Int.J.Curr.Microbiol.App.Sci (2019) *8*(2): 2468-2480

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 8 Number 02 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.802.287

Evaluation of Intergeneric Hybrid Progenies of Papaya for PRSV (Papaya Ring Spot Virus) Tolerance

D.C. Sunil Gowda[1*], C. Vasugi[2], M.R. Dinesh[2] and K.S. Shivashankara[2]

[1]College of Horticulture, UHS campus, Bengaluru, India
[2]Indian Institute of Horticultural Research, Hesaraghatta lake post, Bengaluru-560089, India

**Corresponding author*

Keywords

Breeding, Intergeneric hybridization, Physio-biochemical analysis, PRSV

Article Info

Accepted:
18 January 2019
Available Online:
10 February 2019

A B S T R A C T

The present investigation were undertaken to evaluate the intergeneric population of *Carica papaya* (Arka Surya) and *Vasconcellea cauliflora* for PRSV tolerance. The morphological traits *viz.*, plant height at flowering (60 to 172 cm), plant height at first harvest (127 to 194 cm), stem circumference at flowering (14 to 30cm), stem circumference at first harvest (26.8 to 54cm), canopy spread (N-S, E-W) at flowering (98 to 193 cm, 94 to 188cm), canopy spread (N-S, E-W) at first harvest (130 to 237 cm, 128 to 234 cm) were more in intergeneric progenies compared to the male parent *Vasconcellea cauliflora*. Maximum fruit weight was recorded in the progeny (S6-3) and the minimum weight was recorded by the male parent *Vasconcellea cauliflora.* The maximum fruit length, width, pulp thickness (cm), fruit volume (ml) and fruit cavity index (%) was recorded with progenies likeS11-4, S1-10, S6-2, *Vasconcellea cauliflora* respectively and also the maximum total soluble solids, vitamin C, acidity, total carotenoids, lycopene, and total sugar was recorded with progenies like S12-15, *Vasconcellea cauliflora*, S9-23 and S10-21, respectively. The highly susceptible progeny S2-2 registered the highest peroxidase activity and the resistant male parent (*Vasconcellea cauliflora*) recorded the lowest value. Total phenols recorded among the progenies varied significantly and ranged from 311.87 to 628.59 mg $100g^{-1}$ FW. Based on overall evaluation of F_5 population, two progenies (S6-1 and S6-2) can be advanced to F_6 generation for further evaluation.

Introduction

Papaya (*Carica papaya* L.), one of the major fruit crops, belongs to the family Caricaceae. It is a dicotyledonous, polygamous and diploid species, with geographical origin being Southern Mexico and Costa Rica (Candolle, 1884). Papaya is basically a tropical fruit, which can be grown successfully in sub-tropical conditions. The fruit has high nutritive and medicinal value (Azad *et al.*, 2012) especially vitamin A (2020 IU/100g). India stands first in the production of papaya in the world followed by Brazil, Indonesia, Nigeria, Mexico, Ethiopia and others. The area under papaya in India is estimated at 133‘000 HA, and production at 5639‘000 MT, (NHB, 201 4). The total area under cultivation of papaya has recorded a regular increase in the recent past

but its production has not shown corresponding increase. This might be due to the losses caused by various diseases incited by fungi, bacteria, phytoplasma and viruses. In recent years, the most destructive disease of *C. papaya* worldwide is papaya ring spot caused by papaya ring spot virus (PRSV) type P(Litz, 1984; Manshardt, 1992) a definitive poty virus species in the *Potyviridae* (Shukla *et al.*, 1994). It is grouped into two types, Type P (PRSV – P) infects both papaya and cucurbits and type W (PRSV-W) infects only cucurbits and not papaya (Gonsalves, 1998). Incidence of PRSV has been reported to be more than 90 per cent in India (Hussain and Varma, 1994; Chandra and Samuel, 1999). Almost all cultivated varieties belongs to the genus *Carica* are highly susceptible and resistance has not been found in this genus. However, much effort is being expended to introduce resistance genes from wild species even though the resistance appears to be variable and dependent on the geographic origin of the virus and environmental conditions (Gonsalves *et al.*, 2005). Resistance against PRSV was identified in *Vasconcellea cauliflora* (Jimenez and Horovitz, 1958; Moore and Litz, 1984. Control measures to check the disease incidence of PRSV includes roguing of diseased plants, cultural practices, cross protection and planting of tolerant cultivars (Gonsalves, 1994).However, these methods are not successful and the development of virus resistant/tolerant cultivars through conventional breeding is the only reliable tool for long term control of this disease. Very little work has been attempted using *Vasconcellea cauliflora* which has the desirable gene for PRSV resistance. Keeping this back ground intergenenic hybrid progenies developed at the Indian Institute of Horticultural Research by crossing Arka Surya x *V. cauliflora* after overcoming the incompatibility barriers evaluated for the morphological and fruit characteristics which is one of the basic requirements for crop improvement. As the progenies are highly heterozygous, individual progeny evaluation is essential for the selection of desirable type coupled with PRSV tolerance.

Materials and Methods

The field and laboratory experiments were carried out at Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru during 2013-14.The advanced generation intergeneric hybrid progenies of the cross Arka Surya X *V.cauliflora* numbering 38 and two parents *viz.*, Arka Surya and *V.cauliflora* were used in the experiments. Arka Surya was used as a female parent. It is advanced generation gynodioecious hybrids from the cross Sun Rise Solo X Pink Flesh Sweet. The wild species *viz.*, *Vasconcellea cauliflora* was used as male parent for imparting PRSV-P resistance. It is native to Latin America and exists in dioecious form. It bears small fruits weighing 34- 35 g, oblong shaped, ridged, rich in latex, bitter in taste and on ripening attain pale yellow pulp but are not-edible. Seeds are having prominent spiny hairy structures with light brown colour. Forty five days old healthy seedlings were transplanted in the main field at a spacing of 2.1 × 2.1 m. Standard package of practices were followed during the period of study.

Morphological traits

The observations on morphological traits *viz.*, planth eight (cm), stem circumference (cm), plant canopy spread (N-S, E-W)were recorded at first flowering and at first harvest stage. Petiole colour, leaf pubescence and colour of leaf vein was recorded based on visual scoring. Screening was done during the cropping period and the disease intensity scoring was given based on symptoms in leaves and stem using the scale consists of

five levels as 1-Resistant, 2-Tolerant, 3-Moderately resistant, 4-Susceptible and 5-Highly susceptible based on the symptoms exhibited by the plant.

Fruit traits

The fruit traits *viz*., fruit weight (g), fruit length (cm), fruit width (cm) and pulp thickness were recorded from the ten randomly selected fruits at edible ripe stage and expressed in centimetre, Fruit cavity index was calculated by using the formula and expressed in percent.

$$\text{Fruit cavity index} = \frac{\text{Fruit cavity volume}}{\text{Fruit volume}} \times 100$$

Biochemical parameters

The total soluble solids of the fruit juice were determined using 'ERMA' hand refractro meter and expressed in ^{o} Brix. The pulp colour was recorded in ripe fruits using Royal Horticultural Society (RHS) colour chart. Total carotenoids and lycopene were estimated by spectrophotometric method suggested by (Lichtenthaler, 1987) and expressed in milligrams per 100g.Total sugars were estimated by the method of (Somogyi, 1952) and expressed in g $100g^{-1}$FW.Acidity was determined by titration method (AOAC, 942.15) and expressed as percentage of citric acid equivalents. Vitamin C content was determined by 2, 6-Dichlorophenol indophenol (DCPIP) method (AOAC, 967.21) and expressed as mg of ascorbic acid per 100g fresh weight.

Based on the horticultural parameters and PRSV screening the progenies were selected and the activity of polyphenol oxidase and peroxidase were studied in the tolerant and susceptible progenies. Total phenols content was estimated by the method of Singleton and Rossi, (1965) and expressed as mg $100g^{-1}$ FW. Peroxidase activity was analysed spectrophotometrically (Chander, 1990) and expressed as Units mg^{-1} protein. The basic statistical measures were carried out for the progenies and parents with respect to field observation. The basic statistical measures were carried out for the progenies and parents with respect to the morphological and quality traits.

Results and Discussion

Morphological traits

The plant vigour is being assessed by morphological characters such as first flowering height, first bearing height, plant height, stem circumference. In the present investigation the plant height at flowering stage among the intergeneric progenies and parents varied between 60 to 172 cm and at first harvest it varied between127 to 194 cm (Table 1). The progeny S6-4 recorded a plant height of 190 cm which was on par with the maximum value. The progenies S6 -3, S7-5, S7-14 and S6-2 also recorded a plant height of > 110 cm and > 152 cm at harvest. These progenies were able to tolerate the PRSV incidence and put forth continuous growth. Such progenies could be selected for further advancement. The plant height was lowest (60, 127 cm respectively at flowering and harvest) in the progeny S2-9where there was severe incidence of PRSV and hence the growth was reduced. Multiplication of virus in the susceptible genotypes could have caused a substantial reduction in cell division and elongation there by decreased plant height. Similar kind of findings was observed in papaya due to PRSV infection by Mowlick *et al.*, (2008), Thirugnanavel (2009) also reported that early vigour is an important morphological character, which is considered to be a necessary trait for disease resistance, because before the plant is fully infested, it can able to give a reasonable yield.

Maximum stem circumference (30, 54cm) was observed in S8-17both at flowering and at harvest. The progenies S6-2 and S6-4 recorded a stem circumference of >20 cm and >40 cm at flowering and at harvest respectively which was higher than the female parent (18 and 30.4 cm respectively). This indicates the capacity of these two progenies to tolerate virus infection and bear more fruits, which could be selected for further advancement. Reduction in stem girth was also observed in some genotypes, which could be due to severe infection of PRSV, Similar was reported by Rahman and Akanda (2008) in papaya.

Maximum plant canopy spread of 188 cm at flowering and 237 cm at harvest was recorded in the progenies *viz.,* S8-17andS8-19 respectively (Table 1). The progenies S6-2 and S6-4 also recorded a canopy spread of > 170 and > 180 cm at flowering and at harvest respectively which was higher than both the parents (118 and 170 cm, 98 and 130 cm respectively in female and male parents). (Lal *et al.,* 2000) reported that more canopy spread will help in more photosynthesis and enhance the final yield. Higher yield in papaya was recorded with higher leaf area (Almadia *et al.,* 2003; Jeyakumar *et al.,* 2001).

Morphological traits could be used as a reliable visual marker for preliminary identification of the hybrid prior to genetic analysis. In the present investigation, green with shades of red purple petiole was observed in the progenies such as S2-2, S2-15, S6-12, S7-5, S7-7, S7-10, S7-14 and S7-15similar to that of the male parent *Vasconcellea cauliflora*. Similarly, green with shades purple vein was noticed in the progenies S7-15, S8-4, S8-17, S10-21, S10-27, S11-16, S11-18, S12-15, S12-16 and *Vasconcellea cauliflora.* Intermediate morphological characters have been used previously for the identification of *C. papaya* x *C. cauliflora* interspecific hybrids by Chen *et al.,* (1991). Jayavalli (2010) had also registered intermediate morphological characters in F_1 progenies of the crosses. (Dinesh *et al*., 2013) had also observed segregation of leaf shape in papaya.

The disease scoring carried out during vegetative, flowering, fruiting and at harvest indicated varying level of disease incidence among the progenies evaluated. Based on the final scoring at the time of harvest, the male parent *Vasconcellea cauliflora* did not express any disease incidence and was found to be completely resistant (1), while the female parent Arka Surya expressed disease incidence since flowering and fruiting and was found to be susceptible (4). Among the progenies evaluated, moderate level of resistance was observed in the progenies S6-2and S6-4 which registered disease incidence on leaves at the fag end of the crop and found to be free from symptoms on fruits. Hence, these progenies could be forwarded for next generation (Dhanam, 2006; Roff, 2007). Delay in onset of symptoms which suggests the increased tolerance in the F_2 progenies and the genes conferring tolerance must have been inherited from *V. cauliflora* (Jayavalli, 2010).Leaf pubescence absent in all the progenies and present in only male parent. 55.26% of progenies leaf are similar to the male parent *Vasconcellea cauliflora*(Broad leaf)and 44.70% of the progenies are resembles like female parent Arka Surya (Narrow leaf) and 55.30% of the progenies are green with purple shades of leaf vein colour and 44.70 % are green.

Fruit traits

The fruit size is determined by the fruit weight which also contributes to the final yield. Fruit weight recorded among the intergeneric progenies and parents varied between 69.65g to 810.19g (Table 2). The

wide variation observed in this study might be due to the inherent genetic makeup of the progenies. Similarly higher fruit weight and yield in one of the intergeneric hybrids evaluated for PRSV disease (Praveen, 2005)

Sudha *et al.,* (2013) also reported lower cavity index (15.46 percent) and maximum pulp thickness (2.97) in the cross between CO 7 × *V. cauliflora.* Similarly in the present study the cavity indexwas in the range of10.10 to 79.45 (Table 2). The lowest value was recorded in S9-23and highest cavity index was recorded by *Vasconcellea cauliflora*. The progenies *viz.,* S11-18(11.15), S10-21(11.55), S8-13(11.65), S7-15(11.75), S6-2(11.75),S2-10(11.80), S4-10(14.94), S6-4(15.00) and S2-15(16.16) recorded a cavity index of lower than the mean value (20.12) and the female parent Arka Surya (26.90).The wide variation recorded in this study might be due to the inherent genetic makeup of the progenies. Hence, these progenies could be selected for further advancement. The pulp thickness is one of the important traits which contribute to the final pulp recovery. Hence, this is one of the important criteria in selection of the progenies in the crop improvement programme. The pulp thickness ranged between 0.570 cm and 3.180 cm (Table 4). The maximum value was recorded by the progeny S6-2 and the minimum was recorded by the male parent *Vasconcellea cauliflora.*

Fruit quality traits

In the present study fruit quality traits in majority of the hybrids were marginally affected due to the impact of male parent (*Vasconcellea cauliflora*) used in the intergeneric hybridization. However, some progenies were found to have desirable qualities near to that of the female parent Arka Surya. Fruit quality especially the sweetness as assessed by total soluble solids and sugars in papaya fruits are the important criteria. The total soluble solids estimated among the progenies varied from 9.75 to 12.91 ^{0} Brix (Table 3). The highest value was recorded by the progeny S12-15which was higher than the female parent Arka Surya (12.45 ^{o}Brix) and the mean value (11.68^{0}Brix).Praveen (2005) also reported that the crosses involving *Vasconcellea cauliflora* as male in the interspecific hybridization programme produced desirable quality fruits. Titrable acidity differed among the progenies and ranged from 0.060 to 0.200 per cent (Table 3). The highest value was recorded by *Vasconcellea cauliflora*, while the lowest was recorded by S6-4, Similarly (Zaman *et al.,* 2006) revealed that variation in the titrable acidity of the commercial varieties or intergeneric hybrids hence, these progenies could contribute to the development of lower titrable acidity genotypes.

The total carotenoids exhibited wide differences among the progenies evaluated (Table 3). It ranged from 1.49 mg 100g^{-1}FW (*Vasconcellea cauliflora*) to 13.09 mg 100g^{-1} FW (S9-23). Similarly, the lycopene content among the progenies ranged from 0.26 in *Vasconcellea cauliflora*to 6.02 mg 100g^{-1}FWin S9-23(Table 3), Similarly The progenies with high lycopene may be selected for developing high lycopene types(Aravind*et al.,* 2013)

Biochemical parameters

In the present study peroxidase activity differed to a considerable extent among the progenies and ranged from 0.142 to 0.474 units mg^{-1} protein (Table 4). The highly susceptible progeny S2-2 registered the highest peroxidase activity and the resistant male parent (*Vasconcellea cauliflora*) recorded the lowest value.

Table.1 Morphological traits of intergeneric hybrid progenies of papaya

Progenies	Plant height (cm)		Plant canopy spread (N-S) cm		Plant canopy spread (E-W) cm		Stem circumference (cm)	
	At first flowering	At first harvest	At first flowering	At first harvest	At first flowering	At first harvest	At first flowering	At first harvest
S1-10	75	160	150	185	165	190	24	35
S2-2	72	170	140	153	115	142	15	36
S2-9	60	127	153	160	141	160	15	36
S2-10	70	163	150	164	145	151	18	31
S2-15	75	180	164	175	150	160	19	37
S4-10	70	155	160	175	170	179	24	37
S6-2	110	152	165	180	170	185	20	40
S6-3	128	173	157	168	168	181	22	41
S6-4	135	190	175	185	178	195	23	43
S6-12	105	140	155	170	160	167	20	30
S7-5	120	162	153	178	165	185	20	46
S7-7	161	194	164	183	179	195	28	52
S7-10	152	188	144	168	153	177	24	40
S7-14	128	165	172	176	174	186	17	39
S7-15	135	163	160	173	162	175	19	45
S7-17	145	167	170	178	172	181	22	46
S7-24	137	174	162	188	172	188	19	42
S8-4	134	163	163	182	165	174	25	38
S8-13	114	147	147	167	150	158	20	35
S8-17	152	181	166	219	188	202	30	54
S8-18	135	166	170	204	179	211	22	44
S8-19	128	171	162	237	150	215	18	44
S8-20	139	170	193	217	180	234	22	45
S8-23	95	130	142	162	138	157	14	35
S9-23	128	179	174	190	172	182	25	39
S10-19	127	161	134	156	138	172	20	34
S10-21	172	192	155	205	162	197	29	41
S10-27	154	186	162	168	148	172	25	38
S11-4	128	165	155	170	160	175	19	37
S11-6	98	129	160	187	150	167	18	37
S11-16	120	149	165	185	170	189	18	32
S11-18	115	149	140	158	142	161	15	37
S11-23	135	179	175	197	183	187	21	38
S11-24	120	176	172	216	178	207	19	46
S12-15	127	178	165	181	166	184	24	44
S12-16	136	158	150	174	152	171	21	42
S12-23	141	162	149	179	148	173	20	37
S12-25	131	175	146	160	151	194	21	39
AS	109	176	118.8	169	115.6	170	18	30.4
VC	105	150	98	130	94	128	17.3	26.8
Mean	120.53	165.38	156.40	179.30	157.97	179.43	20.76	39.23
SEm±	0.47	0.32	0.33	0.34	0.36	0.34	0.42	0.39
Cv%	21.64	10.19	10.57	11.42	12.62	11.25	18.00	14.60

Table.2 Fruit characters of intergeneric progenies of papaya

Progenies	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Cavity index (%)	Fruit volume (ml)	Pulp thickness (cm)	Pulp colour
S1-10	797.10	11.85	11.55	21.20	640.15	2.70	Orange group 25 A
S2-2	293.55	10.65	7.30	20.25	271.25	2.55	Yellow orange group 23 B
S2-9	435.50	9.68	8.90	23.25	436.65	1.95	Orange group 26 A
S2-10	382.60	12.90	7.95	11.80	295.00	2.25	Orange group 25 A
S2-15	495.50	13.79	8.57	16.16	405.50	2.40	Orange group 25 A
S4-10	678.85	12.35	10.95	14.94	584.30	2.90	Orange group 25 B
S6-2	794.15	15.60	9.95	11.75	704.00	3.18	Orange group 25 A
S6-3	810.19	14.35	10.25	20.55	709.95	2.70	Orange group 25 A
S6-4	537.75	15.44	8.90	15.00	528.35	2.83	Orange group 25 A
S6-12	738.60	11.17	9.22	24.15	657.50	2.58	Orange group 24 A
S7-5	375.00	11.33	7.68	19.41	252.50	2.43	Orange group 24 A
S7-7	474.35	12.25	9.30	22.66	433.00	2.20	Yellow orange group 23 A
S7-10	258.30	9.95	7.43	17.60	204.15	1.75	Orange group 24 A
S7-14	476.25	9.55	9.75	18.30	430.60	2.60	Orange group 23 A
S7-15	412.50	11.95	8.05	11.75	380.00	2.10	Orange group 25 B
S7-17	482.50	11.20	9.22	20.35	393.50	2.55	Orange group 25 A
S7-24	391.25	10.85	8.65	23.40	300.00	2.25	Yellow orange group 24 A
S8-4	230.00	10.00	7.15	21.40	167.50	2.00	Orange group 25 A
S8-13	275.00	10.15	6.95	11.65	231.60	2.18	Yellow orange group 23A
S8-17	480.00	11.40	8.85	15.20	422.50	2.28	Orange group 24 A
S8-18	350.00	14.30	6.85	12.15	250.00	2.15	Orange group 24 B
S8-19	250.00	9.25	7.60	36.88	207.50	1.90	Orange group 24 A
S8-20	478.30	10.85	9.60	19.35	393.75	2.35	Yellow orange group 23A
S8-23	350.75	10.15	8.30	12.75	323.10	2.15	Orange group 24 A
S9-23	423.30	11.45	8.75	10.10	350.80	2.60	Yellow orange group23 A
S10-19	527.50	10.05	10.70	25.28	437.50	2.85	Orange group 24 A
S10-21	271.65	10.62	6.82	11.55	182.50	2.35	Orange group 28 A
S10-27	436.00	11.19	9.18	23.57	370.00	2.18	Yellow orange group 23 A
S11-4	197.00	8.17	6.71	17.00	157.50	1.95	Yellow orange group 23 B
S11-6	480.00	10.75	9.05	19.80	386.65	2.27	Orange group 25 B
S11-16	237.00	8.22	7.38	16.22	188.00	2.17	Orange group 25 B
S11-18	327.50	10.50	7.70	11.15	271.85	2.43	Orange group 26 A
S11-23	270.00	9.90	7.25	21.80	152.90	2.33	Orange group 28 B
S11-24	448.00	10.84	9.04	13.60	369.50	2.77	Orange group 28 B
S12-15	376.50	11.50	7.95	24.03	326.50	2.05	Orange group 24 A
S12-16	424.95	10.90	8.83	16.30	356.65	2.35	Orange group 24 A
S12-23	433.00	11.47	8.60	17.60	338.50	2.45	Orange group 25 B
S12-25	302.50	10.40	7.90	23.60	200.00	2.10	Orange red group 30 C
AS	525.00	13.05	9.14	26.90	406.75	2.25	Orange group 24 A
VC	69.65	10.85	4.25	79.45	39.85	0.57	Yellow group 4 D
SEm±	37.01	0.63	0.35	4.16	42.68	0.15	
CD at 5%	105.89	1.82	1.00	11.91	122.11	0.44	

Table.3 Fruit quality traits of intergeneric progenies of papaya

Progenies	TSS (^{o}Brix)	Vitamin C (mg100g^{-1}W)	Titrable acidity (mg 100g^{-1}FW)	Total Carotenoids (mg 100g^{-1}FW)	Lycopene (mg100g^{-1} FW)	Total sugars (g 100g^{-1}FW)
S1-10	12.05	57.33	0.10	10.17	3.28	10.49
S2-2	12.85	76.51	0.11	6.60	1.16	5.97
S2-9	12.25	84.67	0.12	8.51	3.10	9.04
S2-10	12.00	88.57	0.07	10.69	3.65	11.99
S2-15	12.07	51.43	0.09	9.49	3.04	8.42
S4-10	12.55	90.67	0.11	11.03	4.79	9.49
S6-2	11.80	62.86	0.09	6.08	2.33	10.03
S6-3	11.85	72.38	0.06	10.56	4.10	14.46
S6-4	11.98	68.25	0.06	7.62	2.34	9.54
S6-12	11.14	72.33	0.08	10.94	3.90	9.74
S7-5	11.20	77.33	0.12	6.86	0.68	8.45
S7-7	10.15	62.22	0.07	6.20	0.59	4.62
S7-10	11.63	72.06	0.08	6.55	0.64	9.15
S7-14	10.58	82.22	0.09	8.95	0.80	9.83
S7-15	10.70	73.33	0.11	10.69	0.88	8.54
S7-17	11.22	78.41	0.11	8.05	0.78	7.34
S7-24	11.70	72.38	0.10	8.32	0.74	7.49
S8-4	12.60	75.56	0.08	9.31	0.93	9.80
S8-13	11.70	76.51	0.06	7.62	0.71	9.21
S8-17	10.60	64.44	0.12	10.36	0.89	6.77
S8-18	10.70	91.00	0.09	10.57	0.93	11.99
S8-19	10.90	72.70	0.07	8.36	0.83	6.54
S8-20	12.40	64.76	0.10	6.56	0.68	7.50
S8-23	10.69	64.76	0.09	11.26	5.04	8.72
S9-23	11.40	83.81	0.08	13.09	6.02	14.88
S10-19	11.70	78.41	0.07	9.26	3.60	8.89
S10-21	12.90	89.21	0.12	12.78	5.12	15.24
S10-27	12.25	80.32	0.08	11.74	4.55	9.97
S11-4	11.89	76.19	0.07	10.03	3.33	9.65
S11-6	11.80	86.00	0.12	10.16	3.69	9.81
S11-16	12.06	74.60	0.06	10.13	3.78	8.98
S11-18	12.80	93.65	0.08	12.08	4.34	11.55
S11-23	11.50	73.33	0.09	11.48	4.38	14.56
S11-24	11.52	72.38	0.06	11.21	4.93	9.52
S12-15	12.91	106.67	0.08	8.79	0.82	8.79
S12-16	11.85	82.54	0.06	6.75	0.65	9.53
S12-23	11.38	70.79	0.06	9.15	3.71	8.57
S12-25	12.05	79.05	0.07	9.44	3.17	11.09
AS	12.45	86.67	0.06	9.88	4.58	10.54
VC	9.75	47.94	0.20	1.49	0.26	0.95
SEm±	0.31	0.927	0.00284	0.20	0.10	0.26
CD at 5%	0.91	2.61	0.00799	0.57	0.28	0.74

Table.4 Peroxidase activity and total phenols of the selected intergeneric progenies of papaya

Progenies	Peroxidase activity (Units mg^{-1} Protein)	Total phenols (mg $100g^{-1}$ FW)
S1-10	0.273	396.41
S2-2	0.474	387.92
S2-15	0.253	431.21
S4-10	0.250	359.60
S6-2	0.199	505.627
S6-3	0.248	370.52
S6-4	0.179	527.46
S6-12	0.438	412.19
S7-5	0.377	311.87
S7-7	0.273	438.48
S7-10	0.394	314.71
S7-14	0.269	412.59
S7-17	0.378	416.637
S7-24	0.301	336.14
S8-4	0.283	351.11
S8-13	0.397	379.42
S8-18	0.339	367.29
S8-19	0.377	313.49
S8-20	0.351	348.27
S8-23	0.219	384.28
AS	0.364	332.50
VC	0.142	628.59
SEm±	0.008	25.71
CD at 5%	0.022	73.53

Table.5 Morphological, quality and biochemical traits of the selected progenies

Traits	Progenies		Parents	
	S6-2	S6-4	Arka Surya	*Vasconcellea cauliflora*
Plant height at harvest (cm)	185*	195*	170	128
Canopy spread at harvest (cm)	180*	185*	169	130
Stem circumference at harvest (cm)	40*	43*	30.4	26.8
Fruit weight (g)	794.15*	537.75*	525.00	69.65
Fruit volume (ml)	704.00*	528.35*	406.75	39.85
Pulp thickness (cm)	3.18*	2.83*	2.25	0.57
Cavity index	11.75*	15.00*	26.90	79.45
TSS (^{0}Brix)	11.80*	11.98*	12.45	9.75
Total sugars (g 100g^{-1} FW)	10.03*	9.54*	10.54	0.95
Pulp colour	Orange group 25 A	Orange group 25 A	Orange group 24 A	Yellow group 4 D
Total carotenoids (mg 100g^{-1} FW)	6.08	7.62	9.88	1.49
Lycopene (mg 100g^{-1} FW)	2.33	2.34	4.58	0.26
Peroxidase (Units mg-^{1} Protein)	0.179	0.199	0.364	0.142
Total phenols (mg 100g^{-1} FW)	505.63*	527.46*	332.50	628.59
PRSV score	2	2	4	1

* Superior compared to parents - Compare with the mean value for each character.
PRSV Score: 1-Resistant, 2- Moderately resistant, 3- Tolerant, 4-Susceptible & 5-Highly susceptible

This was followed by the moderately resistant progenies S6-4 (0.179units mg^{-1} protein) and S6P2 (0.199 units mg^{-1} protein) which recorded slightly higher than the values recorded by the resistant male parent. Similar trend was recorded in the tolerant progenies S8-23(0.219units mg^{-1} protein), S4-10 (0.25units mg^{-1} protein) and S2-15 (0.253units mg^{-1} protein) where higher than the values recorded by the moderately resistant progenies were noticed, as against the susceptible female parent Arka Surya (0.364units mg^{-1} protein), similarly (Kavino*et al.*, 2009) reported that increase in peroxidase activity in disease infected plants. Higher peroxidase and polyphenol oxidase activity in the tolerant papaya genotype CP 50, a castor leaf papaya (Thirugnanavel, 2009; Jayavalli, 2010) reported that an increased peroxidase and polyphenol oxidase activity

The total phenols recorded among the progenies varied to a greater extent and ranged from 311.87 to 628.59 mg 100g^{-1} FW (Table 4). The highest value was recorded in the resistant male parent *Vasconcellea cauliflora* and the lowest was recorded in the susceptible progeny S7-5.The moderately resistant progenies S6-2 and S6-4 recorded> 500 mg 100g^{-1}FW of total phenols which was

higher compared to the susceptible female parent Arka Surya (332.5 mg $100g^{-1}$ FW), Similarly Thirugnanavel, (2009) observed higher total phenol content in the papaya genotype CP 50 which was identified as one of the tolerant genotypes for PRSV in the germplasm collections. Higher total phenol content by the cross Pusa Nanhax *V. cauliflora* (Sudha *et al.,* 2013).

Morphological, quality and biochemical traits of the selected progenies (S6-2 andS6-4)

The morphological traits *viz.*, plant height (185 and 195 cm), canopy spread (180 and 185 cm), stem circumference (40 and 43 cm) were superior in the selected progeniesS6-2and S6-4respectively as compared to parents *viz.*, Arka Surya and *Vasconcellea cauliflora* (Table 5). The selected progenies also registered higher values for the fruit characters *viz.*, fruit weight (794.15g and 537.75g), fruit volume (704.00 and 528.35 ml) and pulp thickness (3.18 and 2.83 cm) than the parents. The cavity index was low (11.75 and 15.00) in the selected progenies as compared to the parents (26.90 and 79.45 ml). The TSS (11.80, 11.98^{o}B) of the selected progenies was close to the female parent (12.45^{o}B). The total sugars (10.03, 9.54 g $100g^{-1}$ FW), total carotenoids (6.08, 7.62 mg $100g^{-1}$ FW) and lycopene (2.33, 2.34 mg $100g^{-1}$ FW) were found to be higher in the selected progenies as compared to the male parent (*Vasconcellea cauliflora*). The peroxidase activity was found to be lower and the total phenols were found to be higher in the selected progenies when compared to the female parent. The selected progenies were found to be moderately resistant (2) compared to the female parent Arka Surya (susceptible).Thus, it is concluded from the present investigation, indicates that *Vasconcellea cauliflora* can be effectively used to develop field tolerance/resistance and creative variable population in *Carica papaya*. The moderately resistant progenies S_6-2 and S6-4 may be advanced to F_6 generation for further evaluation considering the disease intensity score, reaction to the papaya ring spot virus and morphological, fruit and quality performance.

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How to cite this article:

Sunil Gowda, D.C., C. Vasugi, M.R. Dinesh and Shivashankara, K.S. 2019. Evaluation of Intergeneric Hybrid Progenies of Papaya for PRSV (Papaya Ring Spot Virus) Tolerance. *Int.J.Curr.Microbiol.App.Sci.* 8(02): 2468-2480. doi: https://doi.org/10.20546/ijcmas.2019.802.287