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Influence of bumble bee pollination on quantitative and qualitative parameters of kiwifruit

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ABSTRACT

Bumble bees are the most efficient pollinators not only for the wild plants, but also for pollination services, used in both outdoor and greenhouse horticulture and orchards. In this experiment the influence of the bumble bee (*Bombus haemorrhoidalis* Smith) (Hymenoptera: Apidae) was analyzed and compared to honeybee pollination, hand-pollination, open-pollination and control (crop without pollinators) kiwifruit grown under insect proof nylon cages. Buzz pollination resulted in higher fruit set (79.43%), longer fruits (59.56 mm/fruits), higher fruit breadth (40.58 mm/fruit), heavier fruits (68.14 g/fruit), higher total fruit yield (8.14 kg/vine), higher healthy fruits (94.60%), higher seed number (560.13 seeds/fruit) and test weight (1.67 g/1000 seed) in kiwifruit and accounted an increase of 46.05, 41.53, 37.00, 180, 191.75, 107.33, 25.34 and 57.54 per cent, respectively over control. Only A grade and B grade fruits were yielded in bumble bee pollinated fruit vines. Chemical parameters viz. TSS, TSS/acidity ratio, total sugars, reducing sugars and non-reducing sugars of kiwifruits were also found effected with buzz pollination. In kiwifruit, buzz pollination was observed as better mode of pollination next to hand-pollination. Bumble bee (*B. haemorrhoidalis*) pollination proved superior over control (crop without pollinator), open/natural pollination and equally good (at par) to hand-pollination, with respect to all quantitative as well as qualitative parameters. The preliminary present studies indicate that bumble bee pollination is helpful to enhance the quality and quantity of kiwifruit and will definitely increase farmers' income.

Key words: *Actinidia deliciosa*, *Bombus haemorrhoidalis*, buzz pollination, seed number.

INTRODUCTION

Bumble bees are most efficient and natural pollinators of many agricultural and horticultural crops like tomato, kiwifruit, strawberries, cucumber, watermelon and other crops grown under open as well as protected conditions (Parkar and Torchio, 7). The fruit growers benefited from bumble bee pollination because of low cost of cultivation, increased yield and improved fruit quality. Bumble bees are used as pollinators in both outdoor and greenhouse horticulture and orchards (Wolf and Moritz, 11). Minarro and Twizell (5) reported that honey bees were more abundant and visited more kiwifruit flowers per time but bumble bees were more efficient on a per-visit basis. Kiwifruit belongs to the genus *Actinidia* (Actinidiaceae) and grown in temperate to sub-tropical regions. Potential benefits include a rich source of antioxidants and vitamin C. Kiwifruit require a first-class pollination and for this crop bumble bees are well suited to the pollination. Bumble bee makes more reliable contact with the stigmas (♀) than honey bee. According to observations, on average, bumble bee workers contact 45% of the stigmas and bumble bee queen contact 68% of the stigmas while honey bees contact 25% of the stigmas during one flower visit. The buzz-pollination technique utilized by bumble bees is also more efficient at removing the fresh moist pollen, such as early in the morning when the anther has only recently opened (Anonymous, 1).

Conventionally, natural or hand pollination is employed for commercial kiwifruit production. The success of hand pollination depends on the environmental factors and is labour intensive (Naik, 6). Pomeroy and Fisher (9) observed that fruit weight and seed number increased with increasing bee density in the caged male and female vines of kiwifruit. Bumble bees displayed a greater fidelity towards kiwifruit pollen collection than did honey bees (*A. mellifera* L.). Naik (6) studied the effect of different pollination methods on fruit set, yield and quality of kiwifruit (*A. deliciosa* var. Allison) in kiwi block at Nauni (same experimental area of present studies) and reported the highest per cent fruit set in hand-pollination than naturally pollinated kiwifruit. Yankit *et al*. (12) who reported that bumble bee pollinated fruits contained more number of seeds and heavier weight of 1000 seed as compared to tomato crop without bumble bee pollination. Considering their valuable importance in pollination, it becomes important to focus on them for better and efficient use in rapidly growing horticulture to satisfy the increasing need for crop quality, yield and productivity. In India,

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a very few attempts have been made for evaluating the pollination efficiency of bumble bee to encourage the production of fruit crops. Keeping all this view, the present studies were, therefore under taken to evaluate effect of bumble bee pollination in kiwifruit (a buzz-pollinated species).

MATERIALS AND METHODS

This experiment was conducted in 5 years old kiwifruit orchard of Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) India during 2017. Four cages, each measuring 36 × 8 × 10 ft., were erected over single male and a female vine of Allison cultivar. The cages were covered with insect proof nylon net before flowering. Laboratory reared bumble bee (*B. haemorrhoidalis*) colonies and *Apis mellifera* (4-framed) colony were utilized for pollination of kiwifruit at the time of flowering (5-10%) of the crop. In all there were six treatments, one bumble bee colony (10-12 foragers) was placed in the middle of first cage, second cage with *A. mellifera* (4 framed) colony and third with two bumble bee colonies. The fourth cage was without pollinators (control). The other two treatments were hand pollination and open/ natural pollination. In hand pollination, the vines were bagged with muslin cloth after pollination. Three bloom stages in kiwifruit *viz*. early bloom (20-25%), full bloom (75%) and late bloom (90%). The vines of Allison cultivar were spaced at 4 × 6 m and trained on standard T-bar trellis system. The data were recorded on randomly selected branches for five replications from all treatment cages (one bumble bee colony, *A. mellifera* colony, two bumble bee colonies, control (without pollinators), hand pollination and open pollination) for all the productivity and quality parameters (both physical and chemical parameters) of the kiwifruit crop.

RESULTS AND DISCUSSION

The effect of bumble bee pollination on all the quantitative and qualitative parameters of kiwifruit assessed in this study was statistically at par (equally good) to hand-pollination and superior over control and open pollination. Maximum fruit set (83.20%) was obtained in hand-pollination followed by open pollination (81.67%) and in cage with two bumble bee colonies (79.45%) (Table 1). Hand pollination resulted in maximum number (4.60) of fruits per bearing shoot statistically at par with bumble bee pollination in cage with two bumble bee colonies (4.42) and minimum was recorded in control *i.e*. cage without pollinators (2.71). Similarly, significantly higher number (22.40) of fruits per vine was recorded in cage with two bumble bee colonies as compared to control (12.40 fruits/vine). These findings are in agreement with those of Naik (6) who studied the effect of pollination methods on yield and quality parameters of kiwifruit and reported that fruit set in hand-pollination (85.07%) was statistically at par with natural pollination (84.55%). Further Costa *et al*. (3) reported the highest per cent fruit set in hand-pollination (100%) than bee pollination (98%) and control (81%).

Table 1. Effect of bumble bee pollination on the per cent fruit set, fruit weight and fruit size, number of seeds and 1000 seed weight of kiwifruit cv. Allison.

Treatments	Per cent Fruit set (Mean)	Mean weight of fruits (g)	Mean size of fruits		Mean number of seeds per fruit	Mean 1000 seed weight of fruit
			Length (mm)	Breadth (mm)		
T_1 -Cage with one bumble bee colony	72.31 (58.50)	65.30	57.90	39.66	557.60 (23.63)	1.64 (1.64)
T_2 -Cage with *A. mellifera* colony (4-framed)	74.81 (60.15)	52.15	47.13	33.72	522.53 (22.88)	1.43 (1.43)
T_3 -Cage with two bumble bee colonies	79.45 (63.17)	68.14	59.56	40.58	560.13 (23.69)	1.67 (1.67)
T_4 -Control *i.e.*. cage without pollinators	47.05 (43.25)	24.35	42.08	29.62	356.13 (18.90)	1.06 (1.06)
T_5 -Hand-pollination	83.20 (66.43)	72.05	63.17	43.37	572.53 (23.95)	1.73 (1.73)
T_6 -Open pollination	81.67 (64.72)	42.78	48.73	37.68	486.40 (22.07)	1.33 (1.33)
$CD_{(0.05)}$	7.74	7.30	4.08	3.04	0.30	0.08

In the present studies, days after fruit set to maturity (DAFS) has been found to be less (141 days) in cages with one and two bumble bee colonies compared to hand-pollination (146 days) and control (149 days). This indicated that bumble bee pollinated fruits mature earlier than hand and non-bumble bee pollinated crop. Bumble bee pollination also resulted in improved fruit quality as the percentage of misshapen or crooked fruits was less (5.40%) in bumble bee pollinated vines than control. Similarly the number of healthy fruits was higher in bumble bee pollinated kiwi plants (94.60%) than control (82.25 %). *B. haemorrhoidalis* pollinated vines accounted 107.33 per cent increase in healthy fruits over control vines. Bumble bee pollinated kiwi flowers produced significantly longer (59.56 mm/fruit) and heavier (68.14 g/fruit) fruits having higher breadth (40.58 mm/fruit) than control (Table 1) and resulted in 41.52 & 22.22; 180 & 59.28 and 37.00 & 7.66 per cent increase over control and open pollination, respectively (Fig. 1 to 3). Shahera *et al.* (10) reported the diameter of strawberry fruits significantly superior in bumble bee pollinated plants over control.

The present studies also revealed higher kiwifruit weight and size in cage with two bumble bee colonies as compared to cage with one colony *i.e.* low population of bumble bees (Table 1). These findings are in close agreement with those of Pomeroy and Fisher (9) who reported an increase in the fruit weight of kiwifruit with increasing bumble bee density in different treatments. A noteworthy difference in yield was recorded for bumble bee, open pollination and control treatments. Bee pollination recorded significantly higher (8.14 kg/vine) fruit yield than control (2.79 kg/vine) and open pollination (5.54 kg/vine) (Table 2) and accounted an increase of 191.75 and 46.93 per cent over control and open pollination, respectively. Similarly, Costa *et al.* (3) reported the higher average yield per vine in bumble bee pollinated vines compared to control (without pollinators). Besides higher yield, *B. haemorrhoidalis* pollinated vines inside cage with two bumble bee colonies yielded 86.67% B-grade (50-80g) and 13.33% A-grade (>80g) fruits and kiwi vines with one bee colony produced 100% B-grade fruits while in control 100% C-grade (lowest weight) fruits were obtained. It is evident from present study that pollination by bumble bees produce A and B grade fruits, only (Table 2).

The data recorded on number of seeds per fruit clearly indicate that bumble bee pollination enhanced the number of seeds significantly as compared to control. The number of seeds (560.13 seeds/ fruit) and 1000 seed weight (1.67g) in bumble bee pollinated fruits were significantly at par to hand pollination treatment (572.53 seeds/fruit and 1.73 g/1000 seed, respectively) and higher than control and open pollination (Table 1). In kiwifruit, flowers

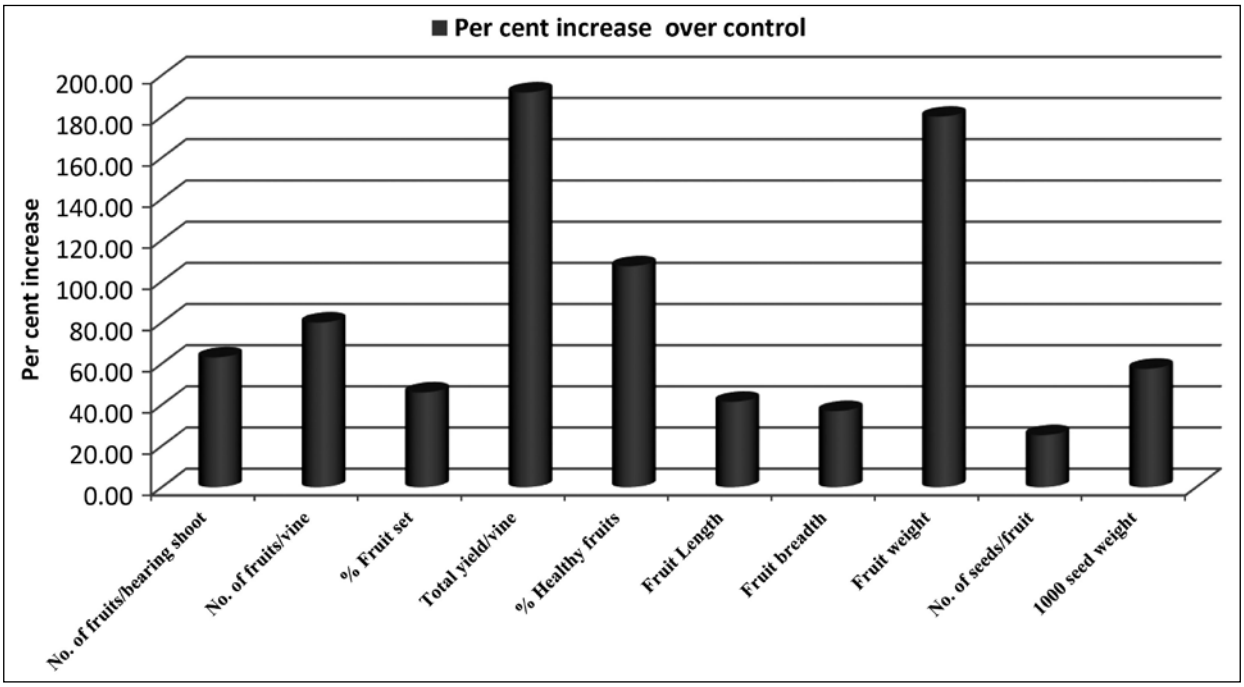

Fig. 1. Per cent increase in physical parameters of kiwifruit with *B. haemorrhoidalis* (bumble bee) pollination over control.

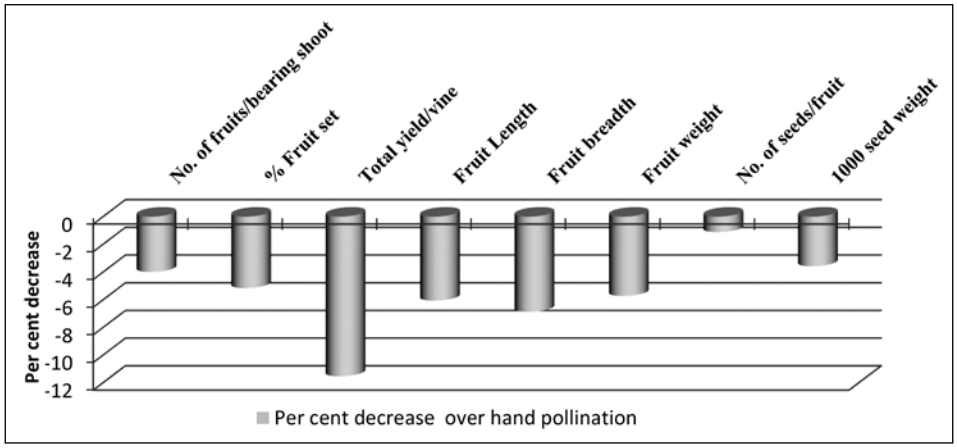

Fig. 2. Per cent decrease in physical parameters of kiwifruit with *B. haemorrhoidalis* (bumble bee) pollination over hand-pollination.

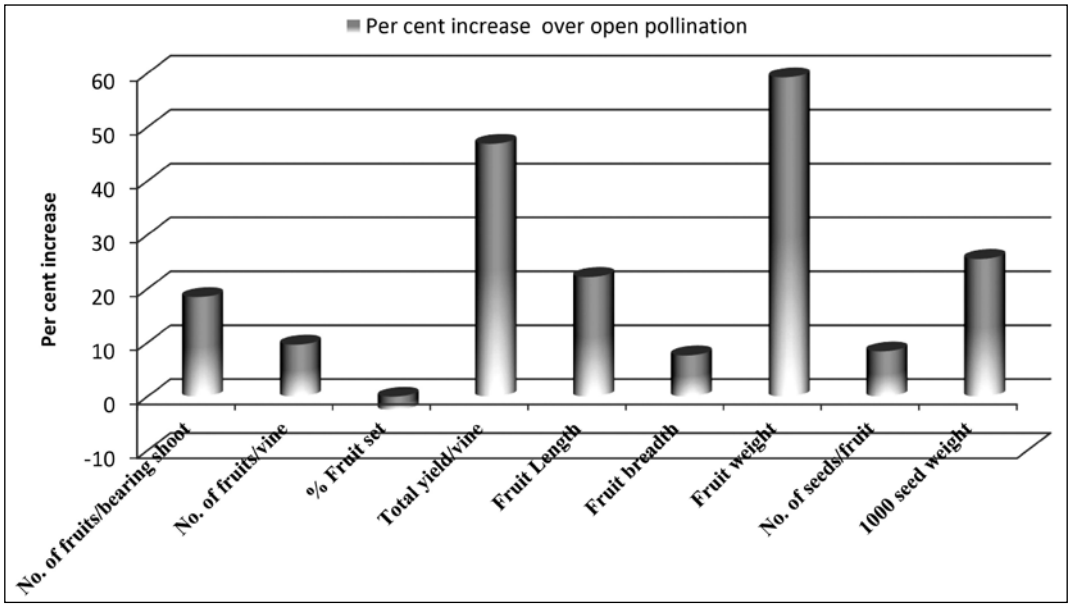

Fig. 3. Per cent increase in quality and production of kiwifruit grown inside cage through *B. haemorrhoidalis* (bumble bee) pollination over open pollination.

Table 2. Effect of bumble bee pollination on the total and graded yield of kiwifruit cv Allison.

Treatments	No. of fruits scored from total vine (5 replications)	Per cent graded yield			Total Yield/vine (kg)
		A-Grade (> 80g)	B-Grade (50-80g)	C-Grade (< 50g)	
T_1 - Cage with one bumble bee colony	97	0.00	100.00	0.00	6.78
T_2 - Cage with *A. mellifera* colony (4- framed)	102	0.00	66.67	33.33	6.22
T_3 - Cage with two bumble bee colonies	112	13.33	86.67	0.00	8.14
T_4 - Control *i.e.* cage without pollinators	62	0.00	0.00	100.00	2.79
T_5 - Hand-pollination	104	86.67	13.33	0.00	9.08
T_6 - Open pollination	107	0.00	26.67	73.33	5.54
$CD_{(0.05)}$		1.16	1.81	0.81	1.93

bloom usually in the morning, accounting for about 77% of total daily flower opening. The bumble bee foraging peaked at morning and evening and thereby facilitate the carryover of viable pollen from pollen-fertile staminate to pollen-sterile pistillate flowers at the right time of blooming. This may be helpful in more number of seed and 1000 seed weight Hongwen (4) recorded in present studies in bee pollination. Similar results were reported by Yankit *et al*. (12) and Chauhan (2) in bumble bee pollinated tomato and cucumber crops, respectively.

In the present investigation, chemical parameters of kiwifruit in bumble bee treatment were found to be better than hand pollinated fruits as higher TSS (11.71%), TSS/acidity ratio (9.55%), total sugar (7.83%), reducing sugars (5.12%) and non-reducing sugars (2.58%) were recorded in *B. haemorrhoidalis* pollinated fruits and accounted an increase of 21.09, 26.65, 41.63, 21.09 and 21.69 per cent, respectively over hand pollination (Table 3). No studies seem to have been carried out in India on effect of bee pollination on the chemical parameters of kiwifruit. However, this kind of study was carried out on strawberry crop by Shahera *et al*. (10) who reported higher sugar content in bumble bee pollinated strawberry fruits (7.8%) than honey bee pollination (7.6%) and minimum in control (7.1%). Similar studies by Paydas *et al*. (8) who reported higher TSS and lowest acidity in bumble bee pollinated strawberries compared to honey bee pollination and control. It may be due to appropriate timing of pollination which is critical for fertilization because pollen viability is affected by flower age. In kiwifruit, the highest pollen germination and viability occurs upto 4-5 days after the male flower opening. It happens mostly during morning hours when semi-opening or just opening of petals of male flower occurs and if pollination coincides with it, the pollen grows faster into stigma with the greatest possibility of fertilization. Therefore, bumble bees are found to be effective pollinators of kiwi bloom. They transfer adequate fresh viable pollens to fertilize the ovules in pistillate flowers within the receptive period and do better and efficient fertilization and pollination. This may be the possible reason for the production of better chemical properties in kiwifruits as compared to control and other treatments. This preliminary studies indicate that *B. haemorrhoidalis* pollination proved superior over control (crop without pollinator) and open/natural pollination with respect to quantitative (number of fruits per bearing shoot, number of fruits per vine, fruit weight, total yield, graded yield, seed number, 1000 seed weight) as well as qualitative (fruit size, healthy fruit, TSS, titratable acidity, TSS/acid ratio, total sugars, reducing sugars, non-reducing sugars) parameters of kiwifruit grown under caged or net conditions. In this investigation, we also observed that bumble bee pollination is as effective as the hand-pollination as the data recorded on bumble bee pollination found equally good or statistically at par to hand pollination for many yield and quality parameters and better for chemical parameters of fruit. Bumble bees pollinated kiwi crop produced large attractive fruits that mature usually faster, thus are of a greater value increasing the profits of kiwifruit growers.

Present studies suggests that bumble bee pollination can be a successful alternative to high cost and high labour input hand pollination and other pollination methods like mechanical shaker or spray or blast pollination used in kiwi. However research pertaining to number of bumble bee colonies required for a particular area of this crop is still to be done.

Table 3. Per cent increase in chemical parameters of kiwifruit with *B. haemorrhoidalis* (bumble bee) pollination over control, hand pollination and open pollination.

Quality parameters	Per cent increase over		
	Control	Hand pollination	Open pollination
TSS	52.87	21.09	29.39
Titratable acidity	9.83*	4.91*	8.19*
TSS/acidity ratio	67.54	26.65	39.01
Total sugars	8.12	41.63	16.04
Reducing sugars	43.94	21.09	31.78
Non- reducing sugars	52.66	21.69	43.21

*Reduction in titratable acidity

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