

CROSSING EFFICIENCY STUDIES IN HYBRID TEA ROSE VARIETIES

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ABSTRACT

Fortytwo hybrid tea rose varieties were used to identify suitable parents for hybridization programme. Pollen morphology were rough in 14, smooth in 9 and medium smooth in 19 varieties. Stigmas were either Capitate or Flat capitates in shape. Pollen diameter and pollen viability ranged from 5.26 μ m to 3.80 μ m and from 70.13% to 38.86% respectively. Range for *in vitro* pollen germination was from 72.62% to 40.26%. Stigma size ranged from 41.88 μ m to 21.56 μ m and only 20 varieties set hips. Based on laboratory studies Melame, Montreal, Bonnie Nuit, Kentucky Derby, Chardony, Kiss of Fire and National Trust as pollen parents and Milky Way, Angel Delight, Forever, Duet, Chablis, Alliance, Grand Masterpiece, Miss Liberte, Apricot Spice, Royal Show, and Queen Elizabeth as female parents were identified. Actual crossing programme when carried out, only 31 crosses produced more than 20 seeds which involved six females and all seven males identified. Hence, it is concluded that Melame, Montreal, Bonnie Nuit, Kentucky Derby, National Trust, Chardony and Kiss of Fire as male parent and Milky Way, Forever, Alliance, Grand Masterpiece, Royal Show and Queen Elizabeth as female parents were identified to be used as parents to enhance the genetic variability in hybridization between hybrid tea roses.

INTRODUCTION

India has an age old tradition of growing flowers for various aspects. Introduction of green house technology for cultivation of cut flowers in India in the recent past years has changed the scenario of Indian floriculture. Huge capital investment has been made by the growers for the production of cut flowers meant to be 100 per cent export oriented. Among the cut flowers grown in India primarily for export, rose tops the area grown under protected conditions and there exists a fierce competition in the international flower market (Kumar *et al.*, 2012 and Makwana *et al.*, 2015). Hence, there is a need to develop good hybrids/ varieties by hybridization programme in rose.

Rose breeding programmes in the twentieth century focused mainly on introduction of new flower colours, thornless stems, higher production and a good post-harvest performance. Yet, the fertility of cut roses, typically tetraploid ($2n = 2x = 28$) hybrid tea roses, is frequently reduced probably due to their interspecific origin but also due to intensive inbreeding (Debeneret *al.*, 2000). To avoid the risk of very low seed production, breeders hybridise using high pollen loads of a limited number of male parents with the desired characteristics (Zlesak, 2006), chosen for their known fertility (i.e., number of seeds produced per hybridization). Pollen donors and female parents represent an economic risk for a breeding programme, as their influence on seed production is unknown. However, generating wider populations in terms of number of seedlings is only one of the aspects that contribute to the overall efficiency of a breeding programme. The successful introduction of new parents into a breeding programme depends on its potential to transmit the desired traits to the offspring. It may be more efficient in some cases to choose a parent with moderate

fertility if it produces offspring with a higher rate of advanced selections and ultimately, cultivars. In any case, recognizing parameters related to fertility could increase the overall efficiency of a breeding programme (Luca *et al.*, 2011, Lakhotia *et al.*, 2012, Peng Hua *et al.*, 2012 and Ahmadi *et al.*, 2013). Several studies concerning pollen quality *in vitro* (germination and pollen tube elongation) or *in vivo* (considering the hip set or the mean number of seeds per hip) were carried out with the aim of improving sexual reproduction of roses (Zlesaket *al.*, 2007, Luca *et al.*, 2011, Lakhotia *et al.*, 2012, Peng Hua *et al.*, 2012 and Ahmadi *et al.*, 2013). No studies carried out on roses have focused on the screening of breeding databases to aid the individuation of fertility marker characters for identifying the suitable pollen and female parent for hybridization (Luca *et al.*, 2011). Keeping in view the above facts the present study was undertaken to study the pollen and stigma characteristics and correlating the data with hybridization characteristics.

MATERIALS AND METHODS

The present experiment was carried out at the field of Satpuda Botanic Garden, Horticulture Section, College of Agriculture, Nagpur. The best quality and beautiful flowering 42 hybrid tea rose varieties with different characteristics were used for study. The 42 rose varieties having 4 plants in each replication were planted in two replications with spacing of 0.9 m x 0.9 m, in 1.8 m x 1.8 m plot of flat bed. Pruning in rose was done twice in a year, first pruning done in 1st fortnight of June and second in 1st fortnight of October. The observations on crossing ability were recorded at the time of crossing to find out the efficiency of the parents as male and female based on the studies carried out by Luca *et al.* (2011), Lakhotia *et al.*

(2012) and Ahmadi *et al.* (2013). The characters like Pollen morphology, Pollen diameter (μm), Pollen viability (%) were recorded according to the technique described by Robert (1977) and Vasil'eva (2009), *In vitro* pollen germination (%) as per the method given by Yang and Endo (2005), Stigma morphology, Stigma size (μm), No. of seeds hip⁻¹ and Hip set percentage (%) were studied in the parents following the method used by Luca *et al.* (2011) and Peng Hua *et al.* (2012). The data on various observations during the course of investigation were statistically analysed as per the method suggested by Panse and Sukhatme (1967). The appropriate standard error of mean SE ($\pm m$) and the critical difference (CD) were calculated at 5 % level of probability for the comparison of treatment means.

RESULTS AND DISCUSSION

Pollen morphology

Pollen morphology of 42 rose varieties studied in laboratory for their surface and shape (Table 1) indicated that, the surface of pollen grains was rough, smooth or medium smooth. Out of 42 rose varieties, 14 varieties recorded rough pollen surface, nine varieties recorded smooth and 19 recorded medium smooth pollen surface. The shapes of the pollen grain was found mostly round except for four varieties (Melame,

Peggylee, Sunset Song and John. F. Kennedy) which showed undulated round shape of pollen. The surface and size of pollen grain were different in different varieties which may be due to the fact that the genetic makeup of these varieties is different. In contrast to this study Pipino *et al.* (2010) reported elliptical and crossed by furrow type pollen, when they used dry pollen for study in case of rose. Pollen morphology of eleven cut rose genotypes were characterised by Luca *et al.* (2011) and observed that pollen was either small, shrunken and irregular (abnormal) or large, elliptical and crossed by furrows (normal).

Stigma morphology

Stigma morphology studied in 42 rose varieties for stigma shape and colour exhibited lot of variation (Table 1). Colour of the stigma observed were yellow (6), light yellow (6) deep yellow (1), light pink (2), light reddish (1) and reddish (1) pinkish – yellow (9), reddish – yellow (2), reddish – yellowish (3), yellowish – greenish (3), reddish – greenish (1), pinkish - greenish (2), greenish - yellow (3), greenish – pink (1) and yellowish – red (1). Shape of stigma was found to be either capitate or flat capitate. Four varieties Saiun, Angel Bells, Kiss of Fire and Rosemary Harkness alone showed flat capitate, while all other 38 varieties exhibited capitate shape. Stigma colour and shape was found different in different varieties due

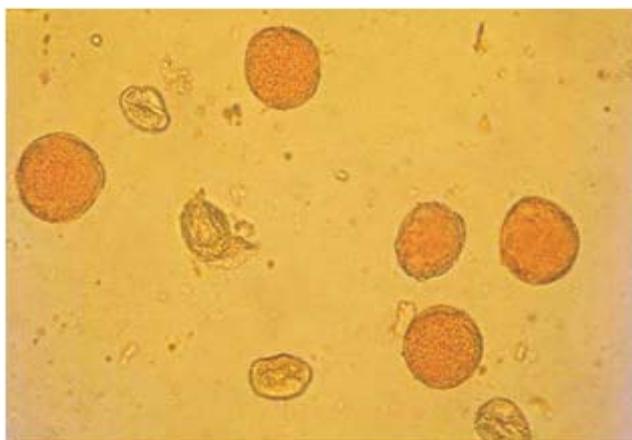


Plate 1: Pollen viability

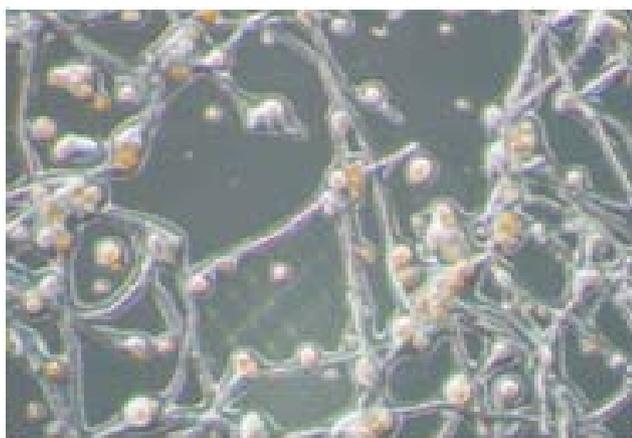
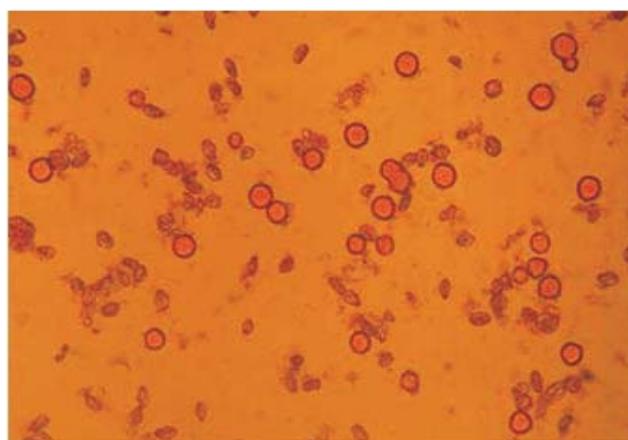


Plate 2: Pollen germination



Plate 3: Hips harvested after crossing

Table 1: Pollen and stigma morphology and hip set as influenced by different hybrid tea rose varieties

Sr. No	Rose varieties	Pollen morphology		Stigma morphology		Hip set	No. of seeds hip ⁻¹
		Surface	Shape	Colour	Shape		
1	Saiun	Rough	Round	Yellowish greenish	Flat capitate	-	-
2	Melame	Smooth	Undulated round	Pinkish yellow	Capitate	-	-
3	Montreal	Medium smooth	Round	Pinkish yellow	Capitate	-	-
4	Ace of Heart	Medium smooth	Round	Reddish yellow	Capitate	-	-
5	Bonnie Nuit	Smooth	Round	Reddish yellow	Capitate	-	-
6	Kentucky Derby	Medium smooth	Round	Deep yellow	Capitate	-	-
7	Bring Crosby	Rough	Round	Yellow	Capitate	-	-
8	RoterChampagner	Rough	Round	Light reddish	Capitate	-	-
9	Dr. Nasirwadia	Rough	Round	Reddish greenish	Capitate	-	-
10	Chardony	Medium smooth	Round	Light yellow	Capitate	-	-
11	Melody	Rough	Round	Light pink	Capitate	-	-
12	Dame De Klor	Medium smooth	Round	Light yellow	Capitate	-	-
13	Lilac Airs	Rough	Round	Pinkish yellow	Capitate	-	-
14	Prima Donna	Medium smooth	Round	Pinkish yellow	Capitate	-	-
15	Hot Pewter	Rough	Round	Yellow	Capitate	-	-
16	Priyoline	Smooth	Round	Pinkish greenish,	Capitate	+	26
17	Milky Way	Smooth	Round	Light yellow	Capitate	+	14
18	Almondeen	Medium smooth	Round	Yellow	Capitate	+	10
19	Angel Delight	Medium smooth	Round	Yellow	Capitate	+	05
20	Forever	Rough	Round	Light yellow	Capitate	+	12
21	Peggylee	Medium smooth	Undulated round	Pinkish yellow	Capitate	+	18
22	Duet	Medium smooth	Round	Pinkish	Capitate	+	07
23	Chablis	Medium smooth	Round	Light yellow	Capitate	+	25
24	Alliance	Medium smooth	Round	Yellow	Capitate	+	32
25	Angel Bells	Medium smooth	Round	Reddish yellowish	Flat capitate	+	10
26	Royal Show	Rough	Round	Reddish yellowish	Capitate	+	34
27	Sunset Song	Smooth	Undulated round	Yellow	Capitate	+	21
28	Queen Elizabeth	Smooth	Round	Pinkish greenish	Capitate	+	38
29	Grand Masterpiece	Medium smooth	Round	Reddish yellowish	Capitate	+	35
30	Grace de Monaco	Smooth	Round	Greenish yellow	Capitate	+	08
31	Garden Party	Rough	Round	Greenish yellow	Capitate	+	10
32	Kiss of Fire	Smooth	Round	Light pink	Flat capitate	-	-
33	National Trust	Medium smooth	Round	Light yellow	Capitate	-	-
34	McGredy's Yellow	Rough	Round	Yellowish greenish	Capitate	+	14
35	John F. Kennedy	Smooth	Round	Reddish	Capitate	-	-
36	Atago	Rough	Round	Pinkish yellow	Capitate	-	-
37	Tanya	Rough	Round	Pinkish yellow	Capitate	-	-
38	New Zealand	Medium smooth	Round	Greenish pinkish	Capitate	-	-
39	Miss Liberte	Rough	Round	Pinkish yellow	Capitate	+	24
40	Apricot Spice	Medium smooth	Round	Yellowish-greenish	Capitate	+	22
41	Rosemary Harkness	Medium smooth	Round	Greenish yellow	Flat capitate	+	16
42	Apartie	Medium smooth	Round	Yellowish red	Capitate	-	-

Note Hip formation (+) and Non hip formation (-)

to the difference in the genetic make up of these varieties.

Seeds set hip⁻¹

Among the 42 rose varieties studied only 20 varieties were found to set hip as observed from Table 1. The number of seeds set hip⁻¹ in those varieties ranged from 5 to 38. Maximum number of seed hip⁻¹ (38) was observed in Queen Elizabeth followed by Grand Masterpiece (35), Royal Show (34) and Alliance (32). The ability of the hip set and number of seeds hip⁻¹ is a genetically and environmental control phenomenon and hence, only some varieties set the hips under Nagpur conditions. Similar finding was reported by Nadeem *et al.*, (2011) who also reported variation for hip set in hybrid rose cultivars and hence from the germplasm the selected nine hybrid rose cultivars which bore hips and seeds were used for the crossing programme in their study. This indicates that ability to bear hip is very essential for seed formation and

also for their use as female parent in crossing programme.

Pollen diameter (μm)

Results presented in Table 2. revealed that, pollen diameter showed significant variation. Pollen diameter of rose varieties ranged from 3.80 μm to 5.26 μm when observed under microscope at 10X x 10X magnification. The variety National Trust recorded maximum pollen diameter (5.26 μm) followed by Bonnie Nuit (5.24 μm). Pollen size was found to vary from variety to variety. In accordance with this result Pipino *et al.* (2010) reported that the mean pollen diameter varied significantly among the genotypes studied. Nadeem *et al.* (2011) also reported that the pollen diameter in hybrid tea rose ranged from 3.00 μm to 4.33 μm . Within the normal pollen, the mean diameter of normal pollen grains also differed for the high and low fertile varieties. The more fertile genotypes produce more abnormal pollen, which was shrunken. Luca

Table 2: Pollen diameter, pollen viability, *in vitro* pollen germination and stigma size as influenced by different hybrid tea rose varieties

Sr. no	Rose varieties	Pollen diameter(μm)	Pollen viability(%)	<i>In vitro</i> pollengermination (%)	Stigma size(μm)
1	Saiun	4.45	42.30 (40.57)	45.60 (42.48)	22.81
2	Melame	4.87	66.77 (54.81)	67.40 (55.19)	26.56
3	Montreal	4.62	51.42 (45.81)	61.40 (51.59)	26.25
4	Ace of Heart	4.19	52.27 (46.29)	55.08 (47.92)	23.44
5	Bonnie Nuit	5.24	70.13 (56.86)	72.62 (58.47)	39.38
6	Kentucky Derby	4.98	56.40 (48.65)	59.18 (50.29)	25.63
7	Bring Crosby	4.41	40.15 (39.32)	43.11 (41.04)	22.81
8	RoterChampagner	4.51	43.55 (41.29)	48.89 (44.36)	38.13
9	Dr. Nasirwadia	4.49	46.28 (42.88)	51.04 (45.60)	27.50
10	Chardony	4.59	61.73 (51.77)	59.84 (50.68)	31.88
11	Melody	5.07	54.92 (47.82)	55.26 (48.02)	25.31
12	Dame De Klor	5.12	59.82 (50.66)	61.20 (51.47)	27.81
13	Lilac Airs	4.67	49.31 (44.60)	53.06 (46.75)	24.38
14	Prima Donna	4.46	50.55 (45.32)	55.43 (48.12)	25.31
15	Hot Pewter	3.82	39.73 (39.06)	39.80 (39.11)	25.31
16	Priyoline	4.49	52.00 (46.15)	53.60 (47.06)	27.19
17	Milky Way	4.27	63.30 (52.69)	64.36 (53.35)	29.69
18	Almondeen	3.84	38.86 (38.56)	40.26 (39.38)	23.44
19	Angel Delight	5.10	45.66 (42.48)	50.68 (45.39)	31.88
20	Forever	4.63	53.27 (46.87)	54.30 (47.47)	29.06
21	Peggylee	4.97	52.86 (46.63)	47.80 (43.74)	23.75
22	Duet	4.77	48.67 (44.23)	52.78 (46.59)	30.63
23	Chablis	4.68	58.65 (49.91)	60.06 (50.80)	24.69
24	Alliance	4.75	59.17 (50.28)	60.47 (51.04)	41.88
25	Angel Bells	4.32	45.52 (42.42)	54.46 (47.56)	30.63
26	Royal Show	4.60	44.20 (41.67)	52.18 (46.25)	26.25
27	Sunset Song	4.57	57.40 (49.26)	56.60 (48.79)	26.56
28	Queen Elizabeth	5.09	64.88 (53.64)	66.84 (54.85)	28.13
29	Grand Masterpiece	4.30	51.30 (45.72)	53.85 (47.21)	25.31
30	Grace de Monaco	4.62	49.14 (44.48)	51.71 (45.98)	24.06
31	Garden Party	4.69	59.32 (50.36)	54.08 (47.34)	27.19
32	Kiss of Fire	4.09	40.59 (39.55)	44.58 (41.89)	27.81
33	National Trust	5.26	54.75 (47.73)	58.44 (49.86)	24.69
34	McGredy's Yellow	4.42	39.31 (38.82)	42.04 (40.42)	24.69
35	John F. Kennedy	5.10	64.02 (53.13)	61.71 (51.77)	21.56
36	Atago	5.13	52.61 (46.49)	56.47 (48.72)	30.63
37	Tanya	4.56	47.31 (43.46)	50.70 (45.40)	30.94
38	New Zealand	3.80	47.11 (43.34)	53.18 (46.82)	24.69
39	Miss Liberte	4.21	51.80 (43.14)	52.34 (46.34)	26.56
40	Apricot Spice	4.68	63.59 (52.87)	57.88 (49.54)	26.56
41	Rosemary Harkness	4.53	44.90 (42.08)	49.66 (44.81)	28.44
42	Apartie	4.31	49.49 (44.69)	51.11 (45.64)	24.69
	G.M.	4.60	46.10	47.50	27.48
	S.E (m) \pm	0.12	0.70	0.58	0.50
	C.D (5%)	0.35	2.00	1.66	1.42

et al., 2011 studied the pollen of 11 hybrid tea rose and observed that a large amount of pollen was abortive or sterile and has a great variability in size already before the anthers dehiscence and reported that pollen size and shape also changes in relation to the genotype and to environmental conditions.

Pollen viability

Pollen viability percentage (%) based on staining varied significantly among the differed varieties(Table 2). The frequency of getting fertile pollen is one of important factor for ensuring the seed set. Fertile pollen along with viable pollen favour a better seed set and consequently an acceptable yield (Sezaiercisli, 2007 and Ranchana et al., 2015). The result of this study revealed that, only one variety Bonnie Nuit recorded pollen viability above 70 % and six varieties viz. Chardony,

Milky Way, Apricot Spice, John F. Kennedy, Queen Elizabeth and Melame recorded in the range of 60-70%, seventeen varieties in the range of 50-60% and other eighteen varieties recorded below 50%.Pollen viability varied in different varieties under Nagpur conditions. It may be due to the fact that genetic makeup of different varieties and response of different varieties to local environment were different. These results are in close agreement with the finding ofLakhotia et al. (2012) who reported that pollen viability varied from 6.45 to 78.07 % in the ten male donor parents and Nadeem et al. (2011) also reported from 35 to 70 percent in rose.

***In vitro* pollen germination (%)**

In vitro pollen germination is an indirect method to estimate the vigour of pollen donor parent. Pollen viability is an ability of a pollen grain to germinate and develop as a pollen tube

Table 3: Crossing success percentage as influenced by different parents

Sr.No	Crosses	No. of buds crossed	No. of hip formed after crossing	No. of seeds formed	No. of seeds hip ⁻¹	Crossing success%
1	Milky Way x Melame	6	6	72	12	100.00
2	Milky Way x Montreal	6	4	32	8	66.67
3	Milky Way x Bonnie Nuit	6	3	24	8	50.00
4	Milky Way x Kentucky Derby	6	6	42	7	100.00
5	Milky Way x Chardony	6	3	30	10	50.00
6	Milky Way x Kiss of Fire	6	3	30	10	50.00
7	Milky Way x National Trust	6	4	36	9	66.67
8	Angel Delight x Melame	4	0	-	-	0
9	Angel Delight x Montreal	4	0	-	-	0
10	Angel Delight x Bonnie Nuit	4	0	-	-	0
11	Angel Delight x Kentucky Derby	4	0	-	-	0
12	Angel Delight x Chardony	4	0	-	-	0
13	Angel Delight x Kiss of Fire	4	0	-	-	0
14	Angel Delight x National Trust	4	0	-	-	0
15	Forever x Melame	4	3	36	12	75.00
16	Forever x Montreal	4	3	12	4	75.00
17	Forever x Bonnie Nuit	5	4	28	7	80.00
18	Forever x Kentucky Derby	4	3	24	8	75.00
19	Forever x Chardony	5	0	-	-	0
20	Forever x Kiss of Fire	5	3	9	3	60.00
21	Forever x National Trust	4	4	32	8	100.00
22	Duet x Melame	4	2	6	3	50.00
23	Duet x Montreal	4	2	6	3	50.00
24	Duet x Bonnie Nuit	4	1	5	5	25.00
25	Duet x Kentucky Derby	4	1	4	4	25.00
26	Duet x Chardony	4	0	-	-	0
27	Duet x Kiss of Fire	4	1	2	2	25.00
28	Duet x National Trust	4	1	5	5	25.00
29	Chablis x Melame	4	3	18	6	75.00
30	Chablis x Montreal	4	3	12	4	75.00
31	Chablis x Bonnie Nuit	4	2	8	4	50.00
32	Chablis x Kentucky Derby	4	2	16	8	50.00
33	Chablis x Chardony	5	3	12	4	60.00
34	Chablis x Kiss of Fire	3	1	6	6	33.34
35	Chablis x National Trust	3	2	20	10	66.67
36	Alliance x Melame	6	6	144	24	100.00
37	Alliance x Montreal	6	5	95	19	83.34
38	Alliance x Bonnie Nuit	7	7	161	23	100.00
39	Alliance x Kentucky Derby	6	6	126	21	100.00
40	Alliance x Chardony	6	5	95	19	83.34
41	Alliance x Kiss of Fire	7	6	132	22	85.71
42	Alliance x National Trust	6	6	120	20	100.00
43	Grand Masterpiece x Melame	3	2	28	14	66.67
44	Grand Masterpiece x Montreal	3	1	6	6	33.34
45	Grand Masterpiece x Bonnie Nuit	3	3	33	11	100.00
46	Grand Masterpiece x Kentucky Derby	3	3	33	11	100.00
47	Grand Masterpiece x Chardony	3	0	-	-	0
48	Grand Masterpiece x Kiss of Fire	3	1	18	18	33.34
49	Grand Masterpiece x National Trust	3	2	24	12	66.67
50	Miss Liberte x Melame	3	1	3	3	33.34
51	Miss Liberte x Montreal	3	1	8	8	33.34
52	Miss Liberte x Bonnie Nuit	3	1	4	4	33.34
53	Miss Liberte x Kentucky Derby	3	1	5	5	33.34
54	Miss Liberte x Chardony	3	1	2	2	33.34
55	Miss Liberte x Kiss of Fire	3	1	14	14	33.34
56	Miss Liberte x National Trust	3	2	12	6	66.67
57	Apricot Spice x Melame	3	1	4	4	33.34
58	Apricot Spice x Montreal	3	2	10	5	66.67
59	Apricot Spice x Bonnie Nuit	3	0	-	-	0
60	Apricot Spice x Kentucky Derby	3	1	3	3	33.34
61	Apricot Spice x Chardony	3	1	2	2	33.34
62	Apricot Spice x Kiss of Fire	3	2	14	7	66.67
63	Apricot Spice x National Trust	3	1	5	5	33.34
64	Royal Show x Melame	2	1	9	9	50.00

Table 3: Cont.....

Sr.No	Crosses	No. of buds crossed	No. of hip formed after crossing	No. of seeds formed	No. of seeds hip ⁻¹	Crossin gsuccess%
65	Royal Show x Montreal	2	0	-	-	0
66	Royal Show x Bonnie Nuit	2	2	42	21	100.00
67	Royal Show x Kentucky Derby	2	2	28	14	100.00
68	Royal Show x Chardony	2	0	-	-	0
69	Royal Show x Kiss of Fire	2	1	16	16	50.00
70	Royal Show x National Trust	2	2	40	20	100.00
71	Queen Elizabeth x Melame	5	5	90	18	100.00
72	Queen Elizabeth x Montreal	5	4	68	17	80.00
73	Queen Elizabeth x Bonnie Nuit	5	2	20	10	40.00
74	Queen Elizabeth x Kentucky Derby	5	2	28	14	40.00
75	Queen Elizabeth x Chardony	5	0	-	-	0
76	Queen Elizabeth x Kiss of Fire	5	2	24	12	40.00
77	Queen Elizabeth x National Trust	5	4	72	18	80.00

(Prajapati and Jain, 2011 and Sarika and Mary Varkey, 2012). They said that the primary determinant of pollen viability is the state of the vegetative cell membranes. It is suggested that in the partly dehydrated grain at the time of dispersal, the membranes are largely dissociated and do not form an osmotic barrier and normal properties are recovered during controlled hydration, which normally would take place on the stigma. The growth of the pollen tube can be taken as the measure of pollen viability since non-viable pollen could not make the growth of a pollen tube (Ranchana *et al.*, 2015). Good seed set cannot be achieved unless pollen is viable with high germination percentage. In this study significant variation for *in vitro* pollen germination (%) among the varieties were observed (Table 2). Pollen germination percentage (%) ranged from 39.80 (Hot Pewter) to 72.62 (Bonnie Nuit). Only one variety Bonnie Nuit recorded maximum *in vitro* pollen germination above 70 %, eight varieties exhibited between 60 to 69 %, twenty four between 50 to 59 % and nine below 50 %. These findings are in close agreement with the finding of Lakhotia *et al.* (2012) who observed significant variation for *in vitro* pollen germination among the rose varieties and Nadeem *et al.* (2011) also performed *in vitro* pollen germination and got significant variation among the cultivars and the mean value ranged from 2.21 % to 52.55 %.

Stigma size (µm)

Stigma size of different varieties was significantly influenced by different varieties (Table 2) which ranged from 21.56 µm to 41.88 µm. Significantly maximum stigma size (41.88 µm) was recorded in variety Alliance followed by Bonnie Nuit (39.38 µm), RoterChampagner (38.13 µm), Chardony (31.88 µm) and Angel Delight (31.88 µm). The result indicated significant difference in size of stigma and hence, stigma size can be considered as one of the trait for identifying female parent.

Luca *et al.* (2011) reported a strong correlation between the pollen characters like pollen diameter, pollen viability, pollen morphology with that of seeds per hybridization in rose. They also reported predominant maternal influence on seed development after hybridization which can be determined by stigma size and hip bearing capacity. In order to characterize the features of pollen donors, this study used pollen diameter, pollen viability, *in vitro* pollen germination and no hip formation as the criteria according to Luca *et al.* (2011) and

Pipino *et al.* (2012). To evaluate the features of female parents this study used flower colour, hip bearing seeds set and stigma size based on the criteria used by Pipino *et al.* (2010) and Lakhotia *et al.* (2012). Based on these criteria eleven hybrid tea varieties viz. Milky Way, Angel Delight, Forever, Duet, Chablis, Alliance, Grand Masterpiece, Miss Liberte, Apricot Spice, Royal Show and Queen Elizabeth were identified to be suitable for female parent and seven hybrid tea varieties viz. Melame, Montreal, Bonnie Nuit, Kentucky Derby, Chardony, Kiss of Fire and National Trust were identified to be suitable for male parents in rose hybridization programme.

Parental effect on seed set

In order to strengthen the database observation by evaluating the paternal and maternal effect on seed set, and to confirm the efficiency of parents for hybridization, a crossing experiment was performed using seven male and eleven female parents identified above, to produce 77 cross combination. The data on numbers of buds crossed, number of hip formed after crossing, number of seeds formed and number of seed hips⁻¹ were recorded for each of 77 crosses and used for calculating crossing success percentage and presented in Table 3. The results revealed that, crossing success percentage ranged from 0 to 100 percent indicating a wide variation. 100 percent success was obtained in 13 crosses. This was followed by Alliance x Kiss of Fire which recorded (85.71 %) success, Alliance x Montreal and Alliance x Chardony (83.34 %), Forever x Bonnie Nuit and Queen Elizabeth x Montreal (80.00 %). It was also observed that in some crosses even though the pollen diameter, pollen viability and *in vitro* pollen germination of the male donors were high, the crossing success percentage was low or even zero in the same cases. This indicates that the hip formation and seed set after crossing not only depends on the characteristics of male and female parents but also on the interaction of pollen on stigma and many other factors as reported by Pipino *et al.* (2010). The interaction of pollen from male donor and stigma of female can only be observed after actually making the crosses.

This study thus reveals that, the criteria followed for selecting the male and female parents can be applied only to reduce the number of the parents to be involved in the actual crossing. The data presented in Table 3 regarding crossing success revealed that, the number of seeds formed after crossing ranged

from 0 to 161. Out of 77 crosses made during the study, 30 crosses reported more than 20 seeds per cross. The parents involved in these crosses viz. Milky Way, Forever, Alliance, Grand Masterpiece, Royal Show and Queen Elizabeth were found suitable for female parents whereas, Melame, Montreal, Bonnie Nuit, Kentucky Derby, National Trust, Chardony, Kiss of Fire were suitable for male parents. This results when compared with the results of pollen and stigma characteristics, it was found that among the 11 female parents only six namely Milky Way, Forever, Alliance, Grand Masterpiece, Royal Show and Queen Elizabeth were found suitable as female but all the seven male parent were found suitable as pollen parent for hybridization programme.

Thus, it is concluded from this study that, Melame, Montreal, Bonnie Nuit, Kentucky Derby, National Trust, Chardony and Kiss of Fire as male parent and Milky Way, Forever, Alliance, Grand Masterpiece, Royal Show and Queen Elizabeth as female parents were identified to be used as parents to enhance the genetic variability in hybridization between hybrid tea roses.

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