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Evaluation of papaya (*Carica papaya* L.) hybrids for yield and papain recovery

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ABSTRACT

Six papaya hybrids, viz., CO-1 × Pusa Nanha, CO-2 × Pusa Nanha, CO-4 × Pusa Nanha, CO-5 × Pusa Nanha, CO-6 × Pusa Nanha and CO-7 × Pusa Nanha, along with their respective parents, were evaluated for fruit yield and quality. Higher fruit yield was recorded in hybrids CO-2 × Pusa Nanha, CO-4 × Pusa Nanha and CO-5 × Pusa Nanha at first harvest. Higher papain recovery was seen in CO-2 × Pusa Nanha and CO-5 × Pusa Nanha and activity of this enzyme was highest in CO-5 × Pusa Nanha. For fruit yield at first harvest, hybrids CO-2 × Pusa Nanha, CO-4 × Pusa Nanha, CO-6 × Pusa Nanha and CO-5 × Pusa Nanha recorded higher heterosis over mid- and better parental values. Fruit yield at first harvest exhibited high genotypic and phenotypic coefficient of variation. Days to flowering had the least genotypic and phenotypic coefficient of variation. Highest heritability estimates were recorded for plant height at first flowering, ascorbic acid content and titrable acidity. Fruit yield at first harvest showed high genetic advance as percentage of mean and the least genetic advance was seen for days to flowering. CO-2 × Pusa Nanha, CO-4 × Pusa Nanha, CO-5 × Pusa Nanha and CO-6 × Pusa Nanha showed better yield and earliness, and are recommended for further evaluation.

Key words: *Carica papaya* L., heterosis, heritability, genetic advance, correlation coefficient, path analysis

INTRODUCTION

Papaya (*Carica papaya* L.) is a polygamous diploid species with a small genome of 372 Mbp/1C (Arumuganathan and Earle, 1991). It has nine pairs of chromosomes and is native to tropical America from where it spread to most of the Caribbean and Asian countries during 16th Century. The fruit is highly nutritious and rich in vitamins A, C and in minerals, especially, calcium. Papaya pulp is used as a major ingredient in fruit processing industries due to its high pectin levels. Papaya is the richest source of carpaine, an alkaloid, and the raw fruit is used for making 'Tutti Frutti'. Papain, a proteolytic enzyme extracted from papaya latex, is used as a meat tenderizer, in many cosmetics, in pharmaceuticals, fabric weaving and in chill-proofing of beer. Papaya seeds are rich in oil and protein. The basic principle in hybridization is to combine desirable characters of the two parents. Generally, hybrid evaluation is based on heterotic expression. Progress in crop improvement through plant breeding is propelled by better understanding and exploitation of heterosis. Heterosis breeding in papaya has been done by several workers earlier to improve yield and papain content (Iyer and Subramanyam, 1981; Chan, 1992; Kamalkumar *et al*, 2010).

In the present study, six hybrids were evaluated along with their parents for yield, yield contributing traits, quality attributes, papain recovery, *per se* performance, heterosis, and genetic components, viz., phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance.

MATERIAL AND METHODS

Six intervarietal hybrids, viz., CO-1 × Pusa Nanha, CO-2 × Pusa Nanha, CO-4 × Pusa Nanha, CO-5 × Pusa Nanha, CO-6 × Pusa Nanha and CO-7 × Pusa Nanha, along with their respective parents, were evaluated in Randomized Block Design, with three replications, during 2009-2010 at the college orchard, Department of Fruit Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. Hybrid seeds were sown in polybags of 20cm x 10cm size, filled with a mixture of red earth, sand, farm yard manure, in 1:1:1 ratio. Polythene bags with 4-5 seedlings 45 days old were transplanted to the main field. Irrigation was applied at five day intervals. Cultural practices, including weeding and plant protection measures, were improved whenever necessary by adopting the package of practices developed by Tamil Nadu Agricultural

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University. Growth parameters, in terms of plant height, stem girth, number of leaves and first-fruiting height, were recorded as per standard methods. Fruit yield was recorded in terms of number of fruits per tree, weight of the fruit, and tree yield at first harvest. Data on mean fruit length, fruit mid-circumference, cavity index, flesh thickness and papain recovery per fruit, were calculated from data recorded with five fruits in each experimental unit. For estimation of papain recovery, five unripe mature, uniform-sized fruits 85-90 days old were selected. These fruits were tapped by making 3mm longitudinal incisions on the fruit surface from the fruit-stalk end to the tip of the fruit, between 6.00 and 8.00 am. Four cuts were uniformly spaced over the four sides of the fruit. The incisions were repeated 4 times, at three day intervals. Latex was collected in specially made aluminum trays. Wet latex was dried in shade and dry weight of this crude, unrefined papain was recorded, and expressed in grams. Papain activity was estimated as per Moore (1984). Fruit quality characters like TSS, total sugars, acidity, ascorbic acid and carotene content were recorded. Total sugars were estimated as per Hedge and Horreiter (1962), titrable acidity estimated by the A.O.A.C. method (1960), ascorbic acid content was estimated as per Rosenberg (1945) and carotene as per Roy (1973). Average values were subjected to standard statistical procedures, namely, analysis of variance (Panse and Sukhatme, 1961); genotypic and phenotypic coefficient of variation, heritability and genetic advance as suggested by Burton (1952), Lush (1940) and Johnson *et al* (1955), respectively.

RESULTS AND DISCUSSION

Mean data on biometrical, yield and quality characters of parents and their hybrids are presented in Tables 1 and 2. Among the hybrids, CO-2 × Pusa Nanha and CO-5 × Pusa Nanha took minimum number of days to flower. Dinesh *et al* (2000) reported early flowering to be one of the vital characters in papaya production. CO-7 × Pusa Nanha recorded the lowest mean value for first-flowering height. Flowering at an earlier node is considered as an index of precocity (Chan, 1992). CO-2 × Pusa Nanha and CO-1 × Pusa Nanha recorded minimum plant height and stem girth at flowering. Higher number of leaves translates as increased leaf area and increased photosynthesis. Among the hybrids, CO-2 × Pusa Nanha registered highest number of leaves and lowest fruiting-height among the hybrids. Hybrids CO-7 × Pusa Nanha, CO-5 × Pusa Nanha and CO-4 × Pusa Nanha registered lower mean plant height at first harvest compared to their respective female parents. Among the crosses, CO-2 × Pusa Nanha recorded highest stem girth at first harvest and highest number of leaves. In

Table. 1. Mean performance of papaya parents and their hybrids for biometrical, yield and fruit (physical) attributes

Parents /hybrid	Days to harvest	First-fruiting height (cm)	Plant height at first harvest (cm)	Stem girth at first harvest (cm)	No. of leaves at first harvest	No. of fruits at first harvest	Mean fruit weight (kg)	Tree yield at first harvest (kg)	Fruit length (cm)	Fruit circumf-erence (cm)	Cavity index (%)	Pulp thickness (cm)
CO-1	273.76	122.94	203.62	32.76	24.66	26.87	1.57	41.88	23.14	41.17	23.70	2.80
CO-2	286.29	99.98	187.71	33.54	23.94	23.23	1.69	39.24	26.11	45.82	25.80	2.88
CO-4	254.61	112.85	216.00	30.14	18.46	22.40	1.38	30.53	23.10	36.09	25.26	2.66
CO-5	258.98	117.14	215.26	28.73	17.51	29.22	1.34	38.86	26.53	37.84	26.49	2.33
CO-6	292.53	109.94	193.94	30.29	24.03	22.99	1.56	35.68	23.10	41.92	27.21	2.68
CO-7	262.59	117.49	189.89	29.20	16.81	14.01	0.75	10.52	22.83	28.26	24.03	2.36
Pusa Nanha	261.05	75.06	134.57	27.66	22.85	19.51	1.34	25.86	23.08	42.85	20.80	2.89
CO-1 × Pusa Nanha	272.98	101.73	195.00	31.78	25.73	27.16	1.61	42.75	24.74	42.30	24.67	2.94
CO-2 × Pusa Nanha	254.74	88.14	189.80	33.54	26.38	36.38	2.02	73.46	27.95	45.37	27.36	2.83
CO-4 × Pusa Nanha	262.47	95.35	179.54	30.40	23.37	33.33	1.90	63.45	27.28	45.84	26.28	2.85
CO-5 × Pusa Nanha	275.18	97.74	176.89	29.40	24.00	31.38	1.89	59.16	26.89	43.50	27.85	2.74
CO-6 × Pusa Nanha	268.96	105.24	196.67	31.92	23.17	35.61	1.61	57.23	24.33	43.41	26.67	2.84
CO-7 × Pusa Nanha	255.56	89.24	172.86	29.80	23.25	22.49	0.87	19.12	22.68	30.21	21.15	2.58
Mean	267.67	102.53	188.59	30.71	22.63	26.51	1.50	41.37	24.75	40.35	25.17	2.72
SEd	10.17	7.44	9.78	1.73	2.48	3.53	0.13	5.51	1.18	2.08	1.92	0.09
CD ($P = 0.05$)	20.99	15.35	20.19	3.56	5.11	7.29	0.26	11.37	2.43	4.29	3.96	0.19

Table 2. Mean performance of papaya parents and their hybrids for fruit quality attributes and papain recovery

Parents /hybrid	TSS (°Brix)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Titrable acidity (%)	Ascorbic acid content (mg/100g)	Carotenes content (mg/100g)	Sugar: acid ratio	Papain recovery (g/fruit)	Papain activity (TU/mg)
CO-1	10.21	9.93	9.31	0.62	0.09	37.78	3.41	115.49	1.97	83.09
CO-2	10.50	10.79	8.53	2.26	0.18	82.23	3.25	31.42	1.96	53.32
CO-4	10.16	6.54	4.31	2.23	0.18	43.34	1.97	24.85	0.78	70.80
CO-5	10.21	11.65	9.86	1.79	0.13	26.67	2.45	92.02	1.61	98.91
CO-6	11.03	9.48	7.61	1.87	0.07	48.89	3.59	137.37	0.73	65.84
CO-7	8.30	7.03	6.33	0.70	0.18	43.34	3.81	40.14	0.60	59.60
Pusa Nanha	10.45	7.84	7.25	0.59	0.17	65.56	1.95	46.98	1.27	144.10
CO-1 × Pusa Nanha	11.58	10.64	9.92	0.73	0.14	60.00	1.57	79.03	1.49	97.36
CO-2 × Pusa Nanha	10.92	10.67	10.09	0.57	0.19	71.12	1.79	55.79	3.25	72.28
CO-4 × Pusa Nanha	9.10	7.96	6.87	1.09	0.10	43.34	1.56	77.83	1.72	49.27
CO-5 × Pusa Nanha	9.10	8.59	7.94	0.65	0.05	54.45	0.94	194.08	2.21	126.30
CO-6 × Pusa Nanha	11.34	12.93	10.25	2.68	0.16	48.89	1.62	64.95	1.57	81.84
CO-7 × Pusa Nanha	8.92	9.14	8.38	0.76	0.12	48.89	2.02	77.13	1.38	88.23
Mean	10.17	9.48	8.21	1.27	0.14	51.88	2.30	79.78	1.56	83.91
SEd	0.07	0.04	0.03	0.06	0.00	0.00	0.00	15.21	0.004	0.12
CD ($P = 0.05$)	0.14	0.09	0.06	0.11	0.01	0.00	0.01	31.38	0.01	0.24

the present investigation, all the hybrids, in general, exceeded their parents for number of fruits at first harvest and fruit yield at first harvest. Among the hybrids, CO-2 × Pusa Nanha registered highest fruit length, followed by CO-4 × Pusa Nanha. Similarly, CO-4 × Pusa Nanha registered the highest circumference, followed by CO-2 × Pusa Nanha among the hybrids. Among the crosses, CO-1 × Pusa Nanha registered highest pulp thickness and total soluble solids. Majority of the hybrids excelled their parents for total sugars and reducing sugars. However, higher mean values for these parameters were obtained in the crosses CO-6 × Pusa Nanha, CO-2 × Pusa Nanha and CO-1 × Pusa Nanha. Among the hybrids, CO-5 × Pusa Nanha recorded lowest titrable acidity, and CO-2 × Pusa Nanha and CO-1 × Pusa Nanha registered higher mean values for ascorbic acid content. For carotene, CO-7 × Pusa Nanha recorded highest content, followed by CO-2 × Pusa Nanha. Highest sugar: acid ratio was seen in CO-5 × Pusa Nanha, among the hybrids.

Among the hybrids, CO-2 × Pusa Nanha and CO-5 × Pusa Nanha registered higher papain recovery per fruit. Kamalkumar (2003) stated that the hybrids Pusa Dwarf × 9-1(D) and CO-5 × 9-1(D) registered higher papain recovery and papain activity, respectively. In the present study, among the hybrids, CO-5 × Pusa Nanha and CO-1 × Pusa Nanha registered higher papain activity, while, among the parents, Pusa Nanha recorded highest papain activity. Chovatia *et al* (2010) reported that CO-6 had better dry weight of latex.

Relative heterosis (di) and heterobeltiosis (dii) values in papaya hybrids for biometrical, yield and fruit characters are presented in Tables 3 and 4. Among the hybrids, CO-5 × Pusa Nanha recorded significantly negative heterosis over the better parent for first-flowering height. Kamalkumar *et al* (2010) stated that dioecious hybrids, viz., CO-2 × Pusa Gaint and CO-5 × 9-1(D) registered negative heterosis for first-flowering height. Among the hybrids, CO-5 × Pusa Nanha registered highly significant and negative heterobeltiosis for first-flowering height. Kamalkumar (2003) also stated that hybrid combination, CO-2 × CO-5, registered highly negative heterosis for this trait. Among the parents, Pusa Nanha, a dwarf variety, when crossed with CO-2, a medium tall variety, exhibited very high heterotic effect. Highest negative heterobeltiosis was noticed in the cross CO-5 × Pusa Nanha for first-flowering height. Among the hybrids, CO-4 × Pusa Nanha registered significantly positive relative heterosis for stem girth at first-flowering. Subhadrabandhu and Nantaswatsri (1997) also reported increased stem girth in progenies, in their study. The cross CO-4 × Pusa Nanha had maximum significantly positive heterosis over mid-parental values for number of leaves at first-flowering. Among the crosses, CO-2 × Pusa Nanha

Table 3. Relative heterosis (di) and heterobeltiosis (dii) in papaya hybrids for biometrical, yield and fruit characters

Character	CO-1 ×		CO-2 ×		CO-4 ×		CO-5 ×		CO-6 ×		CO-7 ×	
	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii
Days to flowering	-0.09	-0.65	-4.45	-5.54	-2.15	-2.16	-7.32*	-8.88#	-1.03	-1.75	-3.83	-6.09
First-flowering height (cm)	20.61#	-5.86	28.56#	2.91	20.62#	-9.70	3.26	-26.16#	21.33#	-7.85	12.34*	-14.97*
Plant height at first flowering (cm)	8.43*	-1.02	35.92#	19.91#	29.01#	19.40#	0.39	-17.60#	5.99	-7.50*	11.88#	0.13
Stem girth at first flowering (cm)	-27.19#	-29.17#	-0.25	-2.04	9.11*	1.12	-0.63	-0.87	0.86	-0.94	3.28	-2.33
Number of leaves at first flowering	-7.32	-8.89	9.74	8.43	23.96#	9.10	1.99	1.15	-3.98	-8.08	6.36	2.34
Days to harvest	2.08	-0.28	-6.92	-11.02#	1.80	0.54	5.83	5.41	-2.83	-8.06*	-2.39	-2.68
First-fruiting height (cm)	2.76	-17.25*	0.71	-11.84	1.48	-15.51*	1.71	-16.56*	13.77	-4.28	-7.31	-24.04*
Plant height at first harvest (cm)	15.32#	-4.23	17.79#	1.11	2.43	-16.88#	1.13	-17.82#	19.73#	1.41	6.55	-8.97
Stem girth at first harvest (cm)	5.20	-2.99	9.61	0.00	5.19	0.86	4.27	2.33	10.16	5.38	4.82	2.05
Number of leaves at first harvest	8.31	4.34	12.76	10.19	13.14	2.28	18.93	5.03	-1.15	-3.58	17.25	1.75
Number of fruits at first harvest	17.12	1.08	70.24#	56.61#	59.06#	48.80#	28.79*	7.39	67.58#	54.89#	34.19	15.27
Mean fruit weight (kg)	10.65	2.55	33.33#	19.53*	39.71#	37.68#	41.04#	41.04#	11.03	3.21	-16.75	-35.07
Tree yield at first harvest (kg)	26.22	2.08	125.68#	87.21#	125.04#	107.83#	82.82#	52.24#	85.99#	60.40#	5.11	-26.06
Fruit length (cm)	7.05	6.91	13.64	7.05	18.15	18.10	8.41	1.36	5.37	5.32	-1.20	-1.73
Fruit circumference (cm)	0.69	-1.28	2.33	-0.98	16.14#	6.98	7.82	1.57	2.42	1.31	-15.03*	-29.50#
Cavity index (%)	10.88	4.09	17.42	6.05	14.11	4.04	17.78	5.13	11.10	-1.98	-5.64	-11.99

*Significant at 5% level, #Significant at 1% level

Table 4. Relative heterosis (di) and heterobeltiosis (dii) in papaya hybrids for fruit quality characters and papain recovery

Character	CO-1 ×		CO-2 ×		CO-4 ×		CO-5 ×		CO-6 ×		CO-7 ×	
	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii	Pusa di	Nanha dii
TSS (°Brix)	12.10#	10.81#	4.25#	4.00#	-11.69#	-12.92#	-11.91#	-12.92#	5.59#	2.81#	-4.85#	-14.64#
Total sugars (%)	19.75#	7.15#	14.55#	-1.11*	10.71#	1.53*	-11.85#	-26.27#	49.31#	36.39#	22.93#	16.58#
Reducing sugars (%)	19.81#	6.55#	27.88#	18.29#	18.86#	-5.24#	-7.19#	-19.47#	37.95#	34.69#	23.42#	15.59#
Non-reducing sugars (%)	20.66*	17.74	-60.00#	-74.78#	-22.70#	-51.12#	-45.37#	-63.69#	117.89#	43.32#	17.83*	8.57
Titrable acidity (%)	7.69*	-17.65#	8.57#	5.56*	-42.86#	-44.44#	-66.67#	-70.59#	33.33#	-5.88*	-31.43#	-33.33#
Ascorbic acid (mg/100g)	16.12#	-8.48#	-3.76#	-13.51#	-20.40#	-33.89#	18.07#	-16.95#	-14.57#	-25.43#	-10.21#	-25.43#
Carotene (mg/100g)	-41.42#	-53.96#	-31.15#	-44.92#	-20.41#	-20.81#	-57.27#	-61.63#	-41.52#	-54.87#	-29.86#	-46.98#
Sugar: acid ratio	-2.03	-25.10	23.17	-8.57	68.22	35.06	172.32#	143.39#	-48.20#	-64.05#	33.11	12.84
Papain recovery (g/fruit)	-8.02#	-24.37#	101.24#	65.82#	67.80#	35.43#	53.47#	37.27#	57.00#	23.62#	47.59#	8.66#
Papain activity (TU/mg)	-14.29#	-32.44#	-26.78#	-49.84#	-54.15#	-65.81#	3.95#	-12.35#	-22.03#	-43.21#	-13.37#	-38.77#

*Significant at 5% level, #Significant at 1% level

recorded highest negative heterobeltiosis for days to first harvest. In the present investigation, some hybrids were found to be positively heterotic. However, positive heterosis is not a favorable attribute for days to first-harvest. Among the hybrids, CO-7 × Pusa Nanha registered highest negative heterobeltiosis for first-fruiting height. The hybrids 'CO-5 × Pusa Nanha' and 'CO-4 × Pusa Nanha' expressed significantly negative heterosis over their better parent. Among the crosses, CO-2 × Pusa Nanha registered highest heterobeltiosis for number of leaves at first harvest.

Among the crosses, CO-2 × Pusa Nanha, CO-6 × Pusa Nanha and CO-4 × Pusa Nanha are the three important cross combinations to be considered for further advancement, since, these recorded high heterotic vigour over the mid-, and better parental values for number of fruits at first harvest. Iyer and Subramanyam (1981) and Chan

(1992) reported high heterosis for this trait. However, Kamalkumar *et al* (2010) recorded significantly positive heterosis for number of fruits per plant in the cross combinations 'CO-2 × Pusa Giant' and '9-1(D) × CO-5'. Among the hybrids, CO-5 × Pusa Nanha, CO-4 × Pusa Nanha and CO-2 × Pusa Nanha recorded higher heterotic values over the mid-, and better parental values for mean fruit weight. Kamalkumar *et al* (2010) reported similar findings by recording higher heterotic value for this trait in the cross combination CO-2 × CO-5.

In the present study, all the hybrid combinations excelled their parents and the overall mean registered positive heterotic vigour over the mid-parental value for tree yield at first harvest. However, except CO-1 × Pusa Nanha and CO-7 × Pusa Nanha, all other cross combinations expressed heterotic vigour over the mid- and better parental values. Among the hybrids, CO-2 × Pusa Nanha, CO-4 × Pusa Nanha, CO-5 × Pusa Nanha and CO-6 × Pusa Nanha with their high heterotic effect, may be forwarded to F_2 generation for further segregation. Suma (1995) recorded higher yield and heterotic vigour in papaya crosses 9-1(D) × CO-2, CO-6 × CO-2 and CP81 × 9-1(D). Similar results were obtained by Kamalkumar (2003) in dioecious and gynodioecious crosses. Among the hybrids, CO-4 × Pusa Nanha is the only hybrid recording higher significant and positive heterosis for fruit circumference over its mid-parental value and higher positive heterosis for fruit length over its mid and better parental value. Higher heterosis for fruit length and fruit circumference has been observed earlier by Iyer and Subramanyam (1981), Chan (1992), and Kamalkumar *et al* (2010). In the present study, none of the hybrids registered significant heterosis for pulp thickness. However, hybrid CO-4 × Pusa Nanha had highly positive relative heterosis for this trait. They also found higher flesh thickness, with maximum heterosis in the cross CO-3 × CO-7.

Three of the hybrids, viz., CO-1 × Pusa Nanha, CO-6 × Pusa Nanha and CO-2 × Pusa Nanha exhibited positive and significant relative heterosis and heterobeltiosis for total soluble solids. Among the hybrids, CO-6 × Pusa Nanha registered higher heterotic values for total sugars, reducing sugars and non-reducing sugars. Kamalkumar (2003) observed maximum relative heterosis and heterobeltiosis for total sugars and reducing sugars in the cross combination CO-5 × 9-1(D). 'CO-5 × Pusa Nanha' recorded highest negative heterosis over mid- and better parental values for titrable acidity. For heterotic vigour, among the hybrids, CO-5 × Pusa Nanha and CO-1 × Pusa Nanha registered higher positive and significant heterosis over mid- parental values for ascorbic acid content. Among the hybrids, CO-5 × Pusa Nanha registered the highest negative heterosis for carotene content. Kamalkumar *et al* (2010) stated that the crosses Pusa Dwarf × 9-1(D) and IIHR 37 × Coorg Honey Dew recorded significant higher heterosis for carotene content. CO-5 × Pusa Nanha exhibited the maximum significant positive heterosis over both mid- and better parents. Kamalkumar (2003) reported that the cross combination CO-5 × 9-1(D) registered highest relative heterosis and heterobeltiosis for sugar acid ratio and high mean value for this trait.

In the present study, the cross CO-2 × Pusa Nanha registered high heterotic value for papain recovery. Except the cross CO-1 × Pusa Nanha, all hybrids registered significant and positive heterosis for papain recovery. Among the hybrids, CO-5 × Pusa Nanha registered higher positive and significant heterosis for papain activity over the mid-parent. Kamalkumar *et al* (2010) stated that hybrids Pusa Dwarf × 9-1(D) and CO-5 × 9-1(D) registered higher heterotic value for papain recovery and papain activity, respectively.

Heritability and genetic advance as per cent of the mean in papaya hybrids for biometrical, yield and fruit characters are presented in Figs. 1 and 2. Very low GCV for days to flowering indicated that the study material had a

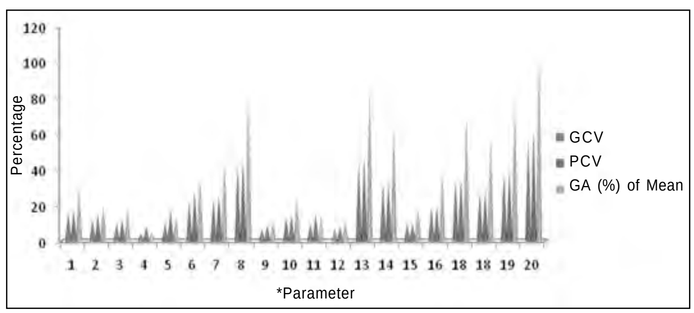

Fig 1. Genetic data for biometrical and fruit attributes in papaya parents and hybrids

1. First-flowering height (cm)
2. First-fruiting height (cm)
3. Plant height at first harvest (cm)
4. Stem girth at harvest (cm)
5. Number of leaves at first harvest
6. Number of fruits at first harvest
7. Mean fruit weight (kg)
8. Tree yield at first harvest (kg)
9. Fruit length (cm)
10. Fruit circumference (cm)
11. Cavity index (%)
12. Flesh thickness (cm)
13. Papain recovery (g/fruit)
14. Papain activity (TU/mg)
15. TSS (°Brix)
16. Total sugars (%)
17. Titrable acidity (%)
18. Ascorbic acid (mg/100g)
19. Carotene (mg/100g)
20. Sugar: acid ratio*

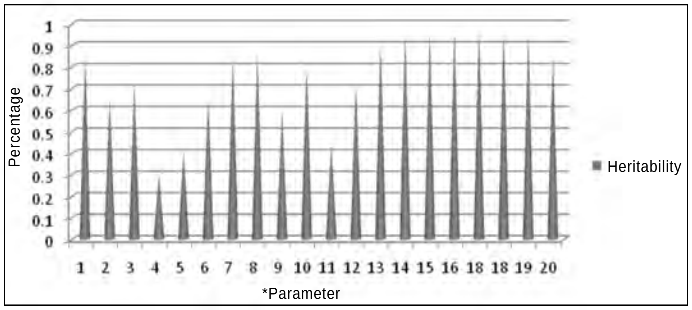

Fig 2. Genetic parameters of biometrical and fruit attributes in the parents and hybrids

1. First-flowering height (cm)
2. First-fruiting height (cm)
3. Plant height at first harvest (cm)
4. Stem girth at harvest (cm)
5. Number of leaves at first harvest
6. Number of fruits at first harvest
7. Mean fruit weight (kg)
8. Tree yield at first harvest (kg)
9. Fruit length (cm)
10. Fruit circumference (cm)
11. Cavity index (%)
12. Flesh thickness (cm)
13. Papain recovery (g/fruit)
14. Papain activity (TU/mg)
15. TSS (° Brix)
16. Total sugars (%)
17. Titrable acidity (%)
18. Ascorbic acid (mg/100g)
19. Carotene (mg/100g)
20. Sugar: acid ratio*

narrow genetic base. Moderate heritability and low genetic advance reported for this trait indicates that the environment had an enormous influence on days to flowering. Kamalkumar (2003) also stated very low GCV, with moderate heritability and low genetic advance for this trait. Higher heritability and higher genetic advance estimates observed for first- flowering height indicated that selection may yield desirable results in a few breeding cycles. A similar result was obtained by Kamalkumar (2003) for first-flowering height when crossing with dioecious parents. However, Giacometii (1987) observed that early-flowering plants produced less number of nodes and, as a consequence lower yield. Genetic coefficient of variation for plant height at first-flowering was just 11.57%. However, higher heritability estimates and computed genetic advance indicated that selection procedure should be effective for this trait. Genetic coefficient of variation noted as very low, with high heritability and moderate genetic advance, for stem girth at first- flowering indicated breeding-worthiness of this trait. High heritability estimates reported for the number of leaves at first-flowering could provide ample opportunities for improving this trait. Moderate heritability and low genetic advance observed for days to first harvest indicate the influence of environment on this trait. High heritability and high genetic advance found in first-fruiting height indicate the possibility of improving the trait. High heritability and moderate genetic advance expressed for plant height at first harvest reveals that selection is possible for this trait. Similar findings were reported earlier by Kamalkumar (2003) and Karunakaran *et al* (2010). Moderate heritability estimates and low genetic advance reported for stem girth at first harvest indicates that environment had much influence on this trait. High heritability for stem girth has been earlier reported by Cynthia *et al* (2000) and Kamalkumar (2003). Moderate heritability estimates and moderate genetic advance found for number of leaves at first-harvest indicates a limited possibility for selection. Examination of genetic parameters governing number of fruits at first-harvest indicates that selection is possible owing to prevalence of a high degree of heritability and high genetic advance. High heritability for this trait has been reported earlier by Cynthia *et al* (2000) and Singh and Kumar, (2010) in papaya. Very high heritability estimates and high genetic advance for fruit weight in the present study indicates a scope for improvement of this trait. Karunakaran *et al* (2010) also reported high values of heritability and genetic advance registered for fruit weight. In the present study, examination of genetic parameters governing fruit yield at first-harvest indicates that selection is possible due to presence of a high degree of heritability and genetic advancement, with high expression of genetic coefficient of variation. Heritability estimates are true indicators of genetic potentiality of an individual and act as a tool for selection (Johnson *et al*, 1955). Mansha Ram and Akhtar (1993) reported high heritability and genetic advance for fruit length and fruit yield characters in papaya. Jana *et al* (2006) also reported similar results for fruit length, fruit yield and number of fruits per plant in papaya. High heritability estimates and higher genetic advance for fruit circumference and high heritability estimates and moderate genetic advance for fruit length were seen. Genotypic coefficients of variation estimates are low for both fruit length and fruit circumference. High heritability and moderate genetic advance for these traits indicate lesser influence of the environment. Similar observations have also been reported by Jana *et al* (2006) and Karunakaran *et al* (2010). For cavity index, a narrow spectrum of variability, moderate heritability and genetic advance result in a limited scope for selection. Karunakaran *et al* (2010) observed high heritability and moderate genetic advance for this trait.

High heritability estimates and moderate genetic advance were recorded for pulp thickness. Genotypic coefficients of variation estimates were low for this trait. High heritability and moderate genetic advance reveal that their trait is not influenced by the environment. High heritability and moderate genetic advance offer better selection opportunities for TSS. Kamalkumar (2003) observed highest values for total soluble solids in Pusa dwarf × 9-1(D). Higher heritability and genetic advance for all the traits, viz., total sugars, reducing sugars and non-reducing sugars, offer a wider base for selection. Moderate genotypic coefficient of variation and genetic advance were noticed for ascorbic acid content. High heritability for this trait provided ample chance for selection. Higher genetic coefficient of variation, heritability and genetic advance for carotene content and sugar:acid ratio too provided better opportunities for selection. High heritability and high genetic advance were recorded for papain recovery and papain activity. High heritability for these characters reveals that environment had no influence on these traits.

Based on mean performance for yield and quality attributes, hybrids CO-2 × Pusa Nanha, CO-4 × Pusa Nanha, CO-5 × Pusa Nanha and CO-6 × Pusa Nanha were found to be better among the hybrids evaluated. Studying F_2 populations of these hybrids will help identify the best hybrid derivatives with desirable biometric characters.

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