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Comparative study on the pollination of strawberry by bumble bees and honeybees under plastic house conditions in Jordan valley

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Abstract

This experiment was conducted in commercial farm located in the Jordan Valley during the growing season 2003/2004. Three plastic houses cultivated with strawberry, Camaroza cultivar, were used for this study. In the first and second plastic house a hive of honeybees and bumble bees was introduced at the blooming stage of plants, respectively, whereas the third plastic house remained without bees. Results indicated that both species of pollinating bees induced a significant increase in the number of berries produced by strawberry plant. Honeybees were most efficient in pollination where the fruit set was in excess of twice compared to the control plants. Bumble bees ranked in the second place causing 60% fruit formation over the control. Around fourth of the berries produced by control plants was misshapen, whereas the proportions of malformed berries did not exceed 13.3% and 6% on plants pollinated by bumble bees and honeybees, respectively. Release of the bees in the plastic houses increased also significantly the yield weight up to 29.6% in comparison with control as the total yield of plants pollinated by bumble bees was leading. Size and length of strawberry berries were greater by plants pollinated by bumble bees than other treatments.

Key words: Pollination, strawberry, bumble bees, honeybees, Jordan valley.

Introduction

In 2002, the total cultivated area in Jordan was estimated by 2,605.9 thousand dunum, 28.8% out of them is under drip irrigation. Approximately 66% of the irrigated lands lay in the Jordan Valley [1]. This province is located 420 meter under sea level and has got a subtropical climate with a warm winter enabling the cultivation of several vegetables during winter season. Nowadays, it is considered as a major basket for the production of a variety of vegetables under field and plastic house conditions, as well as production of citrus.

In recent years farmers in Jordan have started cultivating strawberry in different territories for the local and global market as it is one of the high payoff fruit crops. During the winter season, strawberry is grown in the Jordan Valley predominantly under plastic house conditions, since this crop is vulnerable to the low temperature. For this period of time, production of strawberry is unfeasible else where neither in Jordan or in most other countries. However, the scarcity of pollinating insects is todays chief concern encountering the production of a number of protected crops including strawberry so that growers are often obligated to apply plant growth regulators for the enhancement of fruit set. Low temperatures prevailing during the winter months, particularly at the time of blossoming, could also induce a decrease in the production of viable pollen and as a result turn down the fruit set [2].

Commercial cultivars of strawberry have got hermaphroditic flowers, which are required to be pollinated by combined actions of the gravity and wind to generate maximum fruit size. Scientific reports available from different countries show that yield, size and shape of strawberry fruit depends upon the adequate pollination of its flowers by different insects [3-4]. Connor [5] and Point *et al.* [6] declared that the pollination rate of strawberry flowers rarely exceeds 60% in the absence of insects and thus fruit production is lessening [7]. Up to 48.6% of the berries produced by strawberry could be malformed when pollinating insects are not existing [6-8]. It has been reported that strawberry blossoms are called by different species of flies, beetles, thrips, butterflies and bees [9]. Domesticated species of honeybees such as *Apis cerana* and *Apis mellifera* were found to be essential pollinators for strawberry flower [10-11]. In European and South Asian countries, pollination by those bee species enhances the quality and quantity of strawberry fruit [12-13]. Universally the trend moves currently towards the utilization of honeybees and bumble bees for pollination of plentiful crops in the field and under greenhouse conditions [14-15]. Numerous studies illustrated that bumble bees are a thriving alternative to the honeybees in pollination, principally for the crops planted under greenhouse conditions [14-19], as they do not appear to become as easily disoriented as honeybees [12].

However, since very little work has been done on the insect pollination of agricultural crops, including strawberry in the country generally and in the Jordan Valley in particular, therefore, we studied the impact of honeybees and bumble bees on the

quantity and yield of strawberry fruit under the agro ecological conditions of the Jordan Valley of Jordan.

Materials and Methods

This experiment was conducted in a commercial farm located in Ghor Al-Safi, Jordan Valley, during the growing seasons 2004 and 2005. Three plastic houses, each occupying an area of 500 m^2 were designated for this study. On October 5, 2004, seedlings of the strawberry (*Fragaria ananassa* var. Camaroza) were transplanted on seven raised beds running along each plastic house. Each bed consists of double rows with alternatively plants at a plant to plant distance of 40 cm and inter row spacing of about 1 m. Experimental plants in all plastic houses received the same agricultural practices needed.

When strawberry started blooming, a medium-sized langstroth colony of *Apis mellifera* having 10 frames covered with bees and free of any sign of disease was placed in the first plastic house. Simultaneously, a colony of bumble bees inhabited by 80 workers was positioned in the second plastic house, while the third one remained without bees and served as control. Both pollinating insects were kept in the plastic houses throughout the flowering period of the plants, which extended from December to March.

To determine the effectiveness of both bee species on the productivity and feature of produced berries, three raised beds, each measured seven meter in the length, were randomly selected in each plastic house. At start of blossoming time, 10 strawberry plants were chosen at random in each bed (total 30 plants for each treatment), and one newly formed flower cluster (achens) per selected plant was marked. Similar procedures were done by an indiscriminately selection of other new flower cluster at the same rate at the middle and last flowering time. Then, developmental progression for every flower cluster selected at each time was checked at one week intervals till the fruits mature and the fruit set was calculated. After ripening, the berries from control, honeybee-pollinated, and bumblebee-pollinated plants were picked up. Berries from each treatment were counted and weighed. Number of well-formed (perfect) as well as misshapen berries from each treatment were also counted. Changes in the quality and quantity of berries as a result of bee-pollination were assessed by comparison of the counts of number of berries, weight and length of berries, volume and diameter of entity berries, as well as the percent of misshapen berries per flower cluster. Total sugar content of the fruit was also assessed by the refractometer according to the procedure described by Cruden and Hermann [20]. Data were subjected analyzed statistically using analysis of variance. Means were compared using Fisher's least significant differences test at a 0.05 probability level.

Results

The effects of honeybee and bumble bee pollination on the yield of berries are summarized in Table 1. Introduction of both bee species each into a plastic house enhanced considerably the fruit set of strawberry. There were significant differences in the amount of berries formed by individual flower cluster between treatments. The maximum number of fruits (9.47 per achen) was recorded by plants pollinated by honeybees, whereas in the plastic house containing bumble bees, a single flower cluster produced only 7.5 fruits. Plants without pollinating insects (control) were less productive, generating only 4.5 berries from a single flower cluster. Bee trip to the strawberry blossoms improved also total yield of the fruits. Berry weight was recorded to augment appreciably by 42% and 21.3% by plants pollinated by the bumble bees and honeybees, respectively in comparison with control plants (Table 1). Pollination influenced also the quality of produced berries as the quantity of perfect and malformed fruits fluctuated noticeably within each treatment (Table 2). Proportions of the correctly fashioned fruits constituted 94%, 86.7% and 73.3% of the total berries produced on the basis of an individual flower cluster by plants pollinated by honeybees, bumble bees, or without pollinator (control), respectively. Pollination methods have also an apparent effect on other external morphological spirits of produced berries. Diameter of the fruits formed by control plants was 24.5% significantly inferior than that produced from strawberry pollinated by bumble bees, but it did not differ obviously from the plants pollinated by honeybees (Table 3). The same tendency, but at different level, was observed in the length and volume of fruits. Bumble bees increased substantial difference in this parameter between both bee-pollinated treatments (Table 3). The fruit volume of control plants was although significantly reduced by 28.7% when compared to strawberry pollinated by bumble bees. However, no conspicuous differences in sugar content were detected in the fruits of different treatments (Table3).

Table 1. Effect of honeybees and bumble bees on strawberry fruit set, fruit weight under plastic house conditions in the Jordan Valley during the growing season 2003/2004.

Treatment	No. of fruits/achen	% increase over control	Total fruit weight (g) /achen	% increase over control
Control	4.5	-	17.4	-
Bumble bee- pollinated	7.5	66.7	24.7	42.0
Honeybees-pollinated	9.47	110.4	21.1	21.3
LSD (0.05)	1.9		3.3	

Table 2. Effect of honeybees and bumble bees on the proportion of well-formed and misshapen fruits of strawberry under plastic house conditions in the Jordan Valley during the winter and spring seasons 2003/2004.

Treatment	No. of normal fruits/achen	No. of malformed fruits/achen	% misshapen fruit
Control (without pollinator)	3.3	1.2	26.7
Bumble bee-pollinated	6.5	1.0	13.3
Honeybee-pollinated	8.9	0.57	6.0
LSD (0.05)	1.5	0.57	

Table 3. Length, size and sugar content of strawberry fruits grown under plastic house conditions in the Jordan Valley during winter and spring seasons 2003/2004 as affected by pollination by honeybees and bumble bees.

Treatment	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cm^3)	Sugar content (%)
Plants without pollinator	3.6 a	3.1 a	192.1 a	7.1 a
Plants with bumble bees	4.2 b	4.1 b	269.3 b	7.8 a
Plants with honeybees	3.9 ab	3.7 ab	227.9 ab	7.6 a
LSD (0.05)	0.31	0.87	57.5	0.9

Discussion

The combined actions of the gravity and wind are accountable for the pollination of commercial cultivars of strawberry, but to achieve high fruit quantity and quality, the use of domesticated honeybees as well as other natural insect pollinators is necessary. As a result of the intense use of pesticides on agricultural crops and loss of habitat quality and quantity, pollinations of the natural insect pollinators are nowadays decreasing rapidly in most cases. Therefore, domesticated honeybees and commercial reared bumble bees stay the most essential plant pollinators, particularly for strawberry, since its flowering period extends up to three months, which suggests that this crop can be a valuable source of nectar and pollen to bee.

Results of the present investigation show that bee pollination enhanced significantly the fruit set of strawberry pollinated by honey bees and bumble bees by 110.4 and 66.7 % and total fruit weight by 21.3% and 42% in comparison to control plants respectively. Increase in the fruit set and fruit weight due to bee pollination could be attributed a greater number of the pollinators in the plastic houses and the superior pollinating efficiency of both bee species. Fruit set in the plastic house without pollinating insects was due to some amount of self pollination which might have occurred by pollen blown from anthers on to the stigmas. Natural insect pollinators, on the other hand, could appear in the plastic house without released bees, but probably because of their lower number and lower pollinating efficiency only fewer flowers were pollinated by such insects. This outcome confirms the previous suggestion of Allen [7] who declared that bee trip to the strawberry blossoms improves the fruit production. Also, honeybees have been reported to be more competent for pollination of strawberry under field conditions than other insect species [19, 21]. Studies carried out in different countries show that *Apis mellifera* pollination increased fruit set by 10-25% and fruit yield by 18-100% depending upon the cultivar and experimental conditions [22-24]. Asian bee, *Apis cerana,* enabled moreover an increase in the fruit set of strawberry by 112.3 and 21.4% and weight per fruit by 47.9 and 20.3% in comparison to control and open-pollinated plants, respectively, under field conditions in Nepal [21].

Honeybees and bumble bees pollination also improve the fruit quality by reducing the percentage of misshapen fruits to 6% and 13.3%, respectively. Also, bee species induced a considerable increase in the fruit size, in particular bumble bees, as indicated by diameter, volume, and length of berry. The occurrence of malformed fruits could be attributed to the fact that strawberry blossom contains many carpel's and in an attempt to generate a perfect fruit all of the ovule in carpel's should be fertilized and produce seeds. Hence, it seems that test bee species manipulated well the flowers and transferred adequate pollen grains to fertilize all the ovules in more flowers, thereby leading to the production of a greater number of well-formed fruits and to the reduction of proportion of malformed fruits compared to the control [21]. Jaycox [25] concluded that about 11-15 bee visits per flower are necessary to fertilize all the ovules, whereas more than 20 visits are needed to increase the mean weight of the fruits [9]. To ensure such great number of insect trips per flower, pollination can be managed through domesticated bee species only. In the literature, it has been already reported that *Apis mellifera* pollination increased the number of large and perfect berries by 7-16 and declined misshapen fruits by 8-41% [8, 10, 26].

In contrast to the results recorded in this investigation, Eijnde [14] cited that bumble bees were more efficient in pollination of strawberry plants under greenhouse conditions as 53% of the developed fruits were perfect, whereas the percentage of those fruits decreased to 22% when honeybees were used as pollinators. In addition, bumble bees have been reported to reduce the sum of distorted fruits of strawberry by zero, while 30-38% of misshapen fruits transpired as a result of the use of honey bees in pollination [27]. However, our study indicated that bumble bee pollination promoted significantly higher fruit weight per plant than honeybees, which confirms data made by Eijnde [14].

Some of the variable responses of strawberry to pollination by honeybees and bumble bees that came into sight in this study and in the literature could due to the environmental conditions, especially weather factors, prevailing during the experiments that impact the foraging activity and behavior of the pollinators. Differences in the attractiveness and reactions of strawberry hybrids tested for bee pollinators, in addition to variation in the abundance of used bees might be a further explanation for these contrary results.

Finally, both bumble bees and honeybees enhanced effectively the fruit set and fruit weight and trimmed down the proportion of asymmetrical fruits under plastic house conditions prevailing during the winter and spring seasons in the Jordan Valley. Bumble bees-pollinated strawberry produced large attractive berries that develop usually faster, thus saving the time of the farmer. Such fruits also are of a greater value increasing the profits of the farmer. In addition to that we hypothesize that bumble bees could be an essential alternative to the honey bees for pollination of the plants grown under plastic house in this distinguished region of the country for several reasons. Bumble bees are skilled to keep on foraging in overcast weather unlike honey bees [28], they do not need to be trained for several days to enter a greenhouse if they are placed outside [29], and they do not appear to become as easily disoriented as honeybees [12].

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