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**ARTICLE**

# The value of honey bees (*Apis mellifera*, L.) as pollinators of summer seed watermelon (*Citrullus lanatus colothynthoides* L.) in Egypt

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**ABSTRACT** The value of honey bee, *Apis mellifera* L., as pollinator of summer seed watermelon plants, *Citrullus lanatus colothynthoides* L. was studied. The highest percentage of opened flowers, number of bees/m$^2$/min and amount of trapped pollen/ colony/h were recorded between 9.00 and 10.00 h, with significant (P<0.01) correlations between them. Eleven insect species belonging to eleven families and five orders were recorded as pollinators on summer seed watermelon crop, and A. mellifera L., was the predominant species. One hectare of summer seed watermelon could produce 10.47 kg of honey per season. Open pollination treatment produced the highest number of mature fruits and seed yield as compared with caged plants without any insect visitors which did not produce any fruits at all. It could be recommended to move the honey bee colonies to summer seed watermelon plantations during its flowering period to build-up the colonies and increase seed yield.
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**KEY WORDS**

Honey bees
Summer seed watermelon
*Citrullus lanatus colothynthoides*
pollen
pollination

Pollination plays an important role in flowering plant reproduction and fruit set for wild plant communities (Corbet et al. 1991; Buchmann and Nabhan 1996). Estimates showed that up to 90% of all flowering plant species rely on pollination by insects such as bees (Richards 1986; Buchmann and Nabhan 1996). Agricultural crops often depend, at least in part, on unmanaged pollinator for their productivity (Klein et al. 2003; Kremen et al. 2002, 2004; Ricketts 2004; Ricketts et al. 2004). Watermelon is obligately dependent on multiple bee visits for pollination (Stanghellini et al. 1997). Although insect species such as beetles and solitary bees (Jaycox et al. 1975) and flies and butterflies (Shawer et al. 1981) have been recorded as pollinators of cucurbits, it is generally recognized that honey bee (*A. mellifera* L.) is the most important pollinators in commercial crop production (Free 1993; Delaplane and Mayer 2000).

Animal pollinators are thought to contribute between 15% and 30% of global food production (Roubik 1995). The annual value added to US crops production by honey bees A. mellifera is estimated to be $9.3 billion (Robinson et al. 1989) and $5-14 billion (Southwick and Southwick 1992). In Europe, pollination by honey bees is worth approximately €4.25 billion, and pollination by other taxa worth approximately €0.75 billion (Borneck and Merle 1989).

The dependency of fruit set on insect pollination is well studied in cucumber (*Cucumis sativa* L.) and watermelon (*Citrullus lanatus* (Thunb) Matsun & Nakai) (Free 1993), and squash (*Cucurbita pepo* L.; Shawer et al. 1981). Open pollination and honey bees provided during the whole flowering period treatments produced the highest number of mature fruit and seed yield, while squash caged without bees and other insect visitors did not produce any fruits (Shawer et al. 1981). Stanghellini et al. (1997) noted that there was 100 percent abortion for flowers receiving no entomophilous visitation, and significant abortion rates by flowers receiving low bee visit numbers emphasizing the need for active transfer of pollen in these crops by insect pollinators.

Summer seed watermelon (*Citrullus lanatus colothynthoides* L.) plants have been grown in considerable areas in scattered locations throughout Egypt; 34386 hectares in Lower Egypt, 185 hectares in Middle Egypt, 517 hectares in Upper Egypt and 4179 hectares in El-Noubaria, El-Beheira Governorate (Anonymous 2005). It is obligately rely on cross-pollination by insects, especially honey bees. In the newly reclaimed lands, the insect pollinators are too little; therefore, crop production is not economic. The present investigation aimed to throw the light on the foraging behavior of honey bees and their effects as pollinators on summer seed watermelon flowers.

## Materials and Methods

This investigation was carried out on summer seed watermelon farm (11 hectares) in Dessouk district, Kafr El-Sheikh Governorate, Egypt from mid June till end of July 2006 (the

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**Table 1.** Phenology of summer seed watermelon flowering.

| Items | Total number of flowers | | Sex ratio | Blooming period | | Pollen load | |
|---|---|---|---|---|---|---|---|
| | $m^2$ | Hectare | | Starting | Ending | Weight (mg) | Color |
| | 446.59 | 4464113.64 | 1 :7.5 | 10/6 | 31/7 | 5.59 | Yellowish orange |

**Table 2.** A list of insect pollinators on summer seed watermelon plants at Dessouk region, Kafr El-Sheikh Governorate during 2006 season.

| Order | Family | Scientific name | Percentage |
|---|---|---|---|
| Hymenoptera | Apidae | *Apis mellifera* L. | 61.52±0.42 |
| | Andrenidae | *Andrena ovatula* K. | 5.77±0.33 |
| | Vespidae | *Polistes foederata* Kohl. | 1.93±0.06 |
| Diptera | Muscidae | *Musca domestica* L. | 5.77±0.08 |
| | Syrphidae | *Syrphus corollae* F. | 5.77±0.16 |
| | Tabanidae | *Tabanus taeniola* Pol. | 7.68±0.16 |
| Odonata | Aeschnidae | *Hemianax ephippiger* | 3.85±0.1c2 |
| | Agrionidae | *Ischnura senegalensis* Ramb. | 1.93±0.24 |
| Lepidoptera | Hesperidae | *Gegenes nastrodamus* F. | 1.92±0.33 |
| | Lycaenidae | *Tarucus* sp. | 1.93±.041 |
| Coleoptera | Coccinellidae | *Coccinella undecimpunctata* L. | 1.93±0.16 |

blooming period of the crop). Two apiaries (250 colonies) surrounded the experimental farm at distances between 150 and 300 m. Sixteen nucleus colonies (each had about 10000 bees) of hybrid Carniolan honey bees were moved to the experimental farm to study the following aspects:-

## Foraging behavior of honey bees

To study the behavior of honey bees for pollen collection, three colonies were provided with pollen traps at the peak of emblossoming for two weeks. The trapped pollen loads were collected hourly, from 07.00 to 15.00 h then weighted. The number of opened flowers/$m^2$, sex ratio and number of bees/$m^2$/min were counted at the same times. Mean weight of one pollen load was determined.

## Survey of insect pollinators

At the peak of flowering, all insect species visited the plants and their flowers were collected by taking 20 double sweeps with sweep net randomly in the field. The collections were transferred to the laboratory for counting and identification.

## Nectar secretion and sugar concentration

Certain flowers were bagged in the early morning before anthesis to prevent bees from nectar collecting. The nectar was collected by capillary tube from bottom of the flowers. Sugar concentration was estimated by pocket refractometer immediately in the field. The amount of expected honey per hectare was gravimetrically calculated from the following equations:

$$\text{Amount of nectar/hectare} = \text{Amount of nectar/flower} \times \text{No. flowers/hectare}$$

$$\text{Amount of sugar/hectare} = \text{Amount of nectar/hectare} \times \text{Nectar sugar concentration}$$

$$\text{Amount of expected honey/hectare} = \frac{\text{Amount of sugar/hectare}}{\text{Sugar concentration in honey (80\%)}}$$

## Efficiency of honey bee as pollinator

To determine the effectiveness of insect pollinators on seed yield, two treatments were performed. In the first treatment, plants were left to open pollination, from which three-square meters were randomly selected to procedure the measurements. In the second one, other three square meters were isolated from insect pollinators by using wooden cages (1 ×l ×l m) covered with wire screen, which distributed on plants one week before starting the anthesis. The number of pistillate flowers and number of fruits/ $m^2$ was counted every two days. Successful fruiting index was evaluated according to Shawer et al. (1981), using the following equation:

$$\text{Successful fruiting index} = \frac{\text{Total number of fruits/plant}}{\text{Total number of pistillate flowers/plant}}$$

The number of mature fruits/$m^2$, percentage of aborted fruits, total weight of fruits/$m^2$ and mean fruit weight were recorded. Seeds were collected, dried in sun rays and weighed. The weight of 100 seeds (seed index) was estimated. The value added to the crop production by honey bees *A. mellifera* was calculated.

## Statistical analysis

Data obtained were statistically analyzed according to Steel & Torrie (1980). Treatment means were compared by Duncan 's

**Figure 1.** Number of bees/m2/min and trapped pollen (g)/colony/h in relation to the time of day (h)

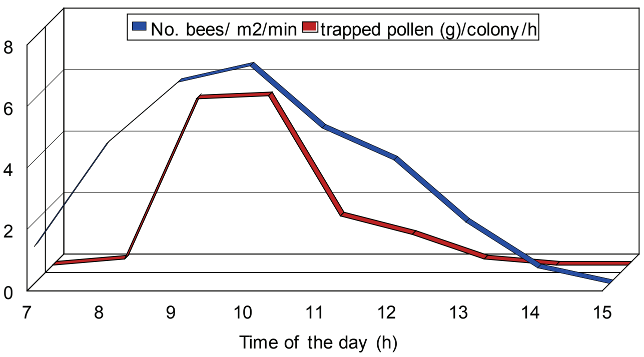
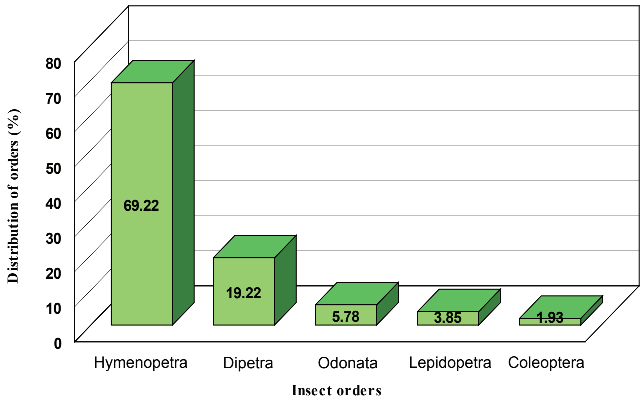



**Figure 2.** Distribution percentage of insect orders found on summer seed watermelon crop.




Multiple Range Test (Duncan 1955). Simple correlation was made by using "SPSS 10.0 for windows".

## Results

### Phenology of flowering

Summer seed watermelon plants start to grow in May, the blooming begins in the 2nd week of June and continues until the end of July. Blooming reached its maximum during the first half of July. The total numbers of flowers were 446.59 flowers/ $m^2$ and 4464113.64 flowers/hectare at the whole period of flowering. Male flowers greatly outnumber the female ones with sex ratio of 7.5 : 1 (male : female). The color of pollen loads is yellowish orange and the weight of one load averaged 5.59 mg (Table 1). The pollen grain was illustrated in Photo 1.

### Foraging behavior of honey bee

The highest percentage (100%) of opened flowers, number of bees/$m^2$/min (6.55 & 7.08 bees) and amount of trapped pollen/colony/h (5.41 & 5.51g) were recorded during 9.00 and 10.00 h, respectively (Fig. 1). After 14.00 h, all flowers became closed and bee activity on flowers stopped.

### Survey of insect pollinators

Data listed in Table 2 and illustrated graphically in Figure 2 showed that there were eleven insect species belonging to eleven families and five orders recorded as pollinators on the plants.

### Nectar secretion and sugar concentration

As shown in Table 3, the amount of secretion nectar (mg/flower) was higher in pistillate flower (14.49 mg) than in staminate one (9.52 mg).

### Efficiency of pollination on fruit set

Data in Table 4 clearly show the effect of pollination on the seed yield of summer seed watermelon crop. The number of fruits/$m^2$ was 30.07 &0.00 fruits/$m^2$ and the successful fruiting index was 57.23 & 0.00 for open pollination and without pollination treatments, respectively. The mean numbers of mature fruits/$m^2$ were 8.56 &0.00 fruits, mean weight of mature fruit were 1386 & 0.00 g/fruit, seed yield/$m^2$ were 243.79 & 0.00 g/$m^2$ and the seed index was 15.33 g/100 seed for open pollination and without pollination treatments, respectively.

## Discussion

The foraging of honey bee on summer seed watermelon plants depend mainly on percentage of opened flowers that related to the time of day. Similar results were recorded on squash by Shawer et al. (1981) who found that the activity of bees to visit flowers

**Table 3.** Amount of secreted nectar and its sugar concentration in summer seed watermelon flowers.

| Expected honey / hectare (kg) | Sugar/hectare (kg) | Nectar/ hectare (kg) | Sugar concentration (%) | weight of nectar (mg) / flower | No. flowers Hectare | $m^2$ | Flower sex |
|---|---|---|---|---|---|---|---|
| 8.64 | 6.90 | 37.49 | 18.45 | 9.52 | 3938923.80 | 394.05 | Staminate |
| 1.83 | 1.48 | 7.69 | 19.24 | 14.64 | 525189.84 | 52.54 | Pistillate |
| 10.47 | 8.36 | 45.18 | - | - | 4464113.64 | 446.59 | Total |

**Table 4.** Effect of pollination on number of female flowers and fruits/m², number of mature of fruits/m², percentage of fruit aborted, average weight of mature fruit and seed yield of seed watermelon crop.

| Treatments | No. female flowers/m² | No. fruits / m² | Successful fruiting index | No. mature fruits/m² | Mature fruit weight (g) | Seed yield (g/m²) | Seed index (g/100 seed) |
|---|---|---|---|---|---|---|---|
| Open pollination | 52.54 | 30.07[a] | 57.23[a] | 8.56[a] | 1386[a] | 243.79[a] | 15.33[a] |
| Without pollination | 53.54 | 0.00[b] | 0.00[b] | 0.00[b] | 0.00[b] | 0.00[b] | 0.00[b] |
| Significant | N.S | ** | ** | ** | ** | ** | ** |

_ N.S and ** indicate no significant and P<0.01, respectively.

**Table 5.** Correlation coefficient values for opened flowers (%), number of bees/m²/min and trapped pollen (g)/colony/h.

| Comparisons | r – values |
|---|---|
| No. bees/m²/min × Opened flowers % | 0.74* |
| Trapped pollen (g)/colony/h × Opened flowers % | 0.95** |
| Trapped pollen (g)/colony/h × No. bees/m²/min | 0.86** |

- * and ** indicate P<0.05 and P<0.01, respectively.

reached its peak near 9.00 h (2.0 & 3.0 visits/ min) for staminate and pistillate flowers, respectively, after which the number of visits decreased and completely disappeared at 12.00 h at the same period of closing the flowers. Highly significant correlations were found between opened flowers percentage and each of number of bees/m²/min and trapped pollen/colony/h, and between trapped pollen/colony/h and number of bees/m²/min (Table 5). In this concern, DeGrandi-Hoffmann et al. (1991) observed that the greatest number of flowers/m² had also the most nectar and pollen per meter and attracted the greatest number of honey bees.

The dominant species visited the plants and their flowers were A. mellifera L. (61.52%), followed by male flies of Tabanus taeniola Pol. (7.68%). However, the insect orders were arranged according to their abundance on the crop as follows: Hymenoptera (69.22%), Diptera (19.22%), Odonata (5.78 %), Lepidoptera (3.85%) and Coleoptera (1.93%; Fig. 3). The obtained results are in harmony with those found by Shenishen and Shawer (1986) who concluded that, the distribution percentages of Hymenoptera were 67.59, 85.00,

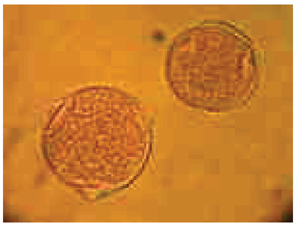


**Photo 1.** Pollen grain of summer seed watermelon.

100.00, 8.07, 24.32 and 74.79% on cabbage, cauliflower, lettuce, carrot, onion and leek crops, respectively. The previous results showed that, although the plurality of pollinators from different orders, the honey bees alone still formed more than sum of the other orders, which due to the high number of bees visited the flowers to collect pollen and/or nectar formed by plants. Bees worldwide stand out as the dominant pollinating group in nearly all geographic regions (Kearns 1992). However, Wilde et al. (1995) reported that in Poland during 1989-91, honey bee formed 66-75% of the population of pollinating insects on field beans (*Vicia faba* L.). In Australia, Rymer et al. (2005) noted that A. mellifera was the most common floral visitor to *Persoonia* flowers, being observed 3 to 10 times more frequently than native bees. On the other hand, flies (Diptera) were the second prevalent species as they represented 19.22% of all pollinators. These results are confirmed by the findings of Kevan and Baker (1983) who reported that, the more notable pollinating flies were belonging to the families: Bombyliidae, Syrphidae, Anthomiidae, Tachinidae, Calliphoridae and Musacidae.

The total amount of nectar (kg/hectare) was higher in staminate flowers (37.49 kg) than in pistillate ones (7.69 kg). This may be due to the highest number of staminate flowers (393893.90 flowers/hectare) in comparison with pistillate ones (525189.84 flowers/hectare).

In respect of sugar concentration, it was higher in pistillate flowers (19.24%) than in staminate ones (18.45%). These results are in agreement with those obtained by Collison and Martin (1979) who found that pistillate cucumber flower produced more nectar and yielded slightly more sugar. The same results were recorded on squash (Shawer et al. 1981). From these results, it could be concluded that one hectare of summer seed watermelon could produce 10.47 kg of honey per season, which is sufficient for building-up one honey bee colony during the dearth period between clover flow and early cotton flow.

Aforementioned results proved the great importance of insect pollinators especially honey bee on fruit set in summer seed watermelon since caged plants without any entomophilous visitation did not produce any fruits at all. These results were confirmed by previous results on cucumber and watermelon (Stanghellini et al. 1997), cantaloup (Iselin et al. 1974) and squash (Shawer et al. 1981; Couto et al. 1990; Skinner and Lovett 1992).

Gravimetrically, it could be theoretically calculate the value added to the crop production by honey bee *A. mellifera*. Non pollinated plants did not produce yield, while open pollinated produced 2436.93 kg seed per one hectare. The price of one kg seed equals 8.00 L.E., so crop of one hectare coasted 19495.44 L.E. As honey bee contributed by 61.52 % of all pollinators, then,

Value added by honey bee = 19495.44 ×61.52/100 =11993.59 L.E.

In this concern, Southwick and Southwick (1989) concluded that the annual value added to US crops production by *A. mellifera*, is estimated to be over 51 billion dollars.

## Conclusion

Lastly, it could be concluded that, movement of honey bee colonies to summer seed watermelon plantations during its flowering period is recommended for economizing the cost of feeding, building-up the colonies and increase seed yield.

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