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Per se performance of parents and hybrids for reproductive parameters in breeding program of papaya

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Abstract

An experiment was conducted at College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat during 2018-2020 with the aim to assess the *per se* performance of parents and hybrids for reproductive parameters in papaya. The experiment consisted of six morphologically diverse parents (PD, CO-2, CO-8, LL, GJP-1 and PS-1) and their resultant 30 F₁ hybrids, obtained by crossing in full diallel fashion. All the parents and hybrids were evaluated in randomized block design with three replications. Based on *per se* performance, amongst all the parents, parents PD, GJP-1 and LL hold enormous potentiality as they offer good yield, precocious flowering, fruiting and fruit set at lower plant height for easy harvesting of papaya, respectively. However, out of all the hybrids; maximum yield, fruit girth and volume was found in hybrid PD x LL; maximum fruit length in cross CO-8 x CO-2; early flowering and harvesting in cross CO-2 x PS-1; minimum inception height of first fruit set in cross LL x PD and maximum number of fruits per plant in cross CO-8 x PD with lowest cavity volume of fruits in cross PS-1 x PD. Based on their mean performance, parents can be used in papaya improvement programmes and hybrids could be exploited for commercial cultivation.

Keywords: Papaya breeding, diallel crossing, mean performance, hybrids, flowering, fruiting, yield

Introduction

Papaya (*Carica papaya* L.) is one of the most widely planted fruit crop, owing third rank in cultivated area, in the tropical and subtropical regions of the world due to its nutritional benefits and pharmacological properties. It is an herbaceous, short-lived crop, bearing fruits continuously at the leaf axils spirally arranged along the single erect trunk. Brazil and India are the largest producers of papaya although; Mexico is the main exporter (Evans and Ballen, 2012) [13]. In India, it is cultivated on 142 thousand hectares area with a production of 6011 thousand MT and productivity of 42.3 MT/ha (Anon., 2020) [1].

Owing to its rapid growth, continuous harvest and multiple uses, papaya is very common in home gardens of tropical regions (Manshardt, 1992) [12]. It is a rich source of vitamin A, vitamin C, potassium, folate, niacin, thiamine, riboflavin, iron and calcium and fibre (Huerta-Ocampo *et al.*, 2012) [13]. Moreover, fruits, stems, leaves and roots of papaya are used in traditional medicine (Ming *et al.*, 2008) [14]. Papaya is a thermo sensitive crop, highly affected by environmental variation. Hybrid cultivars in papaya fare better than pure lines because their heterozygosity provides a buffer against environmental stress and they also exhibit heterosis for yield characteristics (Ibitoye *et al.*, 2011) [9].

To initiate a breeding program in papaya, selection of parents which exhibit maximum genetic diversity is of paramount importance. Due to its highly cross pollinated nature and invariable propagation through sexual means, significant genetic variation is observed in papaya. *Per se* performance is the most simple and effective way to generate preliminary information on the performance of genotypes. A basic idea on the usefulness of parents may be developed from their individual performance, particularly with regard to yield components.

Material and Methods

The present investigation was undertaken to generate information about hybrid vigour and genetic diversity in papaya at Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat (20° 37' N latitude and 72° 54' E longitudes) during 2018-2020. In the present investigation, crossing was carried out in the year 2018-19 by

using six distinct parents [Pusa Delicious (PD), CO-2, CO-8, Lucknow Local (LL), Gujarat Junagadh Papaya-1 (GJP-1) and Pune Selection-1 (PS-1)]. The resultant 30 F₁ hybrids as well as the parents (6) were evaluated along with one commercial check variety (Red Lady) during 2019-20. The full diallel crossing technique developed by Griffing (1956^{a,b}) was employed for crossing. The experiment was laid out in a randomized block design with three replications. Each treatment comprised of 21 plants (2 m x 2 m) at least with seven plants per replication. Uniform cultural practices as recommended by NAU were adopted for the cultivation of papaya crop.

The number of days taken from transplanting to emergence of first flower was recorded from randomly selected five plants and average value was calculated for days taken to first flower. Similarly, days to first harvesting of fruits was calculated. For inception height of first fruit, plant height at first fruiting was recorded with the help of measuring tape. The number of fruits picked on different dates from randomly selected five plants was recorded, summed up and mean number of fruits per plant was calculated. Fruits harvested

from each plant were weighed separately, the average value was worked out and fruit yield was calculated. Fruit length was measured from the apex to base portion of the fruits and fruit girth was measured at the mid-portion of fruits. Five fruits per treatment from each replication were measured using a measuring tape and average value was expressed in centimetre. The fruit and cavity volume of each genotype of papaya was measured by water displacement method and average value was expressed in cc. The data collected for all the parameters were subjected to statistical analysis in WINDOSTAT software.

The qualitative characters *viz.*, colour of the fruit peel, colour of pulp, fruit shape, fruit apex, fruit shape of stalk end (stylar base), shape of central cavity and ridging on fruit surface (Table-1) were recorded as per the guidelines for conduct of test for distinctiveness, uniformity and stability in papaya from Protection of Plant Varieties and Farmers Rights Authority (PPVFRA), Government of India. At the time of fruit ripening, the colour of papaya fruits and pulp was recorded (Fig. 1-3) using RHS Colour Chart guide developed by 6th edition of Royal Horticultural Society.

Table 1: Qualitative characteristics of parent and hybrid papaya fruits

Sr. No.	Treatments	Colour of peel	Colour of pulp	Fruit shape	Fruit apex	Fruit shape of stalk end (Stylar base)	Shape of central cavity	Ridging on fruit surface
1	PD x CO-2	Light orange yellow (16B)	Brilliant yellow (21C)	Oblong ovate	Prominent	Flattened	Circular	Absent
2	PD x CO-8	Strong orange yellow (22A) Vivid yellow (15B)	Strong reddish orange (34C)	Pear shaped	Prominent	Depressed	Star shaped	Present
3	PD x LL	Brilliant yellow (13C)	Light orange yellow (16B)	Oblong ovate	Prominent	Flattened	Star shaped	Absent
4	PD X GJP-1	Brilliant yellow (7A)	Light orange yellow (22B)	Pear shaped	Prominent	Flattened	Circular	Absent
5	PD x PS-1	Vivid yellow (13A)	Strong reddish orange (34C)	Lengthened cylindrical	Prominent	Flattened	Circular	Absent
6	CO-2 x PD	Vivid yellow (13A)	Brilliant yellow (15C)	Pear shaped	Prominent	Flattened	Circular	Absent
7	CO-2 x CO-8	Brilliant orange yellow (21B) Vivid yellow (13A)	Strong reddish orange (32B)	Lengthened cylindrical	Less Prominent	Flattened	Star shaped	Present
8	CO-2 x LL	Brilliant yellow (13B)	Vivid yellow (14A)	Oblong ellipsoid	Blunt	Depressed	Angular	Absent
9	CO-2 x GJP-1	Brilliant yellow (15C)	Brilliant orange yellow (21B)	Mango shape	Prominent	Flattened	Irregular	Present
10	CO-2 x PS-1	Vivid yellow (15A)	Vivid yellow (15A)	Lengthened cylindrical	Blunt	Flattened	Irregular	Absent
11	CO-8 x PD	Strong orange yellow (22A) Vivid yellow (15A)	Vivid reddish orange (33B)	Lengthened cylindrical	Less Prominent	Flattened	Star shaped	Present
12	CO-8 x CO-2	Vivid yellow (9B)	Strong yellowish pink (32D)	Lengthened cylindrical	Highly Prominent	Inflated	Star shaped	Absent
13	CO-8 x LL	Strong orange yellow (22A) Vivid yellow (12A)	Strong reddish orange (34C)	Oblong ellipsoid	Prominent	Depressed	Star shaped	Absent
14	CO-8 x GJP-1	Brilliant yellow (20A)	Strong reddish orange (34C)	Oblong ellipsoid	Prominent	Depressed	Circular	Absent
15	CO-8 x PS-1	Light orange yellow (22B)	Strong reddish orange (34C)	Lengthened cylindrical	Blunt	Flattened	Star shaped	Absent
16	LL x PD	Brilliant yellow (13B)	Vivid yellow (14A)	Oblong ovate	Prominent	Flattened	Circular	Absent
17	LL x CO-2	Brilliant yellow (13C)	Light orange yellow (24C)	Oblong ovate	Prominent	Depressed	Star shaped	Absent
18	LL x CO-8	Vivid yellow (14B)	Moderate reddish orange (35B)	Pear shape	Highly Prominent	Flattened	Circular	Absent
19	LL x GJP-1	Vivid yellow (12A)	Vivid yellow (14B)	Oblong ellipsoid	Less Prominent	Depressed	Circular	Present
20	LL x PS-1	Vivid yellow (15B)	Vivid yellow (15B)	Oblong	Less Prominent	Flattened	Circular	Absent

				ellipsoid				
21	GJP-1 x PD	Brilliant yellow (13B)	Brilliant orange (25C)	Pear shape	Less Prominent	Flattened	Irregular	Absent
22	GJP-1 x CO-2	Vivid yellow (12A)	Light orange yellow (19A)	Lengthened cylindrical	Prominent	Flattened	Circular	Absent
23	GJP-1 x CO-8	Brilliant yellow (13B)	Strong yellowish pink (32C)	Slightly pear shape	Prominent	Depressed	Circular	Present
24	GJP-1 x LL	Vivid yellow (9A)	Vivid yellow (13A)	Oblong ellipsoid	Blunt	Depressed	Circular	Absent
25	GJP-1 x PS-1	Vivid yellow (12A)	Light yellow (20B)	Lengthened cylindrical	Less Prominent	Depressed	Circular	Absent
26	PS-1 x PD	Brilliant yellow (7A)	Vivid yellow (15B)	Pear shape	Prominent	Flattened	Star shaped	Present
27	PS-1 x CO-2	Brilliant orange yellow (21B)	Vivid yellow (14A)	Lengthened cylindrical	Blunt	Inflated	Irregular	Absent
28	PS-1 x CO-8	Vivid yellow (9A)	Light orange (29B)	Lengthened cylindrical	Less Prominent	Depressed	Star shaped	Absent
29	PS-1 x LL	Brilliant yellow (13B)	Vivid yellow (13A)	Lengthened cylindrical	Less Prominent	Flattened	Star shaped	Absent
30	PS-1 x GJP-1	Vivid yellow (14B)	Vivid yellow (13A)	Oblong ellipsoid	Blunt	Inflated	Circular	Present
31	PD	Brilliant orange yellow (21B)	Vivid reddish orange (30A)	Globular to Round	Depressed	Depressed	Star shaped	Present
32	CO-2	Vivid yellow (13A)	Vivid yellow (17C)	Oblong ellipsoid	Highly Prominent	Flattened	Circular	Absent
33	CO-8	Brilliant orange yellow (23B)	Strong reddish orange (31A)	Pear shape	Prominent	Depressed	Star shaped	Present
34	LL	Vivid yellow (15B)	Light orange yellow (23C)	Oblong ovate	Less Prominent	Depressed	Star shaped	Absent
35	GJP-1	Vivid yellow (12A)	Vivid yellow (13A)	Pear shape	Blunt	Flattened	Circular	Present
36	PS-1	Vivid yellow (12A)	Vivid yellow (13A)	Lengthened cylindrical	Less Prominent	Flattened	Circular	Absent
37	Red Lady	Vivid yellow (15B)	Strong reddish orange (32B)	Oblong ellipsoid	Less Prominent	Depressed	Star shaped	Present

N.B.; The colour of papaya fruit and pulp has been recorded by using RHS Colour chart guide developed by Royal Horticultural Society, 6th edition at the time of fruit ripening.

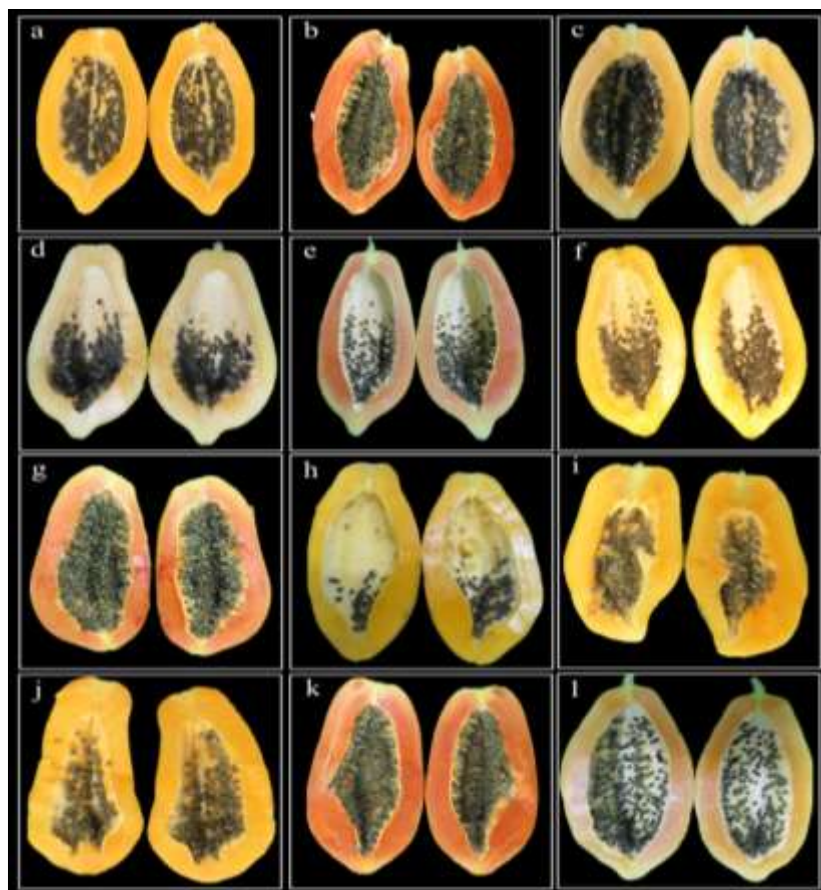


Fig 1: Variation in pulp colour of F₁ hybrids (a- PD x CO-2, b- PD x CO-8, c- PD x LL, d- PD x GJP-1, e- PD x PS-1, f- CO-2 x PD, g- CO-2 x CO-8, h- CO-2 x LL, i- CO-2 x GJP-1, j- CO-2 x PS-1, k- CO-8 x PD, l- CO-8 x CO-2)

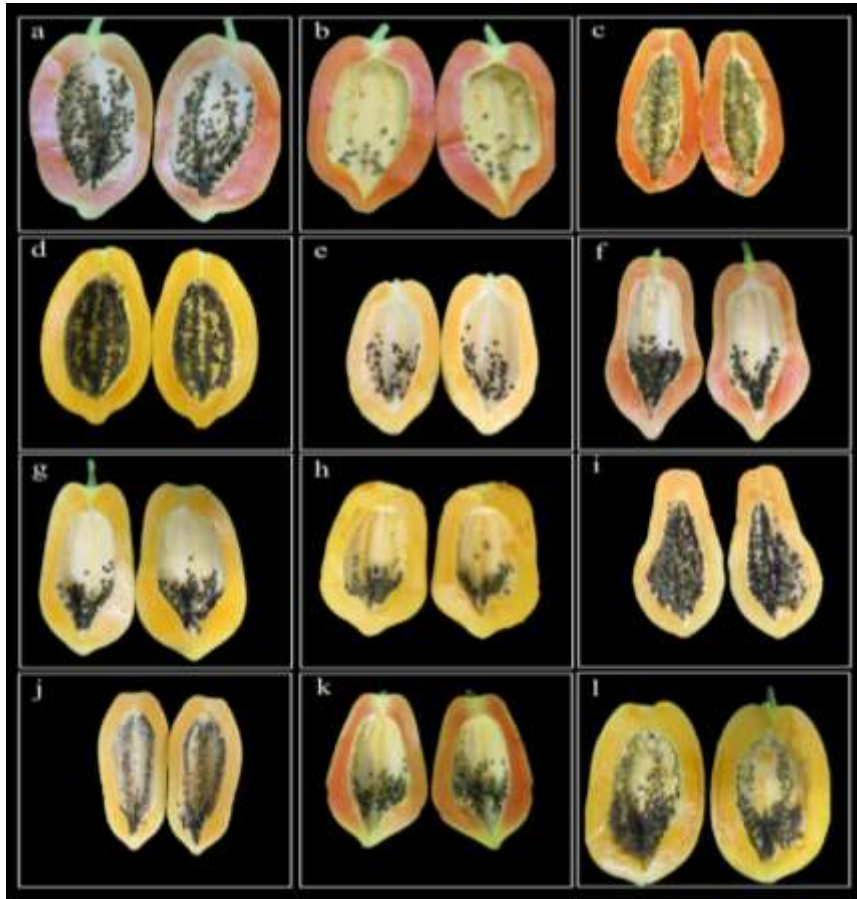


Fig 2: Variation in pulp colour of F₁ hybrids(a- CO-8 x LL, b- CO-8 x GJP-1, c- CO-8 x PS-1, d- LL x PD, e- LL x CO-2, f- LL x CO-8, g- LL x GJP-1, h- LL x PS-1, i- GJP-1 x PD, j- GJP-1 x CO-2, k- GJP-1 x CO-8, l- GJP-1 x LL)



Fig 3: Variation in pulp colour of F₁ hybrids and parents (a- GJP-1 x PS-1, b- PS-1 x PD, c- PS-1 x CO-2, d- PS-1 x CO-8, e- PS-1 x LL, f- PS-1 x GJP-1, g- PD, h- CO-2, i- CO-8, j- LL, k- GJP-1, l- PS-1)

Results and Discussion

The result of the analysis of variance (Table-2) computed for different characters revealed that genotypes as well as parents and hybrids showed significant to highly significant differences for all the characters under study. As far as the parents vs. hybrids comparison is concerned, hybrids were significantly different from the parents for days taken to

inception height of first fruit, fruit girth, fruit volume and cavity volume. Differences were significant to highly significant among F₁ hybrids as well as reciprocals for all the characters. F₁ vs. reciprocals comparison signified that, means of F₁ hybrids were significantly different from the means of the reciprocals for fruit yield, fruit girth, fruit volume and cavity volume.

Table 2: Analysis of variance (MSS) for parents and their hybrids for various characters in 6x6 full diallel crossing of papaya

Source of Variations	df	Days to first flower	Days to harvest	Inception height of first fruit (cm)	Number of fruits/plant	Yield (kg/plant)	Fruit length (cm)	Fruit girth (cm)	Fruit volume (cc)	Cavity volume (cc)
Mean squares										
Replications	2	78.29	151.71	43.96	89.39	179.49	2.04	1.33	24886.11	3767.59
Genotypes	35	415.28**	516.26**	730.99**	167.02**	446.40**	15.14**	135.41**	459021.90**	83172.59**
Parents	5	320.11**	915.59**	1633.17**	140.96*	210.83**	15.16**	234.73**	829182.22**	118008.89**
Hybrids	29	440.16**	464.84**	549.23**	176.69**	501.74**	15.45**	116.05**	364684.44**	69669.89**
Parent Vs. Hybrids	1	169.57	10.70	1491.35**	16.71	19.34	6.12	200.20**	1344006.67**	300569.63**
F ₁ 's	14	477.12**	498.95**	396.24**	130.87**	541.16**	12.32**	91.90**	372526.03**	91152.38**
Reciprocals	14	434.23**	460.66**	727.24**	233.34**	475.27**	19.34**	117.37**	321151.75**	49860.95**
F ₁ Vs. Reciprocals	1	5.78	45.80	198.92	25.25	320.53*	4.67	435.60**	864360.00**	46240.00**
Error	70	72.41	93.51	57.57	51.00	62.80	3.25	7.44	65910.87	5244.74
Total	107	184.67	232.88	277.59	89.67	190.46	7.12	49.19	193731.78	30707.55

* Significant at 5% and **Significant at 1% level of significance

The mean performance of papaya parents, hybrids and commercial check for different characters is indicated in Table-3. Per se performance revealed the lowest days taken to first flowering in parent Gujarat Junagadh Papaya-1 (87.13) and the maximum in parent CO-8 (115.53). The hybrid Gujarat Junagadh Papaya-1 x Lucknow Local was the earliest to flower (85.33 days), whereas, hybrid CO-2 x Pune

Selection-1 exhibited the maximum delay in flowering (129.63 days). Further, the number of days to harvest in case of parents, ranged from 238.27 (Gujarat Junagadh Papaya -1) to 275.27 days (CO-8) and for parents from 233.00 (Gujarat Junagadh Papaya -1 x Lucknow Local) to 276.80 days (CO-2 x Pune Selection-1), respectively.

Table 3: Mean performance of parents, hybrids and commercial check for different characters in 6x6 full diallel crossing of papaya

Sr. No.	Genotypes	Days to first flower	Days to harvest	Inception height of first fruit (cm)	Number of fruits/plant	Yield (kg/plant)	Fruit length (cm)	Fruit girth (cm)	Fruit volume (cc)	Cavity volume (cc)
1	PD x CO-2	115.87	252.40	86.20	42.00	62.79	28.67	50.33	2366.67	583.33
2	PD x CO-8	119.33	264.33	82.53	40.00	58.21	28.33	46.10	1990.00	423.33
3	PD x LL	109.47	256.67	48.13	43.17	73.29	30.33	54.33	2413.33	723.33
4	PD X GJP-1	91.67	239.67	76.40	35.67	52.57	28.67	51.03	2213.33	626.67
5	PD x PS-1	114.73	264.73	77.93	38.67	55.09	31.67	45.50	1976.67	430.00
6	CO-2 x PD	126.33	276.33	87.13	39.33	48.74	28.67	42.00	1830.00	336.67
7	CO-2 x CO-8	117.07	267.07	94.47	37.67	44.68	26.67	45.00	1573.33	280.00
8	CO-2 x LL	90.27	238.93	70.60	26.33	35.31	28.67	43.67	1786.67	400.00
9	CO-2 x GJP-1	104.40	242.93	81.33	26.50	30.30	26.67	34.67	1360.00	186.67
10	CO-2 x PS-1	129.67	276.80	85.60	31.00	39.44	30.83	39.83	1653.33	160.00
11	CO-8 x PD	111.40	261.40	92.13	48.00	62.05	27.83	46.67	1980.00	256.67
12	CO-8 x CO-2	118.47	268.47	100.27	39.67	53.44	33.50	42.67	2013.33	490.00
13	CO-8 x LL	108.40	256.00	69.93	28.00	40.24	27.33	48.40	1953.33	446.67
14	CO-8 x GJP-1	105.47	255.47	75.40	27.44	34.71	26.00	41.33	1546.67	270.00
15	CO-8 x PS-1	93.13	236.20	79.40	31.00	34.50	28.33	35.33	1370.00	116.67
16	LL x PD	86.00	234.00	45.07	44.17	63.16	28.00	48.00	1970.00	493.33
17	LL x CO-2	113.60	263.60	61.20	30.33	37.81	27.83	44.73	1710.00	410.00
18	LL x CO-8	117.87	267.87	65.07	31.00	39.28	31.33	44.50	1763.33	470.00
19	LL x GJP-1	94.60	237.00	63.20	26.67	32.37	25.00	41.50	1523.33	403.33
20	LL x PS-1	119.40	269.40	61.73	21.67	26.48	25.33	40.67	1370.00	246.67
21	GJP-1 x PD	104.20	257.60	74.07	39.00	44.86	25.67	41.33	1626.67	353.33
22	GJP-1 x CO-2	101.93	248.60	83.67	25.00	35.11	29.17	35.13	1826.67	470.00
23	GJP-1 x CO-8	111.67	258.07	81.33	31.67	35.61	26.00	43.33	1493.33	360.00
24	GJP-1 x LL	85.33	233.00	55.00	25.33	26.73	24.67	43.67	1223.33	340.00
25	GJP-1 x PS-1	90.00	252.53	80.27	32.67	43.91	30.33	42.83	1850.00	403.33
26	PS-1 x PD	108.20	254.93	89.20	46.67	45.92	26.33	30.83	1333.33	110.00
27	PS-1 x CO-2	121.80	260.00	91.80	18.50	20.32	29.33	27.33	1036.67	113.33
28	PS-1 x CO-8	103.20	253.20	88.00	31.67	36.43	31.83	34.33	1576.67	303.33
29	PS-1 x LL	105.93	240.00	76.87	24.00	31.43	31.67	37.33	1623.33	360.00

30	PS-1 x GJP-1	95.13	254.47	86.93	30.00	26.37	27.83	32.67	1000.00	153.33
31	PD	111.20	274.27	100.60	32.67	57.34	29.33	54.67	2650.00	753.33
32	CO-2	109.13	263.60	110.93	30.67	47.70	31.33	45.00	2253.33	486.67
33	CO-8	115.53	275.27	108.33	39.33	44.66	25.67	45.67	1586.67	363.33
34	LL	98.47	241.00	54.93	24.22	35.25	26.67	47.60	2050.00	586.67
35	GJP-1	87.13	238.27	65.80	25.00	40.63	25.67	51.00	2256.67	610.00
36	PS-1	101.27	241.00	81.40	40.33	35.47	28.00	29.00	1190.00	193.33
37	Red Lady (CC)	104.27	264.67	106.33	37.67	64.36	27.33	50.33	1920.00	630.00
	CD @ 5 %	13.81	15.70	12.32	11.59	12.87	2.93	4.43	416.83	117.58
	CV%	7.98	3.79	9.64	21.70	18.62	6.37	6.43	14.68	19.01

The lowest inception height of first fruit was observed in parent Lucknow Local (54.93 cm) and the highest in parent CO-2 (110.93 cm). Among the hybrids, lowest height for first fruit set was observed in cross Lucknow Local x Pusa Delicious (45.07 cm). The cross CO-8 x CO-2 recorded the highest inception height of first fruit set (100.27 cm).

Among the parents, the parent Pusa Delicious reported maximum value for fruit yield per plant, fruit girth and fruit volume. It is worth mentioning that parent CO-2 having a prominence for maximum fruit length. Gujarat Junagadh Papaya-1 out of all the parents was recorded least days required for first flowering and harvesting of fruits. The parent Lucknow Local had minimum inception height at first fruit set among the parents. The maximum number of fruits per plant was observed in parent Pune Selection-1 along with minimum cavity volume of papaya fruits.

In case of papaya hybrids minimum days required initiation of first flower and harvesting of fruits was observed in hybrid CO-2 x Pune Selection-1. Among all the crosses, the hybrids having highest yield per plant, fruit girth, fruit volume were reported in cross Pusa Delicious x Lucknow Local. However, minimum plant height for inception of first fruit set was noticed in LL x PD and maximum fruit length was observed in hybrid CO-8 x CO-2. The maximum number of fruits per plant was found in cross CO-8 x Pusa Delicious. Lowest cavity volume of fruits was reported in cross Pune Selection-1 x Pusa Delicious. From the above discussion, it become clear that use of Pusa Delicious, Gujarat Junagadh Papaya-1 and Lucknow Local as parents holds immense potentiality for utilization in papaya hybrid development programme as the hybrids offered better yield, earlier production of fruits and lesser height for inception of first fruit set for better and easy harvesting of papaya, respectively.

Most of the significant variations were found among the parents and hybrids of papaya for different quantitative and qualitative characters is might be based on the fact that every genotypes has its own nature in development of fruits which may be varied due to different physiological phenomenon *viz.* efficiency of photosynthesis, rate of translocation of photosynthates from source to sink and photo-respiration that takes place in the plant body. Different hybrids had differential response to varied environmental factors. The range of data in results are in close conformity with the findings of Das and Dinesh (2004) [3], Singh *et al.* (2005) [16], Jana *et al.* (2010) [11], Meena *et al.* (2012) [13], Ara *et al.* (2013) [2, 4], Davamani *et al.* (2013) [2, 4], Jambhale *et al.* (2014) [10] and Saran *et al.* (2015) [15].

Conclusion

This study demonstrated the genetic variability in papaya hybrids under recommended agronomic practices and highlighted the scope for future breeding programme with potential crosses. Pusa Delicious, Gujarat Junagadh Papaya-1

and Lucknow Local can be used as parents in papaya hybrid development programmes as the resultant hybrids exhibited better yield with early flowering and fruiting.

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Authors' contributions

The research was conceptualized by authors TRA, AI and SJ. The work was carried out by author SJ under the supervision of authors TRA, AIP and BMT. Data curation and statistical analysis were carried out by author SJ and AIP. Author AM and KRL managed the literature searches. This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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