DOI : 10.5958/0974-0112.2016.00041.4

Indian J. Hort. 73(2), June 2016: 165-170

Effect of pollination methods on fruit set and physical characteristics of litchi fruits

Manoj Brijwal*, D.C. Dimri, A. Kishor and D.S. Mishra**

Department of Horticulture, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar 263 145, Uttarakhand

ABSTRACT

An experiment was conducted in *tarai* region of Uttarakhand, to study the effect of different parent combinations in four commercial litchi cultivars ('Rose Scented', 'Calcuttia', 'Early Seedless' and 'Late Seedless') as a result of self, cross and open-pollination methods during two successive years (2013 & 2014). The two-year pooled data indicated the initial fruit set (%) was significantly lower in all cross pollination methods, *i.e.*, 38.55% (Early Seedless × Calcuttia) compared to self-pollination method, *i.e.*, 72.78% in Rose Scented × Rose Scented. However, final fruit retention was significantly higher in all cross-pollinated flowers, *i.e.*, 24.68% (Rose Scented × Early Seedless) compared to self-pollinated flowers, *i.e.*, 8.65% (Early Seedless × Early Seedless). Fruit weight (24.33 g) in Late Seedless × Early Seedless, Fruit length (3.66 cm) in Late Seedless × Early Seedless, peel weight (5.19 g) in Early Seedless × Late Seedless, aril weight (18.66 g) in Late Seedless × Early Seedless and seed weight (3.81 g) in Calcuttia × Rose Scented were significantly increased in cross-pollination methods. However, the maximum fruit width (3.00 cm) was recorded in open-pollinated Late Seedless. Overall, increased fruit retention and fruit physical characteristics under the cross pollination suggests that the inclusion of cross-pollinators in litchi orchards may have beneficial effects on production.

Key words: Fruit retention, fruit quality, fruit set, litchi, pollination.

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an important subtropical evergreen fruit crop belonging to family Sapindaceae. It occupies an area of 84.20 thousand hectares in India with an annual production of 585.30 thousand metric tonnes (Anon, 1). Litchi produces three types of flowers that open in succession on the same panicle. Type-I is defined as a male or staminate (M_1), type-II as an imperfect hermaphrodite with non-dehiscent anthers acting as female (F) and type-III as an imperfect hermaphrodite with abortive stigma acting as a male (M_2). This pattern of flowering would be expected to promote cross-pollination and prevent self-pollination. However, male (M_1 and M_2) and female (F) flowering stages may overlap on the same tree or between trees of the same cultivar, thereby providing an opportunity for self-pollination (Stern and Gazit, 11). The results of pollination studies carried by Stern *et al*. (12) and Degani *et al*. (3) indicated that pollen parent can have an effect on fruit-set, fruit retention and quality of litchi fruits. To date, no studies have been conducted in litchi to examine the effect of self, cross and open-pollination on fruit set and fruit physical characteristics under the *tarai* region of Uttarakhand, India. Therefore, the present study was undertaken.

*Corresponding author's E-mail: manoj.brijwal@gmail.com

**ICAR-CITH, Regional Station, Mukteshwar, Nainital 263138, Uttarakhand

MATERIALS AND METHODS

The present investigation was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during two successive years, 2013 and 2014. Sixteen-year-old healthy fruit bearing trees of litchi cultivars, namely; 'Rose Scented', 'Calcuttia', 'Early Seedless' and 'Late Seedless' having uniform size and vigour, planted at 7 m x 7 m and maintained under uniform cultural practices were selected. The experiment was laid out in randomized block design (RBD) with 20 pollination treatments. Each pollination treatment was replicated thrice and total 40 panicles per replication were selected for the study.

In self-pollination, total 40 randomly selected panicles in four different directions of the tree in each cultivar were covered before anthesis with the muslin cloth bags and labelled. When pistils matured (white and sticky surface), the muslin cloth bags were removed and the already collected pollen grains from the same plant or other panicle of same cultivar were dusted on the pistillate flowers. After pollination, panicles were covered again and the procedure was repeated after 24 h during the following morning. This routine was continued until all receptive female flowers on each panicle were pollinated.

Under open-pollination method, before anthesis 40 randomly selected panicles of each cultivar in

four different directions of the tree were tagged. The number of female flowers (F) with a well-developed stigma, style, ovary and stamens with very short filaments on each panicle were counted and allowed to open-pollinate, whereas, in reciprocal cross pollination method, all the four litchi cultivars under study were reciprocally crossed with each other and thus a total of 12 cross combination treatments were studied under cross pollination. Forty randomly selected panicles of each cultivar in four different directions of the tree were bagged and labelled before anthesis. When pistils were ripe, the muslin cloth bags were removed and the already collected pollen grains of desired male parent were dusted on the pistillate flowers and if any newly opened male flowers (M_2) with well-developed anthers and rudimentary non-functional female parts were noticed, than these M_2 flowers were mechanically removed from the panicle to prevent self-pollination. After pollination, panicles were covered again and the procedure was repeated until all receptive female flowers on each panicle were pollinated. The total pistillate flowers were counted, labelled and covered with muslin cloth bags to avoid contamination with foreign pollen.

The number of fruit set on 40 tagged panicles on each tree at seven days after pollination were counted and average initial fruit set (%) was calculated on the basis of total number of female flower per panicle. The total number of fruits retained on the tagged panicles was counted also at the time of final harvest and average final fruit retention (%) was calculated on the basis of total number of fruits initially set per panicle. Fruit weight was recorded by weighing it on 'pan balance' and the mean weight of ten fruits was computed. Fruit size, in terms of length from fruit apex to stem end and width at the broadest end were measured by digital Vernier calipers and the mean size of 10 fruits was calculated both by length and width.

Ten fruits from each replication were taken and peel, aril and seed was extracted and weight was recorded with the help of 'electronic balance' and average peel, aril and seed weight was calculated over the total weight of fruit. The observations were subjected to statistical analysis by using randomized block design (RBD) as per procedure given by Panse and Sukhatme (7).

RESULTS AND DISCUSSION

The data on initial fruit set revealed that pollination methods significantly affected the initial fruit set of litchi cultivars during both the years (Table 1). Initial fruit set under self-pollination was significantly higher than all crosses and open-pollination methods, except in cultivar Early Seedless, where the initial fruit set under open-pollination was recorded the highest. Among the pollination methods, the pooled data showed the maximum initial fruit set (72.78%) recorded in Rose Scented (selfed) followed by Late Seedless (selfed), *i.e.*, 64.99%, while the minimum initial fruit set (38.55%) was estimated in cross-pollination, *i.e.*, Early Seedless × Calcuttia followed by Calcuttia × Early Seedless (40.72%). The differences in initial fruit set with the use of different pollen sources could be due to their differential ability to fertilize the respective female parents, thus affecting initial fruit set. The litchi flowering pattern tends to promote cross-pollination however, the partial overlap between the female flowering stage and the two male stages enables pollination among trees of the same cultivar, thereby providing an opportunity for self-pollination (Stern and Gazit, 11). A significant high initial fruit set in selfed panicle indicated a high level of self-compatibility of the litchi cultivars. In Israel, self-compatibility of litchi cultivars was confirmed with isozyme analysis by Stern *et al*. (12), mentioning a significant increase in the initial fruit set from self-pollination in 'Mauritius' and 'Floridian' cultivars. Froneman *et al*. (4) also reported the lower initial fruit set in all cross-pollination as compared to self-pollination in 'Wai Chee' litchi cultivar.

The different cross combinations had a significant effect on final fruit retention of litchi cultivars (Table 1). The pooled data showed the maximum final fruit retention (24.68%) recorded in crosses (Rose Scented × Early Seedless) followed by Rose Scented × Late Seedless (23.81%), Early Seedless × Rose Scented (23.49%) and Rose Scented × Calcuttia (22.96%), while the minimum final fruit retention (8.65%) was recorded under selfed panicles (Early Seedless × Early Seedless) followed by Late Seedless × Late Seedless (11.58%), Calcuttia × Calcuttia (11.96%) and Rose Scented × Rose Scented (13.11%). The better final fruit retention with cross combinations may also be explained by embryo degeneration and abortion found in self-pollinated fruit due to inbreeding depression (Sedgley and Griffin, 9). Final fruit retention at harvest was higher in all cross-pollinating donors, demonstrating the potential ability of cross pollinated fruits to out compete self pollinated fruits for available tree resources. These results indicate that self-pollinated litchi cultivars gave the highest initial fruit set percentage, but fruits emanating from these self-pollinated flowers abscised at a higher rate than the fruits resulting from cross-pollination. These results are in close conformity with the findings of Froneman *et al*. (4) who also reported the lower initial fruit set in all cross-pollination methods as compared to self-pollination. However, final fruit retention was higher with all cross-pollinations compared to self-

Table 1. Effect of different cross combinations on initial fruit set, final fruit retention and fruit weight of litchi.

Cross combination	Initial fruit set (%)			Final fruit retention (%)			Fruit weight (g)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Rose Scented × Rose Scented	78.21 (62.25)	67.35 (55.16)	72.78 (58.66)	12.39 (20.56)	13.84 (21.73)	13.11 (21.22)	19.72	20.35	20.03
Rose Scented × Calcuttia	53.57 (47.11)	42.97 (40.95)	48.27 (44.00)	19.51 (26.20)	26.42 (30.75)	22.96 (28.57)	20.71	20.52	20.61
Rose Scented × Early Seedless	56.53 (48.82)	53.05 (46.75)	54.79 (47.75)	25.93 (30.50)	23.44 (28.80)	24.68 (29.78)	21.15	20.92	21.03
Rose Scented × Late Seedless	45.21 (42.23)	46.44 (42.95)	45.82 (42.60)	23.93 (29.26)	23.70 (28.95)	23.81 (29.21)	21.38	21.52	21.45
Rose Scented (Open-pollinated)	58.25 (49.77)	59.79 (50.65)	59.02 (50.20)	21.89 (27.84)	21.19 (27.17)	21.54 (27.65)	20.27	21.05	20.66
Calcuttia × Calcuttia	62.70 (52.36)	56.67 (48.83)	59.68 (50.59)	13.32 (21.29)	10.60 (18.60)	11.96 (20.20)	18.87	17.91	18.39
Calcuttia × Rose Scented	44.11 (41.58)	42.73 (40.81)	43.42 (41.22)	14.93 (22.62)	16.78 (23.74)	15.85 (23.46)	20.19	19.41	19.80
Calcuttia × Early Seedless	44.53 (41.80)	36.92 (37.36)	40.72 (39.64)	13.78 (21.61)	16.17 (23.05)	14.97 (22.75)	20.31	19.57	19.94
Calcuttia × Late Seedless	54.54 (47.62)	42.78 (40.77)	48.66 (44.23)	21.55 (27.62)	24.33 (29.03)	22.94 (28.61)	21.10	19.92	20.51
Calcuttia (Open-pollinated)	60.97 (51.39)	47.38 (43.50)	54.17 (47.42)	19.68 (26.30)	20.44 (26.69)	20.06 (26.61)	20.02	19.31	19.66
Early Seedless × Early Seedless	56.88 (48.95)	58.74 (50.04)	57.81 (49.49)	9.38 (17.52)	7.93 (15.92)	8.65 (17.09)	22.78	22.55	22.66
Early Seedless × Rose Scented	59.37 (50.40)	43.67 (41.36)	51.52 (45.88)	20.90 (27.15)	26.08 (30.51)	23.49 (28.96)	23.83	22.93	23.38
Early Seedless × Calcuttia	36.99 (37.24)	40.12 (39.21)	38.55 (38.38)	17.58 (24.62)	17.55 (23.52)	17.56 (24.78)	23.94	22.90	23.42
Early Seedless × Late Seedless	44.40 (41.65)	41.95 (40.29)	43.17 (41.08)	16.75 (24.14)	21.27 (26.80)	19.01 (25.81)	24.39	23.91	24.15
Early Seedless (Open-pollinated)	58.82 (50.09)	68.74 (56.02)	63.78 (53.04)	19.92 (26.47)	15.50 (23.06)	17.71 (24.85)	24.03	23.29	23.66
Late Seedless × Late Seedless	61.45 (51.62)	68.53 (55.91)	64.99 (53.75)	10.97 (19.09)	12.19 (20.29)	11.58 (19.89)	23.40	21.79	22.59
Late Seedless × Rose Scented	53.51 (47.01)	44.57 (41.88)	49.04 (44.45)	15.59 (23.14)	18.46 (25.29)	17.02 (24.35)	24.52	23.16	23.84
Late Seedless × Calcuttia	50.13 (45.08)	42.26 (40.54)	46.19 (42.81)	15.81 (23.33)	23.79 (29.01)	19.80 (26.31)	24.27	22.89	23.58
Late Seedless × Early Seedless	48.08 (43.90)	54.46 (47.79)	51.27 (45.73)	21.67 (27.67)	17.39 (24.63)	19.53 (26.19)	24.90	23.76	24.33
Late Seedless (Open-pollinated)	52.69 (46.56)	68.43 (55.85)	60.56 (51.18)	19.80 (26.32)	15.63 (23.14)	17.71 (24.85)	24.34	23.61	23.97
CD at 5%	12.68	11.93	12.55	4.44	6.06	5.31	1.15	1.22	0.94

*Figures in parenthesis indicate the angular transformed values.

pollination in 'Wai Chee' litchi cultivar. Degani *et al*. (3) reported that selfed fruitlets abscised at a much higher rate than outcrossed ones, supporting the findings of our study.

The pooled analysis showed the fruits of Late Seedless × Early Seedless gained the largest weight (24.33 g) followed by Early Seedless × Late Seedless (24.15 g), while the minimum fruit weight (18.39 g) was recorded under selfed flowers of Calcuttia × Calcuttia (Table 1). The reduced fruit weight of selfed fruits has been suggested to be due to inbreeding depression (Sedgley and Griffin, 9). The pollen source affects the growth of ovarian tissues with respect to phyto-hormones released by growing endosperm and embryo, which diffuse into the ovarian tissue and exert specific effect on the fruit growth (Shafique *et al*., 10). However, this may also be due to the 'metaxenia' effect. Fruit development is also controlled by phytohormones produced by the developing seed, and it is therefore possible that in inter-cultivar cross pollination, the genetic material derived from the pollen parent could have an influence on fruit and seed size (Sedgley and Griffin, 9). These results agree with the findings of McConchie *et al*. (6) and Xiang *et al*. (13) on litchi who also reported that outcrossed fruits are heavier than selfed ones.

Data pertinent to fruit length presented in Table 2 showed that fruit length of litchi was significantly influenced by different cross combinations. The pooled analysis of data clearly indicated that among all the combinations, cross combination (Late Seedless × Early Seedless) produced the biggest fruits having 3.66 cm length followed by Late Seedless × Calcuttia (3.54 cm), which were statistically *at par* with each other, while the minimum fruit length (2.89 cm) was recorded in selfed flowers, *i.e*., Calcuttia × Calcuttia followed by Calcuttia × Early Seedless (3.00 cm). It is clearly demonstrated from the pooled data that various combinations do not have any significant effect on fruit width of litchi. However, the maximum fruit width (3.00 cm) was recorded in open-pollination (Late Seedless), while the minimum under selfed flowers (Early Seedless × Early Seedless), *i.e*., 2.19 cm. The probable reason for increase in fruit length and width following cross-and open-pollination might be due to successful fertilization and formation of bold seeds. These seeds not only supply auxins and gibberellins in the fruit pedicel but also accelerated the metabolic activity in fruits and other plant parts, which helped in mobilization of carbohydrates, amino acids and other nutrients in preference to their movement to other parts of sink. It was also noted that the pollinizer cultivars with large fruit size, produced the large fruit and *vice-versa*, probably due to the immediate pollen stimulus to the embryo and endosperm, known as 'Xenia' effect which ultimately affected fruit size (Sedgley and Griffin, 9). The current study shows that size of fruit is influenced by pollination and the fruits produced under self-pollination have a lower size. Similar evidences are reported by Rymbai *et al*. (8) in mango and Karimi and Mirdehghan (5) in pomegranate demonstrating that fruit dimension was significantly affected by different pollination sources.

The observations on the peel weight exhibited considerable variation among the different cross combinations (Table 2). The pooled data showed the minimum peel weight (2.33 g) observed in selfed fruits (Calcuttia × Calcuttia) followed by Calcuttia × Rose Scented (2.36 g), while maximum peel weight (5.87 g) was observed in crosses (Early Seedless × Late Seedless) followed by open-pollinated Early Seedless (5.08 g) and Early Seedless × Rose Scented (4.82 g). The probable reason for the increase in peel weight in cross-pollination appeared to be resultant effect of general improvement in fruit weight and size. These results corroborate the earlier records of Karimi and Mirdehghan (5) in pomegranate and Froneman *et al*. (4) in litchi who reported the maximum peel weight under cross-pollination, while the minimum in self-pollination.

The values presented in Table 2, revealed that the aril weight had a significant variation among the different cross combinations. The pooled data showed the highest aril weight (18.66 g) recorded in crosses (Late Seedless × Early Seedless) followed by Late Seedless × Rose Scented (18.53 g), while the lowest aril weight (12.92 g) was estimated under selfed fruits (Calcuttia × Calcuttia). These upshots are in harmony with the earlier finding of McConchie *et al*. (6) and Xiang *et al*. (13) in litchi who also reported the highest aril weight obtained with cross-pollination, whereas the lowest was found under self-pollination.

A glance of the data presented in Table 2 also indicates that the seed weight was significantly influenced by different combinations. The pooled data showed the cross (Calcuttia × Rose Scented) had the maximum seed weight (3.81 g) followed by open pollination (Calcuttia), *i.e*., 3.66 g, which were statistically *at par* with each other, while the minimum seed weight (0.82 g) was observed under selfed fruits (Late Seedless × Late Seedless) followed by open-pollinated Late Seedless (0.86 g) and Late Seedless × Early Seedless (0.88 g). It is known that the pollen parent supplies half of the seed and a third of the endosperm genome. These tissues comprise the main portion of the seed; therefore the pollen parent may have a significant 'xenia' effect on seed characteristics (Stern and Gazit, 11). Earlier, Chu *et*

Table 2. Effect of different cross combinations on fruit length, fruit width, peel weight, aril weight and seed weight of litchi.

Cross combination	Fruit length (cm)			Fruit width (cm)			Peel weight (g)			Aril weight (g)			Seed weight (g)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Rose Scented × Rose Scented	3.00	3.05	3.02	2.62	2.74	2.68	2.32	2.61	2.46	14.40	14.72	14.56	3.00	3.01	3.00
Rose Scented × Calcuttia	3.18	3.14	3.16	2.81	2.35	2.58	2.74	2.17	2.45	14.73	14.86	14.79	3.24	3.49	3.36
Rose Scented × Early Seedless	3.08	3.11	3.09	2.71	2.48	2.59	3.22	2.76	2.99	14.75	15.05	14.90	3.19	3.11	3.15
Rose Scented × Late Seedless	3.22	3.19	3.20	2.79	2.61	2.70	3.44	3.41	3.42	14.69	14.97	14.83	3.24	3.13	3.18
Rose Scented (Open-pollinated)	3.11	3.14	3.12	2.84	2.58	2.71	2.70	2.90	2.80	14.23	14.45	14.34	3.33	3.36	3.34
Calcuttia × Calcuttia	2.95	2.83	2.89	2.23	2.59	2.41	2.70	1.97	2.33	13.05	12.79	12.92	3.12	3.15	3.13
Calcuttia × Rose Scented	3.05	3.10	3.07	2.39	2.31	2.35	2.55	2.18	2.36	13.66	13.26	13.46	3.65	3.97	3.81
Calcuttia × Early Seedless	3.17	2.84	3.00	2.95	2.11	2.53	3.25	2.72	2.98	13.67	13.35	13.51	3.39	3.50	3.44
Calcuttia × Late Seedless	3.09	2.98	3.03	2.77	2.30	2.53	4.00	3.45	3.72	13.66	13.10	13.38	3.44	3.36	3.40
Calcuttia (Open-pollinated)	3.10	2.96	3.03	2.71	2.53	2.62	2.40	2.64	2.52	13.35	12.95	13.15	3.61	3.72	3.66
Early Seedless × Early Seedless	3.19	3.19	3.19	2.17	2.22	2.19	4.25	5.30	4.77	17.54	16.37	16.95	0.95	0.88	0.91
Early Seedless × Rose Scented	3.41	3.23	3.32	3.03	2.58	2.80	4.67	4.97	4.82	17.50	16.64	17.07	1.65	1.32	1.48
Early Seedless × Calcuttia	3.32	3.23	3.27	2.53	3.00	2.76	4.78	4.71	4.74	17.22	16.45	16.83	1.93	1.50	1.71
Early Seedless × Late Seedless	3.31	3.41	3.36	2.88	2.58	2.73	5.40	6.34	5.87	17.57	16.70	17.13	1.45	1.12	1.28
Early Seedless (Open-pollinated)	3.23	3.29	3.26	2.50	2.35	2.42	4.50	5.66	5.08	17.49	16.60	17.04	1.38	1.03	1.20
Late Seedless × Late Seedless	3.13	3.38	3.25	2.93	2.08	2.50	4.25	2.54	3.39	18.33	18.42	18.37	0.81	0.83	0.82
Late Seedless × Rose Scented	3.19	3.38	3.28	2.60	2.84	2.72	4.88	3.95	4.41	18.71	18.35	18.53	0.97	0.87	0.92
Late Seedless × Calcuttia	3.43	3.65	3.54	2.97	3.00	2.98	4.69	3.80	4.24	18.44	18.18	18.31	1.13	0.91	1.02
Late Seedless × Early Seedless	3.63	3.70	3.66	2.57	2.68	2.62	5.29	4.26	4.77	18.69	18.64	18.66	0.91	0.85	0.88
Late Seedless (Open-pollinated)	3.44	3.35	3.39	3.14	2.86	3.00	4.92	4.47	4.69	18.54	18.29	18.41	0.88	0.85	0.86
CD at 5%	0.29	0.33	0.21	0.29	0.27	NS	1.24	1.09	1.09	0.71	1.42	0.66	0.40	0.06	0.29

al. (2) reported the outcrossing markedly increased seed weight and decreased the percentage of shriveled seed of '73-S-20' cv. of litchi. Degani *et al*. (3) also reported that the fruits resulting from cross-pollination are heavier and contained heavier seeds than selfed ones. Stern *et al*. (12) reported that seeds from self-pollinated flowers are more likely to abort than seeds from cross-pollination. The seed weight of fruit is of considerable horticultural and economic importance. The results of this study show that while cross-pollination has the advantage of increasing fruit weight, this advantage is partially negated when seed weight percentage is taken into account. From the present studies, it was concluded that the inclusion of pollenizers in litchi orchards may have beneficial effects on fruit retention and yield of quality fruits.

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Received : December, 2015; Revised : May, 2016;
Accepted : May, 2016