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Impact of bumble bee pollination on bio-chemical parameters of strawberry

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Abstract
Bumblebees are found to be most efficient and reliable pollinators for protected crop as they work well under adverse conditions of weather, possess long tongues, have capacity to forage at low light intensities and temperatures. Most strawberry varieties are self-compatible and stigmas become receptive before the anthers of the same flower release pollen, so that allogamy can take place. To ensure complete pollination, pollen grains must be delivered to each female part of the flower individually. Smaller or deformed berries might result from incomplete pollination in each pistil, resulting in a lower yield of marketable fruit. The flower produces nectar at the base of stamens which are suitable for bumblebees as they have long tongues. In this experiment bumblebees were used for pollinating strawberry crop under protected condition. Bio-chemical parameters of strawberry were recorded for bumblebee pollination which were found to be better as compared to control as higher TSS (11.32%), TSS/acidity ratio (23.26%), total sugars (7.60%), reducing sugars (6.26%) and non-reducing sugars (1.38%) were recorded in *B. haemorrhoidalis* pollination and accounted an increase of 16.26, 30.09, 6.18, 07.98 and 8.02 per cent, respectively over control.

Keywords: Strawberry, *Bombus haemorrhoidalis*, pollination, bumblebee, chemical parameters

Introduction
Bumblebees are good pollinators of strawberry and they can be used singly or in combination with honeybees. Several studies illustrated that bumblebees are a thriving alternative to the honeybees in pollination, mainly for the crops planted under greenhouse conditions (Eijnde, 1992) [3]. They are valuable in buzz pollination of crops as they make more reliable contact with stigma than honeybees. (Buchmann, 1983) [1]. They have a distinctive quality of foraging at low temperatures and very low light intensities which make them important pollinators of various crops (Heemert *et al.*, 1990) [4]. Bumblebees are larger, furrier and sturdier than honeybees. Bumblebees are found to be the most effective pollinators not only for the wild plants, but also for pollination services and can be used in outdoor and greenhouse horticulture and orchards (Wolf and Moritz, 2008) [8]. Strawberry (Fragaria x ananasa Duch.) belongs to family Rosaceae and is widely grown for its sweet fleshy fruits. Besides its value for flavour, strawberry also possesses some health benefits.

Strawberry is wide adapted fruit which can be grown in a wide range of geographical areas. Strawberry plants flower in several successive flowering periods within a season, with flowers becoming smaller over time. Most varieties are self-compatible and stigmas become receptive before the anthers of the same flower release pollen, so that allogamy can take place. The flowers are hermaphrodite in structure with five white petals, a ring of 20-25 yellow anthers and 50-200 stigmas and ovules. The flower produces nectar at the base of stamens which are suitable for bumblebees as they have long tongues.

Chagnon *et al.* (1993) [2] reported that commercially grown cultivars of the strawberry (Fragaria x ananassa Duch.), have hermaphrodite flowers which should be pollinated to yield maximum size strawberries. The scarcity of pollinating insects is a main concern today which affects the production of many crops including strawberry so that growers are often obligated to apply plant growth regulators for the enhancement of the fruit set (Zaitoun *et al.* 2006) [10]. Also, low temperatures during winter months could decrease production of viable pollen and result in poor fruit quality.

Materials and Methods

The experiment was performed in the experimental farm of Department of Entomology of Dr. Y.S. Parmar University of Horticulture and Forestry located at Nauni, Solan (Himachal Pradesh) during 2019-2020. Three cages measuring 10 x 8 x 8 ft. made of insect proof nylon net were erected over five beds of strawberry. The experiment was laid out in a Randomized Block Design with four treatments. Laboratory reared bumblebee colony was brought to the field during the month of April and kept inside strawberry cage at the time of 5-10% flowering of the crop i.e., new flush of strawberry flowers in the April month. Strawberry flowering was divided into three periods i.e., first, second and third period of flowering. Bumblebee nesting box was placed in the wooden box and an opening was left using a plastic pipe to be used as entry and exit path of foragers. Bumblebee colonies were fed with 50% sucrose solution and pollen for first few days till they start foraging efficiently on flowers of strawberry. At the same time in the second cage of strawberry, a nucleus hive of A. mellifera (4 framed) was introduced for pollination. Honeybee colonies were also fed with sugar solution during flowering periods of strawberry. The data was recorded on ten randomly selected plants from each treatment cages (cage with bumblebee colony, cage with honeybee colony, cage without pollinators and control) for all the bio-chemical parameters of strawberry. All the biochemical parameters *viz*., TSS, Titratable acidity, TSS/acid ratio and sugars (reducing and non-reducing) were detected using standard procedures.

Calculations

1. Titratable acidity

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{equivalent weight of acid}}{\text{Weight of fruit pulp taken} \times \text{volume of extract taken for estimation}} \text{X100}$$

2. TSS/acid ratio

$$\text{TSS/acid ratio} = \frac{\text{TSS (\%)}}{\text{Titrable acidity (\%)}}$$

3. Sugars

$$\text{Total sugar (\%)} = \frac{\text{*Factor} \times \text{Dilution} \times \text{Dilution}}{\text{Titre value} \times \text{Weight or Volume of sample taken}} \times 100$$

*Factor = 0.05

Results

Bumblebees and honeybees are very good pollinators of strawberry crop and it led to improved quality of berries. Bumblebee (B. *haemorrhoidalis*) pollination proved superior to control (crop without pollinators) with respect to bio-chemical parameters (TSS, acidity, Sugars) of strawberry. Bumblebee pollination also proved equally good (at par) to honeybee pollination in terms of bio-chemical parameters.

Total soluble solids contents in strawberry were recorded statistically at par in cage with B. *haemorrhoidalis* colony (11.32%) with cage having A. mellifera colony (11.15%) and open pollination (10.37%). The lowest TSS was observed in control i.e., cage without pollinators (9.48%).

The titratable acidity of strawberry was found significantly highest in control i.e., cage without pollinators (0.58%) which was statistically at par with titratable acidity in berries produced in open pollination (0.54%), whereas the lowest titratable acidity was recorded in berries produced by B. *haemorrhoidalis* pollination (0.49%) which was statistically at par with the cage having A. mellifera colony (0.52%), open pollination (0.54%). The TSS/acid ratio ranged from 16.26 to 23.26, being the highest in cage with B. *haemorrhoidalis* colony and lowest in berries produced in control i.e., cage without pollinators. The data on effect of pollination of B. *haemorrhoidalis* on TSS, Titratable acidity and TSS/acid ratio of berries of strawberry are presented in Table 1.

The variations for TSS and titratable acidity in present studies maybe due to chemical changes in fruits and differential maturity levels of fruits used for analysis. The present results revealed higher TSS in strawberries with bumblebee pollination as compared to other treatments. Whereas, studies of Paydas *et al.*, 2000 [7] showed higher TSS in strawberry pollinated by bumblebees and lower TSS in honeybee pollinated strawberries cv. Oso Grande. They also reported higher acidity in control berries (0.86%) and honeybee pollinated (0.86%) than bumblebee pollinated (0.76%) strawberries crop cv. Chandler. Nayak, 2018 [5] reported that TSS was greater in bumblebee pollinated kiwifruit plants (11.69%) as compared to open (9.05%) and control (7.67%) plants.

The observations recorded on the effect of B. *haemorrhoidalis* pollination on sugars content of strawberry are presented in Table 2. Total sugar contents were recorded highest in cage with B. *haemorrhoidalis* colony (7.60%) which was statistically at par with cage with A. mellifera colony (7.51%) and open pollination (7.44%). Significantly lowest total sugars were recorded in berries produced in cage with no pollinators i.e., control (7.13%). Maximum reducing sugars were recorded in cage with B. *haemorrhoidalis* colony (6.26%) which was statistically at par with berries produced in cage with A. mellifera colony (6.21%) and with berries produced in open pollination (6.19%). The minimum reducing sugars in strawberries were recorded in control i.e., cage without pollinators (5.76%). Non-reducing sugars were recorded highest in berries produced B. *haemorrhoidalis* pollination (1.38%) which was statistically at par with berries produced by A. mellifera pollination (1.36%) and open pollination (1.32%), whereas lowest percentage of non-reducing sugars were recorded in berries produced in control plot i.e., cage without pollinators (1.27%).

The observations recorded on per cent increase in bio-chemical parameters of strawberry with B. *haemorrhoidalis* pollination over control, open pollination and A. mellifera

pollination are presented in Fig 1. B. *haemorrhoidalis* pollination resulted in an increase of 16.26, 30.09, 6.18, 7.89, 8.02 per cent in bio-chemical parameters of strawberry *viz*. TSS, TSS/ acid ratio, total sugars, reducing sugars, non-reducing sugars, respectively over control. Whereas, 18.36% decrease was recorded in titratable acidity of strawberry fruits through bumblebee pollination over control. Bumblebee pollination accounted for an increase of 8.56, 16.80, 2.10, 1.11, 4.34 per cent in bio-chemical parameters of strawberry *viz*. TSS, TSS/ acid ratio, total sugars, reducing sugars, non-reducing sugars, respectively over open pollination. Whereas, 10.20% decrease was recorded in titratable acidity of strawberry fruits through bumblebee pollination over open pollination. B. *haemorrhoidalis* pollination resulted in an increase of 1.50, 7.00, 1.18, 0.79, 1.44 per cent in bio-chemical parameters of strawberry *viz*. TSS, TSS/ acid ratio, total sugars, reducing sugars, non-reducing sugars, respectively over A. mellifera pollination. Whereas, 6.12% decrease was recorded in titratable acidity of strawberry fruits through bumblebee pollination over A. mellifera pollination.

The variations for sugar content in present studies maybe due to chemical changes in fruits and differential maturity levels of fruits used for analysis. The present findings corroborated by the findings of Zaitoun *et al.* (2006) [10] who reported higher sugar content in strawberries pollinated by the bumblebees (7.8%) than honeybee pollinated (7.1%). Nayak *et al.* (2019) [6] observed higher sugar content (7.81%) in kiwifruit pollinated by bumblebee, B. *haemorrhoidalis* than honeybee pollinated (6.94%), open pollinated (6.05%) and control (5.13%). The results of the present studies indicate that the bio-chemical parameters in strawberry recorded in bumblebee pollinated plants *viz*. TSS, titratable acidity, TSS/acid ratio and total sugars 'were obtained better over open/natural pollination and control, crop without pollinators. These findings are in close conformity with earlier studies (Paydas *et al.*, 2000; Zaitoun *et al.*, 2006; Yankit *et al.*, 2018; Nayak *et al.*, 2019) [6, 7, 9, 10] which exhibited an increase in yield attributes through bumblebee pollination over control in crops like strawberry, tomato, cucumber under protected conditions. It is apprehended from the present investigation that B. *haemorrhoidalis* pollination provides higher yield of strawberry (cv. Sweet Charlie) as compared to natural pollination and control (strawberry without pollinators) under caged conditions as berries quality was greater for bumblebee pollinated strawberry crop. It should be noted that the pollination experiment did not cover the entire flowering period of strawberry crop which started from 10th January, 2020 to 19th May, 2020 for 130 days. It is possible that bumblebees may become more beneficial if used for whole flowering period of strawberry.

Representation of the results

Table 1: Effect of *B. haemorrhoidalis* pollination on TSS (%), Titratable acidity (%), TSS/acid ratio of strawberry

Treatment	TSS (%)	Titratable acidity (%)	TSS/acid ratio
T_1- Cage with *B. haemorrhoidalis* colony	11.32	0.49	23.26
T_2- Cage with *A. mellifera* colony	11.15	0.52	21.63
T_3- Control i.e., Cage without pollinators	9.48	0.58	16.26
T_4- Open pollination	10.37	0.54	19.35
C.D. (0.05)	0.99	0.05	2.55

Table 2: Effect of *B. haemorrhoidalis* pollination on sugars content of strawberry

Treatment	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1-Cage with *B. haemorrhoidalis* colony	7.60	6.26	1.38
T_2-Cage with *A. mellifera* colony	7.51	6.21	1.36
T_3-Cage without pollinators (control)	7.13	5.76	1.27
T_4-Open pollination	7.44	6.19	1.32
C.D. (0.05)	0.30	0.32	0.06

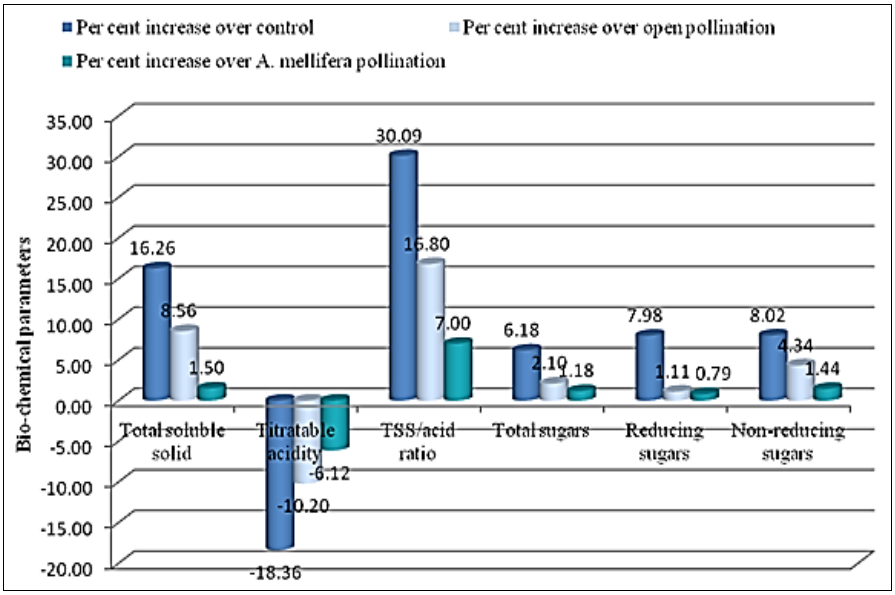

Fig 1: Per cent increase/decrease in bio-chemical parameters of strawberry with *B. haemorrhoidalis* pollination over control, open pollination and *A. mellifera* pollination

Conclusion

Bio-chemical parameters of strawberry with bumblebee pollination were found to be better as compared to control as higher TSS (11.32%), TSS/acidity ratio (23.26%), total sugars (7.60%), reducing sugars (6.26%) and non-reducing sugars (1.38%) were recorded in B. *haemorrhoidalis* pollination and accounted an increase of 16.26, 30.09, 6.18, 07.98 and 8.02 per cent, respectively over control.

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