index	0.435*	0.205NS	-0.066NS	0.018NS	-0.205NS	0.327NS	0.109NS	0.198NS	0.194NS	0.166NS	-0.218NS	0.038NS	0.378*	0.609**	1.000	
Fruit yield	0.556**	0.790**	0.326NS	0.159NS	0.010NS	0.827**	0.701**	0.342NS	0.810**	-0.166NS	0.817**	-0.128NS	0.478**	0.315NS	0.248NS	1.000

*, **Significant at 0.01 and 0.05 levels of probability, NS = Non significant

Table 4. Genotypic correlations matrix of vegetative, reproductive, fruit and yield attributing traits in papaya.

Trait	Plant ht. at flower initiation	Plant ht. at first fruit maturity	Petiole length	Leaf length	Leaf width	Stem dia.	Days to flowering	Inflorescence length	Fruiting zone	Days to fruit maturity	No. of fruits/ plant	Fruit wt.	Fruit dia.	Fruit length	Fruit cavity index	Fruit yield
Plant height at flower initiation	1.000															
Plant height at first fruit maturity	0.844**	1.000														
Petiole length	0.094NS	0.093NS	1.000													
Leaf length	-0.029NS	-0.047NS	0.797**	1.000												
Leaf width	0.158NS	-0.043NS	0.794**	0.819**	1.000											
Stem dia.	0.792**	0.882**	0.167NS	0.023NS	0.011NS	1.000										
Days to flowering	0.338NS	0.625**	-0.108NS	-0.047NS	-0.224NS	0.833**	1.000									
Inflorescence length	0.544**	0.803**	-0.066NS	-0.159NS	-0.304NS	0.353*	0.166NS	1.000								
Fruiting zone	0.750**	0.984**	0.294NS	0.131NS	0.049NS	0.898**	0.672**	0.803**	1.000							
Days to fruit maturity	0.089NS	0.044NS	0.033NS	0.442*	0.229NS	-0.297NS	-0.392*	0.484**	-0.029NS	1.000						
No. of fruits/ plant	0.516**	0.845**	0.235NS	-0.047NS	0.047NS	0.813**	0.681**	0.433*	0.850**	-0.348NS	1.000					
Fruit wt.	0.325NS	-0.021NS	0.576**	0.476**	0.769**	0.013NS	-0.307NS	-0.136NS	0.074NS	0.068NS	-0.114NS	1.000				
Fruit dia.	0.660**	0.452**	0.744**	0.681**	0.728**	0.554**	0.112NS	0.139NS	0.555**	0.205NS	0.276NS	0.668**	1.000			
Fruit length	0.174NS	0.198NS	0.317NS	0.591**	0.069NS	0.388*	0.294NS	0.150NS	0.370*	0.388*	-0.166NS	-0.052NS	0.549**	1.000		
Fruit cavity index	0.467**	0.242NS	-0.073NS	0.015NS	-0.222NS	0.361*	0.105NS	0.274NS	0.283NS	0.221NS	-0.266NS	0.053NS	0.402*	0.824**	1.000	
Fruit yield	0.595**	0.866**	0.331NS	0.162NS	0.008NS	0.955**	0.785**	0.476**	0.943**	-0.210NS	0.836**	-0.132NS	0.508**	0.457**	0.248NS	1.000

*, **Significant at 0.01 and 0.05 levels of probability, NS = Non significant

per plant with traits such as height of plant, fruit weight, fruit diameter, and number of fruits per plant of pomegranate. In case of strawberry also fruit yield per plant was positively and significantly associated with yield attributing traits such as plant height, number of fruits per plant, fruit length, fruit diameter and fruit weight both at phenotypic and genotypic level (Mishra *et al*., 10). From the above discussion, it become clear that use of Pusa Nanha as donor male parents holds immense potentiality for utilization in papaya hybrid development programme. Since, parents have higher fruiting zone and average fruit weight which had subsequently leads the higher fruit yield in parents compare to hybrids.

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