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Spray pollination: An efficient and labour saving method for kiwifruit (*Actinidia deliciosa* A. Chev.) production

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Abstract

Artificial pollination using liquid pollen extenders is a labour saving method as well as it also increases the efficiency of pollination. An attempt was made to develop effective and relatively cheap pollen extenders for spray pollination and also to compare different pollination methods. Different liquid pollen extenders containing basal sucrose solution (BSS) (0.2M sucrose) plus 0.1% agar/0.01% gelrite/0.9% sago powder/1.4% arrowroot powder/1.0% gelatin/0.005% gum *Acacia* were evaluated for spray pollination. Quantity of pollen used in all these extenders was 0.25 g per 50 mL of extender. Maximum fruit set (89.63%) and A-grade fruits weighing > 80g (10.22%) were recorded in BSS + 1.4% arrowroot powder. Positive correlations were observed between fruit weight x fruit length (r=0.882), fruit weight x fruit diameter (r =0.852) and fruit weight x number of seeds/fruit (r=0.980). Regression equations showing relationships between fruit weight, fruit length, fruit diameter and number of seeds/fruit were computed and were found to be highly reliable. Spray pollination using automizer was observed to be more than two times efficient as compared to hand pollination. The pollination efficiency would further be improved using pressure sprayers and/or tractor mounted sprayers.

Key words: Artificial pollination, liquid pollen extenders, kiwifruit, agar, gelatin, arrowroot powder, sago powder, gum *Acacia*, fruit set, fruit weight

Introduction

Kiwifruit is a dioecious plant, with pistillate and staminate flowers occurring on the separate plants (Ferguson, 1990). In male plants, the anthers are functional but they lack functional ovaries. The opposite is true for the female plants. Therefore, the flowers must be pollinated by external means. Moreover, the kiwifruit market is highly demanding for fruit quality. The fruits weighing over 80g are marketable and acceptable for export purposes. Fruit weight is highly dependent on seed number (Pyke and Alspach, 1986) which is further dependent on adequate pollination, an important aspect in kiwifruit production. A well pollinated kiwifruit weighing more than 90 g contains about 1000-1400 seeds (Hopping, 1976; Hopping and Jerram, 1980; Howpage *et al.,* 2001). Therefore, for producing kiwifruits of optimum size and weight, proper proportion of pollinizers and sufficient number of vector insects are required (Spinelli and Colangeli, 2003).

Unfavourable environmental conditions at blossom time and inadequacy of pollinating insects result in pollination deficits that lead to low productivity and reduced quality of fruits. Conventionally natural or hand pollination is employed for commercial kiwifruit production. The success of hand pollination also depends on the environmental factors and is labour intensive. On the other hand, artificial pollination employing various means such as sprayers and dusters guarantees an effective pollination in crops like kiwifruit and lessens the uncertainty arising from natural pollination. Application of pollen in suspension using sprayers is easy, fast and can be mechanized (Holcroft and Allan, 1994) in kiwifruit. Therefore, the present study was aimed at (a) to develop an effective and cheap pollen extender for spray pollination and (b) to compare different pollination methods on fruit production parameters in kiwifruit.

Materials and methods

Plant material: Experiments were performed during 2010-2011 on kiwifruit cultivar Allison in 26 year old experimental orchard at Nauni, District Solan (Himachal Pradesh) situated at 30° 50' North and 77° 11' 30" East. The location is 1260 m above mean sea level and receives annual precipitation of 1000-1300 mm, with most rainfall occurring from June-September. The vines were spaced at 4 x 6 m and trained on standard T-bar trellis system. Male vines of cultivar Allison (male) were uniformly distributed in the orchard in the ratio of 1:9 with female vines of cultivar Allison (female). Male flower buds were collected before anthesis in early morning (before 0800 hrs) and kept under incandescent table lamp for 12-18 hrs. The pollen were separated by fine brush and collected after sieving. Freshly harvested pollen were used in the study.

Pollen extenders: Six different pollen extenders were developed by using thickening agents *viz.*, agar, gelrite, arrowroot powder, sago powder, gelatin and gum *Acacia*. The 0.2 M basal sucrose solution (BSS) as described by Yano *et al.* (2007) was used in combination with different thickners. Matsumoto *et al.* (2007) and Yano *et al.* (2007) used liquid pollen extender consisting of 0.1% agar. Generally, 0.8-1.0% agar is used for solidification in tissue culture (Dodds and Roberts, 1985). Thus, the concentration of agar used by Matsumoto *et al.* (2007) and Yano *et al.* (2007) was 1/10th of the concentration of agar needed for solidification. Based on this information, solidifying concentrations of other thickening agents were determined through solidification experiment. In case of gum *Acacia*, the same concentration of 0.005% as reported by Hopping and Simpson (1982) was used. Liquid pollen extenders containing basal sucrose solution (0.2 M sucrose) plus 0.1% agar / 0.01% gelrite / 0.9% sago powder/ 1.4% arrowroot powder / 1.0% gelatin / 0.005% gum *Acacia* were prepared for spray pollination.

Pollination: Three pollination methods *viz.*, natural pollination, hand pollination and spray pollination using liquid extenders were compared in the present investigation. There were 10 treatments with 3 replications in each treatment. In each replication 38 to 97 flowers were pollinated.

Natural pollination*:* The female flowers were left unbagged and natural pollination through honeybees and wind was allowed.

Hand pollination: In case of hand pollination, the female flowers before anthesis were covered with butter paper bags. At anthesis, when the stigma was receptive, bags were removed and flowers were pollinated with extracted pollen, using fine brush and then re-bagged. After fruit set, bags were removed.

Spray pollination: In spray pollination, female flowers before anthesis were covered with butter paper bags. At anthesis when the stigma was receptive, bags were removed and flowers were pollinated with pollen suspended in different liquid extenders using fine automizer (Fig.1). Liquid extenders were prepared by mixing pre-determined quantities of different thickening agents in 0.2M basal sucrose solution, boiling and adjusting pH to 5.6 after cooling. After adjusting pH, the liquid extenders were filtered through 0.12mm mesh and 0.25g freshly harvested pollen were mixed in 50 mL of extender solution. After pollination, the flowers were re-bagged and after fruit set, bags were removed.

Percentage fruit set and percent yield of different grade fruits were recorded in different treatments. The fruits harvested were categorized into 3 grades on the basis of weight: A-grade (>80g), B-grade (50-80g) and C-grade (<50g). Fruit weight, fruit size, number of seeds per fruit and correlations and regressions between fruit weight and numbers of seeds were computed. Statistical analyses were carried out using M-Stat.

Results

Efficiency of spray pollination: Results obtained in present study indicated that spray pollination (pollination of 56.7 flowers in 10 seconds) was more than two times efficient as compared to hand pollination (pollination of 25 flowers in 10 seconds) (Table 1).

Effect of spray pollination on fruit set and percent grade-wise yield: Fruit set was recorded in 3rd week after pollination. Maximum fruit set (89.63%) was recorded in treatment BSS + 1.4% arrowroot powder followed by hand pollination (85.07%) (Table 2). At maturity (≈ 6 months after pollination), 1295 fruits (95 to 159 in each treatment) were scored and categorized in different grades. Maximum A-grade fruits were recorded in treatment BSS + 1.4% arrowroot powder (10.22%), whereas, no A-grade fruit was obtained in natural pollination. Maximum B-grade fruits were recorded in hand pollination (49.48%) followed by BSS + 1.4% arrowroot powder (42.52%) (Table 3).

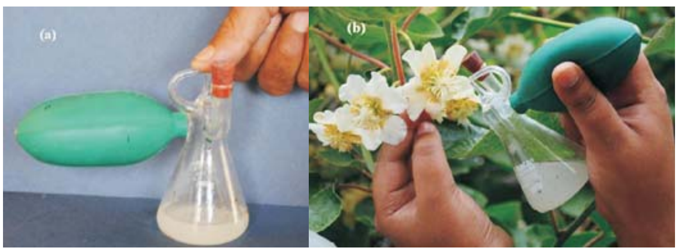

Fig. 1. Pollination using automizer (a) automizer filled with pollen containing liquid extender and (b) spray pollination with automizer.

Table 1. Comparision of spray pollination over hand pollination

Attempt number	Number of flowers pollinated in 10 seconds	
	Hand pollination	Spray pollination
1	20	62
2	28	60
3	25	50
4	25	50
5	27	60
6	22	59
7	26	53
8	25	55
9	28	60
10	24	58
Mean	25	56.7
SEd	0.80	1.39

Relationship among fruit weight, fruit length, fruit diameter and number of seeds per fruit: Correlation and regression among fruit weight (g), fruit length (mm), fruit diameter (mm) and number of seeds per fruit were calculated. Correlations and regression equations were computed for dependent variable (fruit weight) with independent variables (fruit length, fruit diameter and number of seeds per fruit) (Table 4). Correlation coefficients between these fruit attributes were significantly positive with strongest correlation of +0.98 between fruit weight and number of seeds per fruit. Predictive fruit weights were computed based on regression equations with independent variables *viz.*, fruit length, fruit diameter and number of seeds per fruit. Means of

Table 2. Effect of different pollination methods on the fruit set of kiwifruit cv Allison

Treatment	Number of flowers pollinated	Fruit set (%)
T-1 Natural pollination	249	84.55ab
T-2 Hand pollination	176	85.07ab
T-3 Pollen in distilled water	203	73.32c
T-4 Spray pollination: pollen in 0.2M Basal sucrose solution (BSS)	211	84.73ab
T-5 Spray pollination: pollen in BSS+0.1% agar	189	80.55bc
T-6 Spray pollination: pollen in BSS+0.01% gelrite	217	80.18bc
T-7 Spray pollination: pollen in BSS+1.4% arrowroot powder	187	89.63a
T-8 Spray pollination: pollen in BSS+0.9% sago powder	181	83.95ab
T-9 Spray pollination: pollen in BSS+1.0% gelatin	147	77.71bc
T-10 Spray pollination: pollen in BSS+0.005% gum *Acaia*	163	75.42c
LSD (P=0.05)		7.55

Means followed by same letter(s) are not significantly different (P=0.05)

Table 3. Effect of different pollination methods on the percent yield of different grades in kiwifruit cv Allison

Treatment	Number of fruits scored in 3 replications	Fruit under different grades (%)			Average fruit weight (g)
		A-Grade (> 80g)	B-Grade (50-80g)	C-Grade (< 50g)	
T-1: Natural pollination	159	0.00 c	40.85 ab	59.15 bcd	37.37 de
T-2: Hand pollination	142	4.14b	49.48a	46.37 d	46.60 ab
T-3: Pollen in distill water	112	0.83 c	30.00 bcd	69.16 ab	34.40 e
T-4 Spray pollination: pollen in 0.2M Basal sucrose solution (BSS)	144	4.86 b	25.69 cd	69.45 ab	48.40 ab
T-5: Spray pollination: pollen in BSS +0.1% agar	128	7.90 a	31.08 bc	61.02 bc	45.63 abc
T-6: Spray pollination: pollen in BSS + 0.01% gelrite	144	2.10 bc	17.42 d	81.10 a	38.40 cde
T-7: Spray pollination: pollen in BSS + 1.4% Arrowroot powder	136	10.22 a	42.52 ab	47.26 cd	53.07 a
T-8: Spray pollination: pollen in BSS + 0.9% Sago powder	124	4.13 b	32.77 bc	63.10 b	53.20 a
T-9: Spray pollination: pollen in BSS + 1.0% Gelatin	95	2.41 bc	29.19 bcd	68.40 ab	44.77 bcd
T-10: Spray pollination: pollen in BSS + 0.005% Gum *Acacia*	111	4.41 b	40.37 ab	55.21 bcd	46.77 ab
CV %		42.30	20.71	12.25	9.48
SEd		1.42	5.74	6.20	3.47
LSD (*P*=0.05)		2.97	12.06	13.04	7.30

Means followed by same letter(s) are not significantly different (*P*=0.05)

Table 4. Relationships between fruit weight (dependent variable Y) and independent (X) variables fruit length, fruit diameter and number of seeds per fruit.

Dependent variable (Y)	Independent variable (X)	Correlation coefficient (r)	Regression equation (Y = a + b X)
Fruit weight (g)	Length (mm)	0.882*	Y= - 75.03+2.35X
Fruit weight (g)	Diameter (mm)	0.852*	Y= - 87.42+3.548X
Fruit weight (g)	Number of seeds	0.980*	Y= 7.53+0.086X

*Significant at *P*=0.01

these predictive fruit weights were similar to means of actual fruit weight and they were statistically insignificant (Table 5).

Discussion

The results of the present study clearly indicate that spray pollination using automizer was two times more efficient than hand pollination (Table 1). This is in agreement with the findings of Yano *et al.* (2007) on kiwifruit. They showed that the time required for hand pollination was 135 seconds/4 m^2 as against only 65 seconds/4 m^2 by spray pollination using liquid extenders. Thus, spray pollination is indeed a time- and labor-saving technology for commercial cultivation of kiwifruit.

Gonzalez *et al.* (1998) studied hand, mechanical and natural pollination in kiwifruit and observed that percent fruit-set was comparable in all methods. A similar pattern was observed in present research, where statistically non-significant fruit-set was recorded in BSS + 1.4% arrowroot powder (89.63%), hand pollination (85.07%) and natural pollination (84.55%). Highest fruit-set in liquid extender containing arrowroot powder may perhaps be due to the presence of various nutritional components (carbohydrates, proteins, vitamins, minerals *etc*) in it. Minimum fruit-set of 73.32% in distilled water is in accordance with the findings of Hopping and Jerram (1980) and Hopping and Simpson (1982), who reported that pollen suspended directly in water loses its viability due to osmotic shock.

The data on percent fruits in different grades reveal that maximum A-grade fruits were obtained in BSS + 1.4% arrowroot powder, B-grade fruits in hand pollination and C-grade fruits in BSS + 0.01% gelrite (Table 3). In general, spray pollinations with different pollen extenders exhibited better fruit-set and produced large sized fruits as compared to natural pollination and pollination with distilled water. This can be attributed to better distribution of pollen on all the stigmas of the female flower as postulated by Blanchet *et al.* (1991). Increase in average fruit weight after spray pollination (except in distilled water treatment) and hand pollination observed in this study indicated the adequacy of pollen transfer through these methods to ensure maximal fruit size. The trends of our results on percentage of fruits in different grades are similar to those of Gonzalez *et al.* (1998), who studied effect of different pollination methods (hand, mechanical and natural pollination) on number of fruits in different grades in cv. Hayward. They observed that number of fruits in extra category (> 110g) were higher in hand pollination (45%) and mechanical pollination (25%) as compared to natural pollination (15%). On the contrary, we recorded lower proportion of A-grade fruits in all the treatments. This discrepancy can be attributed to the genotypic and environmental differences between the studies.

There are many reports indicating that number of seeds/fruit is positively correlated with fruit weight. Hopping (1976) advocated that adequate pollination to increase number of seeds per fruit is important in kiwifruit for production of export quality kiwifruits. Pyke and Alspach (1986) observed that fruit weight in kiwifruit depends on seed number which in turn depends on effective pollination. In the present study we obtained a very strong positive correlation (r = 0.98) between fruit weight and number of seeds/fruit (Table 4 and 5). Positive correlations were also observed between fruit weight X fruit length (r = 0.882) and fruit weight X fruit diameter (r = 0.852).

The study clearly indicates that saving of labour and improving fruit quality in terms of size can be achieved by spray pollination using suitable liquid extender (BSS + 1.4% arrowroot powder). The pollination efficiency can further be improved using pressure sprayers and/or tractor mounted sprayers.

Table 5. Actual and predicted fruit weight computed based on regression equations

Treatment/ Fruit grade	Fruit number	Actual fruit weight (g)	Length (mm)	Diameter (mm)	Number of seeds/ fruit	Predicted fruit weight based on Y= - 75.03+2.35X (X=Fruit length)	Predicted fruit weight based on Y= - 87.42+3.548X (X=Fruit diameter)	Predicted fruit weight based on Y=7.53+0.086X (X=No. of Seeds/fruit)
T-1/B	1	74.00	68.88	41.73	725	86.84	60.64	69.88
T-1/B	2	58.60	60.05	44.99	534	66.09	72.20	53.45
T-1/C	3	36.78	49.41	32.21	389	41.08	26.86	40.98
T-1/C	4	41.57	50.86	35.90	455	44.49	39.95	46.66
T-2/A	5	107.39	75.57	47.67	1120	102.56	81.71	103.85
T-2/A	6	113.10	76.60	47.92	1222	104.98	82.60	112.62
T-2/B	7	60.13	59.31	43.77	566	64.35	67.88	56.21
T-2/B	8	62.51	59.29	46.54	714	64.30	77.70	68.93
T-2/C	9	45.96	54.58	40.01	425	53.23	54.54	44.08
T-2/C	10	43.25	53.65	38.77	417	51.05	50.14	43.39
T-3/B	11	68.69	53.09	46.13	702	49.73	76.25	67.90
T-3/B	12	56.69	58.04	40.69	538	61.36	56.95	53.80
T-3/C	13	38.35	47.49	37.40	312	36.57	45.28	34.36
T-3/C	14	43.28	52.43	37.91	489	48.18	47.08	49.58
T-4/A	15	82.47	58.92	50.25	917	63.43	90.87	86.39
T-4/A	16	83.17	63.50	45.80	804	74.20	75.08	76.67
T-4/B	17	68.22	58.79	43.86	714	63.13	68.20	68.93
T-4/B	18	61.28	56.07	41.57	569	56.73	60.07	56.46
T-4/C	19	42.56	55.33	36.61	390	55.00	42.47	41.07
T-4/C	20	43.97	50.39	37.72	450	43.39	46.41	46.23
T-5/A	21	84.58	53.11	53.20	800	49.78	101.33	76.33
T-5/A	22	80.00	60.42	43.58	950	66.96	67.20	89.23
T-5/B	23	75.00	56.35	44.53	786	57.39	70.57	75.13
T-5/B	24	68.10	57.17	44.91	702	59.32	71.92	67.90
T-5/C	25	43.90	52.79	39.66	440	49.03	53.29	45.37
T-5/C	26	36.56	47.32	37.10	380	36.17	44.21	40.21
T-6/B	27	66.60	61.97	40.65	686	70.60	56.81	66.53
T-6/B	28	60.00	59.06	43.09	570	63.76	65.46	56.55
T-6/C	29	42.00	49.75	40.19	388	41.88	55.17	40.90
T-6/C	30	37.30	49.44	37.89	326	41.15	47.01	35.57
T-7/A	31	80.10	64.84	50.69	832	77.34	92.43	79.08
T-7/A	32	81.26	67.71	45.04	858	84.09	72.38	81.32
T-7/B	33	73.15	66.43	43.62	755	81.08	67.34	72.46
T-7/B	34	72.26	62.81	43.61	738	72.57	67.31	71.00
T-7/C	35	43.40	52.14	34.31	380	47.50	34.31	40.21
T-7/C	36	40.20	50.33	34.12	408	43.25	33.64	42.62
T-8/A	37	82.26	69.05	45.53	831	87.24	74.12	79.00
T-8/A	38	82.01	64.93	46.37	916	77.56	77.10	86.31
T-8/B	39	52.30	58.03	40.82	568	61.34	57.41	56.38
T-8/B	40	71.38	65.00	42.65	781	77.72	63.90	74.70
T-8/C	41	44.79	49.08	38.88	481	40.31	50.53	48.90
T-8/C	42	41.65	54.88	35.74	407	53.94	39.39	42.53
T-9/A	43	80.00	63.10	44.17	877	73.26	69.30	82.95
T-9/B	44	67.60	59.51	43.68	650	64.82	67.56	63.43
T-9/B	45	67.10	57.48	42.33	683	60.05	62.77	66.27
T-9/C	46	47.48	55.11	38.37	427	54.48	48.72	44.25
T-9/C	47	43.50	49.83	39.78	417	42.07	53.72	43.39
T-10/A	48	87.20	67.63	48.47	836	83.90	84.55	79.43
T-10/A	49	80.19	67.10	44.45	877	82.66	70.29	82.95
T-10/B	50	60.31	59.14	45.69	637	63.95	74.69	62.31
T-10/B	51	57.24	54.53	40.28	540	53.12	55.49	53.97
T-10/C	52	46.77	54.24	37.75	485	52.43	46.52	49.24
T-10/C	53	40.28	49.53	38.01	398	41.37	47.44	41.76
Mean		61.67	57.96	42.01	627.58	61.18	61.64	61.50
Standard deviation		18.71	7.00	4.50	212.62	16.46	15.95	18.29
Standard Error ±		2.57	0.96	0.62	29.21	2.26	2.19	2.51

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