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Effect of different pollination treatments on sweet pepper plants grown under plastic house

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Abstract

The experiments were evaluated the effect of bumble bee (Hymenoptera: Apidea) and compared to non-bumble bee pollinated sweet pepper plants (*Capsicum annum* L.) variety Gedeon F_1 under plastic house. An investigation that carried out in the experiment farm of Faculty of Agricultural, Kafr El-Sheikh, Egypt during the winter of two seasons of 2010 and 2011. The experiment consisted of four treatments as follows hand pollination, bumble bee (*Bombus impatient* C R), electric vibration and control under greenhouses sweet pepper.

Results indicated that the effect of four methods of pollinations were in three categories; the first one was first class of mean weight each one sweet pepper fruit > 90g. It was found that the pollinated by bumble bee that held most mean fruit numbers of sweet pepper in February and March in two seasons (6.36, 6.956, 4.60 and 7.2 fruits/m^2 respectively) and weight these fruits were (578, 685.5, 519.5 and 663.1 g/m^2, respectively) while control in the same category was (2.2, 2.4, 2.2 and 3.1 fruits/m^2, respectively and 246, 242.3, 270.7 and 288.3 g/m^2 respectively). The second category was the second class of mean weight each fruit of sweet pepper was 50 to 90g. In this category it was clear that the highest mean number of fruits of pollinated with hand (6.39, 6.58, 12.2 and 7.4 fruits/m^2, respectively) and weight these fruits were (454.7, 458.9, 731.7 and 597.4 g/m^2, respectively) while, bumble bee came in the second order in this category and the third category was third class of mean weight each one fruit sweet pepper <50 g. It was found out that the pollinated by hand that held most mean number fruit sweet pepper (15.38, 15.56, 22.14 and 16.3 fruits /m^2 respectively and weight these fruits were (507.2, 478.2, 774.9 and 700.9 g/m^2, respectively). While, bumble bee came in the second order in this category. On the other hand, effect of bumble bee pollination on yield, the bumble bee plants had increased total yields in February by (30.54% and 34.46%) and in March by (22.58% and 22.40%) of two seasons, respectively.

B. impatient colony activity in Daylong indicated clearly, that hive traffic were the maximum mean numbers bumble bee traffic in February and March in two seasons. On the other hand, *B. impatient* colony activity in weekly was recorded. Resulted recorded that hive traffic was the maximum mean number bumble bee in the first week of February of two seasons. Bumble bee pollination showed that the highest average yield as Kg/ m^2 followed by hand pollination, then control and the least for electric vibration method. Also, the results showed that increase in mean fruit weight and mean number fruit of sweet pepper according to Bumble bee pollination.

Key words: *Bumble bee, pollination, Vibration, Greenhouse, Sweet Pepper*.

1. Introduction

Peppers are widely cultivated in temperate and tropical regions of the world, because of the nutritional value of the fruits. *Capsicum annuum* L. is a commercially important crop of the family Solanaceae, which is cultivated in Egypt for vegetables. The development in the use of plastics in greenhouses have taken place in Egypt since 1995.

Insects are important pollinators of Agricultural crops and the value of it to Canadian Agriculture was $ 1.5 billion[1]. In the United States, the annual benefit has been estimated at $ 1.6-8.3 billion[2]. Insect pollinators include bees, flies, moths, butterflies and beetles[3].

Bumble bees are regarded as one of the most efficient pollinators of many crops such as sweet pepper, tomato, cucumber, red clover, cotton, alfalfa, and berry crops[4-6].

Banda and Paxton[7] recorded that bumble bees were effective pollinator of greenhouse tomatoes. Bumble bees were compared with traditional vibration pollination of tomatoes. The effectiveness of the bees was determined by measuring fruit set, size and weight and seed content. Bumble bee queens introduced in tomato greenhouses resulted in increased productivity up to 70%, in Belgium.

Morandin *et al.*[8] studied the effect of Bumble Bee (Hymenoptera: Apidae) pollination intensity on the quality of Greenhouse Tomatoes. They conducted laboratory studies to assess tomato, *Lycopersicon esculentum* Mill. (Solanaceae), quality in relation to the level of buzz- pollination by bumble bees. The experiments were conducted in commercial tomato greenhouses in the leamington, Ontaio, area to categorize bruising of tomato anther cones by bumble bees into five levels of bruising. They found that experimental flowers were pollinated by bumble bees and assigned to bruising levels based on the degree of anther cone discoloration. They found that fruit set, tomato weight, minimum diameter, the number of days until ripe, roundness, weight, percentage sugars, and number of seeds were assessed and compared among bruising. in flowers. The study indicated that intense bruising may not be required to ensure adequate pollination and consequently, colony densities may not need to be as high as before[9].

The use of bumble bee within greenhouses posed an attractive and eventually cost- effective alternative to manual pollination[10].

Bumble bee pollination benefited the growers because of lower production costs, increased yield and improved fruit quality. Bumble bees are the most efficient pollinators not only for the wild plants, but also used in both outdoor and greenhouse horticulture and orchards for pollination[11].

Wahizatul, A. A. *et al.*[12] concluded that besides manual pollination, stingless bees *Heterotrigona itama* can be considered as an effective pollinator for the chilies grown in greenhouse.

Cruz, D. O. *et al.*[13] studied that pollination efficiency of the stingless bee *Melipona subnitida* on greenhouse sweet pepper (*Capsicum annuum* L.). They recorded that despite sweet pepper flowers are considered autogamous, pollination by *M. subnitida* benefited this crop by producing fruits significantly heavier and wider, containing a greater number of seeds and of better quality (lower percentage of malformed fruits) than self- pollinated sweet pepper. So that, *M. subnitida* can be considered an efficient pollinator of greenhouse sweet pepper.

Medrzycki *et al.*[14] studied some effects which can come from purposeful use of chemical attractant and repellents on a blooming crop. They reported that negative consequences of pesticide interactions with pollinating crops are a serious concern. They recorded methods to
assess risk to individual bees and colonies from toxic effects of chemicals are established and are expanding to include sublethal behavioral effects such as disorientation of foragers. They concluded that any environmental toxins which affect the health of a colony may impact the effectiveness of the colony as a pollinating unit by altering foraging activity.

Panma Yankit, *et al.*[15] recorded the effect of bumble bee pollination on quality and yield of tomato (*Solanum lycopersicum* Mill.) grown under protected conditions. They estimated the effectiveness of the bumble bee *Bombus haemorrhoidalis* Smith (Hymenoptera: Apidae) and compared to non- bumble bee pollinated tomato (*Solanum lycopersicum*) crop grown under protected conditions. Results based on measurements such as number of fruits, fruit size showed highly significant difference between with and without bumble bee colony. Bumble bee pollination accounted per cent increase in number of fruits per plant, healthy fruits, fruit length, fruit breadth, fruit weight, fruit yield, number of seeds and 1000 seed weight.

Putra, D.P. *et al.*[16] studied the Pollination in chili pepper (Capsicum annuum L.) by *Trigona laeviceps* and *T. minangkabau* (Hymenoptera, Meliponini) in West Sumatera. He recorded that pollination by *T. leaviceps* and *T. minangkabau*, each could increase the following parameters: fruit sets 12.32 and 9.66%, number of seeds 56.36 and 45.91%, number of fruits 29.31 and 25.06, fruit weight per plant 66.46 and 49.75%, and yields ha-1 54.26% and 40.83% if compared to pollination by wind. However, it did not affect length and diameter of fruit.

The studies aimed to use honey bees as pollinators in greenhouse production started in 1950. Although honey bees have been successfully used for the pollination of many plant species, they are not effective pollinators of Solanacea crops[17].

Bombus impatients and *B. terrestris* are used pollinators of tomato, sweet pepper and other greenhouse crops in North America, Europe and New Zealand because of their adaptability to the greenhouse environment, their small colony size and their ability to forage during cool or cloudy conditions. *Bombus* spp. have proven to be effective pollinators of greenhouse tomatoes and sweet pepper[18,19&6].

Al-Abbadi, S. Y.[20] conducted the experiments 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. He concluded that treatment of Solanaceous plants with honeybee's nuclei increased fruits quality, quantity and exhibited better appearance.

Sweet pepper (*Capsicum annuum* L.) flowers are self-fertile and seed production occurs by self or cross pollination. In the field population usually occurs by wind agitation or by occasional entomophilous cross-pollination. *Bombus* spp. were shown to be effective pollinators of sweet peppers plant under greenhouse [4,6,22].

In Egypt, the studies of effect of bumble bee pollination under plastic walk – in tunnels at Kafr El-Sheikh are a very few attempts have been made for determination the pollination effect of *B. impatiens*.

The objectives of the study were to determine, the pollination effect of *B. impatiens*, hand and electric vibration for greenhouse sweet peppers based on the number and weigh of fruits, the density of *B. impatiens* required for effective pollination and the patterns of *B. impatiens* foraging activity over the growing season.

2. Materials and Methods

Greenhouse Description and Experimental Set-up:

The experiment was carried out in the protected cultivation site Sakha Ministry of Agriculture, Kafr El-Sheikh, Egypt during February and March of the two seasons of 2010 and 2011 under plastic greenhouse on one of Dutch sweet pepper (*Capsicum annuum*, L.) variety Gedeon F_1. The experiments green house area was (9 m X 60 m) of each and consisted of one thousand two hundred plants were arranged in 5 double rows. The density of plant was 2.2 plant/m^2.

The first season plants were grown under two greenhouses, the first consisted of two treatment replicates pollination were, hand pollinate, electric vibration pollinated and control in the same greenhouse. On the other hand, the second greenhouse consisted of one treatment pollinated only by bumblebees. On the other hand, plants under two greenhouses were sprayed with three fertilizers elements flowed, K. (potassium sulphate) by rate 20g/L., P. (super phosphate) by rate 20g/L., sugar solution by rate 20 g/L. and mixed from fertilizers elements were (L. 20 g/L., P. 20g/L. and Boron 2 p.p.m.) were applied during the growth seasons monthly.

***Bombus impatiens* Colony Activity:**

A colony of approximately 55-75 individual workers and closed broads without Queen were purchased from koppert Biological systems. The colony was introduced into the greenhouse on 10th January 2010 and 1st February 2011, provided with a continuous sucrose solution and placed at center of the greenhouse on a 1 m height shaded plate form. Screened windows inhibited *B. impatiens* from exiting the greenhouse. Hive traffic were recorded as average every week at 2 hours intervals from 9.00 a m. to 5.00 p.m. hours during the period of two months after the entering of bees. Hive traffic was measured as the numbers of bees exiting and entering the hive for 15 minutes period each 2 hours. Fruit developed at harvest the number per m^2 and weight these fruits were counted per m2. On the other hand, the weight fruits divided into three class were, the first class over 90 g. fruit the second g/fruit class was between 50-90 g fruit and the third class was smaller than 50g. fruit.

Three parameters were evaluated in this experiment: mean fruit weight, mean number of fruits and fruit yield and percentages according to Rasmussen[22].

These obtained data were statistically analyzed according to Duncan [23].

3. Results

3.1 Bombus impatiens colony activity:

3.1.1In daylong:

Results in Table (1) showed the maximum mean numbers bumblebee traffic was in 11.00 a.m. in February & March 2010 and 2011 while in 9 a.m. came in second order. On the other hand, in 13.00 hour was the third order and in 17.00 hour was the least. While, in 15.00 hour was between them. Generally, the highest total average numbers traffic was descending orders.

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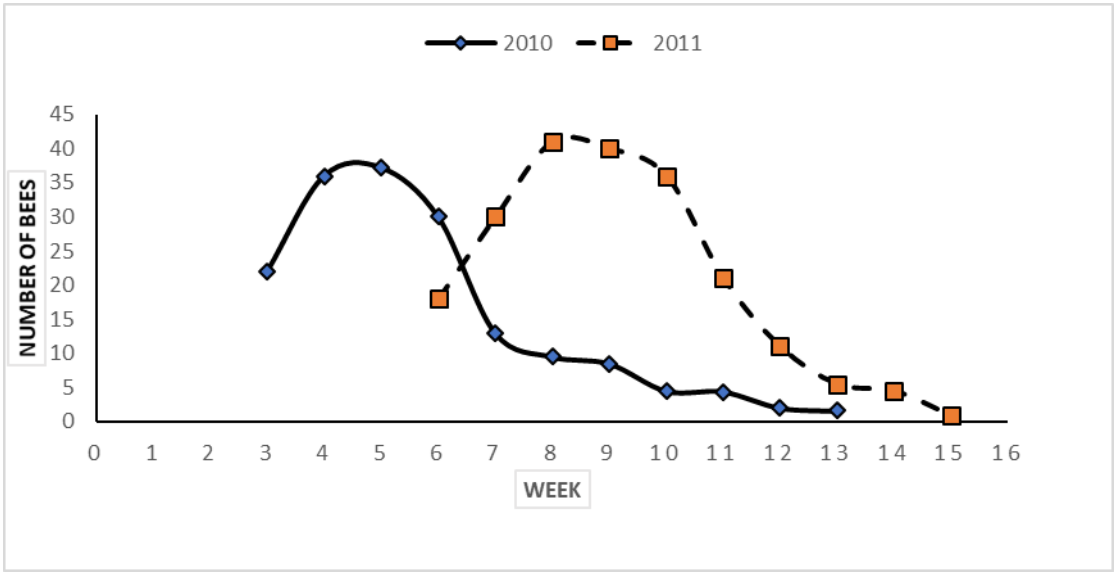
Table (1). Numbers and percentage of bumblebee hive traffic under greenhouse in daylong on sweet pepper during two seasons 2010 and 2011.

Months during 2010/2011	1. Time/2 hours					Total
	9	11	13	15	17	
Feb-10	62.80 b	73.60 a	57.60 c	39.60 bc	7.50 d	241.1
%	25.05	30.53	23.89	16.42	3.12	
Mar-10	31.30 b	43.10 a	27.10 c	12.00 bc	3.20 d	116.7
%	26.82	36.93	23.22	10.28	2.75	
Feb-11	71.20 b	89.70 a	61.20 c	42.60 bc	9.30 d	274
%	25.99	32.47	22.33	15.55	3.39	
Mar-11	35.20 b	51.00 a	27.60 c	10.60 bc	5.60 d	13
%	27.08	39.23	21.23	8.15	4.31	
Total	200.50 b	257.40 a	173.50 c	104.80 bc	25.60 d	761.8
%	26.32	33.69	22.78	13.75	3.36	

The differences significant between the number bumblebee in hive traffic at 11.00 and in other four periods of hive traffic.

In weekly:

Fig. 1: Mean number of Bumblebees hive traffic under greenhouse weekly



Results in Fig. (1) recorded that hive traffic (exit and return bumblebee) were maximum mean number of bumblebee traffic in the third week of February of the first and second season were 37.0 and 41.0 individuals respectively after two weeks from enter the hive in each season.

1.1

3.2. Effect methods pollination hand, bumblebee and vibration on the number and weight of sweet pepper:

A. Mean fruit numbers and mean fruit weights:

Results shown in Table (2 and 3) indicated that effect of three methods of pollination were hand, bumblebee and electric vibration of greenhouse sweet pepper in three categories:

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Table (2). Effect of pollination method on number/m^2 and fruits weight(g/m^2) during February 2010&2011

1.1.1 February 2010												
Methods of pollination	First class m^2				Second class m^2				Third class m^2			
	Mean number	%	Mean weight	%	Mean number	%	Mean weight	%	Mean number	%	Mean weight	%
Hand	3.2 b	24.19	303 b	24.03	6.39 a	40.24	454.7a	42.89	15.38a	41.38	507.2a	38.82
Bumblebee	6.36 a	48.10	578 a	45.84	5.13 a	32.30	278.5a	26.33	9.19b	24.72	294 b	22.50
Vibration	1.47 c	11.11	134 c	10.63	2.36 c	14.86	186.2c	26.23	6.5c	17.49	280.5c	21.47
Control	2.2 c	16.60	246 c	19.50	2.0 c	12.60	141.2c	17.56	6.1 c	16.14	225.0c	17.22
Total	13.23		1261		15.88		1060.1		37.17		1306.7	
February 2011												
Hand	3.5 b	23.73	335.8 b	22.55	6.58 a	32.88	458.9a	13.31	15.56a	36.41	478.2a	36.46
Bumblebee	6.95 a	47.12	685.5 a	46.04	6.23 a	31.14	442.9a	32.34	9.98b	23.36	360.4b	27.48
Vibration	1.90 c	12.88	225.4 c	15.14	3.80 c	18.99	266.6c	31.21	8.84c	20.69	240.4c	18.33
Control	2.40 c	16.27	242.3 c	12.27	3.40 c	16.99	250.9c	18.77	8.35c	19.54	232.5c	17.73
Total	14.75		1489		20.01		1419	17.68	42.73		1311.5	

Mean fruit numbers and mean fruits weight with different alphabetical letter are significant different (p=0.05) Duncan[30].

Table (3). Effect of pollination method on number/m^2 and fruits weight (g/m^2) during March 2010&2011.

1.1.2 March 2010												
Methods of pollination	First class m^2				Second class m^2				Third class m^2			
	Mean number	%	Mean weight	%	Mean number	%	Mean weight	%	Mean number	%	Mean weight	%
Hand	3.5 b	26.66	263.0 b	21.59	12.2a	35.37	431.7 a	34.82	22.14a	30.65	774.9a	32.83
Bumblebee	4.6 a	38.98	519.5a	42.65	11.00 a	31.89	793.7a	37.77	20.0b	27.68	640.7b	27.14
Vibration	1.5 c	12.71	160.0c	13.55	7.00 c	20.30	283.0c	13.46	15.9c	22.00	500.7c	21.21
Control	2.2 c	18.65	270.7c	22.21	4.29 c	12.44	293.2c	13.95	14.2 c	19.67	444.2c	18.82
Total	11.8		1218.2		34.49		2101.6		72.24		2360.5	
March 2011												
Hand	3.8 b	23.03	364.8b	23.08	7.4 a	30.87	597.4	34.43	10.3 a	35.51	700.9a	34.84
Bumblebee	7.2 b	43.64	663.1 a	41.95	7.1 a	32.17	526.1a	30.31	11.2b	24.40	504.5b	25.06
Vibration	2.4 c	14.55	266.4 c	16.75	4.4 c	17.83	287.2c	16.55	9.3 c	19.83	347.5c	17.26
Control	3.1 c	18.79	288.3 c	18.22	4.1 c	19.13	324.8c	18.72	9.1 c	20.26	460.4c	22.87
Total	16.5		1580.6		23.00		1735.5		45.9		213.3	

Mean fruit numbers and mean fruits weight with different alphabetical letter are significant different (p=0.05) Duncan[30].

1. Class A: It was first class of mean weight each one sweet pepper fruit > 90g during February and March 2010& 2011. It was found out that the pollinated bumblebees that held the highest mean fruit number sweet pepper and the highest weight of these fruits, while pollinated with hand was the second order in this category while, mean number fruits and weight these fruits in control was the third in the same category.

On the other hand, pollinated by electric vibration was the least of the mean fruit numbers and weight of these fruits.

There were significant differences between pollination by bumblebee hand electric vibration and control. On the other hand, no significant relationship between vibration and control mean number of sweet pepper fruits and weight these fruits in the same category.

2. class B: It was second class of mean weight of one fruit sweet pepper between 50-90g during February

and March 2010& 2011. from the same tables it was clear that the highest mean number of fruits and weight these fruits of pollinated with hand while, were the same trend While, bumblebee came in second order and pollinated vibration was the third order in the same category. On the other hand, control was the least.

In the same tables, it was found that significant difference between pollination by bumblebees and hand but there were no significant differences between vibration pollination and control of mean number of sweet pepper fruits and weight these fruits in the same category.

3. Class C: It Was the third class of mean weight of one fruit sweet pepper <50g. In the same tables, it was found out that the pollinated by hand that held the most of mean number of fruits and weight of these fruits of sweet pepper. While, pollinated by bumblebees was the second order of the mean number fruits and weight these fruits in this category. The pollinated with vibration came in the third order of the mean number fruits and weight these fruits of sweet pepper in this category. On the other hand, control was the least. It was found a significant relationship between pollination by hand and the other pollinated methods bumblebees, vibration and control. On the other hand, no significant relationship between pollinated vibration and control sweet pepper under greenhouse.

B. Total mean fruit number and total mean fruit weight sweet pepper:

Results in Table (4) indicated that the total fruit numbers and total mean fruit weight were affected with the three kinds of pollinating.

Table (4): Total mean number and weight and its percentage of sweet pepper fruit in February and March seasons 2010&2011 under greenhouse.

Methods of pollination	Season 2010				Season 2011			
	February				February			
	Mean number	%	Mean weight	%	Mean number	%	Mean weight	%
Hand	24.97 a	37.11a	1264.9a	34.86	25.64a	33.09	1272.9a	30.17
Bumblebee	21.68 a	32.22a	1150.a	31.71	23.16a	29.89	1488.8a	35.28
Vibration	10.33 c	15.35c	612.7c	16.89	14.54c	18.76	732.1c	17.35
Control	10.30 c	15.32c	600.2c	16.54	14.15c	18.26	725.78c	17.20
Total	78.28		3628.3		77.49		4219.58	
Methods of pollination	March				March			
	Mean number	%	Mean weight	%	Mean number	%	Mean weight	%
Hand	37.14 a	31.34	1788.4a	31.49	257.2a	31.85	1693.7a	31.77
Bumblebee	35.80 a	25.98	1769a	31.15	25.5a	30.21	1663.1a	31.19
Vibration	25.40 a	21.43	1129.6c	19.88	16.8c	19.67	1073.5c	20.14
Control	20.19 c	21.25	992.7c	17.48	15.6c	18.27	901.1c	16.90
Total	118.53		5680.3		85.4		5331.4	

Mean fruit numbers and mean fruits weight with different alphabetical letter are significant different (p=0.05) Duncan[30].

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The results as shown in Table (4) indicated that the hand pollinated held the majority in February 2010 and 2011 of total mean fruit numbers and total mean fruit weight. While Bumblebee pollinated came in the second order in the same trend.

Results in Table (4) indicated the total mean fruit numbers and mean fruits weight in March 2010 and 2011 could be arranged into the following descending orders according to methods pollination hand, bumblebee, vibration and control. The results reported that no significant relationships between pollination by hand and bumblebee and between vibration and control in February 2010 and 2011 and March 2011. On the hand, there was found that a significant relationship between vibration pollinated and control during March 2010.

3.3 Effect of bumblebee pollinated on yield of weight g/m^2 sweet pepper under greenhouse during two seasons 2010 and 2011:

Data from Table (5) showed that bumblebee pollinated plant had increased total yield of 31.44% in February and 22.58% in March in the first year and similarly had total yields increases of total yield in the second year. The differences of yield between bumblebee and hand pollination was a significant during the two studied seasons.

Table (5): Effect of Bumblebee pollination on yield g/m^2 of sweet pepper during two seasons 2010 and 2011.

Methods of pollinated	February 2010		February 2011		March 2010		March 2011	
	Mean weigh t	%	Mean weight	%	Mean weigh t	%	Mean weight	%
Bumblebee	1150.5a	65.72	1488.8a	67.23	1788.4a	61.29	1693.7a	61.20
Control	600.2c	34.28	725.78c	32.77	1129.6c	38.71	1073.5c	38.80
Total	1750.7		2214.58		2918.0		2767.2	

Mean fruit weight/m^2 with difference alphabetic letter are significant different (p=0.05) Duncan[30].

3. Effect of bumblebee pollination on fruit numbers of sweet pepper under greenhouse during two seasons 2010 and 2011.

The data of table (6) showed that the percentage of fruit numbers had increased 27.60% and 23.47% fruits/m^2, during the first season in February and March, respectively. Comparing bumblebee pollinated with control in second year in February and March, results indicated that the percentage of mean fruit number of sweet pepper were 24.14% and 21.12 fruits/m^2, respectively during the second season. It was found that a significant relationship between bumblebee and control pollinated during the two studied seasons.

Table (6): Effect of Bumblebee pollination on fruit numbers of sweet pepper during two seasons 2010 and 2011.

Methods of pollinated	February 2010		February 2011		March 2010		March 2011	
	Mean number s	%	Mean number s	%	Mean numbers	%	Mean numbers	%
Bumblebee	21.68a	63.80	23.156a	62.07	35.80a	61.73	25.80a	60.56
Control	12.30c	36.20	14.15c	37.93	22.19c	38.26	16.80c	39.44
Total	33.98		37.31		55.99		42.60	

Mean fruit numbers/ m^2 with difference alphabetic letters are significant different (p=0.05) Duncan[30].

4. Discussion

Although sweet pepper is widely considered a self-pollinating plant, it is not 100% self-pollinated, Abak *et al.*[5]. Kristijanssen and Rasmussen[24] founded that Bumblebee pallination increased fruit weight and the percentage of extra-large and large fruit compared with self-pollinated fruit. The results were obtained from this study on sweet pepper confirm with studies obtained from these authors. Also, Cruz, D.O.*et al*.[13] recorded that pollination efficiency of the stingless bee *Melipona subnitida* on greenhouse sweet pepper in Northeastern region of Brazil. They reported that *M. subnitida* is a very efficient species to increase fruit weight, number of seeds and to reduce fruit malformation, if compared to the traditional system of greenhouse cultivation of sweet pepper without bees. These results confirm with the conclusion of this study.

The increased percentage of extra-large fruit, this is the first documented evidence of significant improvement in fruit quality and yield in greenhouse sweet pepper with the use of bumblebees as pollinator[4,6]. In the same studies by the same authors, recorded that a 33% increase in bee-pollinated fruit weight during studies period was observed for extra large and large fruit compared with no bee-pollinated fruit.

In the study of Panma *et al.*[15] studied the effectiveness of the bumblebee *bombus haemorrhoidalis* which was estimated and compared to non- bumblebee pollinated tomato (*Solanum lycopersicum*). They found that bumblebee pollination increased per cent in number of fruits per plant, healthy fruits, fruit length, fruit breadth, fruit weight, fruit yield, number of seeds and 1000 seed weight by 38.41, 21.94, 46.45, 50.82, 57.66, 64.79, 78.54 and 78.80 %, respectively which confirm the results on sweet pepper in this study.

The pepper plants grown in unheated or in heated only against frost greenhouses along the Mediterranean coastal area can produce sufficient amounts of pollen, but that viability and germination rates are low[25,26]. The results clearly showed that with the use of an effective pollinator, the low rate of pollen production and quality can be compensated for enough fruit set of an acceptable yield and quality obtained. Abak *et al.*[5], showed that bumblebees can be used as an effective pollinator for pollination of greenhouse pepper in the Mediterranean region.

Meisels and Chiasson[21,6] showed that *B. impatiens* can effectively pollinate greenhouse sweet pepper. According to a positive correlation between seed number and fruit weight. Effective pollination of greenhouse sweet peppers occurred with a maximum of only 3 *B. impatiens* workers foraging on 425 plants, or approximately 176 *B. impatiens* per hectare (i.e., 25000 plant) European guidelines for stocking rates of *B. terrestris* in tomato greenhouse suggest 500-600 *B. terrestris* workers per hectare[27]. On the other hand, Meisels and chiasson[6] used stocking rated of *B. impatiens* workers in sweet pepper greenhouse suggest 30-40 *B. impatiens* workers per 244 m^2 or 465 plants. On the other hand, in this study were used stocking rates of *B. impatiens* workers in sweet pepper greenhouse suggest 55-75 *B. impatiens* workers per 540 m^2 or 1200 plants.

The greatest *B. impatiens* activity occurred between 11.00 and 13.00 hours, which is the optimal time for self-pollination of sweet pepper flowers since the stigma is receptive , anther dehiscence has usually taken place and the pollen has the highest probability of germination[28,6]. *B. impatiens* are likely more attracted to sweet pepper flowers at his time since greater floral nectar volumes occur after 11.00 hours[22].

Morandin *et al.*[9] assessed the level of bumble bee activity on a tomato flower is in straight forward. Their results indicated that any level of bumble bee pollination increased fruit set in relation to no pollination. Bin and Sorressi[37]stated that pollination of tomato flowers by bumble bees caused bruising or necrotic spotting on the anther.

The decrease in *B. impatiens* from first period (February to last period (March). Similar results were obtained from them previous studies on sweet pepper, Meisels and Chiasson[6] suggest that resources available in the greenhouse were not sufficient to maintain or increase *B. impatiens* colony size. Continual nectar collection allowed existing adults to survive, but new workers were probably not produced due to a lack of pollen and not found queen in colony. Hence, the colony size slowly decreased. For a greenhouse of this size, it may be beneficial for *B. impatiens* colony size and health to allow individuals to forage outside the greenhouse so as to procure additional resources[38]. These results also showed that the colony size of *B. impatiens* decreased and may be related to the explanation of Medrzycki, *et al.*[14] who reported that negative consequences of pesticide interactions with pollinating crops are a serious concern. They recorded methods to assess risk to individual bees and colonies from toxic effects of chemicals are established and expanding to include sublethal behavioral effects such as disorientation of foragers. They concluded that any environmental toxins which affect the health of a colony may impact the effectiveness of the colony as a pollinating unit by altering foraging activity.

Al-Abbady[27] concluded that 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. By comparison among the treatments, there were significantly differences 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 appearance.

On the other hand, low increases in fruit weight in last season in greenhouse sweet pepper cloud be related to changes in the population dynamics of the bumblebee colonies[8].

Conclusion:

In the present study, Pollination on sweet pepper plants by bumblebee (*Bombus impatiens*) was effective in increasing mean fruit numbers and weight of fruits and fruit yield of sweet pepper under greenhouse in two studied seasons. Also, the results showed the maximum mean numbers of bumblebee traffic was in 11.00 a.m. in February & March 2010 and 2011. It was found that a significant relationship between bumblebee and control pollinated during the two studied seasons. Also, the differences of yield between bumblebee and hand pollination was a significant increase during the two studied seasons. So, bumblebees play a vital role in increase the productivity in sweet pepper under protected condition.

Significance Statement: This study will help the researchers to use the pollination by bumblebee to increase mean fruit numbers and weight of fruits and fruit yield.

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