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Heterosis for growth, yield and fruit quality traits in papaya

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ABSTRACT

An experiment was conducted during 2016-2017 to determine the magnitude of heterosis in papaya for growth, yield and fruit quality traits. A total of eight genotypes consisting three hybrids along with their five parents were evaluated in a Randomized Block Design with three replications. Appreciable heterosis was found over better over mid parent in traits like days to fruit maturity, number of fruits per plant, fruit yield, fruit shelf life, fruit firmness, antioxidant activity of fruit, total carotenoid content and lycopene content in desirable direction. A hybrid, of progeny of Red Lady (Self) × Pusa Nanha (14.57%) showed significant relative heterosis for yield, whereas none of the hybrids were recorded with better parent heterosis. Two hybrids, Red Lady (Self) × Pusa Nanha (2.93%) and Pune Selection 3 × P-7-9 (22.13%) was observed with high heterosis for number of fruits per plant. All three hybrids exhibited heterosis in negative direction for days to fruit maturity. For fruit shelf life at ambient temperature, hybrid Red Lady (Self) × P-9-5 (3.12%) exhibited better parent heterosis, whereas all three hybrids showed positive mid parent heterosis for the same trait. All three hybrids showed positive mid-parent heterosis for traits like number of fruits per plant, shelf-life, total phenolic content and antioxidant activity. The hybrid Red Lady (Self) × Pusa Nanha exhibited better parent and mid parent heterosis for total carotenoid and lycopene content along with total phenolic content and antioxidant activity. Moreover, none of the hybrids showed positive heterosis for TSS, leaf length, fruit weight, fruit diameter and fruit length. However, hybrid Red Lady (Self) × Pusa Nanha has shown moderate heterosis for important economic traits and same may be exploited further to develop a commercial hybrid of papaya.

Key words: *Carica papaya*, heterobeltiosis, relative heterosis.

INTRODUCTION

Papaya (*Carica papaya* L.) is an important fruit crop which is widely cultivated in the tropical and subtropical regions of the world owing to its high yield potential and nutritional value. India leads in papaya production in the world with a production of 6.1 MT from an area of 0.14mha resulting in productivity of 44.91 t/ha (Anonymous, 1). Other papaya growing countries of the world like Brazil, Indonesia and Mexico has the productivity much more than that of India. One of the major problems behind less productivity could be the lack of high yielding hybrid varieties with quality fruits and resistance to pests and diseases. Papaya is a seed propagated crop that can be improved either by developing purelines or inbreds or hybrids. Heterosis or hybrid breeding resulting in heterozygous F_1 hybrid are better than purelines because their heterozygosity ensures more variability for high yield and enhanced quality of fruits along with better genetic buffering against environmental and biotic stress. To know the potentiality of hybrid in particular crop, the magnitude and direction of heterosis is of paramount important. The magnitude of heterosis largely depends upon genetic divergence among the parents taken for the study. Heterosis has been exploited in crops like maize, rice, tomato and melons. In papaya, some of the studies conducted on hybridization demonstrates the existence of heterosis. The previous studies that reports heterosis in papaya between the cultivars were done by Chang and Wu (4), Subramanyam and Iyer (12), Chan (2), Kamalkumar *et al.* (6) and Davamani *et al.* (5). Thus, the present experiment was conducted to evaluate the magnitude of heterosis for vegetative, reproductive, fruit yield attributing and fruit biochemical traits and to identify the best heterotic combination.

MATERIALS AND METHODS

The experiment was conducted during 2016-2017 at the Main Experimental Orchard, Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi-110012. The trial was laid out under a randomized block design (RBD) with four replications. The experimental material consisted of five parent and three hybrid genotypes of papaya namely, Red Lady (Self) (a homozygous gynodioecious line), Pusa Nanha (PN), P-9-5, Pune Selection 3 (PS 3), P-7-9, Red Lady (Self) × Pusa Nanha, Red Lady (Self) × P-9-5 and Pune Selection 3 × P-7-9, papaya seedlings of parents and F_1 hybrids were raised under uniform field conditions and 12 uniform healthy looking plants were maintained

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for each genotype. The plants were raised as per the recommended package of practices for papaya cultivation under north Indian plains (Singh *et al*., 8). The hybrids and parents were analysed for a total of 7 vegetative and reproductive, 7 yield attributing, 8 fruit quality and biochemical traits under field and laboratory.

The observations such as the plant height at flower initiation (cm), plant height at first fruit maturity (cm), petiole length (cm), leaf length (cm), leaf width (cm), stem diameter (cm) and days to first flower initiation. The yield and yield attributing traits included days to first fruit maturity, fruiting zone (cm), number of fruits per plant, fruit diameter (cm), fruit length (cm), fruit weight (g), fruit central cavity index (%) and fruit yield per plant (kg) were recorded. For fruit quality and biochemical included traits like total soluble solids (TSS), total phenolic content (TPC) as determined by the Folin-Ciocalteau reagent method described by Singleton *et al.* (11), total flavonoid content (TFC) based on aluminum chloride colorimetric assay as demonstrated by Zhishen *et al.* (13), DPPH antioxidant activity assay was carried out according to the method described by Musa *et al.* (7), total carotenoid content and lycopene content was estimated by the method described by Rao *et al.* (9). The data obtained for different traits were statistically analyzed to find out the significance of the difference among the papaya hybrid progenies. The data was analyses online (http://hau.ernet.in/about/opstat.php) using OP Stat software (Sheoran *et al.,* 10).

RESULTS AND DISCUSSION

Analysis of variance as presented in Table 1 indicates significant differences among the parents and the hybrids for most of the traits under the study. Per cent heterosis for vegetative, reproductive, yield and fruit quality traits over mid-parent and better parent are presented in Table 2, 3 and 4, respectively.

The data of better parent heterosis (BPH) and mid parent heterosis (MPH) for vegetative and reproductive traits revealed that the petiole length, leaf length, leaf width and number of days required for flower initiation exhibited better parent heterosis in negative direction in all the three hybrids. For the same traits mid parent heterosis was also in negative direction except for the hybrid Red Lady (Self) × Pusa Nanha that showed positive heterosis for petiole length and leaf width whereas the Red Lady (Self) × P-9-5 that exhibited positive heterosis for days to flower initiation. Similar observations were also recorded by Kamalkumar *et al.* (6) for days to flowering for two hybrids CO2 × Pusa Giant and CO 5 × 9-1(D). Davamani *et al.* (5) also noted similar results for all the hybrids under study. Negative heterobeltiosis and relative heterosis were also observed for the plant height at initiation of first flower in two hybrids {Red Lady (Self) × Pusa Nanha and PS 3 × P-7-9} while one hybrid *i.e.,* Red Lady (Self) × P-9-5 showed positive heterobeltiosis (7.8%) and relative heterosis (11.34%) for the trait. Negative significant heterosis for plant height at flower initiation was also reported by Kamalkumar *et al.* (6) and Davamani *et al.* (5) in some of the hybrids. In case of plant height at first fruit maturity, only one hybrid {Red Lady (Self) × Pusa Nanha} showed negative better parent (-12.93%) and mid parent heterosis (-0.38%) while for other two hybrids it was positive. The trait, stem diameter was noted with significant heterobeltiosis which was positive for the hybrid Red Lady (Self) × P-9-5 (2.95%) and negative for the other two hybrids (Table 2).

Data presented in Table 3 for better parent and mid parent heterosis for yield, yield attributing and fruit characters revealed that heterobeltiosis and relative heterosis was observed to be in negative direction in all the hybrids for traits like number of days to fruit maturity, fruit weight, fruit length and fruit diameter. However, other researchers reported positive heterosis for fruit weight, fruit length and fruit diameter. In case of another yield determining trait like fruiting zone, better parent heterosis was negative for all the hybrids, whereas, PS 3 × P-9-5 (0.78%) was the only hybrid to show positive relative heterosis for the trait. Number of fruits per plant being an important yield attributing trait showed positive heterobeltiosis for two hybrids *i.e.,* Red Lady (Self) × Pusa Nanha (2.93%) and PS 3 × P-9-5 (22.13%). For the same trait, Iyer and Subramanyam (12), Chan (2), Kamalkumar *et al.* (6) and Davamani *et al.* (5) reported significant positive heterosis. In case of fruit cavity, two hybrids *i.e.,* Red Lady (Self) × Pusa Nanha and PS 3 × P-9-5} exhibited heterobeltiosis and relative heterosis in negative direction while it was positive in case of the hybrid Red Lady (Self) × P-9-5. Similar negative heterosis for fruit cavity index was also reported by Kamalkumar *et al.* (6). For yield, heterosis over the better parent ranged from 12.17% in PS 3 × P-9-5 to -8.49% in Red Lady (Self) × P-9-5, whereas heterosis over mid parent ranged from -6.18% in Red Lady (Self) × P-9-5 to 14.57% in Red Lady (Self) × Pusa Nanha. The Red Lady (Self) × Pusa Nanha was the only hybrid to exhibit positive significant heterosis. Positive significant heterosis for yield was also reported by Chan (3), Kamalkumar *et al.* (6) and Davamani *et al.* (5).

The heterobeltiosis and relative heterosis data for biochemical properties of fruit presented in Table

Table 1. Mean performance of papaya hybrid and their parent genotypes.

Traits	RL (S)	PN	RL(S) × PN	P-9-5	RL(S) × P-9-5	PS3	P-7-9	PS3 × P-7-9	Mean	LSD ($_{0.05}$)	C.V.
Plant height at flower initiation (cm)	86.50	63.75	73.75	81.00	93.25	83.95	96.50	81.75	82.56	4.80	3.33
Plant height at maturity (cm)	205.88	154.00	179.25	197.25	209.50	224.25	224.00	227.25	202.67	11.80	4.25
Petiole length (cm)	83.20	59.25	83.18	96.23	55.95	70.73	80.18	68.68	74.67	1.97	1.78
Leaf length (cm)	76.08	48.23	57.98	63.25	35.20	53.98	55.45	45.38	54.44	1.30	1.62
Leaf width (cm)	73.05	53.88	64.83	66.98	53.45	49.85	55.45	56.60	59.26	1.26	1.43
Stem diameter (cm)	12.50	9.25	10.95	12.70	13.08	13.18	11.83	12.53	12.00	0.93	5.20
Days to flowering	95.75	82.25	84.00	92.25	95.50	99.50	81.75	98.75	91.22	5.53	4.10
Days to fruit maturity	141.75	138.00	133.00	125.50	126.50	137.00	144.25	130.75	134.59	5.84	2.93
Fruiting zone (cm)	117.75	85.63	98.00	120.25	112.25	129.75	124.25	128.00	114.48	12.29	7.25
No. of fruits/ plant	33.52	20.56	34.50	35.17	34.69	36.57	33.87	44.67	34.19	2.76	5.44
Fruit weight (g)	1323.75	1160.00	1120.25	1247.00	1123.75	1436.25	1199.75	1020.00	1203.84	162.47	9.12
Fruit diameter (cm)	31.25	17.93	24.48	30.13	24.48	25.35	30.05	21.33	25.62	1.01	2.66
Fruit length (cm)	24.03	21.48	20.48	25.10	21.65	18.60	24.30	20.93	22.07	1.25	3.82
Fruit cavity index (%)	31.67	30.58	26.81	32.35	34.73	37.63	34.40	24.00	31.52	1.51	3.23
Fruit yield (kg/ plant)	42.98	23.75	38.23	45.20	41.36	52.75	40.43	46.33	41.38	2.76	4.51
TSS (°Brix)	14.53	9.98	11.75	10.05	10.70	13.68	13.50	12.78	12.12	1.54	8.59
Total Phenolic Content (mg/100g)	3.15	1.85	3.85	6.20	14.50	4.29	5.43	7.63	5.86	1.14	13.18
Total Flavonoid Content (mg/100g)	23.20	18.50	20.12	19.73	24.15	10.56	19.48	14.30	18.75	3.13	11.23
Antioxidant activity [DPPH (µmol/g)]	16.89	8.85	38.57	44.78	46.42	29.04	40.62	37.55	32.84	3.77	7.75
Total carotenoids (mg/100g)	4.36	3.52	5.77	4.57	4.31	5.40	6.09	4.31	4.79	0.49	6.92
Lycopene (mg/100g)	5.73	2.66	7.31	1.27	5.79	5.27	3.61	3.78	4.43	0.84	12.83
Fruit firmness (kg cm^{-1})	1.89	1.46	1.69	1.79	1.77	1.74	1.90	1.92	1.77	0.09	3.56
Shelf- life (days)	8.00	4.00	6.75	6.75	8.25	7.25	8.00	7.75	7.09	0.99	9.44

RL (S) = Red Lady (Self), PN= Pusa Nanha, PS 3= Pune Selection 3.

Table 2. Per cent heterosis for vegetative and reproductive traits of the papaya hybrids.

Genotype	Plant height at flower initiation		Plant height at first fruit maturity		Petiole length		Leaf length		Leaf width		Stem diameter		Days to flowering	
	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH
Red Lady (S) × Pusa Nanha	-14.73	-1.83	-12.93	-0.38	-0.03	16.77	-23.79	-6.71	-11.25	2.14	-12.40	0.68	-12.27	-5.61
Red Lady (S) × P-9-5	7.80	11.34	1.76	3.93	-41.85	-37.63	-53.72	-49.47	-26.83	-23.65	2.95	3.76	-0.26	1.59
Pune Selection 3 × P-7-9	-15.28	-15.28	1.33	1.33	-14.34	-14.34	-18.16	-18.16	-12.07	-12.07	-4.93	-4.93	-0.75	-0.75
LSD ($_{0.05}$)	7.9	8.2	11.1	NS	3.5	2.8	1.7	2.3	3.6	3.8	11.1	NS	8.2	7.3

Table 3. Per cent heterosis for yield, yield attributing and fruit traits of the papaya hybrids.

Genotype	Days to fruit maturity		Fruiting zone		No. of fruits/ plant		Fruit weight		Fruit diameter		Fruit length		Fruit cavity index		Fruit yield	
	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH
Red Lady (S) × Pusa Nanha	-6.17	-4.91	-16.77	-3.62	2.93	27.58	-15.37	-9.79	-21.68	-0.45	-14.77	-10.00	-15.34	-13.85	-11.05	14.57
Red Lady (S) × P-9-5	-10.75	-5.33	-6.65	-5.67	-1.37	0.99	-15.10	-12.57	-21.68	-20.24	-13.74	-11.85	7.38	8.52	-8.49	-6.18
Pune Selection 3 × P-7-9	-9.35	-7.02	-1.34	0.78	22.13	26.81	-28.98	-22.61	-29.03	-23.01	-13.88	-2.44	-36.20	-33.34	-12.17	-0.55
LSD $_{(0.05)}$	NS	NS	NS	NS	11.6	18.3	NS	NS	4.4	6.7	NS	5.8	8.6	9.0	NS	9.8

Table 4. Per cent heterosis for fruit quality traits of the papaya.

Genotype	Total soluble solids		Total phenolic content		Total flavonoid content		Antioxidant activity (DPPH assay)		Total carotenoid		Lycopene		Fruit firmness		Fruit shelf life	
	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH
Red Lady (S) × Pusa Nanha	-19.13	-4.12	22.22	54	-13.27	-3.5	128.36	199.68	32.33	46.44	67.66	74.26	-10.59	0.82	-15.62	12.50
Red Lady (S) × P-9-5	-26.35	-12.93	133.87	210.16	4.09	12.5	3.66	50.54	-5.68	-3.47	26.7	65.43	-6.49	-3.94	3.12	11.86
Pune Selection 3 × P-7-9	-6.57	-5.92	40.51	56.99	-26.59	-4.79	-7.55	7.8	-29.22	24.97	-37.93	-14.86	0.92	5.21	-3.12	1.63
LSD $_{(0.05)}$	NS	NS	43.4	65.1	NS	NS	52.1	49.1	9.6	10.7	30.1	33.9	NS	NS	NS	NS

4 which indicates the negative better parent and mid parent heterosis in all the hybrids for fruit TSS, whereas in case of total phenolic content, heterosis in positive direction was observed for all the hybrids. In case of total flavonoid content one hybrid (Red Lady (Self) × P-9-5) displayed positive heterobeltiosis (4.09%) and relative heterosis (12.5%) while it was negative for the other two hybrids (Red Lady (Self) × Pusa Nanha and PS 3 × P-7-9). Data recorded for antioxidant activity through DPPH assay, exhibited positive significant heterobeltiosis in hybrid Red Lady (Self) × Pusa Nanha(128.36%) and Red Lady (Self) × P-9-5 (3.66%), whereas in case of relative heterosis, it was positive for all the hybrid progenies studied. Significant better parent heterosis in positive direction was observed for the total carotenoid content in only one hybrid *i.e.,* Red Lady (Self) × Pusa Nanha (32.33%) while two of the hybrids were observed with positive mid parent heterosis i.e., Red Lady (Self) × Pusa Nanha (46.44%) and PS 3 × P-7-9 (24.97%) for the same trait. Positive heterosis for the same trait was also reported by Kamalkumar *et al.* (6). In case of lycopene content, the hybrids Red Lady (Self) × Pusa Nanha and Red Lady (Self) × P-9-5 exhibited significant positive heterobeltiosis (67.66% and 26.7%) and average heterosis (74.26% and 65.43%) whereas, it was negative for the hybrid PS 3 × P-9-5. Heterobeltiosis was positive for fruit firmness in only one hybrid *i.e.,* PS 3 × P-7-9 (0.92%), whereas positive mid parent heterosis was noted in Red Lady (Self) × Pusa Nanha (0.82%) and PS 3 × P-7-9 (5.21%). In case of fruit shelf life at ambient temperature, the hybrid Red Lady (Self) × P-9-5 (3.12%), showed positive better parent heterosis whereas, in case of relative heterosis for the same trait all the hybrids exhibited positive results.

In the present study, the hybrid combination, Red Lady (Self) × Pusa Nanha excelled over their parents and was recorded with positive heterobeltiosis and mid-parent heterosis for several economic traits such as number of fruits per plant, total phenolic content, antioxidant activity, total carotenoid and lycopene content. Further, Red Lady (Self) × Pusa Nanha was the only hybrid combination to be recorded with positive mid parent heterosis for fruit yield. So, it is evident from the above discussion that the magnitude of heterosis was low to moderate for majority of traits under study. The hybrid combination Red Lady (Self) × Pusa Nanha was identified with best results that can be further exploited in the papaya hybrid development.

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