Original Research Paper

Evaluation of intergeneric F$_1$ hybrid progenies of papaya (Arka Prabhath x *Vasconcellea cauliflora* and Arka Prabhath x *Vasconcellea cundinamarcencis*) for morphological, fruit and yield traits coupled with PRSV tolerance

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ABSTRACT

Papaya is one of the most important fruit crops of tropical and subtropical regions of the world including India. Though India stands first in production in the world, the productivity is low as compared to other countries due to high incidence of papaya ring spot virus (PRSV-P) attack. As all the cultivated varieties under genus *Carica* are susceptible to PRSV, investigations were carried out to evaluate fifteen intergeneric hybrid progenies of Arka Prabhath x *V. cauliflora* and eighty-five progenies of Arka Prabhath x *V. cundinamarcencis* for morphological, fruit and yield traits coupled with PRSV- P tolerance. Out of fifteen, seven progenies of 'Arka Prabhath' x *V. cauliflora viz.*, IGHF$_1$S4-1, IGHF$_1$S4-12, IGHF$_1$S4-13, IGHF$_1$S4-14, IGHF$_1$S4-15, IGHF$_1$S4-17, IGHF$_1$S4-18 and out of eighty-five, six progenies of 'Arka Prabhath' x *V. cundinamarcensis viz.,* IGHF$_1$S1-17, IGHF$_1$S1-19, IGHF$_1$S6-20, IGHF$_1$S2-14, IGHF$_1$S5-12 and IGHF$_1$S5-14 recorded desirable traits such as days to first fruiting (240 to 250 days), bearing height (48 to 74 cm), plant height (175 to 200 cm), trunk circumference (37 to 48 cm), fruit weight (1133.67 to 2202.00 g), pulp thickness (2.45 to 4.05 cm), TSS (11.50 to 13.80 °Brix), fruits/tree (40 to 58) and yield (45.00 to 78.20 kg/tree) coupled with PRSV tolerance with disease score1 (only a few tiny chlorotic spots on leaves). These progenies were selected and forwarded for next generation (F$_2$). The hybridity was also confirmed using SSR marker (mCpCIR59).

Keywords : Evaluation, intergeneric hybrids, papaya, PRSV-P, *Vasconcellea cauliflora, Vasconcellea cundinamarcensis*

INTRODUCTION

Papaya (*Carica papaya* L; Caricaceae) is one of the most important fruit crops of the world due to its wide acceptance amongst the consumers and food processing industries. It is believed to have originated from Mexico to Panama and now has spread throughout the tropics and sub-tropics. It is a rich source of vitamins having an approximate composition of 2020 IU of vitamin A, 40 mg of vitamin B$_1$ and 46 mg of vitamin C per 100 g of fruit. India stands first in world production contributing 44.04 *per cent* followed by Brazil, Mexico, Indonesia, Dominican Republic and Nigeria (FAO, 2020). Though, there is an increase in area under cultivation of papaya in the recent past, the corresponding increase in production has not been realized in India due to several factors (Sharma and Tripathi, 2019). Among them, papaya

ring spot virus (PRSV) type P (Litz *et al.*, 1984) a definitive poty virus species in the Potyviridae is the most devastating one in all the major papaya growing areas in the world (Sharma and Tripathi, 2019) causing yield loss upto 95 *per cent* (Babu and Banerjee, 2018). None of the control measures are successful and all the commercial cultivars of *Carica papaya* are susceptible to this disease. Hence, development of resistant/ tolerant cultivars using virus resistant wild relatives (*Vasconcellea* genus) through conventional breeding is the reliable tool for long term control of this disease (Pujar, 2019). Keeping this view, an attempt was made to evaluate the F$_1$ intergeneric hybrid progenies of the cross Arka Prabhath x *V. cauliflora* and Arka Prabhath x *V. cundinamarcencis* for morphological, fruit quality and yield traits coupled with PRSV tolerance.

MATERIALS AND METHODS

The field and laboratory experiments were carried out at the Division of Fruit Crops, ICAR-Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru during 2019-2021. The seeds obtained from the cross combination of Arka Prabhath x *V. cauliflora* and Arka Prabhath x *V. cundinamarcensis* were sown for raising F_1 population. A total fifteen intergeneric hybrid progenies of Arka Prabhath x *V. cauliflora* and eighty-five progenies of Arka Prabhath x *V. cundinamarcencis* were field evaluated along with its parents under the natural source of inoculum without challenge inoculation in order to know its potential for PRSV tolerance and to forward to next generation. All the individual seedlings were planted at a spacing of 2 x 2 m and standard package of practices were followed. The morphological, fruit and yield traits coupled with PRSV tolerance under natural condition were recorded as per the standards followed for papaya. All the observations pertaining to morphological and fruit traits were recorded at the time of first fruiting. Observations on yield and PRSV score were continued up to 14 months of field planting and progenies were selected based on the cumulative yield performance and average PRSV score recorded up to 14 months.

Morphological traits

The morphological traits *viz.,* days to first fruiting, bearing height (cm), plant height (cm), number of nodes, plant canopy spread (N-S & E-W in cm), number of leaves, trunk circumference (cm), number of fruits and yield per tree were recorded at first fruiting. PRSV scoring was done based on the intensity of visual symptoms on petiole, lamina and stem using the scale of 0-5 (0- resistant, 1- tolerant, 2- moderately tolerant, 3- moderately susceptible, 4- susceptible and 5- highly susceptible) as given by Dhanam (2006).

Fruit traits

The fruit traits *viz.*, fruit weight (g), fruit length (cm), fruit width (cm), pulp thickness (cm), fruit volume (ml), cavity volume (ml), fruit cavity (%), pulp colour, TSS (°Brix) and taste were recorded in 10 randomly collected ripe fruits at edible ripe stage. TSS was recorded using 'ERMA' hand refractometer and pulp colour was recorded using Royal Horticultural Society (RHS) colour chart. Fruit cavity (%) was calculated using the formula given below:

$$\text{Fruit cavity (\%)} = \frac{\text{Fruit cavity volume}}{\text{Fruit volume}} \times 100$$

Statistical analysis

The basic statistics like standard error of mean (S.E.m±), coefficient of variation (%) were performed by following the methods suggested by Singh and Chaudhary (1999).

Validation of progenies using molecular markers

Around 29 microsatellite (SSR) markers were screened to check the polymorphismin of both female (Arka Prabhath) and male parents (*V. cauliflora* and *V. cundinamarcencis*) to confirm the hybridity, out of which mcpCIR59 was selected for validating the selected hybrids. Following methodology was followed.

Isolation of DNA

DNA was extracted using CTAB method developed by Lodhi *et al.* (1994). Freshly matured leaves, free from diseases and developmental deformities were used for DNA extraction. They were brought to the laboratory in butter paper bags and cleaned using 76% ethanol to remove traces of dirt.

Polymerase chain reaction (PCR)

The PCR reaction was performed in a 15 µL reaction volume containing 10X buffer consisting 25 mM MgCl2, 1 mMdNTP's, 100 mM primers, 0.3 U of Taq DNA polymerase (Genei, Bangalore) and 20 ng template DNA in Eppendorf thermal cycler. The SSR primers were obtained from Bioserve, Hyderabad. The Primer sequence of optimized microsatellites from *Carica papaya* is as follows;

Locus name	Primer sequences (5'-3')	Ta (°C)
mCpCIR59	F: GTTGTTTGCATCCCACTGC	60
	R: CTCGCCATTCCATCTGGT	

The PCR amplification programme for SSR was followed involving i) Initial denaturation: 94 ºC for 5 minutes, ii) Denaturation: 94 °C for 30 seconds, iii) Annealing: 60 ºC for 1 minute, iv) Extension: 72 °C for 45 seconds, v) Repeat step 2 to step 4 for 35 cycles vi) Final extension: 72 °C for 4 minutes

20

RESULTS AND DISCUSSION

Morphological traits

The morphological parameters varied significantly among all intergeneric hybrid progenies (Table 1 & 2). The days to first fruiting recorded in the intergeneric progenies of Arka Prabhath x *V. cauliflora* was ranged from 240 to 270 and in Arka Prabhath x *V. cundinamarcencis* it was 240 to 280 days. The early fruiting (240 to 248 days) was recorded in the selected intergeneric progenies of Arka Prabhath x *V. cauliflora* (IGHF₁S4-1, IGHF₁S4-12, IGHF₁S4-13, IGHF₁S4-15, IGHF₁S4-17, IGHF₁S4-18) and Arka Prabhath x *V. cundinamarcencis* (IGHF₁S1-17, IGHF₁S1-19, IGHF₁S5-12, IGHF₁S5-14, IGHF₁S6-20 and IGHF₁S2-14). The earliness in the fruiting observed in the progenies could be attributed to the early bearing nature of the female parent (250 days) compared to the male parents (*V. cauliflora*: 345 days and *V. cundinamarcencis*: 353 days). Early bearing progenies can escape PRSV infection and can result in quality fruits so that the farmers can get premium price in the market (Lichamo, 2015; Jayavalli, 2010).

The traits *viz.*, plant height at first fruiting, bearing height and number of nodes showed significant differences among the progenies of Arka Prabhath x *V. cauliflora* (133 to 223 cm, 56 to 86 cm and 14 to 23, respectively) and Arka Prabhath x *V. cundinamarcencis* (90 to 227 cm, 48 to 85 cm and 14 to 30, respectively). Lesser the number of nodes, lower is the bearing height. These traits are of much importance with respect to its suitability to the recent hi-tech horticultural practices like HDP to achieve higher productivity per unit area. Additionally, it was observed that lower number of nodes resulted in precocious or early bearing in papaya (Magdalita and Signabon, 2017). Hence, these traits were considered for selection of progenies.

With respect to plant canopy spread (E-W and N-S) and number of leaves, variations were observed among the progenies of Arka Prabhath x *V. cauliflora* (110 to 195 cm, 100 to 200 cm and 13 to 27, respectively) and Arka Prabhath x *V. cundinamarcencis* (107 to 220 cm, 100.00 to 290 cm and 11 to 34, respectively). All the progenies in both the combination recorded narrow leaf type (papaya type). The number of leaves play an important role in deciding the photosynthetic area of a genotype. Hence, wider canopy indicates more the number of leaves and more photosynthates for the developing fruits which helps in enhancing the final yield. In addition, source- sink relationship influences the rate

Table 1 : Morphological parameters of IGHF₁ progenies of Arka Prabhath x *Vasconcellea cauliflora*

Progeny	Days to first fruiting	Height to first fruiting (cm)	Plant height at first fruiting (cm)	No. of nodes to first fruiting	Plant canopy spread		No. of leaves at first fruiting	Trunk circumference (cm)	Number of fruits		Yield (Kg/tree)	PRSV Score
					E-W (cm)	N-S (cm)			At first fruiting	14 months after planting		
Range	240.00-270.00	56.00-86.00	133.00-223.00	14.00-23.00	110.00-195.00	100.00-200.00	13.00-27.00	26.00-48.00	18.00-35.00	20.00-50.00	11.00-58.00	Tolerant (1) to highly susceptible (5)
Mean	257.59	68.65	177.82	19.41	172.76	172.82	21.35	36.94	29.82	38.12	35.09	-
SEm±	5.85	2.26	5.22	0.51	5.41	6.23	1.03	1.34	2.50	3.51	4.07	-
CV (%)	9.37	13.59	12.10	10.78	12.91	14.87	19.87	14.99	34.55	37.96	47.82	-

Table 2 : Morphological parameters of IGHF₁ progenies of Arka Prabhath x *Vasconcellea cundinamarcencis*

Progeny	Days to first fruiting	Height to first fruiting (cm)	Plant height at first fruiting (cm)	No. of nodes to first fruiting	Plant canopy spread		No. of leaves at first fruiting	Trunk circumference (cm)	Number of fruits		Yield (Kg/tree)	PRSV Score
					E-W (cm)	N-S (cm)			At first fruiting	14 months after planting		
Range	240.00-280.00	48.00-85.00	90.00-227.00	14.00-30.00	107.00-220.00	100.00-290.00	11.00-34.00	30.00-50.00	11.00-46.00	13.00-58.00	12.75-78.20	Tolerant (1) to highly susceptible (5)
Mean	260.40	66.87	185.24	19.49	174.60	175.52	22.23	39.23	27.51	31.98	34.71	-
SEm±	1.52	0.79	2.40	0.31	2.23	2.50	0.49	0.45	0.86	1.26	1.46	-
CV (%)	5.46	11.00	12.09	15.04	11.93	13.27	20.47	10.68	29.20	36.83	39.11	-

21

of increase in yield, the resilience of yield and nutritional quality. It was observed that higher leaf area had a positive contribution towards higher productivity in papaya genotype Sunrise Solo (Paixao *et al.*, 2019).

Stem circumference, number of fruits and yield per tree showed a wide difference among the progenies of Arka Prabhath x *V. cauliflora* (26 to 48 cm, 20 to 50 fruits/tree and 11 to 58 kg/tree, respectively) and Arka Prabhath x *V. cundinamarcencis* (30 to 50 cm, 13 to 58 fruits/tree and 12.75 to 78.20 kg/tree, respectively). As the fruiting behavior of papaya is cauliflorus in nature, thicker stem indicates the capacity of such progenies to tolerate virus infection and bear more number of fruit**s** (Magdalita and Signabon, 2017). Yield is a complex trait contributed by several factors. Hence, in the present investigation, the progenies with more number of fruits were considered as a selection criterion to advance further as it contributes to the final yield. Under the PRSV infection, it was observed that there was a considerable reduction in the growth as well as yield but the progenies which were having tolerance were able to put forth the leaves continuously and were able to yield considerable number of fruits. It was observed in the present study that the crosses involving *V. cauliflora* and *V. cundinamarcencis* as male parents were able to produce more number of fruits (80 and 85 fruits/tree, respectively in *V. cauliflora* and *V. cundinamarcencis*) which could have been inherited to the progenies resulting in the more number of fruits.

In the present study, based on the final score after 14 months of field evaluation, the male parents (*V. cauliflora* and *V. cundinamarcencis*) remained non-symptomatic, while, the female parent expressed disease symptoms after eight months of field planting (at first harvest) and was found to be highly susceptible. The intergeneric progenies *viz.,* IGHF$_1$S4-1, IGHF$_1$S4-12, IGHF$_1$S4-13, IGHF$_1$S4-14,

IGHF$_1$S4-15, IGHF$_1$S4-17 and IGHF$_1$S4-18 of Arka Prabhath x *V. cauliflora* and IGHF$_1$S1-17, IGHF$_1$S1-19, IGHF$_1$S2-14, IGHF$_1$S5-12, IGHF$_1$S5-14 and IGHF$_1$S6-20 of Arka Prabhath x *V. cundinamarcencis* developed few chlorotic spots and mild symptoms on fruits but the plants were able to tolerate the disease incidence and were vigorous with continuous growing tip. This result corroborated with the findings of Magdalita and Signabon (2017) showing that reduction in symptom severity could be attributed to the disease tolerance that could have been inherited from the resistant parents. As expected, in the present investigation also, the intergeneric progenies of *Carica* and *Vasconcellea* were found to be tolerant compared to the female parent (Jayavalli, 2010; Sudha *et al.,* 2013; Sunil, 2014; Lichamo, 2015; Pujar, 2019).

Fruit traits

Fruits are the economic part of the plant contributing to the final yield and related traits (Table 3 and 4). Wide variations were observed among the intergeneric progenies with respect to fruit shape, size and colour (Figure 1 and 2). These traits are highly heritable, hence, they are of high importance in progeny evaluation and selection. The fruit size is determined by the fruit weight which also contributes to the final yield.

Fruit weight recorded wide variations among the progenies of Arka Prabhath x *V. cauliflora* which ranged from 572.60 to 1245.00 g. With respect to Arka Prabhath x *V. cundinamarcencis,* it was ranged from 833.00 to 2267.25 g. Medium to big sized fruits are having more demand for both fresh fruit consumption as well as for processing industries (Magdalita and Signabon, 2017). The variations in fruit size could be due to the different heterotic combinations of the progenies. Wide variation in fruit size was also obtained (Jayavalli, 2010; Sudha *et al.*, 2013) in intergeneric hybrids of papaya.

Table 3 : Fruit quality parameters of IGHF$_1$ progenies of Arka Prabhath x *Vasconcellea cauliflora*

Progeny	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Pulp thickness (cm)	Fruit volume (ml)	Fruit cavity (%)	Pulp colour	TSS (°Brix)
Range	572.60-1245.00	13.18-21.49	9.70-13.22	2.13-3.00	407.50-1099.00	16.38-43.37	Orange-orange red	8.20-12.80
Mean	969.40	16.48	11.35	2.53	722.42	26.28	-	11.16
SEm±	76.65	0.71	0.54	0.14	65.79	1.71	-	0.38
CV (%)	32.60	17.84	19.48	23.16	37.55	26.80	-	14.18

22

Table 4 : Fruit quality parameters of IGHF₁ progenies of Arka Prabhath x *Vasconcellea cundinamarcencis*

Progeny	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Pulp thickness (cm)	Fruit volume (ml)	Fruit cavity (%)	Pulp colour	TSS (°Brix)
Range	833.00-2267.25	15.10-25.38	10.18-16.28	2.45-4.05	620.00-1666.67	16.76-33.85	Orange-orange red	7.00-14.85
Mean	1576.62	20.04	12.85	3.17	1138.69	22.83	-	12.97
SEm±	33.68	0.26	0.20	0.04	25.48	0.47	-	0.11
CV (%)	19.93	12.04	14.70	12.08	20.87	19.04	-	8.27

Variation in fruit shape and size   Variation in pulp colour

Fig. 1 : Variation in fruit shape, size and pulp colour of F₁ intergeneric progenies of Arka Prabhath x *V. cauliflora*

Variation in fruit shape and size   Variation in pulp colour

Fig. 2 : Variation in fruit shape, size and pulp colour of F₁ intergeneric progenies of Arka Prabhath x *V. cundinamarcencis*

A wide variation was also observed in the pulp thickness and cavity per cent recorded among the progenies of Arka Prabhath x *V. cauliflora* (2.13 to 3.00 cm and 16.38 to 43.37 %) and Arka Prabhath x *V. cundinamarcencis* (2.45 to 4.05 cm and 16.76 to 33.85 %). The pulp colour varied from orange to orange-red in both the combinations. The cavity per cent is an important parameter which determines the final pulp recovery. A thick pulp is an important trait of a genotype as it contributes considerably to the edible portion of the fruit. The reason attributed to the thick and firm pulp with lower cavity in the intergeneric progenies could be inherited from the female parent, Arka Prabhath (Jayavalli, 2010; Sudha *et al.,* 2013). Thus, the progenies with lower cavity per cent, higher pulp percentage and attractive pulp colour were given preference for further advancement. The earlier workers have reported that pulp contained rich carotene and lycopene in the intergeneric progenies of papaya involving female parent *viz.,* Arka Surya (Lichamo, 2015), 'Arka Prabhath' (Pujar, 2019), C0 7 and Pusa Nanha (Jayavalli, 2010).

Total soluble solids recorded wide variations among the progenies of Arka Prabhath x *V. cauliflora* (8.20 to 12.80 °Brix) and Arka Prabhath x *V. cundinamarcencis* (7.00 to 14.85 °Brix). Magdalita and Signabon (2017) were opined that TSS is an important trait to be considered in selection of genotypes for fresh fruit consumption.

It was also observed that majority of the intergeneric progenies (99.00%) recorded excellent to intermediate taste similar to that of female parent (Arka Prabhath) which might have been inherited from the female parent. Though, the wild species used in the study is of poor quality, none of the progenies were found to have the linked trait of poor quality but were found to be superior in taste. Several workers have also reported that the intergeneric hybrids of papaya produced good quality fruits (Jayavalli, 2010; Sudha *et al.*, 2013; Lichamo, 2015).

Morphological, fruit quality, yield traits and PRSV score of the selected progenies

The traits of the selected progenies are depicted in Table 4, 5 and 6. The selected progenies of Arka Prabhath x *V. cauliflora* (IGHF₁S4-1, IGHF₁S4-12, IGHF₁S4-13, IGHF₁S4-14, IGHF₁S4-15, IGHF₁S4-17 and IGHF₁S4-18) and Arka Prabhath x *V. cundinamarcencis* (IGHF₁S1-17, IGHF₁S1-19, IGHF₁S6-20, IGHF₁S2-14, IGHF₁S5-12 and IGHF₁S5-14) were found semi-dwarf (1 to 2 m), low bearing height (<1 m), thick stem circumference (>30 cm), medium-big sized fruit (>1 kg), thick pulp (>2.50 cm), low cavity (<25%), high TSS (>11 °Brix), more number of fruits/tree (>30) and high yielding (>45 kg/tree) coupled with PRSV-P tolerance (reduced symptom severity and

23

Table 5 : Morphological, fruit quality, yield traits and PRSV score of the selected IGHF$_1$ progenies of Arka Prabhath x *V. cauliflora*

| Trait | Progenies | | | | | | | | Parents | |
	IGHF$_1$ S4-1	IGHF$_1$ S4-12	IGHF$_1$ S4-13	IGHF$_1$ S4-14	IGHF$_1$ S4-15	IGHF$_1$ S4-17	IGHF$_1$ S4-18	Mean	Arka Prabhath	*V. cauliflora*
Days to first fruiting	242.00	248.00	245.00	250.00	246.00	240.00	245.00	257.59	250.00	345.00
Plant height at first fruiting (cm)	188.00	178.00	180.00	175.00	182.00	182.00	184.00	177.82	190.00	160.00
Bearing height (cm)	71.00	65.00	72.00	69.00	74.00	66.00	67.00	68.65	74.00	58.00
Stem circumference at first fruiting (cm)	41.00	38.00	38.00	37.00	38.00	39.00	40.00	36.94	38.00	27.00
Number of nodes at first fruiting	19.00	19.00	21.00	20.00	22.00	20.00	19.00	19.41	20.00	17.00
Canopy spread E-W (cm)	185.00	190.00	185.00	190.00	185.00	195.00	185.00	172.76	185.00	170.00
Canopy spread N-S (cm)	190.00	200.00	190.00	195.00	190.00	190.00	180.00	172.82	180.00	145.00
Number of leaves at first fruiting	25.00	23.00	25.00	25.00	23.00	27.00	26.00	21.35	23.00	19.00
Number of fruits (14 months after planting)	45.00	45.00	42.00	45.00	40.00	50.00	48.00	38.12	38.00	80.00
Yield (kg/tree)	52.00	55.00	45.00	54.00	47.00	58.00	51.00	35.09	35.00	4.50
Fruit weight (g)	1225.00	1234.63	1165.20	1222.00	1245.00	1244.70	1133.67	969.40	1100.00	67.23
Fruit length (cm)	19.50	18.81	13.52	17.10	18.38	21.49	20.43	16.48	17.60	9.65
Fruit width (cm)	11.50	13.05	12.50	12.44	12.92	11.56	12.30	11.35	9.60	3.95
Fruit volume (ml)	970.00	1099.17	735.00	1032.50	735.00	943.57	828.33	722.42	975.40	38.83
Pulp thickness (cm)	3.00	2.78	2.45	2.50	2.78	2.76	3.00	2.53	2.50	0.51
Pulp colour (RHS colour chart)	Orange 25B	Orange 25A	Orange red 30A	Orange 28B	Orange red 30C	Orange 28B	Orange 25A	-	Orange red 30C	Yellow group 4D
Fruit cavity (%)	20.62	16.38	27.21	19.37	34.01	16.96	25.35	26.28	25.63	25.75
TSS (°Brix)	11.50	12.2	12.80	12.76	12.32	12.38	12.70	11.16	12.50	9.60
PRSV score	Tolerant (1)	Tolerant (1)	Tolerant (1)	Tolerant (1)	Tolerant (1)	Tolerant (1)	Tolerant (1)	-	Highly susceptible (5)	Resistant (0)

delayed expression of disease). The progenies were found vigorous even under the diseased condition indicating their tolerance to the disease. Hence, these progenies provide significant reductions in use of land, water, fuel and other inputs (cost of production) and thereby increasing the profitability as well as productivity. These progenies had recorded more number of fruits and yield than the female parent indicating that they are superior even under stressed condition reflecting their tolerance to the disease (Chalak and Hasbanis, 2017). These progenies performed better than the female parent due to the heterotic effect and this hybrid vigour for the traits of interest *viz.,* fruit quality and tolerance to disease can be exploited in the breeding program (Jayavalli; 2010; Sunil, 2014; Lichamo, 2015; Magdalita and Signabon, 2017). Hence, based on the morphological, fruit and yield traits coupled with PRSV tolerance theses progenies were advanced to next generation (F$_2$).

Validation of progenies using molecular markers

A total 29 microsatellite (SSR) markers were screened, one SSR marker (mCpCIR59) was selected which produced polymorphic banding pattern (367- 378 bp) in both female (Arka Prabhath) and male parents (*V. cauliflora* and *V. cundinamarcencis*). The selected intergeneric hybrid progenies of the combinations Arka Prabhath x *V. cauliflora* (IGHF$_1$S4-1, IGHF$_1$S4-12, IGHF$_1$S4-13, IGHF$_1$S4-14, IGHF$_1$S4-15, IGHF$_1$S4-17 and IGHF$_1$S4-18) and Arka Prabhath x *V. cundinamarcencis* (IGHF$_1$S1-17, IGHF$_1$S1-19, IGHF$_1$S6-20, IGHF$_1$S2-14, IGHF$_1$S5-12 and IGHF$_1$S5-14) screened using mCpCIR59 exhibited polymorphic bands of both the parents thereby, confirming their hybridity (Figure 3). Pujar (2019) and Naveen (2021) have also confirmed the hybridity in the intergeneric progenies of papaya using SSR markers.

24

J. Hortic. Sci.
Vol. 18(1) : 19-26, 2023

Table 6 : Morphological, fruit quality, yield traits and PRSV score of the selected IGHF₁ progenies of Arka Prabhath x *V. cundinamarcencis*

| Trait	Progenies							Parents	
	IGHF₁ S1-17	IGHF₁ S1-19	IGHF₁ S6-20	IGHF₁ S2-14	IGHF₁ S5-12	IGHF₁ S5-14	Mean	Arka Prabhath	*V. cundina-marcencis*
Days to first fruiting	240.00	245.00	245.00	246.00	245.00	245.00	260.40	250.00	353.00
Plant height at first fruiting (cm)	200.00	199.00	189.00	188.00	190.00	188.00	185.24	190.00	180.00
Bearing height (cm)	68.00	48.00	62.00	72.00	66.00	66.00	66.87	74.00	80.00
Stem circumference at first fruiting (cm)	41.00	47.00	43.00	48.00	46.00	40.00	39.23	38.00	35.00
Number of nodes at first fruiting	17.00	15.00	15.00	18.00	17.00	18.00	19.49	20.00	30.00
Canopy spread E-W (cm)	190.00	180.00	190.00	210.00	190.00	183.00	174.60	185.00	175.00
Canopy spread N-S (cm)	175.00	185.00	210.00	205.00	192.00	178.00	175.52	180.00	150.00
Number of leaves at first fruiting	27.00	27.00	25.00	29.00	27.00	26.00	22.23	23.00	20.00
Number of fruits (14 months of planting)	58.00	54.00	52.00	50.00	58.00	53.00	31.98	38.00	85.00
Yield (kg/tree)	69.00	75.33	76.00	72.00	69.83	78.20	34.71	35.00	6.87
Fruit weight (g)	1540.00	1395.00	1545.54	2070.20	1204.00	2202.00	1576.62	1100.00	124.37
Fruit length (cm)	21.83	21.23	22.06	20.82	18.06	20.10	20.04	17.60	8.40
Fruit width (cm)	11.51	11.29	11.96	14.90	12.18	14.95	12.85	9.60	4.80
Fruit volume (ml)	1114.71	939.64	1163.18	1100.00	867.50	1490.00	1138.69	975.40	63.75
Pulp thickness (cm)	3.15	3.12	3.42	3.10	2.78	4.05	3.17	2.50	0.85
Pulp colour (RHS colour chart)	Orange red 30B	Orange red 30A	Orange red 30A	Orange red 30A	Orange red 30A	Orange red 30A	-	Orange red 30C	Yellow group 12C
Fruit cavity (%)	18.39	20.75	16.76	19.55	20.75	18.79	22.83	25.63	18.82
TSS (°Brix)	12.50	13.00	13.30	13.75	13.00	13.80	12.97	12.50	8.20
PRSV score	Tolerant (1)	Tolerant (1)	Tolerant (1)	Tolerant (1)	Tolerant (1)	Tolerant (1)	-	Highly susceptible (5)	Resistant (0)
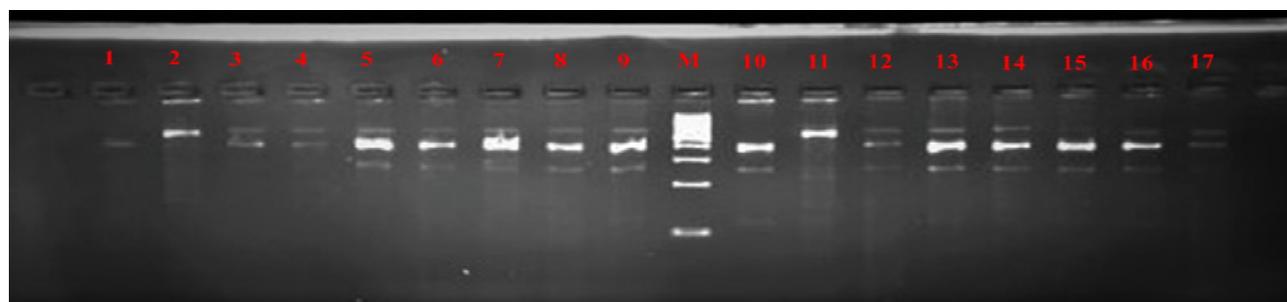
Fig. 3 : Hybridity confirmation using SSR primer (mCpCIR59): M- ladder (100 bp), Lane 1- Arka Prabhath, Lane 2- *V. cauliflora,* Lane 3 to 9- Selected progenies of Arka Prabhath x *V. cauliflora* (IGHF₁S4-1, IGHF₁S4-12, IGHF₁S4-13, IGHF₁S4-14, IGHF₁S4-15, IGHF₁S4-17 and IGHF₁S4-18); Lane 10- Arka Prabhath, Lane 11- *V. cundinamarcencis,* Lane 12 to 17- Selected progenies of Arka Prabhath x *V. cundinamarcencis* (IGHF₁S1-17, IGHF₁S1-19, IGHF₁S6-20, IGHF₁S2-14, IGHF₁S5-12 and IGHF₁S5-14)

CONCLUSION

In the present study, seven progenies of Arka Prabhath x *V. cauliflora* (IGHF₁S4-1, IGHF₁S4-12, IGHF₁S4-13, IGHF₁S4-14, IGHF₁S4-15, IGHF₁S4-17, IGHF₁S4-18) and six progenies of Arka Prabhath x *V. cundinamarcensis* (IGHF₁S1-17, IGHF₁S1-19, IGHF₁S6-20, IGHF₁S2-14, IGHF₁S5-12 and IGHF₁S5-14) were found superior in morphological, fruit and yield traits coupled with tolerance to PRSV – P. The hybridity of the selected progenies was also confirmed using SSR marker (mCpCIR59).

25

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26

J. Hortic. Sci.
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