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Study on Cross Compatibility of Intergeneric Hybridization between *Carica* with *Vasconcellea* Species

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ABSTRACT

Intergeneric hybridization was carried out to know the cross compatibility between papaya varieties (Arka Prabath, Arka Surya and Red Lady) with *Vasconcellea* species (*V. cauliflora*, *V. cundinamarcensis* and *V. parviflora*). Arka Prabath was found to be a good combiner with all the three wild species (*V. cauliflora*, *V. cundinamarcensis* and *V. parviflora*) which has recorded good fruit set (85.42, 78.13 and 84.38 % respectively), fruit retention (98.96, 83.33 and 73.96 % respectively) and more mean number of fertile seeds per fruit (63.99, 70.82 and 28.14 respectively). Among male parents, *Vasconcellea. cauliflora* was found to be good combiner with all three female parents (Arka Prabath, Arka Surya and Red Lady) which has resulted better fruit set (85.42, 85.42 and 76.04 % respectively), fruit retention (98.96, 19.79, 43.75 % respectively) and more mean number of fertile seeds per fruit (63.99, 11.00 and 4.50 respectively). Hence Arka Prabath with *V. cauliflora* cross combination was found to be good for intergeneric hybridization which has resulted in more mean number of fertile seeds (heterotic combinations) which ultimately helps in generating more number of intergeneric population for screening of papaya ring spot virus (PRSV).

Keywords

Papaya, intergeneric hybridization, *Vasconcellea*, compatibility

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Introduction

Papaya with its botanical name as *Carica papaya* L. belongs to the family Caricaceae, is one amongst the economically vital fruit crops of both subtropical and tropical zones of the world. It is basically a tropical fruit crop and believed to have originated from Mexico to Panama (Nakasone and Paull, 1998).

Papaya is a polygamous species with three basic sex forms as male (staminate), female (pistillate) and hermaphrodite forms of inflorescence (Storey, 1938; Singh, 1964). It is a diploid species with a small genome of 372 Mbp/1C (Arumuganathan and Earle, 1991) and nine pairs of chromosomes (Bennett and Leitch, 2005). The fruit of papaya has high nutritive and medicinal value

(Azad *et al.*, 2012) especially vitamin A (2020 IU/100g). The proteolytic enzyme 'papain' obtained from raw fruits of papaya is used for meat tenderization, wool pre-shrinking, chewing gum preparation, removal of gum from natural silk and in preparation of many cosmetics. Papaya has been successfully cultivated in India, USA, Mexico, Peru, Brazil, Jamaica, Nigeria, China, Taiwan, Indonesia, Philippines and Thailand.

According to recent past data, papaya cultivation with respect area has increasing trend but with respect to production is stagnant or the consequent production has not observed. This might be due to several factors of biotic such as diseases caused by bacterial, fungal, viral and phytoplasma and many pest attack and abiotic factors such as drastic variation in temperature, humidity, soil moisture and irregular rains.

In recent years, throughout the world, papaya ringspot virus (PRSV) type P Litz, (1984) is the most destructive disease of papaya which is a perfect potyvirus from potyvirus viridae (Shukla *et al.*, 1994). PRSV is grouped into two types as PRSV-P and PRSV-W. The infection level is differing for both types as PRSV-P infects both papaya and cucurbits where as PRSV cannot infect papaya (Gonsalves, 1998). The incidence of PRSV has been reported to be more than 90 per cent in India (Hussain and Varma, 1994, Chandra and Samuel, 1999) and rendering papaya orchards economically unviable. Almost all cultivated varieties belong to the genus *Carica* are highly susceptible to PRSV. However, much effort is being spent to introduce resistant genes from wild species even though the resistance appears to be variable and depend on the geographical origin of the virus environmental conditions (Gonsalves *et al.*, 2004). Resistance against PRSV was identified in genus *Vasconcellea*

species viz, *Vasconcellea cauliflora*, *V. parviflora*, *V. cundinamarcensis*, *V. candicans*, *V. quercifolia* and *V. stipulata* (Badillo, 2000).

The symptoms of PRSV can be observed as chlorosis, mosaic, water soaked oily streaks on the petiole and the upper part of the trunk. Shoe string like symptom which sometime due to distortion of young leaves which look like the mite damage symptoms similar to stunting of infected plants and flower abortion. This will cause decreased production as well as quality of the fruit as decrease in sugar level by 50 per cent or more (Purcifull *et al.*, 1984; Gonsalves, 1994).

For the control of the disease caused by PRSV includes control measures such as roguing or removal of infected plants, for some extent cultural practices, cross protection and planting of tolerant cultivars (Gonsalves, 1994). Though these methods are found to be not successful in controlling the disease and its effects. Hence remaining and best method is the development of virus tolerant/resistant cultivars through conventional breeding which can be consistent tool for long-term disease control. In this perspective, very little work has been attempted using genus *Vasconcellea*, which has the desirable gene for PRSV resistance.

Work on intergeneric hybridization for PRSV tolerance or resistance was carried out by several workers, viz., Muthulakshmi *et al.*, 2007, Chan, 2004, Magdalita *et al.*, 1997, Manshardt *et al.*, 1995, Zee, 1985, Conover and Litz, 1981, however complete success has not been achieved so far and still a variety resistant to PRSV for commercial cultivation is lacking. Hence, work on intergeneric hybridization using commercial cultivars viz., Arka Surya, Arka Prabhath and Red Lady with wild species viz., *Vasconcellea cauliflora*, *V. cundinamarcensis* and *V.*

parviflora (after overcoming the crossability barriers using 5 per cent sucrose, pollen germinating media) could help in the generation of progenies tolerant/ resistant to PRSV. Keeping this information as a baseline, an objective was set to know the cross compatibility between two distant genera viz., *Carica* and *Vasconcellea* for PRSV tolerance or resistance.

Materials and Methods

The experiment was carried out at the ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru located at 13° 58' North latitude and 78° East longitudes and at an altitude of 890 m above mean sea level. The soil is red sandy loam with a pH of 5.2-6.4. The maximum mean temperature ranges from 27.00°C to 35.00°C with a mean of 31.00°C while, the minimum mean temperature ranges from 10.00°C to 21.00°C with a mean of 15.50°C. The mean relative humidity, mean wind speed and total rainfall were 65.00 per cent, 4.38 km per hr and 478.70 mm resp.

This experiment was carried out using three gynodioecious cultivars like Arka Surya, Arka Prabhath and Red Lady as female parents and wild species like *Vasconcellea cauliflora*, *V. cundinamarcensis* and *V. parviflora* as male parents. The brief descriptions of the parents used in the study are as follows (Plate 1-6).

Arka Prabhath

An advanced generation hybrid derivative from the cross of (Arka Surya x Tainung-1) x Local Dwarf released from ICAR- Indian Institute of Horticultural Research. It is gynodioecious in nature, with large sized fruits of 900-1200 g and with smooth skin. The pulp is deep orange red in colour with good keeping quality and high TSS (12-13°B) (Plate 1).

Arka Surya

An advanced generation hybrid derivative from the cross of Sunrise Solo x Pink Flesh Sweet released from ICAR-Indian Institute of Horticultural Research. It is gynodioecious in nature, with medium sized fruits weighing about 600-800 g. The pulp is deep pink colour, free from typical papaya odour with high TSS (12-13°B) and small fruit cavity (Plate 2).

Red lady

It is a gynodioecious F₁ hybrid. The plants are semi-dwarf, good yielding, fruits are medium to big size, pulp deep orange-red in colour and sweet in taste (Plate 3).

Vasconcellea cauliflora

It is a wild species native to Latin America and dioecious in nature. Plants are semi-dwarf, bearing small fruits weighing 34-35 g, oblong-shaped, ridged and on ripening attain yellow colour but are non-edible. Seeds are having prominent spiny hairy structures with light brown colour (Jimenez and Horovitz, 1958). Plants are reported (Badillo, 2000) to be resistant to virus disease (Plate 4).

Vasconcellea cundinamarcensis

The mountain papaya is native to Andean regions from Venezuela to Chile at altitudes between 6,000 and 10,000 ft (1,800-3,000 m). It occurs as both monoecious and dioecious forms (Badillo, 2000). It grows on mountains in Ceylon and South India. The plant is stout and tall but bears a small, yellow, five angled fruit of sweet flavour. The fruit is edible but highly rich in papain for eating raw. It is cooked as vegetable and is canned for domestic consumption and also for export. It is reported to be resistant to virus disease and frost (Jimenez and Horovitz, 1958) (Plate 5).

Vasconcellea parviflora

This is native to Tropical South America and grown widely in South America. It is an evergreen shrub, dioecious small trees growing up to 50-200 cm tall. It can grow up to sea level to over 2, 000 m. It bears edible fruit which is harvested from the wild for local use. Fruits are having fragrance and flavour of mombin (*Spondias* sp.). Fruits are orange in colour, 30-40 mm long and 10-15 mm wide (Jimenez and Horovitz, 1958) (Plate 6).

Intergeneric hybridization was carried out using *Carica papaya* varieties viz., Arka Prabhath, Arka Surya and Red Lady as female parents with *Vasconcellea* species viz., *V. cauliflora*, *V. cundinamarcensis* and *V. parviflora* as the male parents. In the selected female parents (Plate 7), fully developed and unopened (about to open) female flowers (Plate 8a) were selected and bagged using butter paper bags (Plate 8b). Pollen grains were collected from the already identified male parents, where the fully developed male flowers were selected and bagged using butter paper bags, in order to avoid contamination by foreign pollen. The pollen grains were collected in the petri plates and were made into a slurry using the nutrient solution (Sucrose 5% + Boric acid 100 ppm + MgSO₄ 200 ppm + CaNO₃ 300 ppm + KNO₃ 100 ppm) (Plate 8c). Selected female flower was forced to open (Plate 8d) for crossing (Plate 8e).

Pollination was effected by smearing the prepared pollen slurry on to the stigmatic surface (Plate 8f) of the bagged female flowers and were labelled (Plate 8g) and re-bagged again (Plate 8h&i). In order to see the effect of nutrient solution in fruit set, crosses were also made using only pollen grains and without nutrient solution (Plate 8). The details of different cross combinations are given in Table 1.

Statistical analysis

The data on seed characters were subjected to Fisher's method of analysis of variance (ANOVA) as given by Sundarraj *et al.*, (1972). A simple randomised complete block design was followed with eighteen treatments and two replications. Wherever the F test was significant for comparison of treatment means, CD values were worked out at 0.05 probability level. The treatment means were separated by using Duncans Multiple Range Test (DMRT). Data obtained were subjected to arc sin transformation.

Results and Discussion

Flowers crossed (number) and fruit set (%)

Across different intergeneric cross combinations, a total of 1802 crosses were made (Table 10 and Fig. 1), which included both nutrient solution (928) and control (874). The number of flowers crossed under each cross combination ranged from 89 to 120 depending upon the availability of flowers at the time of crossing.

The data on fruit set recorded among various intergeneric crosses (Table 2) revealed significant differences among the treatments. Out of 1802 crosses made, fruit set ranged from 37.50 to 97.92 per cent. Highest fruit set was recorded in Arka Prabhath x *V. cauliflora* (T₁, 97.92 %) (Control) and Arka Surya x *V. cundinamarcensis* (T₁₀, 97.92 %) using nutrient solution which was on par with Arka Surya x *V. cundinamarcensis* (T₁₀, 97.92 %), followed by Arka Surya x *V. cauliflora* (T₇, 96.88 %). The lowest fruit set (T₁₇, 37.50 %) was recorded in Red Lady x *V. parviflora* (Plate 9).

Fruit set is an indication of initial compatibility in intergeneric hybridization. Nutrient solution not only increases seed set

but also has some beneficial influence on fruit set and fruit growth which can be termed as metaxenia (effect of pollen parent on fruit growth and development). This phenomenon was reported by Abbas and Ibrahim, 1998, in date palm, where pollen parent influences physiology of fruit growth and ripening.

In the present investigation, wide range of fruit set per cent (37.50 to 97.92) was observed among different cross combination. This might be due to differential compatibility of pollen parents with female parents. Among different female and male parents used in the study, Arka Prabhath with *V. cauliflora* and Arka Surya with *V. cundinamarcensis* were found to be a good combiner which resulted in highest fruit set percentage (97.92). Similar results were obtained by earlier workers using wild species of *V. cauliflora* and *V. cundinamarcensis* as male parents (Dinesh *et al.*, 2007; Bharathi., 2011; Jayavalli *et al.*, 2011 and Azad *et al.*, 2012).

Fruit retention (%)

The data on fruit retention (Table 2) across various intergeneric crosses exhibited significant difference among the treatments. It ranged from 5.21 to 98.96 per cent among various crosses. Highest fruit retention was recorded in Arka Prabhath x *V. cauliflora* (T₂, 98.96 %) using nutrient solution, which was significantly superior to other treatments. The next best significant treatments were Arka Prabhath x *V. cundinamarcensis* (T₄, 83.33 %) and Arka Prabhath x *V. parviflora* (T₆, 73.96 %) using nutrient solution. The lowest fruit retention (5.21 %), was recorded in the combination of Arka Surya x *V. parviflora* (T₁₁), Arka Surya x *V. cauliflora* (T₇, 6.25 %) and Red Lady x *V. parviflora* (T₁₇, 7.29 %) without nutrient solution.

In the present investigations, even though initial fruit set percentage was high (97.92 %

in Arka Prabhath X *V. cauliflora*) in control treatments, the fruit retention was high (98.96 % in Arka Prabhath X *V. cauliflora*) when nutrient solution was used for crossing. This could be due to beneficial effect of use of nutrient solution which has helped in further fruit development till maturity. As parthenocarpic fruit development has been noticed in papaya, the trigger of pollen could have helped in initial fruit set and not up to final fruit retention and seed development. This result was in confirmation with Jayavalli *et al.*, 2011, who also recorded higher fruit set in nutrient solution treatments than control.

In case of control treatments, sequential fruit drop was noticed which might be due to improper pollen germination and pollen tube growth. Similar result was obtained by earlier worker (Jayavalli *et al.*, 2011). Among different cross combinations, Arka Prabhath was found to be a good combiner for all male parents which resulted in good fruit set (85.42, 78.13 and 84.38 % in three wild species of nutrient solution treatments) and fruit retention percentage (98.96, 83.33 and 73.96 % in all three wild species of nutrient solution treatments) as compared to other female parents (Arka Surya and Red Lady). This could be due to genotypic nature of Arka Prabhath which responded very well in intergeneric crosses using wild relatives. As regards male parents both the wild species *V. cauliflora* and *V. cundinamarcensis* helped in high fruit retention compared to wild species *V. parviflora* (Jimenez and Horovitz, 1958). Similar results were obtained by Jayavalli *et al.*, 2011, where *V. cauliflora* has resulted in good set and final recovery.

Mean number of fruits harvested with fertile seeds

The data on mean number of fruits harvested with fertile seeds among various intergeneric crosses (Table 3) revealed the significant

difference among the treatments, which ranged from 0.00 to 30.00. The significantly highest mean number (30.00) was recorded in the cross Arka Prabhath x *V. cauliflora* (T₂) using nutrient solution. The next best treatments were Arka Prabhath x *V. cundinamarcensis* (T₄, 19.50) and Arka Prabhath x *V. parviflora* (T₆, 14.00). In cross combinations Arka Surya x *V. cauliflora* (T₇), Arka Surya x *V. cundinamarcensis* (T₉), Arka Surya x *V. parviflora* (T₁₁), Red Lady x *V. cauliflora* (T₁₃) and Red Lady x *V. parviflora* (T₁₇) no fruits were produced with fertile seeds.

In the present investigations, highest number of fruits (30.00, 19.50 and 14.00 in nutrient solution with wild species) with fertile seeds were recovered when Arka Prabhath was used as a female parent irrespective of male parents. It might be due to the better compatibility of Arka Prabhath with *Vasconcellea* genus and also due to the beneficial influence of nutrient solution in pollen germination and pollen tube growth as demonstrated earlier by Dinesh *et al.*, 2007; Jayavalli *et al.*, 2011 and Lichamo, 2015.

Mean number of seeds per fruit

The data on mean number of seeds per fruit among various intergeneric crosses (Table 3) revealed significant difference among the treatments, which ranged from 0.00 to 204.14. The significantly highest mean number (204.14) was recorded in the cross Arka Surya x *V. cauliflora* (T₈). The next best treatments were Arka Prabhath x *V. cauliflora* (T₂, 165.78) and Arka Prabhath x *V. cundinamarcensis* (T₄, 133.89). In cross combinations Arka Surya x *V. cundinamarcensis* (T₉), Arka Surya x *V. parviflora* (T₁₁) and Red Lady x *V. parviflora* (T₁₇) no seeds were produced (Plate 10-12). In the present investigations, highest number of seeds was recovered (204.14) in Arka

Surya x *V. cauliflora* followed by (165.78) Arka Prabhath X *V. cauliflora* when nutrient solution was used than control. The reason might be due to component of nutrient solution *viz.*, sucrose (major source of carbohydrate) and micronutrients. Both sucrose and micronutrients are reported to improve pollen germination and pollen tube growth ultimately resulting good seed set in intergeneric crossing (Dinesh *et al.*, 2007). This indicates efficiency of nutrient solution in complete development of embryo upon intergeneric hybridization. In the earlier study by Jayavalli, (2011) the combination resulted in high (400) number of seeds per fruit CP 50 X *V. cauliflora*.

Mean number of fertile seeds per fruit

The data on mean number of fertile seeds per fruit recorded among various intergeneric crosses presented (Table 3) revealed significant differences, which was in the range of 0.00 to 70.82. The significantly highest mean number (70.82) of fertile seeds per fruit were recovered in the combination Arka Prabhath x *V. cundinamarcensis* (T₄) followed by Arka Prabhath x *V. cauliflora* (T₂, 63.99). The next best treatments were and Arka Surya x *V. cundinamarcensis* (T₁₀, 28.50) and Arka Prabhath x *V. parviflora* (T₆, 28.14) using nutrient solution. No seeds were recovered in the combinations *viz.*, Arka Surya x *V. cauliflora* (T₇), Arka Surya x *V. cundinamarcensis* (T₉), Arka Surya x *V. parviflora* (T₁₁), Red Lady x *V. cauliflora* (T₁₃) and Red Lady x *V. parviflora* (T₁₅).

In the present study, it was observed that the use of nutrient solution proved its superiority in producing good number of fertile seeds (70.82 and 63.99 in ArkaPrabhath crosses). This might be due to micronutrients results in chemotropism of pollens towards ovaries in presence of glucose and water ultimately helps in better pollen germination (Regeret

al., 1992).F₁ seeds of most of cross combinations without nutrient solution resulted in infertile seeds (non-viable) (Mekako and Nakasone, 1975). This may be due to post zygotic embryo abortion due to improper pollen tube growth and lack of food reserve (endosperm) for embryo development which occurred in control treatments (Manshardt and Wenslaff, 1989). However sufficient carbohydrate source (sucrose) and micronutrient had helped in getting high number of fertile seeds in flowers crossed with help of nutrient solution.

Germination percentage of F₁ intergeneric progenies

The data on germination percentage of F₀

intergeneric progenies among various intergeneric crosses (Table 4) revealed significant differences, which was in the range of 0.00 to 82.29.

The significantly highest germination (82.29 %) was recorded in the cross Red Lady x *V. cundinamarcensis* which was on par with Red Lady x *V. parviflora* (T₁₈, 50.00 %).The next best treatment was Red Lady x *V. cauliflora* (T₁₄, 30.00 %). As no seeds were recovered in the treatment combinations viz.,Arka Surya x *V. cauliflora* (T₇), Arka Surya x *V. cundinamarcensis* (T₉), Arka Surya x *V. parviflora* (T₁₁), Red Lady x *V. cauliflora* (T₁₃) and Red Lady x *V. parviflora* (T₁₅), no seedlings were obtained.

Table.1 Details of cross combinations

Treatments	Cross combination
T ₁	Arka Prabhath × <i>Vasconcellea cauliflora</i>
T ₂	Arka Prabhath × <i>Vasconcellea cauliflora</i>
T ₃	Arka Prabhath × <i>Vasconcellea cundinamarcensis</i>
T ₄	Arka Prabhath × <i>Vasconcellea cundinamarcensis</i>
T ₅	Arka Prabhath × <i>Vasconcellea parviflora</i>
T ₆	Arka Prabhath × <i>Vasconcellea parviflora</i>
T ₇	Arka Surya × <i>Vasconcellea cauliflora</i>
T ₈	Arka Surya × <i>Vasconcellea cauliflora</i>
T ₉	Arka Surya × <i>Vasconcellea cundinamarcensis</i>
T ₁₀	Arka Surya × <i>Vasconcellea cundinamarcensis</i>
T ₁₁	Arka Surya × <i>Vasconcellea parviflora</i>
T ₁₂	Arka Surya × <i>Vasconcellea parviflora</i>
T ₁₃	Red Lady × <i>Vasconcellea cauliflora</i>
T ₁₄	Red Lady × <i>Vasconcellea cauliflora</i>
T ₁₅	Red Lady × <i>Vasconcellea cundinamarcensis</i>
T ₁₆	Red Lady × <i>Vasconcellea cundinamarcensis</i>
T ₁₇	Red Lady × <i>Vasconcellea parviflora</i>
T ₁₈	Red Lady × <i>Vasconcellea parviflora</i>
Replication	Two
Number of flowers per replication	50
Design	Randomised complete block design (RCBD)

Table.2 Details on number of flowers crossed, fruit set (%) and fruit retention (%) in various intergeneric crosses

Treatment	Number of flowers crossed	Fruit set (%)	Fruit retention (%)
T ₁ : Arka Prabhath x <i>V. cauliflora</i> (Control)	95	97.92 (83.90) ^a	28.13 (32.02) ^{ef}
T ₂ : Arka Prabhath x <i>V. cauliflora</i> (Nutrient solution)	120	85.42 (67.59) ^{bcde}	98.96 (85.64) ^a
T ₃ : Arka Prabhath x <i>V. cundinamarcensis</i> (Control)	93	67.71 (55.44) ^{efgh}	42.71 (40.80) ^d
T ₄ : Arka Prabhath x <i>V. cundinamarcensis</i> (Nutrient solution)	125	78.13 (62.27) ^{defg}	83.33 (65.90) ^b
T ₅ : Arka Prabhath x <i>V. parviflora</i> (Control)	94	59.38 (50.41) ^{ghi}	32.29 (34.62) ^e
T ₆ : Arka Prabhath x <i>V. parviflora</i> (Nutrient solution)	120	84.38 (66.81) ^{cdef}	73.96 (59.32) ^c
T ₇ : Arka Surya x <i>V. cauliflora</i> (Control)	98	96.88 (82.55) ^{ab}	6.25 (14.47) ^j
T ₈ : Arka Surya x <i>V. cauliflora</i> (Nutrient solution)	96	85.42 (67.59) ^{bcde}	19.79 (26.40) ^{gh}
T ₉ : Arka Surya x <i>V. cundinamarcensis</i> (Control)	102	80.21 (66.97) ^{cdef}	8.33 (16.65) ^j
T ₁₀ : Arka Surya x <i>V. cundinamarcensis</i> (Nutrient solution)	97	97.92 (83.90) ^a	14.58 (22.40) ^{hi}
T ₁₁ : Arka Surya x <i>V. parviflora</i> (Control)	92	61.46 (51.75) ^{fghi}	5.21 (13.13) ^j
T ₁₂ : Arka Surya x <i>V. parviflora</i> (Nutrient solution)	94	95.83 (78.61) ^{abc}	8.33 (16.77) ^j
T ₁₃ : Red Lady x <i>V. cauliflora</i> (Control)	100	88.54 (70.71) ^{abcd}	13.54 (21.46) ⁱ
T ₁₄ : Red Lady x <i>V. cauliflora</i> (Nutrient solution)	89	76.04 (60.95) ^{defg}	43.75 (41.40) ^d
T ₁₅ : Red Lady x <i>V. cundinamarcensis</i> (Control)	102	60.42 (51.01) ^{ghi}	22.92 (28.60) ^{fg}
T ₁₆ : Red Lady x <i>V. cundinamarcensis</i> (Nutrient solution)	104	42.71 (40.79) ^{hi}	43.75 (41.40) ^d
T ₁₇ : Red Lady x <i>V. parviflora</i> (Control)	98	37.50 (37.75) ⁱ	7.29 (15.62) ^j
T ₁₈ : Red Lady x <i>V. parviflora</i> (Nutrient solution)	83	84.38 (66.72) ^{cdef}	48.96 (44.40) ^d
Total	1802.00	-	-
CV (%)	0.11	11.34	6.15
CD (p=0.05)	-	15.23	4.48
SEm±	-	5.1	1.5

Values in parenthesis indicate arc sin transformed ones

Values following same alphabets in the column are not significantly different at P= 0.05

Table.3 Details on mean number of fruits harvested with fertile seeds, mean number of seeds per fruit and mean number of fertile seeds per fruit in various intergeneric crosses

Treatment	Mean number of fruits with fertile seeds	Mean number of seeds per fruit	Mean number of fertile seeds per fruit
T ₁ : Arka Prabhath x <i>V. cauliflora</i> (Control)	5.00 (2.33) ^d	56.76 (7.56) ^d	20.91 (4.77) ^{bc}
T ₂ : Arka Prabhath x <i>V. cauliflora</i> (Nutrient solution)	30.00 (5.51) ^a	165.78 (12.89) ^b	63.99 (8.02) ^a
T ₃ : Arka Prabhath x <i>V.cundinamarcensis</i> (Control)	1.00 (1.22) ^{ghi}	4.40 (2.21) ^{ij}	5.00 (2.33) ^{ef}
T ₄ : Arka Prabhath x <i>V. cundinamarcensis</i> (Nutrient solution)	19.50 (4.47) ^b	133.89 (11.56) ^{bc}	70.82 (8.42) ^a
T ₅ : Arka Prabhath x <i>V. parviflora</i> (Control)	2.00 (1.58) ^{efg}	18.21 (4.32) ^g	3.50 (1.99) ^{fg}
T ₆ : Arka Prabhath x <i>V. parviflora</i> (Nutrient solution)	14.00 (3.80) ^c	47.57 (6.93) ^{de}	28.14 (5.35) ^b
T ₇ : Arka Surya x <i>V. cauliflora</i> (Control)	0.00 (0.70) ^j	37.66 (6.16) ^{ef}	0.00 (0.70) ^h
T ₈ : Arka Surya x <i>V. cauliflora</i> (Nutrient solution)	2.50 (0.72) ^{ef}	204.14 (14.27) ^a	11.00 (3.38) ^{de}
T ₉ : Arka Surya x <i>V. cundinamarcensis</i> (Control)	0.00 (0.70) ^j	0.00 (0.70) ^k	0.00 (0.70) ^h
T ₁₀ : Arka Surya x <i>V. cundinamarcensis</i> (Nutrient solution)	1.00 (1.22) ^{ghi}	120.90 (10.97) ^c	28.50 (5.37) ^b
T ₁₁ : Arka Surya x <i>V. parviflora</i> (Control)	0.00 (0.70) ^j	0.00 (0.70) ^k	0.00 (0.70) ^h
T ₁₂ : Arka Surya x <i>V. parviflora</i> (Nutrient solution)	1.50 (0.40) ^{fgh}	0.50 (1.00) ^{jk}	3.00 (1.87) ^{fgh}
T ₁₃ : Red Lady x <i>V. cauliflora</i> (Control)	0.00 (0.70) ^j	31.62 (5.98) ^{ef}	0.00 (0.70) ^h
T ₁₄ : Red Lady x <i>V. cauliflora</i> (Nutrient solution)	1.00 (1.14) ^{hi}	14.79 (3.89) ^{gh}	4.50 (1.89) ^{fg}
T ₁₅ : Red Lady x <i>V. cundinamarcensis</i> (Control)	0.50 (0.96) ^{ij}	8.09 (2.92) ^{hi}	1.00 (1.14) ^{gh}
T ₁₆ : Red Lady x <i>V. cundinamarcensis</i> (Nutrient solution)	3.00 (1.85) ^e	24.09 (4.93) ^{fg}	13.00 (3.60) ^{cd}
T ₁₇ : Red Lady x <i>V. parviflora</i> (Control)	0.00 (0.70) ^j	0.00 (0.70) ^k	0.00 (0.70) ^h
T ₁₈ : Red Lady x <i>V. parviflora</i> (Nutrient solution)	0.50 (0.96) ^{ij}	6.72 (2.68) ^{hi}	0.50 (0.96) ^{gh}
CV (%)	10.60	11.51	19.17
CD (p=0.05)	0.39	1.35	1.18
SEm±	0.12	0.45	0.39

Values in parenthesis indicate arc sin transformed ones

Values following same alphabets in the column are not significantly different at P= 0.05

Table.4 Details on germination (%) of F1 intergeneric hybrid progenies and yield of crossed fruits recorded under various intergeneric crosses

Treatment	Germination (%)	Yield of crossed fruits (kg/ per tree)
T ₁ : Arka Prabhath x <i>V. cauliflora</i> (Control)	0.00 (0.10) ^c	13.50 ^{ef}
T ₂ : Arka Prabhath x <i>V. cauliflora</i> (Nutrient solution)	1.02 (5.77) ^c	48.50 ^a
T ₃ : Arka Prabhath x <i>V. cundinamarcensis</i> (Control)	0.00 (0.10) ^c	20.50 ^d
T ₄ : Arka Prabhath x <i>V. cundinamarcensis</i> (Nutrient solution)	3.20 (10.30) ^{bc}	40.00 ^b
T ₅ : Arka Prabhath x <i>V. parviflora</i> (Control)	0.00 (0.10) ^c	15.50 ^e
T ₆ : Arka Prabhath x <i>V. parviflora</i> (Nutrient solution)	3.81 (11.24) ^{bc}	38.00 ^b
T ₇ : Arka Surya x <i>V. cauliflora</i> (Control)	0.00 (0.10) ^c	3.00 ⁱ
T ₈ : Arka Surya x <i>V. cauliflora</i> (Nutrient solution)	0.00 (0.10) ^c	9.50 ^{gh}
T ₉ : Arka Surya x <i>V. cundinamarcensis</i> (Control)	0.00 (0.10) ^c	4.00 ⁱ
T ₁₀ : Arka Surya x <i>V. cundinamarcensis</i> (Nutrient solution)	0.00 (0.10) ^c	7.00 ^h
T ₁₁ : Arka Surya x <i>V. parviflora</i> (Control)	0.00 (0.10) ^c	2.50 ⁱ
T ₁₂ : Arka Surya x <i>V. parviflora</i> (Nutrient solution)	0.00 (0.10) ^c	4.00 ⁱ
T ₁₃ : Red Lady x <i>V. cauliflora</i> (Control)	0.00 (0.10) ^c	8.50 ^{gh}
T ₁₄ : Red Lady x <i>V. cauliflora</i> (Nutrient solution)	30.00 (25.43) ^{bc}	21.00 ^{cd}
T ₁₅ : Red Lady x <i>V. cundinamarcensis</i> (Control)	0.00 (0.10) ^c	11.00 ^{fg}
T ₁₆ : Red Lady x <i>V. cundinamarcensis</i> (Nutrient solution)	82.29 (71.68) ^a	21.00 ^{cd}
T ₁₇ : Red Lady x <i>V. parviflora</i> (Control)	0.00 (0.10) ^c	3.50 ⁱ
T ₁₈ : Red Lady x <i>V. parviflora</i> (Nutrient solution)	50.00 (45.00) ^{ab}	23.50 ^c
CV (%)	182.35	8.41
CD (p=0.05)	36.49	2.90
S.Em±	12.23	0.96

Values in parenthesis indicate arc sin transformed ones

Values following same alphabets in the column are not significantly different at P= 0.05

Plate.1 Female parent (Arka Prabhath) used in hybridization: a) Fully grown tree, b) Unopened female flower bud, c) Female flower, d) Fruit, e) L.S. of fruit, f) C.S. of fruit

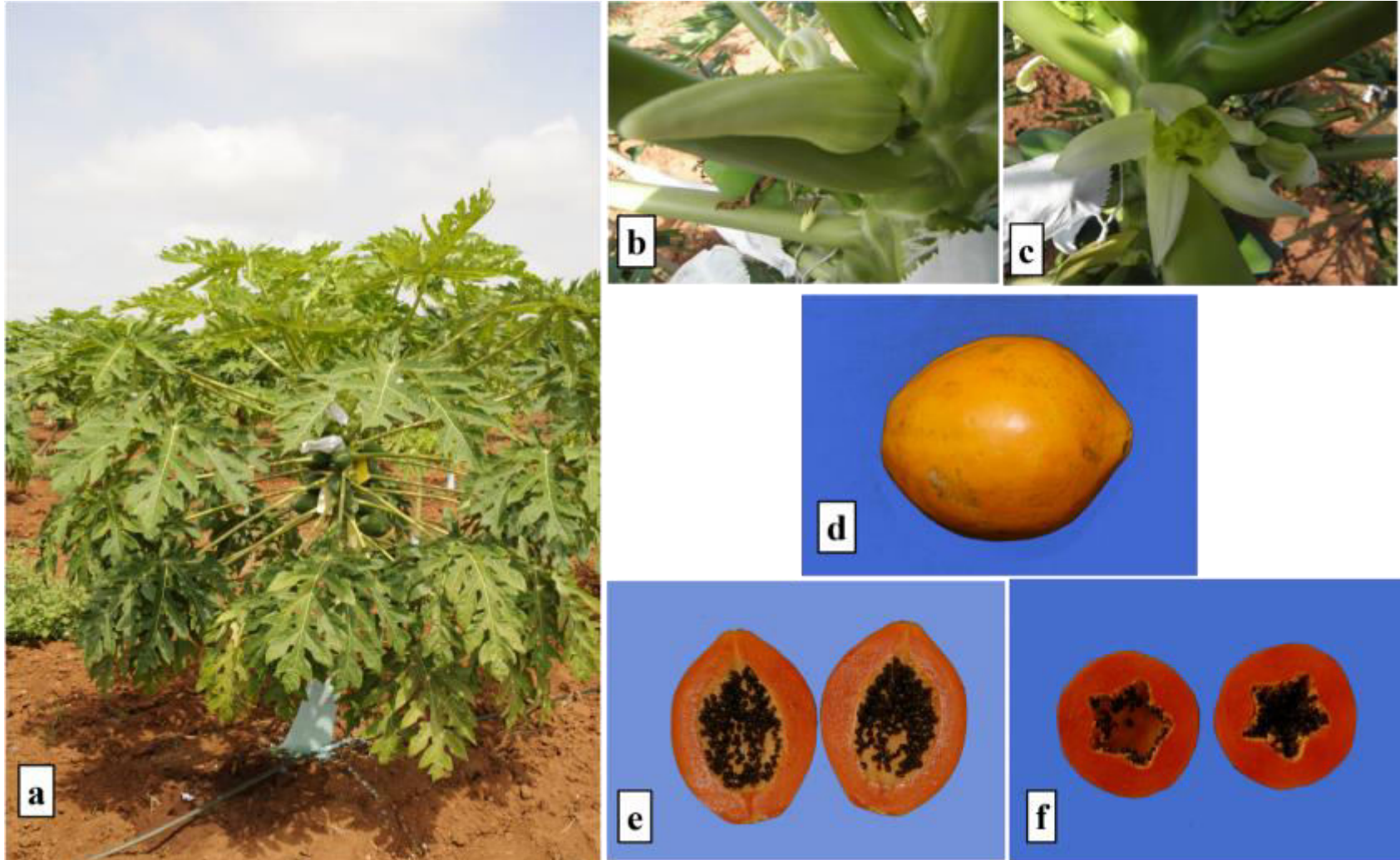


Plate.2 Female parent (Arka Surya) used in hybridization; a) Fully grown tree, b) Unopened female flower bud, c) Female flower, d) Fruit, e) L.S. of fruit, f) C.S. of fruit

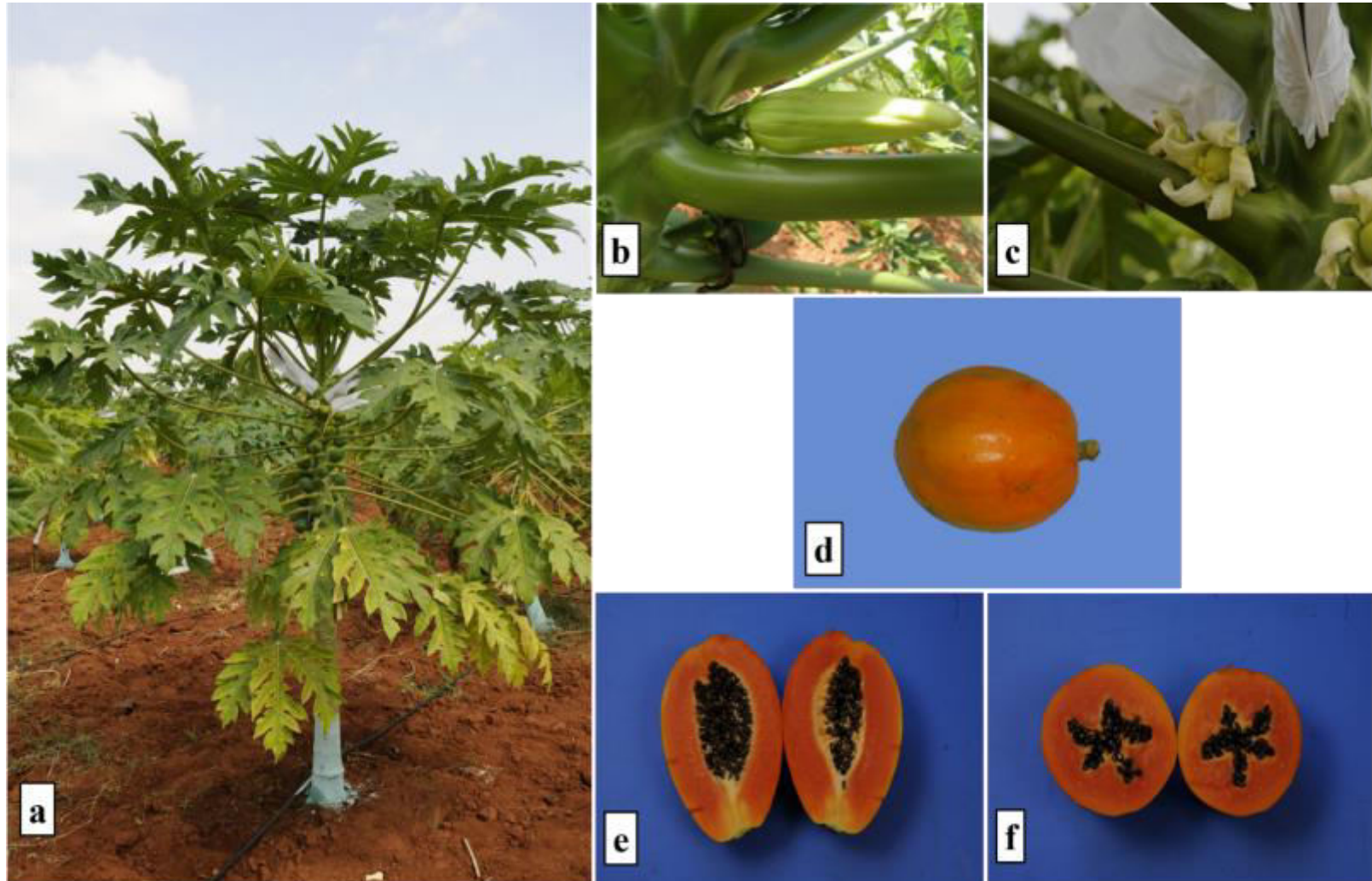


Plate.3 Female parent (Red Lady) used in hybridization: a) Fully grown tree, b) Unopened female flower bud, c) Female flower, d) Fruit, e) L.S. of fruit, f) C.S. of fruit

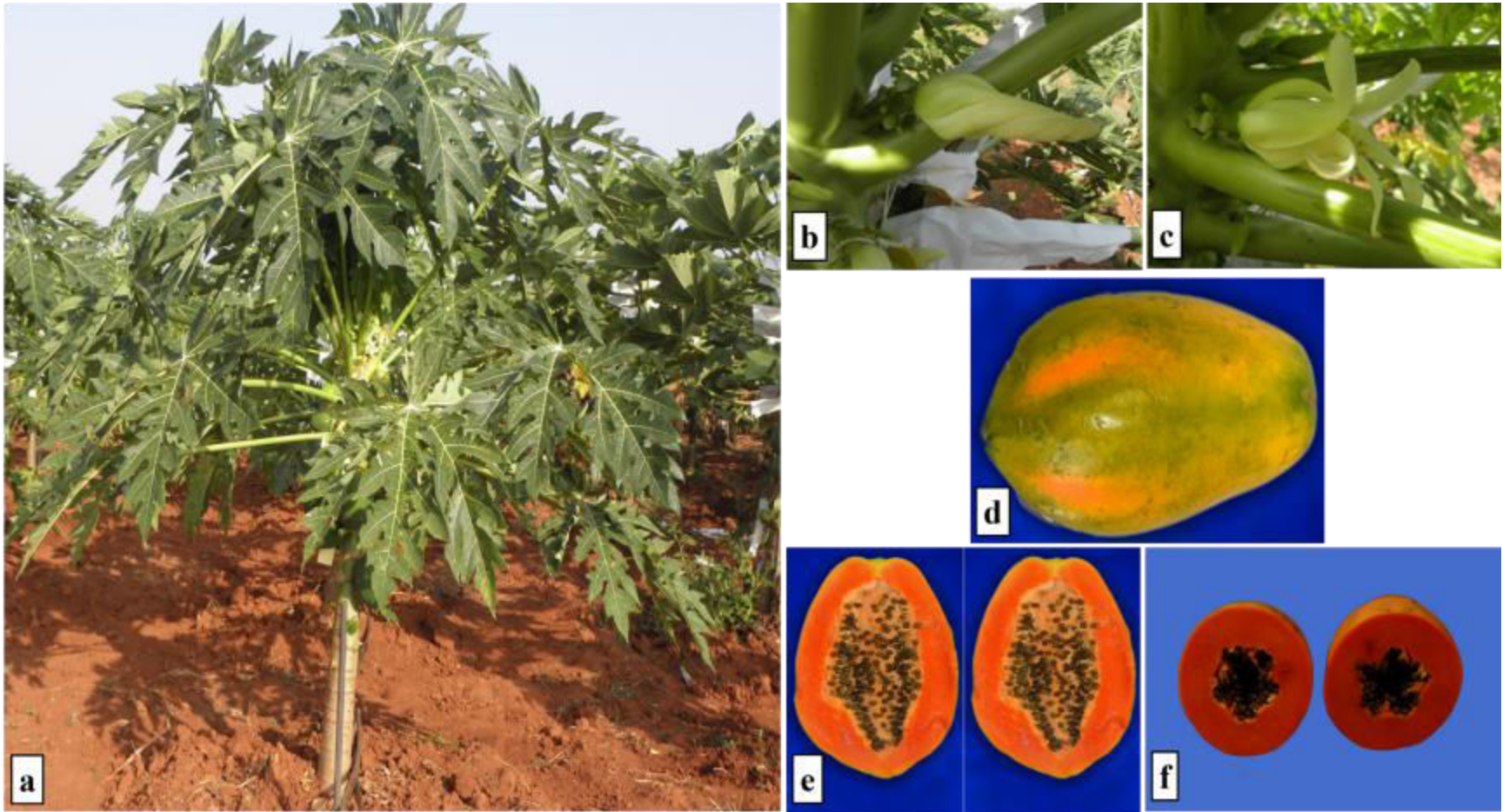


Plate.4 Male parent (*Vasconcellea cauliflora*) used in hybridization :a) Fully grown male tree, b) Unopened male flower bud, c) Male flower, d) Fruit, e) Fully grown female

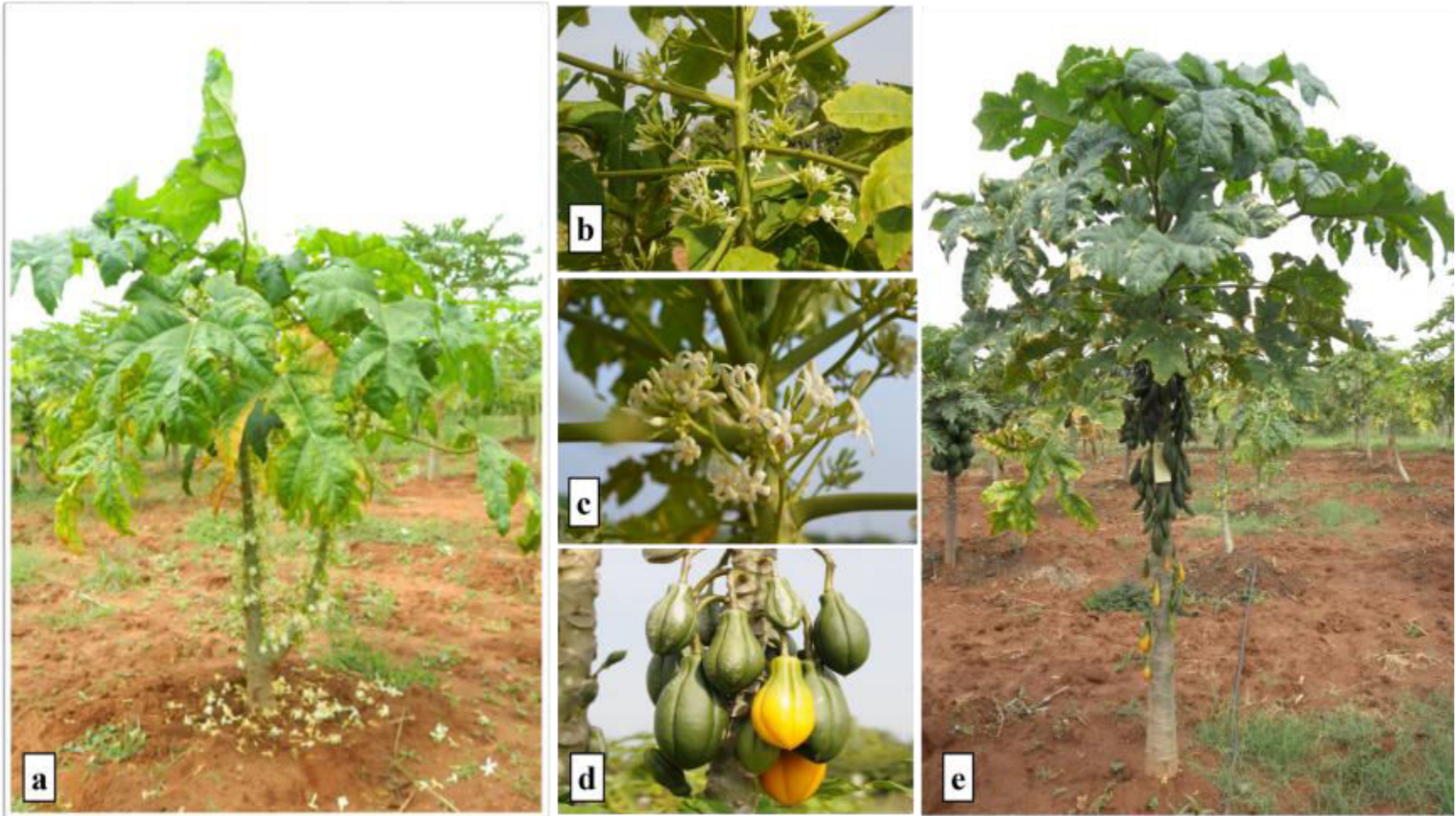


Plate.5 Male parent (*Vasconcellea cundinamarcensis*) used in hybridization: a) Fully grown male tree, b) Unopened male flower bud, c) Male flower, d) Fruit, e) Fully grown female

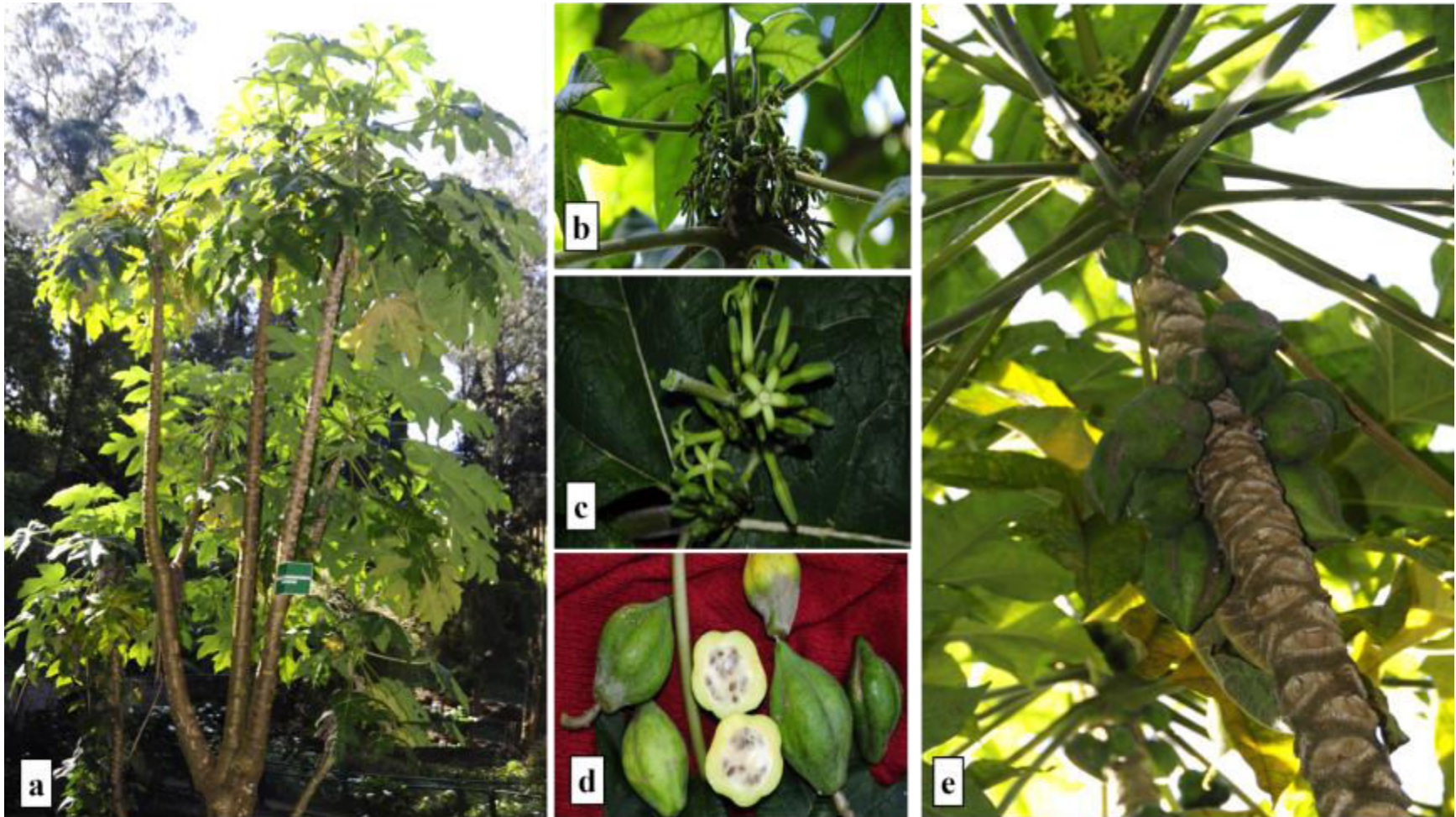


Plate.6 Male parent (*Vasconcellea parviflora*) used in hybridization: a) Fully grown male tree, b) Unopened male flower bud, c) Male flower, d) Fruit, e) Fully grown female tree

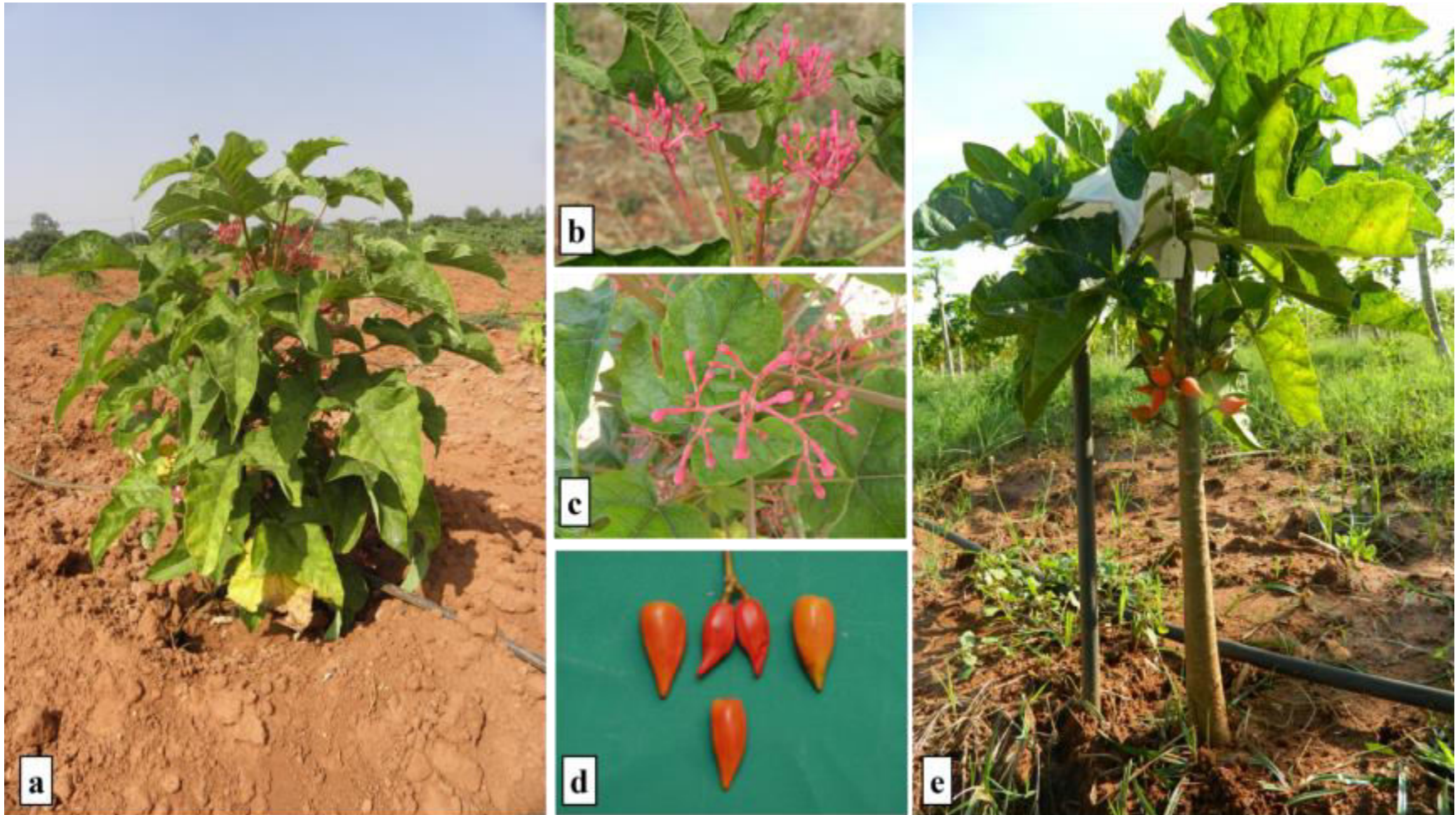


Plate.7 Field view of female parents used in hybridization



Plate.8 Steps involved in hybridization



Plate.9 Field view of fruit set recorded under various intergeneric crosses



Arka Prabhath



Arka Surya



Red Lady

Plate.10 View of seed set recorded in Arka Prabhath across different male parents used for hybridization



Arka Prabhath X *V. cauliflora* (Control)



Arka Prabhath X *V. cauliflora* (Nutrient solution)



Arka Prabhath X *V. cundinamarcensis* (Control)



Arka Prabhath X *V. cundinamarcensis* (Nutrient solution)



Arka Prabhath X *V. parviflora* (Control)



Arka Prabhath X *V. parviflora* (Nutrient solution)

Plate.11 View of seed set recorded in Arka Surya across different male parents used for hybridization



Arka Surya X *V. cauliflora* (Control)



Arka Surya X *V. cauliflora* (Nutrient solution)



Arka Surya X *V. cundinamarcensis* (Control)



Arka Surya X *V. cundinamarcensis* (Nutrient solution)



Arka Surya X *V. parviflora* (Control)



Arka Surya X *V. parviflora* (Nutrient solution)

Plate.12 View of Seed set recorded in Red Lady across different male parents used for hybridization



Red Lady X *V. cauliflora* (Control)



Red Lady X *V. cauliflora* (Nutrient solution)



Red Lady X *V. cundinamarcensis* (Control)



Red Lady X *V. cundinamarcensis* (Nutrient solution)



Red Lady X *V. parviflora* (Control)



Red Lady X *V. parviflora* (Nutrient solution)

In the present study, as expected, good germination (82.29, 50.00 and 30.00 % in Red lady crosses) was recorded in the seeds obtained using nutrient solution for crossing, which is attributed to the proper development of embryo with good bold seeds having sufficient food reserve for seedling development. Similar results were obtained by earlier workers (Thirugnanvel, 2010). In control treatments due to lack of food reserve (endosperm) improper growth and development of embryo was observed resulting in poor germination.

Yield of crossed fruits (kg/tree)

The data on yield of crossed fruits per tree recorded in the intergeneric crosses (Table 4) revealed significant differences, which was in the range of 2.50 to 48.50 kg/tree. Highest yield was recorded in cross involving Arka Prabhath x *V. cauliflora* (T₂, 48.50 kg/tree) followed by Arka Prabhath x *V. cundinamarcensis* (T₄, 40.00 kg/ tree) and Arka Prabhath x *V. parviflora* (T₆, 38.00 kg/tree). The lower yield was recorded in cross involving Arka Surya x *V. parviflora* (T₁₁, 2.50 kg/tree) which was on par with Arka Surya x *Vasconcellea cauliflora* (T₇, 3.00 kg/ tree), Red Lady x *V. parviflora* (T₁₇, 3.50 kg/ tree) and Arka Surya x *V. cundinamarcensis* (T₉, 4.00 kg/tree).

In the present study, as expected, all the cross combinations which used nutrient solution for crossing, had resulted in higher fruit recovery (48.50, 40.00 and 38.00 kg in Arka Prabhath crosses) as compared to control treatments. As yield is a component of several factors involving the genotypes, its cross compatibility, initial fruit set, development and final recovery. The combination involving Arka Prabhath as female parent has resulted in higher yield per tree (48.50, 40.00 and 38.00 kg) as compared to other two female parents, indicating its ability to be the

best combiner for intergeneric cross with the *Vasconcellea* species used in the present investigation.

In conclusion, intergeneric hybridization was carried out to know the cross compatibility between papaya varieties (Arka Prabhath, Arka Surya and Red Lady) with *Vasconcellea* species (*V. cauliflora*, *V. cundinamarcensis* and *V. parviflora*). Arka Prabhath was found to be a good combiner with all the three wild species (*V. cauliflora*, *V. cundinamarcensis* and *V. parviflora*). Among male parents, *Vasconcellea. cauliflora* was found to be good combiner with all three female parents (Arka Prabhath, Arka Surya and Red Lady). Hence Arka Prabhath with *V. cauliflora* cross combination was found to be good for intergeneric hybridization which has resulted in more mean number of fertile seeds (heterotic combinations) which ultimately helps in generating more number of intergeneric population for screening of PRSV.

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