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STUDIES ON GENETIC VARIABILITY PARAMETERS, CHARACTER ASSOCIATION AND PATH ANALYSIS AMONG YIELD AND YIELD CONTRIBUTING TRAITS IN PAPAYA [*CARICA PAPAYA* (L.)]

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ABSTRACT
An investigation was carried out to study the genetic variability, association among the yield component traits, their direct and indirect effects on the yield. All the genotypes showed considerable amount of variation in their mean performances with respect to the characters studied except TSS (0.267) indicates presence of sufficient variability for breeding of superior desirable genotypes. High heritability with high genetic advance as per cent mean recorded for characters seeds per fruit (98.3, 148.75), pulp to seed ratio (79.70, 91.47), yield per plant (83.5, 37.64), fruit length (84.5, 34.04), distance of first fruiting node from ground level (78.0, 31.66), fruits per plant (71.8, 24.18), fruit cavity, fruit diameter and average fruit weight indicating that these traits are predominantly governed by additive gene action. Yield per plant exhibited highly significant positive correlation with fruit cavity (0.88, 0.68), number of fruits per plant (0.87, 0.85), average fruit weight (0.77, 0.67) and pulp thickness (0.63, 0.54) at both genotypic and phenotypic levels respectively, indicating improvement in these traits will increase the fruit yield. Number of fruits per plant had the highest direct effect (0.97) on yield per plant followed by average fruit weight (0.56), length of fruit (0.19) indicating importance of these characters and which can be strategically used to improve the yield of papaya.

INTRODUCTION

India is a major papaya producing country which produced about 25% of the world's production from about one fourth of total global area of 1.06 lakh ha in 2012(Anonymous, 2011). Papaya was introduced in India from Malaysia in the 16th century. Although, India is not a hotspot for papaya biodiversity, it contains a large pool of genetic variability owing to five centuries of cultivation. Reported biodiversity in the family *Caricaceae* is spread over 6 genera and 35 species. Out of various genera of the family *Caricaceae*, only *Carica papaya* is cultivated in India. They show great morphological diversity in their height (tall, medium or dwarf), objective of cultivation (fresh fruit or papain), flesh colour (yellow, orange, pink or red), and sex expression (dioecious or gynodioecious).The basic idea of the research is that work out high genetic diversity among local papaya cultivars in India and utilize them for the up gradation of yield as well as quality.

In Papaya, selection is a complicated process, influenced by a number of factors including both genetical and environmental. For any crop improvement, variability is basic need. The genetic variability along with heritability gives a reliable idea of the genetic improvement in a crop (Subramanyam and Iyer, 1981). Papaya although heterozygous has comparatively shorter economic life span and is propagated by seeds. High heritability estimates showed that selection programme based on these characters would be more effective in improving the quality parameters of papaya (Ghanta and Mondal, 1992). Hence the study of the variability in papaya was undertaken with the objectives of genetic improvement by studying the variability parameters.

A positive genetic correlation between two desirable traits makes the job of the plant breeder easy for improving both traits simultaneously. Path coefficient analysis was performed to find out the direct and indirect contribution from each of the characters. Therefore the present investigation was carried out to study the genetic variability, relationships among quantitative traits and Path coefficient analysis in selected genotypes of papaya. Similar types of works were carried out in papaya by Dash *et al.* (2000), Barua (2002), Magdalita *et al.* (1984) and Jana *et al.* (2006) Therefore the present investigation was carried out to study the genetic variability, relationships among quantitative traits and path coefficient analysis in selected genotypes of papaya.

MATERIALS AND METHODS

Twenty four genotypes from local 'Bakshi' collection were originated from heterozygous gynodioceous population of papaya available with Horticulture Department were used for the present investigation (Table 1).

The orchard was planted on 1st Dec, 2012. The Randomized Block design was used for three replications and the distance was 2.25 X 2.25m.Observations were recorded on three qualitative, 12 quantitative and two biochemical characters. The analysis of variance was done by using method suggested by Panse and Sukhatme (1985). The datawas analyzed

statistically for genotype and phenotypic coefficients of variation (Burton, 1952), Heritability (Allard,1960) and genetic advance (Johnson, *et al.*, 1955). The genotypic and phenotypic correlation co-efficient, path coefficient analysis was done to partition the genotypic correlation co-efficient into direct and indirect effects. Association among the characters is useful in formulation of breeding programme aimed at achieving the desired combinations of various components of yield and also and help to differentiate vital associations useful in breeding

The GCV and PCV are classified as suggested by Sivasubramaniam and Madhavamenon (1973). Co-variance analysis between all the pairs of characters under study was carried out as per the procedure of analysis of variance and covariance as described by Singh and Chaudhari (1979). Path coefficient analysis was done according to procedure suggested by Dewey and Lu (1959) developed Wright (1921).

Table 1: List of 24 genotypes of papaya

Sr. No.	Name of genotype	Sr. No.	Name of genotype
1.	Selfed 31(H)	13.	2 x 66 (G x H)
2.	Selfed 35(H)	14.	43 x 59 (G x H)
3.	Selfed 49(H)	15.	46 x 54 (G x H)
4.	Selfed 54(H)	16.	51 x 49 (G x H)
5.	Selfed 59(H)	17.	60 x 35 (G x H)
6.	Selfed 66(H)	18.	63 x 31 (G x H)
7.	31 x 66(H x H)	19.	2 x 31 (G x H)
8.	35 x 59(H x H)	20.	43 x 35 (G x H)
9.	49 x 54(H x H)	21.	46 x 49 (G x H)
10.	54 x 49(H x H)	22.	51 x 54 (G x H)
11.	59 x 35(H x H)	23.	60 x 59 (G x H)
12.	66 x 31(H x H)	24.	63 x 66 (G x H)

G = Gynoecious; H = Hermaphrodite

RESULTS AND DISCUSSION

Analysis of variance for fourteen characters of papaya, Mean sum of square for treatment, replication and error for all the characters studied are present in Table 2. All most all the genotypes showed considerable amount of differences or variation in their mean performances with respect to the characters studied except TSS. This indicates that there is presence of sufficient variability for the characters in the genotypes studied indicating scope for further selection and breeding superior and desirable genotypes or varieties. Similar

Table 2: Analysis of variance for fourteen characters of papaya

Sr. No.	Characters	Mean sum of squares		
		Replications (d.f. 2)	Treatments (d.f. 23)	Error (d.f. 46)
1.	Number of fruits per plant	1.206	42.184**	4.891
2.	Number of seeds per fruit	0.953	81.483**	0.463
3.	Days to first flower appearance	4.222	120.034**	8.468
4.	Distance of first fruitingnode from ground level (cm)	15.297	82.165**	7.064
5.	Length of fruit (cm)	0.166	44.614**	2.567
6.	Pulp thickness(cm)	0.017	0.161**	0.013
7.	Plant height(cm)	0.887	328.714**	58.884
8.	TSS(^{0}B)	0.068	0.267	0.164
9.	Yield per plant(kg)	1.639	70.510**	4.355
10.	Average fruit weight(kg)	0.005	0.037**	0.003
11.	Fruit diameter(cm)	0.063	10.160**	0.415
12.	Fruit cavity(cc)	155.625	10878.813**	625.707
13.	â-carotene(mg/100g)	0.003	0.013**	0.006
14.	Pulp to seed ratio	202299.300	2273813.65**	178049.637

*, ** Significant at 5 and 1 per cent level of probability respectively.

Table 3: Estimates of genetic parameters of twenty four genotypes of papaya

Sr.. No	Character	Mean	Range	Genotypic Variance	Phenotypic Variance	Environmental Variance	GCV	PCV	ECV	Heritability (%)	Genetic Advance	Genetic Advance as % of mean
1	No. of fruits per plant	25.45	15.88-29.88	12.43	17.32	4.89	13.86	16.36	8.69	71.8	6.15	24.18
2	No. of seeds per fruit	7.14	2.04-22.13	27.01	27.47	0.46	72.82	73.44	9.53	98.3	10.62	148.75
3	Days to first flower appearance	111.02	100.88-122.46	37.19	45.66	8.47	5.49	6.09	2.62	81.5	11.34	10.21
4	distance of first fruiting node from ground level (cm)	28.76	17.67-40.33	25.03	32.10	7.06	17.40	19.70	9.24	78.0	9.10	31.66
5	Length of fruit (cm)	20.83	16.42-29.71	14.02	16.58	2.57	17.98	19.55	7.70	84.5	7.09	34.04
6	Pulp thickness(cm)	2.16	1.85-2.74	0.05	0.06	0.01	10.29	11.53	5.19	79.7	0.41	18.93
7	Plant height(cm)	143.56	125.13-162.42	89.94	148.83	58.88	6.61	8.50	5.35	60.4	15.19	10.58
8	TSS(^{0}B)	13.38	12.77-13.91	0.03	0.20	0.16	1.38	3.33	3.03	17.3	0.16	1.19
9	Yield per plant(Kg)	23.49	15.56-30.75	22.05	26.41	4.36	20.00	21.88	8.89	83.5	8.84	37.64
10	Averagefruit weight (kg)	0.92	0.74-1.22	0.01	0.01	0.00	11.58	13.02	5.95	79.1	0.19	21.23
11	Fruit diameter(cm)	14.79	12.70-19.09	3.25	3.66	0.42	12.19	12.94	4.35	88.7	3.50	23.64
12	Fruit cavity (cc)	446.68	334.09 - 556.46	3417.70	4043.41	625.71	13.09	14.24	5.60	84.5	110.72	24.79
13	â-carotene (mg/100g)	0.79	0.65-0.90	0.00	0.01	0.01	5.95	11.65	10.01	26.1	0.05	6.25
14	Pulp to seed ratio	1680.37	509.64-4222.08	698588.00	876637.60	178049.60	49.74	55.72	25.11	79.7	1537.02	91.47

Table 4: Genotypic and Phenotypic correlation coefficient for different characters in papaya

Particulars		No. of fruit Plant	No. of seeds/ fruit	Days to first flower appearance	Height of first fruit from (cm) ground level	Length of fruit	Pulp thickness (cm)	Plant height (cm)	TSS (cm)	Average fruit weight	Fruit diameter (kg)	Fruit cavity (cm)	²-carotene (mg/100g) (cc)	Pulp to seed ratio	Yield/ Plant (kg)
No. of fruits per plant	G	1	0.2283	-0.3001*	-0.1013	0.1947	0.2646*	0.4694**	-0.7095**	0.3596	0.4202**	0.7031**	0.4015**	0.4934*	0.8692**
	P	1	0.19	-0.2264	-0.0625	0.1726	0.1968	0.3613**	-0.1895	0.2008	0.3573**	0.4829**	0.3965***	0.3190**	0.8498**
No. of seeds per fruit	G		1	-0.2147	-0.1256	0.5177**	-0.0044	0.0474	0.4562**	-0.1104	0.4402**	-0.18	0.1147	-0.0014	0.0664
	P		1	-0.1911	-0.1268	0.4759**	0.0074	0.0357	0.1674	-0.0701	0.4079***	0.1578	0.0564	-0.0027	0.0692
Days to first flower	G			1	0.1388	0.0426	0.0996	0.0588	0.1261	-0.0628	-0.0013	-0.1683	0.2731*	-0.0864	-0.2527*
appearance	P			1	0.0888	-0.0393	0.0244	0.0826	0.0698	-0.0532	-0.0033	-0.139	0.1039	-0.0755	-0.2056
Ht .of first fruit from	G				1	0.1434	0.2654*	-0.2959*	-0.2081	0.3950**	0.069	0.1272	-0.0142	0.1091	0.1107
ground level (cm)	P				1	0.1131	0.1934	-0.1761	-0.049	0.2564*	0.0712	0.106	0.0163	0.0373	0.0737
Length of fruit (cm)	G					1	0.4030**	0.1798	-0.0489	0.3580**	0.9109**	0.0907	0.0589	0.2604*	0.2938*
	P					1	0.3381**	0.112	0.0648	0.3187**	0.8348***	0.053	0.0415	0.197	0.2725*
Pulp thickness(cm)	G						1	0.2879*	-0.0428	0.8825**	0.3767**	0.7959**	0.8684**	0.3925**	0.6320**
	P						1	0.1926	0.0605	0.7154***	0.3472**	0.6280***	0.3788**	0.3250**	0.5414**
Plant height(cm)	G							1	-0.0985	0.3402**	0.3165**	0.3839**	0.143	0.3335**	0.5215**
	P							1	0.0562	0.2637*	0.2729*	0.2385*	0.1112	0.2459*	0.4262**
TSS(°B)	G								1	-0.4355**	-0.2819**	-0.5710**	0.3881**	-0.5374**	-0.6868**
	P								1	-0.1108	0.0003	-0.2962*	-0.0951	-0.2372*	-0.1918
Average fruit weight(Kg)	G									1	0.4034**	0.7345**	0.6004**	0.3769**	0.7716**
	P									1	0.3426**	0.5953***	0.2186	0.3514**	0.6729**
Fruit dia(cm)	G										1	0.2775*	0.1254	0.2265	0.4830**
	P										1	0.2166	0.0777	0.1557	0.4362**
Fruit cavity (cc)	G											1	0.7787**	0.3544**	0.8845**
	P											1	0.2833*	0.2994*	0.6830**
'-carotene (mg/100g)	G												1	0.3894**	0.5715**
	P												1	0.1456	0.4312**
Pulp to seed ratio	G													1	0.5026**
	P													1	0.3983**
Yield per plant(kg)	G														1
	P														1

G = Genotypic correlation coefficient P = Phenotypic correlation coefficient *, ** indicates significance at 5% and 1% level

Table 5: Path coefficient analysis showing direct (diagonal) and indirect (above and below diagonal effects) on yield in papaya

Particulars	No. of fruits/ plant	No. of seeds/ fruit	Days to first flower appearance	distance of first fruiting node from ground level (cm)	Length of fruit (cm)	Pulp thicknesst (cm)	Plant height (cm)	TSS(^{0}B)	Average fruit weight (Kg)	Fruit diameter (cm)	Fruit cavity (cc)	Â-carotene (mg/100g)	Pulp to seed ratio	Genotypic correlation with yield
No. of fruits per plant	0.9687	-0.0691	0.0337	-0.0045	0.0363	-0.0126	0.0207	-0.0934	0.2009	-0.0283	-0.1783	0.0565	-0.0614	0.8692**
No. of seeds per fruit	0.2211	-0.3028	0.0241	-0.0056	0.0966	0.0002	0.0021	0.06	-0.0617	-0.0296	0.0457	0.0161	0.0002	0.0664
Days to first flower appearance	-0.2908	0.065	-0.1123	0.0062	0.0079	-0.0048	0.0026v	0.0166	-0.0351	0.0001	0.0427	0.0384	0.0108	-0.2527*
distance of first fruiting node f rom ground level (cm)	-0.0981	0.038	-0.0156	0.0445	0.0268	-0.0127	-0.0131	-0.0274	0.2207	-0.0046	-0.0323	-0.002	-0.0136	0.1107
Length of fruit (cm)	0.1886	-0.1568	-0.0048	0.0064	0.1866	-0.0193	0.0079	-0.0064	0.2	-0.0612	-0.023	0.0083	-0.0324	0.2938**
Pulp girt(cm)	0.2564	0.0013	-0.0112	0.0118	0.0752	-0.0478	0.0127	-0.0056	0.4931	-0.0253	-0.2019	0.1222	-0.0489	0.6320**
Plant height(cm)	0.4547	-0.0143	-0.0066	-0.0132	0.0335	-0.0138	0.0441	-0.013	0.1901	-0.0213	-0.0974	0.0201	-0.0415	0.5215**
TSS(^{0}B)	-0.6874	-0.1382	-0.0142	-0.0093	-0.0091	0.002	-0.0043	0.1316	-0.2434	0.019	0.1448	0.0546	0.0669	-0.6868**
Average fruit weight(Kg)	0.3483	0.0334	0.0071	0.0176	0.0668	-0.0422	0.015	-0.0573	0.5588	-0.0271	-0.1863	0.0845	-0.0469	0.7716**
Fruit diameter(cm)	0.4071	-0.1333	0.0001	0.0031	0.1699	-0.018	0.014	-0.0371	0.2254	-0.0672	-0.0704	0.0176	-0.0282	0.483**
Fruit cavity(cc)	0.6811	0.0545	0.0189	0.0057	0.0169	-0.038	0.0169	-0.0751	0.4104	-0.0187	-0.2536	0.1096	-0.0441	0.8845**
â-carotene (mg/100g)	0.3889	-0.0347	-0.0307	-0.0006	0.011	-0.0415	0.0063	0.0511	0.3355	-0.0084	-0.1975	0.1407	-0.0485	0.5715**
Pulp to seed ratio	0.478	0.0004	0.0097	0.0049	0.0486	-0.0188	0.0147	-0.0707	0.2106	-0.0152	-0.0899	0.0548	-0.1245	0.5026**

Residual effect = 0.0472 *, ** indicates significance at 5 % and 1 % level

results were observed by Dash *et al.* (2000), Barua (2002), Magdalita *et al.* (1984), Jana *et al.* (2006), Silva Filho *et al.* (2008) and Rakesh Kumar *et al.* (2013). The results of estimates of genetic variability, heritability, genetic advance for grain yield per plant and other characters are presented in Table 3. The PCV was higher than GCV for all the characters studied showing that all the traits were highly influenced by environment. However differences between them were not of high magnitude. High estimates of genotypic and phenotypic coefficient of variation were observed for no. of seeds per fruit(72.82,73.44) and pulp to seed ratio(49.74,55.72) . Low GCV and PCV were noticed for TSS(1.38,3.33) followed by days to first flower appearance(5.49, 6.09) and plant height(6.61,8.50).The effectiveness of selection for any character depends not only the extent of genetic variability but also in the extent to which it will be transferred from one generation to the other generation. High heritability with high genetic advance as per cent mean recorded for characters seeds per fruit, pulp to seed ratio, yield per plant, fruit length, distance of first fruiting node from ground level, fruits per plant, fruit cavity, fruit diameter and average fruit weight indicating that these traits are predominantly governed by additive gene action and directional phenotypic selection of these traits could be more effective for desired genetic improvement. These results are in accordance with findings of Subramanyam and Iyer (1981), Karunakaran *et al.*(2010), Mondal *et al.* (1992), Dwiwedi *et al.* (1999), Cynthia *et al.* (2000), Singh *et al.* (2001), Singh and Kumar (2010) and Arunkumar (2014).

High heritability was observed for no. of seeds per fruit (98.5) followed by fruit diameter (88.7), fruit cavity (84.5), length of fruit (84.5), yield per plant (83.5), pulp thickness (79.7) and pulp to seed ratio (79.7), average fruit weight (79.1), distance of first fruiting node from ground level (78.0), number of fruits per plant (71.8) and plant height (60.4). While the low magnitude of heritability was observed for TSS (17.3) and â-carotene (26.1).

High heritability with high genetic advance as per cent mean recorded for characters seeds per fruit, pulp to seed ratio, yield per plant, fruit length, distance of first fruiting node from ground level, fruits per plant, fruit cavity, fruit diameter and average fruit weight indicating that these traits are predominantly governed by additive gene action and directional phenotypic selection of these traits could be more effective for desired genetic improvement. These results are in accordance with findings of Subramanyam and Iyer (1981), Karunakaran *et al.* (2010), Mondal *et al.* (1992), Dwiwedi *et al.* (1999), Cynthia *et al.* (2000), Singh *et al.* (2001), Singh and Kumar (2010). Mondal and Ghanta (1993) reported high heritability coupled with high to moderate genetic advance was observed for seed weight per fruit, individual fruit weight, 100-seed weight, peel weight per fruit, number of seeds per fruit, number of fruits per plant, pulp weight per fruit, length of the fruit, diameter of the fruit and fruit yield.

Correlation coefficient is a statistical measure, which denotes the degree and magnitude of association between any two casually related variables. This association is due to pleitropic gene action or linkage or more likely both. In plant breeding correlation coefficient analysis measures the mutual

relationship between two characters and it determines character association for improvement yield and other economic characters. Since the association pattern among yield components help to select the superior genotypes from divergent population based on more than one interrelated characters. Thus information on the degree and magnitude ofassociation between characters is of prime important for the breeder to initiate any selection plan. In general the genotypic correlation was generally of higher magnitude than phenotypic correlation (Table 4), indicating that inherent association between various characters studied.

Yield per plant exhibited highly significant positive correlation with fruit cavity (r_g = 0.885), number of fruits per plant (r_g = 0.869), average fruit weight (r_g = 0.772), pulp thickness (r_g = 0.632), â-carotene (r_g = 0.572), plant height (r_g = 0.522), pulp to seed ratio (r_g = 0.503), fruit diameter (r_g = 0.483), and length of fruit (r_g = 0.294). This results are in agreement with Jana *et al*. (2006) and Zamudio and Hernandez (1998), Dwivedi (1998), Singh *et al*.(1997), Magdalita *et al*. (1984). Hence, yield components had higher correlation with overall yield, indicating that selection based on these parameters would indirectly favour high yields.

Yield per plant exhibited significant negative correlation with days to first flower appearance (r_g = -0.253) and TSS (r_g = -0.687) will help in developing early maturing and high yielding varieties. Cynthia *et al*. (2000) reported that first flowering was negatively associated with yield.

Due to mutual cancellation of component traits, the estimation of correlation alone may be often misleading so it is necessary to study the path co-efficient analysis which takes into account the casual relationship in addition to the degree of relationship. Hence genotypic and phenotypic correlation was partitioned into direct and indirect effects to know the relative importance of the components (Table 5). The Path coefficient analysis revealed that no. of fruits per plant had the highest direct positive effect on fruit yield followed by average fruit weight, length of fruit, â-carotene, TSS, distance of first fruiting node from ground and plant height are the major components. It has been suggested that emphasis should be given on these characters while making selection for desired improvement in papaya.

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