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ROLE OF THE INSECT POLLINATORS, ESPECIALLY HONEY BEE ON PRODUCTIVITY OF SUNFLOWER SEED YIELD AND ITS RELATION TO SOME OTHER FACTORS

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Abstract: The present investigation was carried out in Assiut region during blooming period (August, 2005) to evaluate the role of insect pollinators on sunflower. The effects of nearness of the fields to honey bee colonies and the weather conditions on pollinators, activity during blooming period as well as the impacts of these factors on seed setting and yield of sunflower crop were also studied. The results showed that the highest activity of insect pollinators especially honey bee was noticed at 10:00 a.m. Honey bee comprised about 96% of all pollinators of sunflower. There was a significant difference in the average numbers of honey bee individuals between the two distances, 500 and 1000 m away from the bee colonies. The bee numbers decreased to one-half with increasing the distance by two-folds. Positive correlations were found between honey bee activity and each of maximum, minimum and average daily temperature. Negative correlations were found between the bee activity and each of maximum, minimum and average relative humidity, and wind velocity. The coefficient of determination was 0.79, indicating that the daily temperature, relative humidity and wind velocity accounted for 79% of bees activity changes. Bee pollination increased seed number by 81% and 71% for near and faraway field, respectively. The setting of seeds was significantly higher (96.9%) in the near field than in the faraway field (86.8%). The increment in seed weight of unbagged heads was about 365% and 340% for near and faraway fields, respectively as compared to bagged heads.

Key words: Honey bee, sunflower, pollinators, weather factors, seed yield.

Introduction

Sunflower (*Helianthus annuus* L.) is among the most important oilseed crops, which has been introduced recently to Egypt. Within such a short time of

introduction, it has proved itself as having great prospects for both horizontal and vertical expansion.

Pollination is an essential factor which affects the production of crops and fruit setting. The majority of pollinators are hymenopterous; honey bees, wild bees, wasps and hornets (Ortiz-Sanchez and Tinaut-Ranera, 1987; Swaminathan and Bhardwaj, 1982; Dimitrov *et al.*, 1992; Toit *et al.*, 1992; Zandigiacomo *et al.*, 1992; Singh *et al.*, 1993).

Sunflower pollen is heavy and sticky so it cannot be carried away by wind. Honey bees are the main agency responsible for transfer of pollen from male to female flowers. Most of the time, phantom seed set, that is no kernel inside seed coat or unfilled seeds, occurs mainly due to inadequate pollination.

Sunflower plants are known of their self incompatibility and the production of abundant pollen and nectar during flowering. This gave sunflower the advantage of being attractive to honey bees and other insects (Free, 1993). It belongs to typical allogeamic (cross pollinated), entomofillic plants, which require pollinators in order to effect high quality fertilization. The productivity of the crop is mainly affected by insect pollinators which improve the quantity and the quality of seed yield. Honey bees are the most important pollinators of commercial agricultural and horticultural crops, which require pollination for production of economic yields. The value of the honey bee as a pollinator is far greater than its value as a honey producer (Free, 1993).

Honey bee pollinators are considered the most important factors affecting productivity of sunflower (McGregor, 1984). It is efficient pollinators because of their physical and behavioral characteristics (Headings, 1984), as well as bees indiscriminate movement between male and female flower heads (Parker, 1981). Many studies showed that there was a difference among sunflower hybrids regarding their pollination by honey bees (Singh and Singh, 1999) caused by differences in activity of bees in various weather conditions. (Miklic, 1996: DeGrandi-Hoffman *et al.*, 2000).

The present investigation was carried out to evaluate the insect pollinators that are in abundance. and the influence of the distance between the honey bee colonies and sunflower fields and weather conditions on pollinators, activity during blooming period and the impacts of affects these factors on seed setting and yield of sunflower crop.

Materials and Methods

The field work of this study was carried out at two fields in Assiut region, the first is located 500 m apart from the honey bee colonies and the second was 1000 m

apart from the honey bee colonies. The variety of sun-flower was Fedowk and the date was during blooming period (August, 2005).

Activity of pollinators at day-time:

During the flowering season, 50 sunflower plants were observed to record the number of insect pollinators visiting the flower heads. The numbers were monitored during the day time at five intervals, namely 7 a.m., 10 a.m., 1 p.m., 4 p.m. and 7 p.m., to assess the time of activity of honey bee and other insect pollinators.

Insect pollinators on sunflower at two fields:

In order to estimate the spatial activity of honey bee on pollinating the sunflower heads, the study was conducted in two fields; one was located near the honey bee colonies (500 m far from the bee colonies) and other was about 1000 m far from the honey bee colonies.

The insect visitors to sunflower heads were counted once every three days, starting by the first open flowers and ending by the last open ones. The diurnal inspection was fulfilled at three times a day; at 10 a.m., 12 n. and 2 p.m.

Meteorological data:

Record of tested weather factors at the inspected dates were obtained from the Meteorological Station located at the Faculty of Agriculture Farm of Assiut University. The following meteorological factors were tested:

- Maximum, minimum and mean daily temperature.
- Maximum and minimum daily relative humidity.
- Wind velocity.

Meteorological effects were assessed through the correlation coefficients of pollinators activity with either of weather factors.

Insect pollinators and seed yield:

The experiment was managed on the two fields located near and faraway from the apiary, that previously mentioned. At the beginning of blooming, 30 heads from each field were selected randomly and divided into two groups, each contains 15 heads. The heads of the first group were covered by a mousseline cloth to prevent insect pollinators and insure good ventilation. The second group was left unbagged. The bags were removed after the seed setting. At the harvest time, the heads of each group were collected and left to dry under laboratory conditions. Seed samples were taken randomly from the inspected heads. Each sample contained 100 seeds randomly chosen from the pooled seeds. Ten samples were taken from each group of inspected heads. The seeds were subjected to certain examination. The weight of each seed samples (100 seeds), the

successful setting of seeds in which the true seeds were separated from the failed setting seeds. Also, the increment of seed weight due to insect pollination was calculated using the following equation:

$$\text{Increase in seed weight (Increment \%)} = \frac{\text{W. unbagged sample - W. bagged sample}}{\text{W. bagged sample}} \times 100$$

Statistical analysis:

The statistical analysis was conducted using the SAS general linear models procedure. Differences among means were determined by Duncan's multiple range test or t-test. Significant differences were determined at $P<0.05$. Simple and multiple correlations for the relation between studied factors were calculated (SAS Institute, 1990).

Results and Discussions

Activity of pollinators at day-time:

Table (1) shows the effect of day-time on the activity of insect pollinators on sunflower plants.

Table(1): Activity of insect pollinators at the day-time on sunflower plants, in Assiut region during August, 2005.

Day-time	Number of pollinators per 50 sunflower heads & (%)			
	Honey bees	Carpenter bees	*Vespa* spp.	*Syrphus* spp.
7 a.m.	55 (100)	0	0	0
10 a.m.	81 (87)	10 (10.75)	1 (1.07)	1 (1.07)
1 p.m.	60 (100)	0	0	0
4 p.m.	55 (98)	1 (2)	0	0
7 p.m.	51 (100)	0	0	0
Mean (%)	60.4 (95.87)	2.2 (3.49)	0.2 (0.3)	0.2 (0.3)

Numbers of honey bees and other pollinators of sunflower peaked at 10.00 h. This is close to observations in India by Kumar *et al.* (2002), who reported that the peak period of honey bee activity was between 09:00 h and 11:00 h. The highest activity of honey bee and carpenter bee was noticed at 10:00 a.m. for both, in which 81 and 10 individuals/50 heads for honey bee and carpenter bee, respectively. At 01:00 h p.m. honey bee showed marked activety, whereas the lowest activity was noticed at 07:00 a.m., 04:00 and 07:00 p.m.

In general, honey bee comprised about 96% of all pollinators of sunflower, followed by carpenter bee (3.5%). Similar results in the same area were obtained by Hussein and Abdel-Aal (1982) who reported that honey bee comprised 96.2%.

Meanwhile, honey bee comprised 75.3% of all pollinators of sunflower in India (Singh *et al.*, 1993); 52-76%, in Italy (Zandigiacomo *et al.*, 1992); 93.9%, in Brazil (Butignol, 1990); 62.4%, in Bulgaria (Dimitrov *et al.*, 1992) and 46.9%, in South Africa.

Insect pollinators on sunflower fields at two distances:

Percentage and mean number of pollinators were recorded on flowering sunflower, located at two distances from honey bee colonies. The results illustrated in Table(2) indicated that hymenopterous pollinators specially honey bees and carpenter bee (*Xylocopa* sp.) comprised almost 100% of all studied pollinators. Honey bees constituted 98.5% and *Xylocopa* wasp was 1.5% of pollinators. In general, there is significant difference in the mean numbers

Table(2): Percentages and numbers of pollinators on flowering sunflower, located at two different distances from the bee colonies, during August 2005 in Assiut region.

Sampling	Sampling time	Number of pollinators/50 heads & (%)			
		The near field (500 m)		The faraway field (1000 m)	
		Honey bees	Carpenter bees	Honey bees	Carpenter bees
15 August	10 a.m.	63 (98.44)	1 (1.56)	28 (100)	0 (0)
	12 n.	37 (100)	0 (0)	18 (100)	0 (0)
	2 p.m.	38 (95)	2 (5)	15 (93.75)	1 (6.25)
	Mean	46	1.0	20.3	0.3
18 August	10 a.m.	33 (94.29)	2 (5.71)	14 (93.33)	1 (6.67)
	12 n.	27 (100)	0 (0)	13 (100)	0 (0)
	2 p.m.	24 (100)	0 (0)	14 (100)	0 (0)
	Mean	28	0.7	13.7	0.3
21 August	10 a.m.	13 (100)	0 (0)	16 (100)	0 (0)
	12 n.	22 (100)	0 (0)	13 (100)	0 (0)
	2 p.m.	26 (100)	0 (0)	10 (100)	0 (0)
	Mean	20.3	0	13	0
24 August	10 a.m.	23 (95.83)	1 (4.17)	14 (100)	0 (0)
	12 n.	13 (100)	0 (0)	11 (100)	0 (0)
	2 p.m.	12 (100)	0 (0)	10 (100)	0 (0)
	Mean	16	0.3	11.7	0
27 August	10 a.m.	10 (100)	0 (0)	3 (100)	0 (0)
	12 n.	10 (100)	0 (0)	2 (100)	0 (0)
	2 p.m.	5 (100)	0 (0)	6 (100)	0 (0)
	Mean	8.3	0	3.7	0
30 August	10 a.m.	4 (80)	1 (20)	1 (100)	0 (0)
	12 n.	1 (100)	0 (0)	2 (100)	0 (0)
	2 p.m.	3 (100)	0 (0)	0 (0)	0 (0)
	Mean	2.7	0.3	1.0	0
Mean (±SD) (%)		20.22±15.79* (97.97)	0.39 (2.03)	10.56±7.21* (99.28)	0.11 (0.72)

Figures followed by the asterisk (*) are significantly different between near and faraway fields at 0.05 probability.

of honey bees between the two distances (500 and 1000 m). The average numbers of honey bee pollinators were 20.22 bees/50 heads in the near field, but 10.56/50 heads at the distance of 1000 m from the honey bee colonies indicating that the number of honey bee decreased to only one-half with distance. The maximum activity of honey bee pollinators was observed at 10 a.m. while the lowest activity was noticed at 2 p.m., for the two studied distances.

Among the diverse flower visitors of sunflower at the study area, honey bee was the most abundant and important floral visitor in effecting pollination. This confirm the results of Calmasur and Özbek (1999) who reported that the species with the highest number of bees visiting sunflowers was *Apis mellifera* (80-88%), whereas the wild bee species accounted for 12-20% of sunflower visits.

Other studies have also reported the importance of honey bee in sunflower production e.g., Moretia *et al.* (1993) and Hoffmann (1994) who found that 80% of sunflower pollinators were honey bees. Pollination efficiency of non-honey bees were low, confirming their unreliability as pollinators of sunflower. Honey bee were shown to forage efficiently and visits many sunflower heads in presence of more non-honey bees (De Grandi -Hoffman and Watkins, 2000; Greenleaf and Kremen, 2006). The ability of honey bees to forage on many sunflower heads improves their pollination potential better than non-honey bee. The results of this study confirmed that non-honey bees are inefficient pollinators and play only a secondary role in sunflower pollination (Radford *et al.*, 1979 and El-Sarrag *et al.*, 1993). Sunflowers are highly attractive to many species of bees, but the primary pollinator of commercial plantings is the honey bee (Parker, 1981). According to Headings (1984), honey bees are efficient pollinators because of their physical and behavioral characteristics. Also, the indiscriminate movement of honey bees between male and female flower heads (Parker, 1981).

Honey bee activity as related to meteorological factors:

The relationships between honey bee activity and three weather factors namely daily temperature, relative humidity and wind velocity during blooming period of sunflower plants are shown in Figure (1). Total daily visit of the bees was dependent on weather conditions.The most frequent visit occurred on the 15th of August (33.2 individuals/50 heads), during the day, daily average temperature was 31.06°C, 49% R.H. and 2.5 m/sec wind velocity.

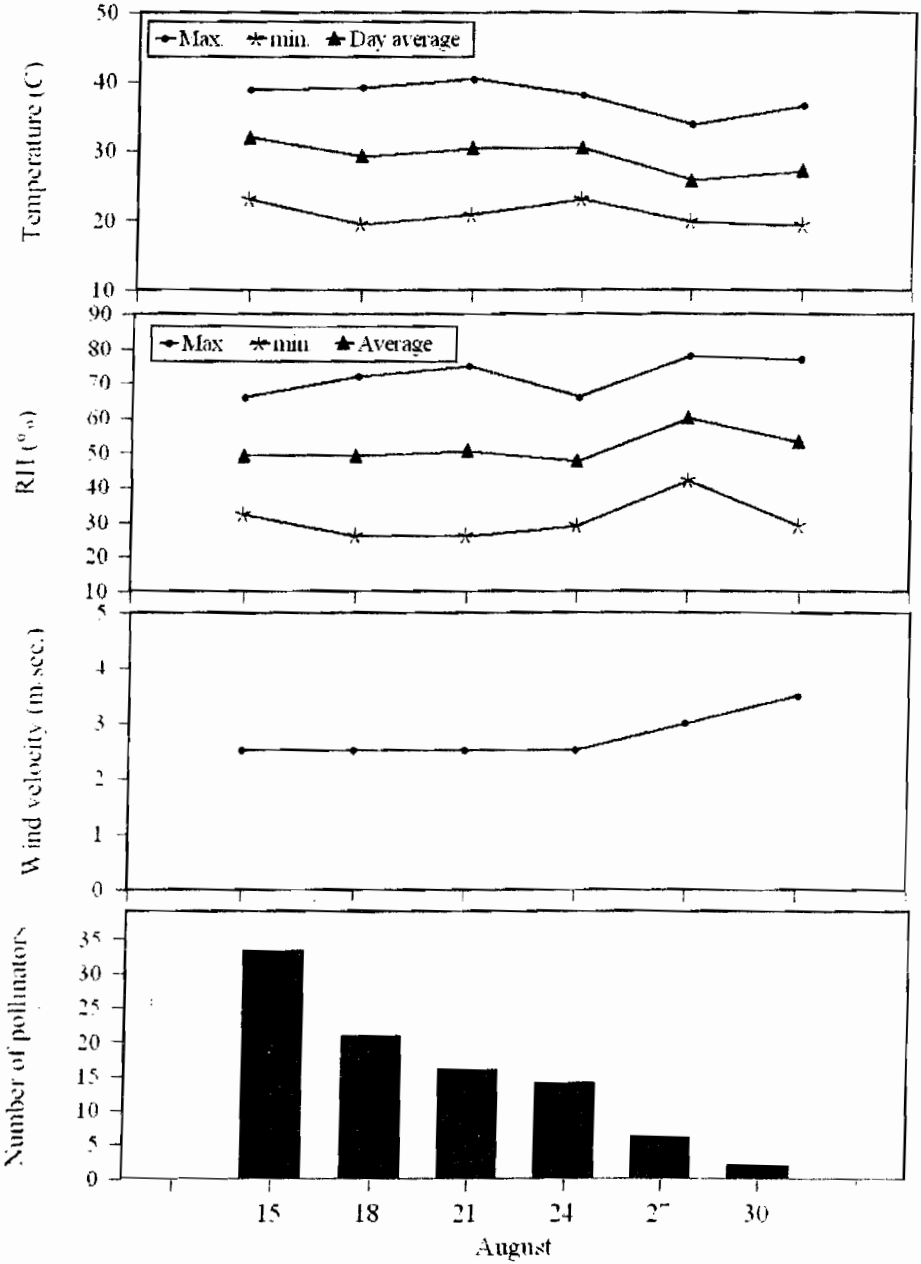

Fig 1. Honey bee activity as related to meteorological factors, temperature, relative humidity and wind velocity during blooming period of sunflower plants, August, 2005

Whereas the minimal value was observed during 30th of August (1.9 individ-uals/50 heads) at 27.1°C, 53% R.H. and 3.5 m/sec., this occurred at the end of sunflower blooming period.

Many correlations were found between honey bees activity and each of temperature, relative humidity and wind velocity during sunflower flowering period. Positive correlations were found between honey bees activity and each of maximum daily temperature (r=0.634), minimum temperature (r=0.609)and average day temperature (r= 0.871). This means that the bees activity increased with increased day temperature at the range of 19.2-41.2°C. Negative correlations were found between the bees activity and each of maximum relative humidity (r=-0.735), mini-mum relative humidity(r= -0.362), average of humidity (r= -0.604) and wind velocity (r= -0.78).Thus, bees activity decreased with increased relative humidity at range of 22-83% and wind velocity at 2.5-3.5m/sec. Statistical analysis indicated that the coefficient of determination was 0.79, indicating that the three mentioned variable factors, daily temperature, relative humidity and wind velocity were responsible for 79% of the bees activity changes during sunflower blooming period.

Influence of weather conditions on honey bee activity during sunflower blooming period in different regions were studied by many authors. They noticed the bee activity during different weather conditions, depending on particular investigation site and its weather conditions (Miklic, 1996; Sihag and Khatkar, 1999; De Grandi-Hoffman *et al.*, 2000 and Mordago *et al.*, 2002). In India nearly similar results were obtained by Kumar *et al.* (2002) who observed that the most intensive bee activity was at 20-28°C and 40-50% R.H. They found also significant differences regarding honey bee activity on sunflower with temperature, humidity, rain and wind velocity. The present results confirm those of Jocic *et al.* (2000) and Puskadija *et al.* (2007) who found positive correlations between average and maximum daily temperature, and bee activities. However, higher humidity, heavy rainfall, strong wind and lower temperature (if lower than 10°C) had negative impact on sunflower inflorescence visits. They also suggested that the ideal ratio between minimum and maximum daily temperature would be at 10-30°C. This has also been approved by the present investigation. Bees begin to lose interest in foraging when wind velocity reaches 6.7 m/sec. (Goodman, 1994).

Based on the above results and previous studies, it can be concluded that a little or no honey bee flight activity occurs at below

10°C, some flight will be seen at temperatures of 12-16°C. Foraging activity increases sharply as the temperature continuous to rise. Above 20°C, it tends to reach a relatively constant high level. Relative humidity, is an important factor in combination with temperature, it is most important in the ripening of the anthers of the flowers, and the availability of pollen to visiting insects.Optimum conditions for pollen release are temperatures of 20°C and above, and humidities of 70% or less. Therefore, low temperatures and high humidities have the double effect of reducing bee activity and slowing the release of pollen. High winds tend to slow the flight speed of bees and hence reduce the number of flights per day. On the other hand, temperature, humidity and wind affect the quantity and sugar concentration of the nectar which the flowers secrete, and hence their attractiveness to bees. Most flowers of plants being open in shape are very susceptible to changes in temperature, humidity and wind. In general, the higher of sugar concentration the more attractive a nectar is to bees. High temperatures (not extreme), low humidities and some air movement give high nectar sugar concentration, which plays a great role in honey bee attraction (Goodman, 1994).

Effect of insect pollinators on seed yield of sunflower:

Since the seeds are produced from the successful self and/or insect pollination, the number of setting seeds among the failed seeds in each sunflower head can used as a criterion resembles the improvement of seed yield. The seeds produced from the bagged and unbagged heads in sunflower fields located at two fields, near to and faraway from the honey bee colonies were recorded in Table (3). Apparently, the bagged heads produced small numbers of setting seeds in both near and faraway field which averaged 15.4 and 15.2 seeds, while the unbagged heads produced high level of setting seeds (96.9 and 86.8 seeds, from the two fields, respectively). It means that the cross-pollination took hold in the bagged heads at lower level of successful compared with the unbagged heads. The open heads made allowance to the insect pollination to take place and improved the seed setting. The insect pollinators help to solve the problem of the sunflower pollination. As is well known, the sunflower plant is characterized by the presence of the sorophytic system of self-incompatibility, which may explain its high percentage of cross-fertilization under natural conditions that sometimes reach 95%. The insect pollinators carry the pollen grains from different sunflower heads to insure the pollination process, the

Table(3): Numbers of setting seeds produced from the unbagged and bagged sunflower heads from the near and faraway fields from bee colonies, in Assiut region.

Samples	Numbers of setting (100 seeds/sample)			
	The near field (500 m)		The faraway field (100 m)	
	Unbagged heads	Bagged heads	Unbagged heads	Bagged heads
1	98	4	74	0
2	97	32	86	16
3	96	14	88	0
4	96	12	87	18
5	100	19	92	18
6	97	15	85	26
7	97	30	92	14
8	93	3	87	17
9	98	11	87	23
10	97	13	90	20
Mean ± SD	96.90 A ± 1.79	15.40 C ± 9.44	86.80 B ± 5.10	15.20 C ± 8.72

Means have the same letter(s) do not significantly different at 0.05 level of probability.

first step for successful germination and yielding seeds. The present results show that the setting seeds were higher (96.90%) in the near field than that the faraway field (86.8%). The two means were significantly different which explain that honey bee was the most active insect pollinator that restricted their activity nearby the bee colonies more than the faraway field. However, it has been claimed that the seed yield depends on the nearness crop to honey bee colonies. These results are confirmed by Manning and Boland (2000), they found that the number of seeds decreased as distance from the bee colonies. Bee pollination increased sunflower seed number by 81% and 71% for near and faraway field.

Table 4 illustrate the weight of produced seeds obtained from bagged and unbagged heads cultivated in near and faraway fields. The highest weight of 9.35 gm (per 100 seeds) was obtained from unbagged heads of the near field, that differed significantly over the other compared mean. The weight of seeds obtained from the unbag-ged heads in the faraway field arranged the next, since 7.50 gm was recorded. On the other hand, the two means of the bagged heads in the near and

faraway fields reported the least weight of 2.27 and 2.02 gm. which differed significantly from the unbagged heads of the near field. The increment in seed weight of unbagged heads was about 365% and 340% for near and faraway field, respectively compared to bagged heads (Table 4). The present results are in agreement with many previous authors who reported that the open pollination of sunflower caused an increase in seed yield over no bee treatment.

Table(4): Weight of seeds produced from the unbagged and bagged sunflower heads from the near and faraway fields from bee colonies, in Assiut region.

Samples	Weight of 100 seeds per gm					
	The near field			The faraway field		
	Unbagged	Bagged	Increment (%)	Unbagged	Bagged	Increment (%)
1	11.25	1.26	793	6.66	0.85	684
2	11.12	3.58	211	7.65	2.34	227
3	10.98	1.87	487	7.94	0.81	880
4	10.69	1.98	440	7.70	2.24	244
5	9.67	2.62	269	6.76	2.23	203
6	7.87	2.12	271	7.50	2.72	176
7	8.31	3.57	133	7.71	1.96	293
8	7.82	1.25	526	8.00	2.17	269
9	7.79	1.99	292	7.37	2.27	225
10	8.01	2.45	227	7.68	2.60	195
Mean	9.35 A	2.27 C	364.9	7.50 B	2.02 C	339.6
± SD	± 1.53	± 0.81		± 0.45	± 0.66	

Means have the same letter(s) do not significantly different at 0.05 level of probability.

Calmasur and Özbek (1999), showed that the highest number of filled seeds and seed weight were obtained in natural conditions and the lowest values were obtained in cages. Seed setting ratios were 86.8% in natural conditions, 67.8% in cages with bees and 31.5% in cages without bees. The weight of 100 seeds in natural conditions and without bees were 5.2 g and 2.0 g.

The present results are confirmed by many studies elsewhere

in the world, it have also reported increased seed yield by 53-75% (e.g., Moretia *et al.*, 1993; Hoffmann, 1994; Paiva *et al.*, 2003 and Nderitu *et al.*, 2008). Bee pollination also improves the seed oil content, which is the main reason of growing sunflower crop. Langridge and Goodman (1981) showed that the seeds obtained from sunflower exposed to pollinators especially, honey bee had high oil content.

Other authors (Kevan, 2001; Kumar *et al.*, 2002, 2003; Pidek and Pohorecka, 2004) confirmed such results and also emphasized the importance of introduction of honey bees pollination as a regular technologic measure in the cultivation of sunflowers. The activities of honey bees in pollination of agricultural crops such as sunflower, because of their high numbers, intensive daily activity, as well as their body structure assure pollen transportation from one sunflower head inflorescence to another. This provides for high quality pollination of the tube shaped sunflower flowers. Sunflower plants are known of their self incompatibility and the production of abundant pollen and nectar during flowering (Free,1993). This gave sunflower the advantage of being more attractive to honey bees and other insect pollinators. As a result, seeds of good quality and high yield were produced (El-Sarrag *et al.*, 1993).

The increment in seed numbers and seed weight when sunflower heads were available to insect pollinator especially, honey bee could have been caused by both increased self-pollination and possibly cross-pollination. Bees transfer pollen among florets on the same head, while they forage and also frequently transfer pollen between heads and different plants.

Based on the present findings and previous informations, it can be concluded that the honey bee play an important role as pollinator agent among the other insect pollinators to improve the sunflower seed yield. Honey bee activity as a pollinator affected in a combination by many factors such as, day-time, the nearness crop to honey bee colonies and weather conditions.

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دور الملقحات الحشرية وخصوصاً نحل العسل على إنتاجية محصول بذور عباد الشمس وعلاقة ذلك ببعض العوامل الأخرى

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أجريت هذه الدراسة فى منطقة أسيوط خلال فترة التزهير لمحصول عباد الشمس (أغسطس 2005م) . بغرض معرفة أنواع الملقحات الحشرية وأيضا لدراسة تأثير كل من مدى قرب طوائف نحل العسل من حقول عباد الشمس و العوامل الجوية (الحرارة والرطوبة والرياح) على نشاط الملقحات الحشرية خلال فترة التزهير . بالإضافة إلى دور تلك العوامل على العقد وكمية المحصول . وأوضحت النتائج أن أعلى نشاط للملقحات الحشرية وخصوصاً نحل العسل سجّل الساعة العاشرة صباحاً . وكان نحل العسل يمثل 96% من إجمالى الملقحات الحشرية المتواجدة . وأوجدت الدراسة إختلافات معنوية فى تعداد نحل العسل ما بين حقلى الدراسة الواقعة على مسافة 500 متر ، 1000 متر من طوائف نحل العسل . حيث قل تعداد النحل إلى النصف فى حالة زيادة المسافة إلى الضعف . وأوضحت الدراسة وجود علاقات موجبة ما بين نشاط نحل العسل وكل من درجة الحرارة العظمى والصغرى والمتوسط اليومى . كما أوضحت أيضا وجود علاقات سالبة ما بين نشاط نحل العسل وكل من نسبة الرطوبة العظمى والصغرى والمتوسط اليومى وسرعة الرياح . وكان مقدار معامل التقدير 0.79 موضحاً أن هذه العوامل مجتمعة أثرت بنسبة 79% على التغيرات فى نشاط نحل العسل . وبينت هذه النتائج أن التلقيح بنحل العسل أحدث زيادة فى عدد البذور الناتجة بمعدل 81% ، 71% للحقل القريب والبعيد عن طوائف نحل العسل على التوالى . وكان معدل عقد البذور أعلى بصورة معنوية فى الحقل القريب (96.9%) عن الحقل البعيد (86.8%) لطوائف النحل . وقدرت الزيادة فى وزن البذور للنباتات مفتوحة التلقيح بـ 365% و 340% لكل من الحقل القريب والبعيد عن طوائف نحل العسل على التوالى وذلك بالمقارنة بالنباتات المعزولة .