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Efficiency of Different Pollination Treatments on Solanaceae Yields Grown in Plastic House

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Abstract: The experiments were conducted to study the performance of *Bombus terrestris* L. and *Apis mellifera* L. different nuclei as pollinators on quality and quantity of the egg plant, sweet and chili pepper crops grown in plastic house compared with control. Bees showed no problem in visiting flowers at a temperature range between 16 and 36°C during daytime. Two honeybee nuclei pollinated plants produced significantly higher yield than the other treatments. Each section demarcated 15 plants labeled inflorescence; fruit set percentages for eggplant were 66, 59, 52 and 30%, for sweet pepper were 82, 69, 55 and 49% and for chili pepper were 83, 75, 61 and 35%, for the two honeybees nuclei, one honeybees nuclei, bumblebees and control treatments, respectively. The average weight and length of individual fruits collected randomly from the demarcated plant were higher for two honeybee's nuclei, one honeybee's nuclei, bumblebees and control treatments, respectively. Moreover, fruits average number related to the weight showed significant differences among the four treatments, lower fruits number and high weight for two honeybees' nuclei and vice versa for control treatment. In conclusion, treatment of Solanaceous plants with honeybee's nuclei increased fruits quality, quantity and exhibited better appearance.

Key words: Pollination, *Apis mellifera*, eggplant, sweet pepper, chili pepper, *Bombus terrestris*

INTRODUCTION

Eggplant, sweet pepper and chili pepper are important crops in the Mediterranean countries. For many agriculture crops, bees play a vital role as pollinators, which are required for producing 15–30% of the human food supply and farmers rely on managed honeybees throughout the world to provide these services (Greenleaf and Kremen, 2006). Pollinating insects also play a crucial role in maintaining natural plant communities and ensuring production of seeds in the most flowering plants (Isaacs and Tuell, 2007). In Jordan, protected agriculture mainly plastic houses were introduced to produce vegetables in different seasons along the year. Eggplant, sweet and chili pepper breeding and seed production received limited research emphasis in Mediterranean countries. Information is limited on the pollination efficiency of bumble and honeybees on the yield and quality, therefore, efforts should be directed to cultural and varieties' improvement through finding high yielding Solanaceous crops and new seed production technologies. Proper pollination is needed for most greenhouse vegetable flowers to set fruit. Solanaceous crops such as eggplant, sweet and chili pepper flowers are self-pollinating and require insect pollination to set fruits. Multiple pollinator visits increase size, number of seed and the consistency in the shape of the fruits. Many growers introduce honey and bumblebees that are the

most common commercial pollinators in the world. This can be a tremendous labor savings over manual pollination with an electric pollinator. In open fields, the natural pollination agents like insects and wind are available, but in plastic houses, these pollination agents are limited or not available due to completely isolation by covering with plastic sheet covers and net meshes. Inadequate pollination is still a major constraint to the potential yield of eggplant, sweet and chili pepper. To maximize fruit set in different vegetable crops, honeybees and bumblebees are frequently used (Paydas *et al.*, 2000). Jordanian farmers started to plant eggplant, sweet and chili pepper and other vegetable crops under plastic house conditions during cold winter against frost and to gain high prices. Natural pollinators are important for better production in commercial product (Hayo Velthuis and Adriaan van, 2006). Adequate pollination of egg plant, sweet and chili pepper guarantees better fruit quality and higher yields (Bellelli and Quagliotti, 1995). The contribution of honeybees and bumblebees in eggplant, sweet and chili pepper pollination is interdependent relationship. Honeybees and bumblebees visit flowers to obtain significant of pollen to sustain the nutritional needs of the colony (Thorpe, 2000). However, most of Solanaceous plant types lack sufficient nectar, so the honey and bumblebees need to be provided with a sugar solution, which is introduced in the nuclei to increase the pollen collection and pollination by bees.

Therefore, the objectives of the present study were to provide information to farmers on the use of native pollinators and develop protocols to be used by them for integrating native pollinators into farming systems in order to accomplish this objective, direct and indirect effect of pollination with bumble and honeybees on yield and yield component of eggplant, sweet and chili pepper were assessed in the present studies.

MATERIALS AND METHODS

The experiments were carried out between early April until late August in 2004 growing season in uncontrolled plastic house at the Agriculture College Research Station at Mu'tah University/Karak-Jordan. The selected plastic house dimensions were 40 m length, 8 m width and 3 m. in height. The area of the plastic house was divided into four sections, the area of each section was 80 m² equipped with closing apparatus by using fine mesh. Each section was divided into 9 similar longitudinal beds (7.5 m length and 0.5 m width) and 0.55 m inters beds distance. Seed of eggplant, sweet and chili pepper after germination, the young seedlings were transferred to plastic house section nominated for pollination and control, each section was planted with grand total of 225 seedlings, 75 plants from each species, 25 plants in each row planted alternatively, at apart of 30 cm. Space between the plants resulted in planting density of about 7 plants m⁻². The plastic house was drip irrigated with needed water. The mineral nutrient solution containing all the essential elements was provided. For periodic observations, 15 plants from each species were demarcated with iron rod (5 plants per each bed row) in each section, for each plant one inflorescence was labeled to observe flowering, fruits set percentage, fruits number, weight and length. The foraging activity on the nightshade species blooms was determined by observers, who counted bees during there active hours by means of a mechanical counters, activities of foraging bees on the flowering Solanaceous species were observed at weekly interval 6.00-11.00 h. Totally, 6 days for 60 min per day (10 min each hour) totaling 6 h per section (Zaitoun and Vorwohl, 2003). Honey and bumblebee foraging activity and nightshade different varieties blooming intensity was evaluated by counting the number of flowers were recorded weekly during the blooming period, which it approximately similar and not showed differences among the treatments, temperature maintained in the various growth stages of the crops. The obtained data were analyzed by using MSTAT program and mean separation was done by Duncan Multiple Range Test (DMRT) (Steel and Torrie, 1980).

Plant and bee's material

Eggplant flowers structure: The eggplant (*Solanum melongena*) has a perfect flowers with a purple petals and green or purple sepals (Sambandam, 1964), flowers with five lobed corolla and yellow stamen, lack sufficient nectar. The anthers are yellow and sit on short filaments surrounding the style. The cone of stamens surrounding it, with the lowest one in the cluster being the most developed (Aguilar, 2008). The eggplant is a self-fertile and self pollinating plant however, cross-pollination through insects is possible and in many cases desirable. The eggplant doesn't self without the aid of bees or man pollination (Kakizaki, 1931).

Pepper flowers structure: The sweet pepper (*Capsicum annuum* sp.). Flowers have 5-7 petals of the color white, greenish and in some varieties purple. The flowers are self-pollinating, producing plenty of pollen and nectar and lacking any scent in the sweet pepper. Occasionally there are small clusters of flowers. It has five stamens with bluish anthers and a single stigma that may vary from slightly shorter than the anthers to much longer; the corolla is somewhat bell-to wheel-shaped (Smith and Heiser, 1951). The flowers are visited by bees for both the nectar and the pollen (Markus, 1965) and high flower set by bees pollination (Nagarathnam and Rajamani, 1963).

Bumble and honeybee's management: Bumblebees, (*Bombus terrestris* L.) colony housed in a box containing 50-60 worker bees (mainly imported from Europe) with a small opening which allows the bees to enter and exit, were placed in section nominated for bumblebees pollination. The bumblebees are generally regarded as the most important group of insect pollinators (Armstrong, 1979) and also mentioned that the female and male may visit a variety of flowers to gather nectar. It's capable of shaking the flower using the buzz-pollination mechanism, in which it specializes, the nest provided with a sugar-water solution, a substitute to the nectar, which is not always sufficient in Solanaceae plant flowers. Honeybees moved after sunset to avoid losing foraging bees and during flower blooming to provide pollen and nectar, although honeybees mortality was more than usual the number of dead bees per nucleus being collected each day was 20 bees. In addition, honey combs were introduced to the honeybees before placing hives (Al-Abbadi, 2007). Water for bees introduced in stock tank with wooden floats on which they can land, it's important for brood rearing and later for cooling the nuclei. The value of the honeybees as a pollinator is far greater than it is value as a honey producer. For that

reason, three methods of pollination were selected. The first plastic house section provided with bumblebees nest, the second provided with two honeybees nuclei, the third section provided with one honeybees nuclei and the fourth section was left as a control. In most circumstances, honeybees' colony contains three to four combs of brood, queen and bees (Al-Abbadi, 2007). Nuclei's were managed to ensure that the maximum number of bees visit the crops to be pollinated. The bumblebees' nest and honeybee's nuclei placed 1 m above the ground at equidistantly for the two nuclei in a place that is opposite to the sun rise to lead early foraging activities and to encourage the bumble and honeybees to work over the whole section. The bee's flight holes closed during transportation bee's nuclei or nest to the plastic house section and open again after closing the plastic house with fine mesh to prevent bee escaping.

RESULTS

The temperature was monitored at weekly intervals, total of six times during the experiment period, recorded every 1/2 h integral presented in Table 1. The bees visited the flowers from early morning till 11:00 o'clock before temperature increased up to 40°C towards 12:00 o'clock, when the bee's visitation decreased. The foraging activity on the nightshade species blooms data were collected between 6:00 and 11:00 h because the observation showed that after 11:00 o'clock fewer bees

visited the flowers and each bees spent less time at each flower. The average visit per flower recorded at weekly interval (visitation rate) during 10 min at each hour observation period. Visitation rates were high in eggplant and two honeybees nuclei, the average flower received 5.73 visit during hour, which indicates significant effect of the variety flower on the bee activity attractiveness level, high in eggplant, approximate in sweet and chili pepper and the maximum visitation time increased between 9-10 am daily (Table 2).

The effects of three pollination treatments on the labeled inflorescence and their fruits set percentage for the demarcated 15 plants, for each species compared with control treatment. The highest fruits set were obtained by using two honeybee nuclei (66%) compared with one honeybee nuclei (59%), bumblebees (52%) and control (30%) for eggplant, (82%) compared with one honeybees nuclei (69%), bumblebees (55%) and control (49%) for sweet pepper and (83%) compared with one honeybees nuclei (75%), bumblebees (61%) and control (35%) for chili pepper (Table 3). Two honeybees' nuclei pollinated eggplant, sweet and chili pepper flowers produced significantly the highest average fruit weight and yield per plant than other treatment. The lowest average fruits weight and yield per plant were produced from the control treatment. The average fruits weight of eggplant was 85, 68 and 30%. In sweet pepper, these were 90, 35 and 22% and in the chili pepper were 63, 38 and 19% higher than in control plants for two honeybee nuclei, one honeybee nuclei and bumble bees, respectively (Table 4).

Table 1: Weekly interval temperature recorded every 1/2 h in plastic house during experiment period in 2004

Time (am)	Date						Average
	24 June	1 July	7 July	14 July	23 July	1 Aug.	
6:00	13	14	16	16	20	25	17
6:30	15	15	16	17	22	26	19
7:00	17	18	19	19	24	27	21
7:30	18	20	22	24	27	27	23
8:00	20	22	26	27	28	28	25
8:30	21	24	28	29	29	29	27
9:00	22	25	28	30	32	33	28
9:30	23	28	29	34	34	34	30
10:00	27	31	32	36	36	36	33
10:30	28	35	37	37	37	40	36
11:00	39	39	41	41	41	42	41

Table 2: Average bee visitation for the fifteen demarcated plant flowers recorded 10 min each hour at weekly intervals

Time (am)	Treatments								
	Eggplant			Sweet pepper			Chili pepper		
	Two honeybee nuclei	One honeybee nuclei	Bumblebees	Two honeybee nuclei	One honeybees nuclei	Bumblebees	Two honey bee nuclei	One honey bee nuclei	Bumblebees
6:00	3.47a	2.47b	1.00c	2.00a	1.47b	1.47c	2.00a	1.00b	1c
7:00	4.47a	3.47a	1.07b	2.74a	2.47b	1.47c	2.47a	1.47b	1c
8:00	4.73a	5.00a	2.00b	4.73a	3.00b	0.06c	3.00a	3.47a	1b
9:00	7.73a	6.00a	2.47b	5.73a	4.00b	1.47c	3.47a	4.00a	1b
10:00	9.00a	5.00b	1.47c	4.73a	4.00a	0.06b	8.00a	6.00b	1.47c
11:00	5.00a	2.00b	1.00c	4.00a	3.00a	1.47b	3.47a	6.00b	0.06b
Avg. visit	5.73	4.00	1.50	4.00	3.00	1.00	3.75	3.75	1.00

*Values within the same column having same letter(s) are not significantly different at 5% probability level according to DMRT

Table 3: Number of inflorescence, fruits set percentage for each 15 demarcated species as influenced by different treatments

Crops	Treatments			
	Two honeybee nuclei	One honeybee nuclei	Bumble bees nuclei	Control
Eggplant				
Number of inflorescence	2.3a	2.9ab	2.9ab	3.00a
Fruits number and set percentage	1.8a (66)	1.4b (59)	1.3c (52)	0.7d (30)
Sweet pepper				
Number of inflorescence	4.2a	4.1a	4.00a	3.5b
Fruits number and set percentage	3.4a (82)	2.7b (69)	2.2c (55)	1.7d (49)
Chili pepper				
Number of inflorescence	3.9b	4.5a	4.3ab	3.00c
Fruits number and set percentage	3.3a (83)	3.3b (75)	2.4c (61)	1.1d (35)

*Values within the same column having same letter(s) are not significantly different at 5% probability level according to DMRT

Table 4: Average weight and length of individual plant recorded from the demarcated 15 Solanaceous crops grown in plastic house under different pollination treatment

Treatments	Crops					
	Eggplant		Sweet pepper		Chili pepper	
	Average fruit weight (g)	Average fruit length (cm)	Average fruit weight (g)	Average fruit length (cm)	Average fruit weight (g)	Average fruit length (cm)
Two nuclei honeybees	242a*	14.0a	137a	8.00a	26.0a	16.0a
One nuclei honeybees	220b	14.0a	97b	8.00a	22.0b	15.0a
Bumblebees	170c	13.0b	88b	7.00b	19.0c	14.0b
Control	131d	12.0c	72b	7.00b	16.0d	13.0b

*Values within the same column having same letter(s) are not significantly different at 5% probability level according to DMRT

Table 5: Average fruits weight and fruit numbers for the demarcated different Solanaceous plants crops

Crops	Treatments			
	Two honeybees nuclei	One honeybees nuclei	Bumblebees nuclei	Control
Eggplant				
Fruits weight (g)	2065a*	1937b	1577c	393.3d
Fruits number	8.53b	8.8ab	9.27a	3.00c
Sweet pepper				
Fruits weight (g)	1648a	1494b	1223c	1115.8d
Fruits number	12.00c	15.4ab	13.87b	15.53a
Chili pepper				
Fruits weight (g)	2484.3a	1468.9b	1224c	921.3d
Fruits number	95.4a	67.00b	64.47c	57.6d

*Values within the same column having same letter(s) are not significantly different at 5% probably level according to DMRT

Eggplant, sweet and chili pepper average length were higher in two and one honey bee's nuclei pollinated species than the species grown under bumble bees and control treatments (Table 4).

The average fruits weight and fruit numbers for the demarcated plants showed inverse relationship for the three Solanaceous crops, less fruits number and higher weight. The average fruit numbers for each plant were 8.53, 8.80, 9.27 and 3, weight were 2065, 1937, 1577 and 393.3 g for eggplants, fruit numbers were 12, 15.40, 13.87 and 15.53, weight were 1648, 1494, 1223 and 1115.8 g for sweet pepper and fruit numbers were 95.40, 67, 64.47 and 57.60, weight were 2484.3, 1468.9, 1224 and 921.3 g for chili pepper, for the two honeybees nuclei, one honeybees nuclei, bumblebees and control treatments, respectively (Table 5).

The fruits quality from the flowers pollinated by honey and bumble bees were superior, early harvested were with more seeds, fruits fitness and exhibited better appearance.

DISCUSSION

The pollination efficiency was compared among treatments through the percentage of fruit set, weight of individual fruits, fruits number per weight unite and fruits length. Bee pollination of our study accelerated fruit set rate of the nightshade plants and these results in agreement with Abak *et al.* (1995) for eggplants, Belletti and Quagliotti (1995) for sweet pepper and Bashir (1953) for chili pepper. There are few studies conducted on eggplant pollination, concerning the fruit set percentage of eggplant pollination under bumblebee's treatment, our present result disagreed with the results of Abak *et al.* (1995) who reported a percentage of bumblebees pollination fruit set 23% higher than the control, while in our study the similar treatment percentage was 52%. It might be that the difference in the current study and earlier ones are due to the fact of different egg plant cultivars, different temperatures and relative humidity was used in the different studies. Moreover, sweet and chili

pepper receive more research in pollination fields, our present results are in agreement with results of Kristjansson and Rasmussen (1991) and Ruijter *et al.* (1991), who reported that the pollination by bees increased the weight of the sweet pepper fruits.

Also, present study in agreement with Kwon and Saeed (2003), who mentioned there were strong correlation between foraging activity and plastic house average temperature, which increased below 32°C and decreased up to this degree and the average length of bumblebees pollinated chili pepper fruits still similar. These results showed that the bees, mainly *Apis mellifera* remain the most economically valuable pollinators of crop monocultures and the principal species used for crop pollination worldwide (McGregor, 1976; Free, 1993; Watanabe, 1994).

The experiment results showed that *Apis mellifera* L. Nuclei's can potentially acclimate to conditions inside plastic house during experiment period and resulted in pollination effects if not similar, higher to those obtained by using bumble bees in experiment treatment (Table 4, 5) or other mechanical vibration which cost intensive and expensive labor.

The influence of high temperature variables on the foraging activity was also analyzed some of efforts may directed to water collection to decreased temperature towards 11.00 o'clock (Table 1); which needs further economic evaluation.

Honeybees mortality rate was more than usual, this factor need future studies for bee's management, relocating bee's nuclei before introducing to plastic house will be useful to avoid forager loosing, which is common in honeybee nuclei used for plastic house pollination (Free, 1993), however that the nuclei's survived until the end of experiment and this could be an advantage in terms of colony management. On the internal nuclei dynamics and the observed little foraging number need further investigation and studies the plant and bees relationship (Table 2).

Also, the amount of nectar for most of Solanaceous plant flowers is low (Free, 1993) which need supplementary honey or granulated cane sugar syrup and the attractiveness of the flowers need further more research.

CONCLUSION

Efficient pollination and successful fertilization of the plastic house eggplant, sweet pepper and chili pepper are needed to ensure maximum fruit, pod set and proper development of high quality fruit. Yield and quality of harvestable fruits were considerably improved by using two honeybee's nuclei, one honeybee's nuclei and bumblebees, respectively. Differences among treatments

were statically significant for all studied traits per varieties. Flowers of eggplant were significantly visited higher numbers of bee's species than those of chili and sweet peppers for the demarcated 15 plants, where all species could be observed.

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