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Behavior, Activity and Pollination Effect of *Apis mellifera* L. and Native Bees Foraging on Hybrid and Open-Pollinated Varieties of Sunflower, *Helianthus* annuus L.

Murtadha K. Glaiim * Siena'a M. Abid Ayad K. Al-Sindy Ali A. Kareem

Department of Plant Protection, College of Agriculture,
Kerbala University, Iraq

Abstract :

This field study carried out in 2008 at the College of Agriculture, Kerbala University dealt with different aspects of behavior, activity and pollination effect of *Apis mellifera* L. and native bees foraging on heads of two varieties of sunflower, *Helianthus annuus* L., a hybrid produced in Turkey and called " Coban " and an open-pollinated variety called " Sinn el-Theeb ". The percentages of total recorded individuals of *A.mellifera* and all native bees were 52.34 and 47.66%, respectively. The most abundant species of native bees were *Megachile* sp. and *Nomia* sp. while *Xylocopa fenestrate, X.aestuans* and other unidentified species were in fewer numbers. About 72 and 28% of all *A.mellifera* individuals were nectar-collectors and pollen-collectors, respectively. The displacement behavior practiced by all insect species was very remarkable. About 44% of *A.mellifera* and 22 to 50% of native bee individuals were forced to leave flowers through physical disturbance committed by other visitors. The study also covered other aspects including seasonal and diurnal visitation patterns and duration of a single visit / insect. The pollinating insects had insignificant effect on the yield of hybrid variety for it was highly self-compatible while they had a great benefit in this regard for the open-pollinated variety which was highly self-incompatible. For instance, mean seed-setting rates of first variety reached 88.1 and 81.4% in open and bagged heads, respectively. The rates of second variety were 79.8 and only 10.1% in open and bagged heads, respectively.

الخلاصة:

تعنى هذه الدراسة التي أجريت في كلية الزراعة / جامعة كربلاء خلال الموسم الربيعي ٢٠٠٨ بدراسة جوانب مختلفة من سلوك ونشاط وتأثير تلقيح نحل العسل *Apis mellifera L.* وأنواع النحل البري السارحة على صنفين من عباد الشمس *Helianthus annuus L.* : صنف هجين منتج في تركيا يسمى " كوبان " وصنف مفتوح التلقيح يسمى محلياً " سن الذيب " . بلغت النسبة المئوية لأعداد كل من نحل العسل وعموم النحل البري ٥٢.٣٤ و ٤٧.٦٦% على التوالي . كان النوعان *Megachile* sp. و *Nomia* sp. أكثر أنواع النحل البري غزارة في عدد الأفراد الزائرة للأزهار بينما كانت هناك أعداد قليلة من النوعين *Xylocopa fenestrata* و *X. aestuans* وكذلك أنواع أخرى غير معرفة . ومن بين كل أفراد نحل العسل شكلت تلك الجامعة للرحيق حوالي ٧٢% والأفراد الجامعة لحبوب اللقاح ٢٨% . لوحظ إن سلوك الإزاحة التي تمارسها الأفراد التابعة لكل أنواع النحل لبعضها البعض واضح وجلي جداً حيث وجد أن حوالي ٤٤% من أفراد نحل العسل و ٢٢-٥٠% من أفراد النحل البري قد تمت إزاحتها من على أقراص عباد الشمس من قبل أفراد زائرة أخرى ، قد تكون تابعة لنفس النوع أو لنوع آخر . شملت الدراسة أيضاً جوانب أخرى تمثلت بالكثافات العددية لأنواع الحشرات الملقحة خلال الأسابيع وساعات النهار المختلفة إضافة إلى مدة الزيارة الواحدة التي يقضيها فرد واحد على زهرة واحدة . أما بالنسبة لتأثير تلقيح الحشرات على زيادة إنتاج البذور فإنه لوحظ بأن الصنف الهجين كان عالي التوافق الذاتي ولذلك لم تكن لزيارة تلك الحشرات تأثيراً معنوياً على إنتاجه . على العكس من ذلك فإن دور الحشرات كان معنوياً وحاسماً في زيادة إنتاج بذور الصنف المفتوح التلقيح الذي كان بمستوى عالي من عدم التوافق الذاتي . فعلى سبيل المثال بلغ معدلا عقد البذور في الأقراص المكشوفة لزيارة الحشرات والأقراص التي غطيت بأكياس لمنع زيارة الحشرات في الصنف الأول ٨٨.١% و ٨١.٤% على التوالي بينما بلغا في الصنف الثاني ٧٩.٨ و ١٠.١% في الأقراص المكشوفة والأقراص المكيسة على التوالي .

Introduction

Flower self-incompatibility is a common characteristic found in many varieties of sunflower, *Helianthus annuus* L., although the florets are hermaphrodite (McGregor, 1976; Free, 1993).

There has been a body of literature emphasizing the prominent role of *Apis mellifera* L. and native bees in increasing rates of seed setting, number of seeds per head, seed weight, seed germination percentage, seed oil content, . . . etc. (e.g. Furgala *et al*., 1979; Krause and Wilson, 1981; Parker, 1981; Freund and Furgala, 1982; Mahmood and Furgala, 1983; Moalif and Al-Azzawi, 1989; Jyoti and Brewer, 1999; Greenleaf and Kremen, 2006). During the last decades plant breeders have employed the phenomenon of male sterility to produce commercial hybrid cultivars of sunflower that are highly self-compatible. Production of hybrid cultivars, of course, alleviates the need of honey bee and native bees for pollination. Fick (1979), however, reported " even the hybrid varieties, which are as high as 80 to 90% self-compatible, benefit from cross pollination because there is variation in the levels of self-compatibility in sunflowers ".

Although *A. mellifera* is the principal species used for crop pollination worldwide (Free, 1993), it has been found that it is inefficient pollinating insect on the basis of a single-visit when working in the farms of sunflower (Free, 1993; Greenleaf and Kremen, 2006). Many workers have found that honey bees are rarely observed collecting sunflower pollen; they confine their activities to gathering nectar. Also, individual honey bee forgers specialize in collecting either nectar or pollen on each trip. In contrast, most native bees collect both pollen and nectar on each foraging trip; hence they tend to cross between the rows (Tepedino and Parker, 1989; Corbet, 1987; Corbet *et al*. 1991; Freitas and Paxton, 1998; Satyabir *et al*. 1999; Greenleaf and Kremen, 2006; Basualdo *et al*., 2007). The role of native bees in pollination of sunflower as well as other crops has highly been emphasized recently (Corbet, 1987; Moalif and Al-Azzawi, 1989; Kelin *et al*., 2003; Shuler *et al*., 2005; Greenleaf and Kremen, 2006). Kevan (2001) (cited by Greenleaf and Kremen, 2006) reported that supplies of *A. mellifera* have declined, in part because of problems caused by parasitic mites and pesticide misuse. This author added that the number of honey bee colonies in USA declined from > 4 million colonies in 1970's to 2.41 million. Such a decline has also takenplace in Europe. Greenleaf and Kremen (2006) found that 33 native bee species visit sunflowers growing in Yolo county, Califorina. In Basra, Iraq, Moalif and Al-Azzawi (1989) recorded five identified species. Goulson (2003) reviewed many studies dealing with the behavior of competition and displacement of *A. mellifera* and native bees forging on different crops.

The objectives of this study are: 1. surveing diversity and abundance of native bees visiting sunflower, 2. studying patterns of activity of different pollinating insects, 3. studying the behavior of competition and displacement of different bee species, 4. determining the effect of *A. mellifera* and native bees on the yield of self-compatible & self-incompatible varieties of sunflower grown in Iraq.

Materials and Methods

The study was conducted in 2008 at the College of Agriculture, Kerbala University, Iraq using two commercial varieties of sunflower, *Helianthus annuus* L. One of the varieties is a hybrid called " Coban " and supplied by Monsanto Gida Ve Tarim Ticaret, Ltd., Turkey. The another is an open-pollinated variety called locally " Sinn el-Theeb ". The field was dividied into six plots containing eight 3-m long rows each. Each plot was divided into two equal subplots containing four adjacent rows each, and each of the subplots was used randomly for a variety. The seeds were sown on ridges by dibbling in the rows on March 12th, 2008. The rows and plants were kept 65 and 25cm apart, respectively. There were 10 colonies of honey bee, *Apis mellifera* L., housed in modern Langstroth hives about 100m from the field. There were also other colonies kept by some people living in the immediate vicinity. The individuals of honey bee and native bees foraging on sunflower heads were counted every other hour during blooming period from 6.00 a.m. to 6.00 p.m. This count was done at three-day intervals from May 15th to June 11th ,2008. Pollen and nectar collecting honey bees were counted separately, honey bees with pollen in their corbiculae were categorized as pollen collectors and those without pollen in the corbiculae as nectar-collecting honey bees. Such a categorization was not applied for native bees, for it has been found that most honey bee workers specialize as either nectar or pollen foragers while most native bees collect both pollen and nectar on each foraging trip (e.g. Free, 1993; Greenleaf and Kremen, 2006). Sunflower heads found in complete or partial stage of anthesis were counted just before each count of foraging insects. Aside from this counting process which was done for studying insect population density, foraging honey bees and all native bees were watched carefully during the whole period of study to determine two aspects of their foraging behavior: 1. displacement act committed on sunflower heads by all insect species, 2. duration of a single visit per insect per flower. The visit duration was only recorded when an individual lands on the head and then leaves it " willingly ", i.e. without disturbance of another individual. When an individual was forced to leave the head, both species of displaced and displacing individuals were recorded. The identification of all native bee species was carried out by Prof. Dr. Ali S. Moalif, College of Science, Babylon University, Iraq. In order to determine the efficacy of pollinating insects on seed production, some heads in each subplot were covered with cheesecloth bags just before anthesis stage to exclude these heads from visits of all foraging insects. Other heads were left open for insect visits but these heads were covered later (at the stage of seed maturity) with perforated paper bags to prevent birds picking up the seeds. Finally, open and bagged heads of all treatments were taken randomly and then threshed separately for counting and weighing their seeds. Each sunflower variety was represented by 72 heads at the ratio of 1:1 for open and bagged heads. The statistical analysis of variance (ANOVA) was based on the split-plot design (Little and Hills, 1978).

Result and Discussion

1. Diversity and Abundance of Pollinating Insects

Figure (1) shows blooming patterns of both varieties of sunflower. Blooming period of hybrid variety started and ended earlier than that of open-pollinated variety. It seems that period of anthesis stage of hybrid variety is shorter than that of the another variety. The heads of the first variety were also smaller than those of the second variety. All these factors may explain why the total number of all pollinating insects recorded on the hybrid variety was obviously smaller than that recorded on the open-pollinated variety as shown in Figure (2). Total numbers and percentages of all pollinating insects counted on the two varieties were 222 (21.2%) and 825 (78.8%) insects, respectively.

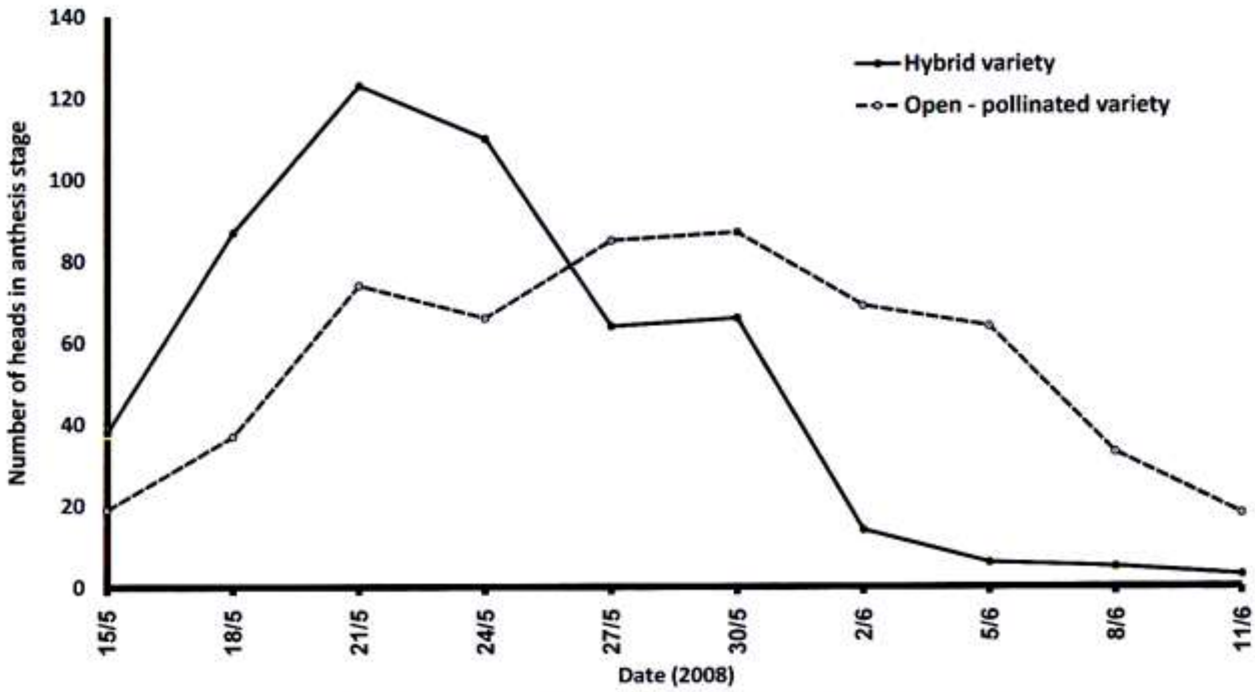
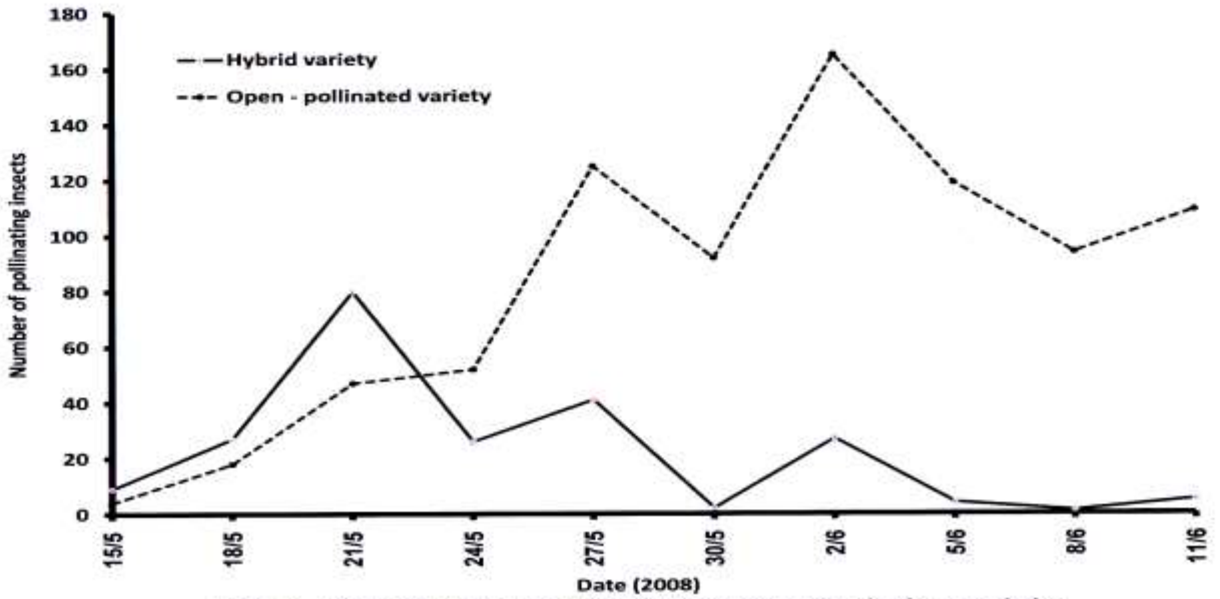


Figure 1 . Total numbers of heads found in anthesis stage of two varieties of sunflower , *Helianthus annuus* L.



Date (2008)
Figure 2. Total number of pollinating insects counted on heads of two varieties

The identified pollinating insects were belonging to the following species and species groups: *Apis mellifera* L., *Megachile* spp., *Nomia* spp., *Xylocopa fenestrata* F. and *X. aestuans* L. There were also individuals belonging to other unidentified species but they only represented 3.72% of the total number of pollinating insects. Table (1) shows total numbers and percentage of these species individuals. The ratio of *A. mellifera* individuals to those of all native bees was nearly one to one (52.34 and 47.66%, respectively). Greenleaf and Kremen (2006) found that honey bees were the most abundant pollinator species in sunflower fields in California, USA for they comprised 72% of all bee visits of this crop by 33 bee species. Most honey bees were nectar collectors; about 72 and 28% of honey bee individuals were nectar-collectors and pollen-collectors, respectively. There have been many studies emphasizing that honey bees are rarely observed collected sunflower pollen; they concentrate their activities to gathering nectar (Tepedino and Parker, 1982; Free, 1993; Greenleaf and Kremen, 2006; Basualdo *et al*., 2007). Satyabir *et al*. (1999) believe that attractivity of the pollen for honey bees can be affected by lipid content. These authors found that honey bees prefer *Brassica campestris* pollen, which has a high lipid content, over sunflower pollen, which has a low lipid content. Most of the native bee individuals belonged to *Megachile* spp. and *Nomia* spp. for they comprised about 83% of all native bees. *Xylocopa fenestrata*, *X. aestuans* and other unidentified species were found in small numbers. Moalif and Al-Azzawi (1989) found that *Xylocopa fenestrata* and *Ceratinia laevifrons* were the most abundant species found visiting sunflower in Basra, Iraq while *X. aestuans*, *Megachile* spp. and *Halictus* spp. were in small numbers. Greenleaf and Kremen (2006) found 33 native bees visiting sunflower grown in Yolo County, California. Of these, the most important visitors were *Melissodes* sp., *Diadasia* sp., *Svastra* sp., *Bombus vasensenskii* and *Halictus ligatus*. It may be speculated that there were some factors affecting the numbers of both honey bee and native bees recorded in this study. There were two major sources of food for bees, *Trifolium alexanderinum* and *Eucalyptus* sp., blooming during the same period in the region. It is well known that these two species are among the most competitive sources for attracting bees, especially they were grown in large land areas. Moreover. *T. alexanderinum* started blooming before sunflower and this benefited the first species in attracting the bees, especially honey bee. The latter is highly characterized by possessing the phenomenon of pollen constancy (Gary, 1992; Free, 1993). With regard to the native bees, it seems that the region of present study was deficient in habitat requirements of native bees including nest sites, food resources and nesting material. Greenleaf and Kremen (2006) reported, " the abundance of native bees is six times higher on organic farms that relatively close to natural habitat, and on fields where sunflower have been planted within one mile every year for several years ". Furthermore, while honey bees are known to forage over 5-10 kilometers from their nests, solitary bees are generally thought to travel only a few hundred meters at most (Gathmann and Tscharntke, 2002; Goulson, 2003).

Table (1). Total numbers of different pollinating insects counted on heads of sunflower, *Helianthus annuus* L.

Insect	Number	%
Apis mellifera (Nectar collectors)	394	37.63
Apis mellifera (Pollen collectors)	154	14.71
Megachile sp.	247	23.59
Nomia sp.	167	15.95
Xylocopa fenestrata	40	3.82
X. aestuans	6	0.57
Other species	39	3.72
Total	1047	

2. Seasonal and Diurnal Visitation

Patterns of Pollinating Insects

Table (2) shows seasonal visitation pattern of all visiting insects. All visitors recorded on May 15th and 18th were only honey bees. Although native bee visits started at a very low level on May 21st, their remarkable visitation was noticed for the first time on May 24th and stayed in progress until the end of blooming period. This pattern of native bees, however, could mainly be related to the abundant species, *Megachile* sp. and *Nomua* sp. A pattern for *Xylocopa fenestrata* and *X. aestuans* would be inconclusive because of their rarity. It is worth mentioning that adverse weather conditions affecting insect flight activity were prevalent in some days. These conditions, such as those characterizing dusty and windy days, might be, to some extent, responsible for some fluctuations of insect numbers at different dates. Moalif and Al-Azzawi (1989) found that the visitation of *Xylocopa fenestrata*, *X.aestuans* and *Megachile* spp. peaked during the second week of sunflower blooming period in Basra, while those of *Ceratinia laviforons* and *Halictus* spp. tookplace during the last third of this period.

Table (2). Seasonal visitation pattern of different pollinating insects counted on heads of sunflower, Helianthus annuus L.,

Insect	Number of individuals counted at different dates (in 2008)									
	15/5	18/5	21/5	24/5	27/5	30/5	2/6	5/6	8/6	11/6
A. mellifera (Nectar collectors)	13	30	112	35	38	26	43	29	28	40
A. mellifera (Pollen collectors)	0	15	5	6	27	7	33	20	15	26
Megachile sp.	0	0	5	11	35	10	93	46	23	24
Nomia sp.	0	0	0	18	48	35	8	20	17	21
X. fenestrata	0	0	2	5	11	12	3	4	3	0
X. aestuans	0	0	0	0	0	1	2	3	0	0
Other species	0	0	3	3	7	3	10	1	9	3
Total number	13	45	127	78	166	94	192	123	95	114
%	1.24	4.30	12.13	7.45	15.85	8.98	18.34	11.75	9.07	10.89

Table (3) shows diurnal visitation pattern of all visiting insects. Honey bees were found in remarkable percentages during different daytime hours. Nectar-collecting honey bees, however, were found in larger numbers at the expense of pollen-collecting honey bees at 2 pm and 4 pm. This might be attributed to the need of nectar to be utilized in nest thermoregulation (Gary, 1992). It has been found that the proportion of honey bees carrying pollen decreased when ambient temperature exceeds 35°C (Garry, 1992) or even stopped at ambient temperature above 40° C (Cooper *et al*., 1985). Also, the load of nectar enables the honey bee to fly at high ambient temperatures for the bees may regurgitate honey stomach contents to regulate head temperature through evaporative cooling (Heinrich, 1980). This is why *Apis mellifera* can fly at ambient temperature as high as 46° C (Cooper *et al*., 1985). Most of the visits of *Megachile* spp. and *Nomia* spp. were recorded during the period extending from 8 am to midday but they were found in smaller numbers at 6 am and in the afternoon. Moalif and Al-Azzawi (1989) found somewhat similar diurnal visitation pattern of *Megachile* spp. on sunflower in Basra. Goulson (2003) reported that many studies had found that both honey bees and bumble bees begin foraging earlier in the morning that many native bee species.

Table (3). Diurnal visitation pattern of different pollinating insects counted on heads of sunflower, *Helianthus annuus* L.,

Insect	Number of individuals counted at different daytime hours						
	6 am	8 am	10 am	12	2 pm	4 pm	6 pm
A. mellifera (Nectar collectors)	33	39	42	53	89	107	31
A. mellifera (Pollen collectors)	33	21	29	36	8	4	23
Megachile sp.	12	71	60	53	22	17	12
Nomia sp.	9	26	44	45	30	8	5
X. fenestrata	2	11	15	6	2	4	0
X. aestuans	3	2	0	0	0	1	0
Other species	10	12	8	4	1	1	3
Total number	102	182	198	197	152	142	74
%	9.74	17.38	18.91	18.81	14.52	13.56	7.07

3. Foraging Behavior of Pollinating Insects

Apart from the above mentioned counting, 953 single visits of different pollinating insects were watched carefully to study the behavior of different species while foraging on sunflower heads. It was found that 41.34% of all pollinating insects had terminated their visits under compulsion of other individuals (i.e. displacement act) while 58.66% of them terminated their visits " willingly ", i.e. without physical disturbance of other insect individuals (Table 4).

Table (4). Numbers and percentages of visits terminated willingly and visits terminated under compulsion of different pollinating insects foraging on heads of sunflower, *Helianthus annuus* L.

Insect	Total number of observed single-visits	Number of willingly terminated visits	%	Number of visits terminated under compulsion of other insect individuals	%
A. mellifera	411	229	55.72	182	44.28
Megachile sp.	189	94	49.74	95	50.26
Nomia sp.	107	57	53.27	50	46.73
X. fenestrata	191	136	71.20	55	28.80
X. aestuans	55	43	78.18	12	21.82
Total	953	559	58.66	394	41.34

a. Behavior of Displacement

There were variations between different species of pollinating insects regarding the frequencies of displacement acts they were subjected to or acts they were practicing (Table 5). While 44.28%, 50.26 and 46.73% of individuals belonging to *Apis mellifera*, *Megachile* sp. And *Nomia* sp., respectively were forced to leave flowers, only 28.80 and 21.82% of individuals belonging to *Xylocopa fenestrata* and *X. aestuans*, respectively were forced to do so. The most " pugnacious " species in this regard were *Nomia* sp. and *Megachile* sp, for they were responsible for 41.88 and 27.92% of all displacement acts, respectively. *Apis mellifera* was responsible for only 9.64% acts. It is worth mentioning that any insect individual could be forced to leave by either an individual belonging to its species or to another one. It was found that 44.0, 27.37 and 14.83% of displaced individuals belonging to *Nomia* sp., *Megachile* sp. and *A. mellifera*, respectively were forced to leave by individuals belonging to same species. It seems that displacement is not necessarily size related. Goulson (2003) reported that the presence of honey bees had been found to deter foraging by hummingbirds and some species of bumblebees. Recently, Greenleaf and Kremen (2006) have conducted a very comprehensive and conclusive study on the behavioral interaction between honey bees and native bees foraging in fields of sunflower in California. These authors stated, " after a honey bee encountered a wild bee, 20 percent of honey bees buzzed off to another row . . . . Wild bees make the honey bee more skittish so they move more frequently between the different cultivars ".

Table (5). Numbers and percentages of visits terminated under compulsion of other insect individuals of different pollinating insects foraging on heads of sunflower, *Helianthus annuus* L.

Insect subjected to displacement act	Number of total observed single-visits	Numbers and percentages of visits terminated by other insect individuals *					
		By *A. mellifera*	By *Megachle* sp.	By *Nomia* sp.	By *X. fenestrata*	By *X. aestians*	By Other species
A. mellifera	182	27 (14.83)	60 (32.97)	64 (35.16)	3 (1.65)	3 (1.65)	25 (13.74)
Megachile sp.	95	3 (3.16)	26 (27.37)	46 (48.42)	1 (1.05)	2 (2.10)	17 (17.89)
Nomia sp.	50	2 (4.0)	12 (24.0)	22 (44.0)	2 (4.0)	1 (2.0)	11 (22.0)
X. fenestrata	55	5 (9.09)	10 (18.18)	27 (49.09)	2 (3.64)	0 (0.0)	11 (20.0)
X. aestuans	12	1 (8.33)	2 (16.66)	6 (50.0)	0 (0.0)	0 (0.0)	3 (25.0)
Total	394	38 (9.64)	110 (27.92)	165 (41.88)	8 (2.03)	6 (1.52)	67 (17.00)

* Percentage values are in parentheses.

b. Duration of Insect Single-Visit

Table (6) shows durations of visits of those individuals which terminated their visits willingly. Mean duration of a single visit / insect / flower of *A. mellifera*, whether nectar collectors or pollen collectors, was the longest compared with those of all native bees. The means were 3.06 , 3.04 , 0.50 , 0.56 , 0.48 and 0.68 min of *A. mellifera* (nectar collectors), *A. mellifera* (pollen collectors), *Megachile* sp., *Nomia* sp., *X. fenestrata* and *X. aestuans*, respectively. Most of both nectar collecting and pollen-collecting honey bees spent 1- 5 min / single visit / flower while most of *Megachile* sp., *Nomia* sp. and *X. fenestrata* individuals spent less than one min. Individuals of *X. aestuans* were divided into almost two equal groups regarding length of visit duration, 51.16%

spent less than one min and 46.51% spent 1–5 min. The longest duration in present study reached 19 minutes recorded for a nectar-collecting honey bee. It is important to mention that honey bees were usually steady and stable when they were gathering food on sunflower heads. On the contrary, the native bees, particularly *Megachile* sp., were clearly unstable on the heads and practicing intermittent gathering of food. Individuals of *Megachile* sp. were usually seen either running irritably on the head or hovering over it alternately with food gathering. There have been many studies proving that solitary bees switch between plants more often than social bees, thereby offering a higher enhance of cross pollination (Corbet, 1987; Corbet *et al*., 1991; Free, 1993; Frietas and Paxton, 1998; Greenleaf and Kremen, 2006).

Table (6). Duration of visits terminated willingly (without displacement) of different pollinating insects foraging on heads of sunflower, Helianthus annuus L.

Insect	Number of total observed single-visits	Duration / single visits / insect (min)		Numbers and percentages of visits lasted different periods of time *			
		Range	Mean	Less than 1 min	From 1 to 5 min	From 5.01 to 10 min	More than 10 min
A. mellifera (Nectar collectors)	167	0.03-19.00	3.06	33 (19.76)	112 (67.07)	18 (10.77)	04 (2.40)
A. mellifera (Pollen collectors)	62	0.05-10.00	3.04	13 (20.97)	38 (61.29)	11 (17.74)	0 (0.0)
Megachile sp.	94	0.01-6.50	0.50	65 (69.15)	28 (29.79)	1 (1.06)	0 (0.0)
Nomia sp.	57	0.01-6.00	0.56	43 (75.44)	12 (21.05)	2 (3.51)	0 (0.0)
X. fenestrata	136	0.02-11.00	0.48	101 (74.26)	33 (24.26)	1 (0.73)	1 (0.73)
X. aestuans	43	0.02-6.00	0.68	22 (51.16)	20 (46.51)	1 (2.32)	0 (0.0)
Total	559						

* Percentage values are in parentheses

4. Effect of Pollinating Insects on Sunflower Seed Production

The results indicate that the hybrid variety " Coban " was highly self-compatible and there was no significantly beneficial effect of pollinating insects on its yield of seeds. Although mean number and mean weight of filled seeds in heads exposed to insect visits were larger than those in heads excluded from insect visits, the differences among these means were not significant at $P<0.05$ (Table 7). In contrast, the open-pollinatd variety " Sinn al-Theeb " was highly self-incompatible and the contribution of pollinating insects to its seed production was highly decisive and significant. The results undoubtedly show that this variety cannot give even minimal economic level of seed production without being visited by honey bee and native bees. While the means of number of filled seeds, percentage of seed setting and weight of filled seeds / head of this variety reached 624 g , 79.8% and 63.9g, respectively in heads exposed to insect visits, they reached only 67 g, 10.1% and 7.3g, respectively in heads excluded from these visits. The only insignificant differences among means were those of total number of seeds (filled and empty) / head and weight of a single filled seed. There have been so many worldwide studies proving the efficient role of both honey bee and native bees in enhancing seed production of sunflower, especially of those varieties suffering heavy self-incompatibility. However, most early studies were focusing on the role of honey bee while paying less attention to the role of native bees (McGregor, 1976). The situation has been rectified recently. After conducting a two-year study on the role of both honey bee and native bees in production of hybrid seeds of sunflower in California, Greenleaf and Kremen (2006) stated, " Up until now, we have thought that honey bees alone were doing most of the pollination, but now we know that a lot of honey-bee pollination happens because of their interaction with wild native bees. This means that wild bees are much, much more important than we previously thought ". These authors found that when wild bees were rare, honey been pollination produced three seeds per single visit on average, but honey bee pollination efficiency increased strongly with wild bee abundance and richness up to 15 seeds per visit on average. In Iraq, Moalif and Al-Azzawi (1989) found that native bees alone were responsible for multiplying seed production of a less self-fertile variety of sunflower.

Table (7). Seed production of heads exposed to pollinating insects (unbagged heads) and heads completely excluded from pollinating insects (bagged heads) of two varieties of sunflower, *Helianthus annuus* L. *

a. Mean number of filled & unfilled seeds per head

Sunflower variety	Sunflower head type		Mean
	Unbagged	Bagged	
Coban (hybrid) variety	814	716	765
Sinn al-Theeb (open pollinated) variety	774	784	779
Mean	794	750	

L.S.D. of varieties = n.s. L.S.D. of head types = n.s. L.S.D. of interaction = n.s

b. Mean number of filled seed (seeds with kernels) per head

Sunflower variety	Sunflower head type		Mean
	Unbagged	Bagged	
Coban (hybrid) variety	706	575	640
Sinn al-Theeb (open pollinated) variety	624	067	346
Mean	665	321	

L.S.D. of varieties = 132.5 L.S.D. of head types = 228.6 L.S.D. of interaction = 226

c. Mean number of unfilled (empty) seeds per head

Sunflower variety	Sunflower head type		Mean
	Unbagged	Bagged	
Coban (hybrid) variety	108	141	125
Sinn al-Theeb (open pollinated) variety	150	717	434
Mean	129	429	

L.S.D. of varieties = 306.1 L.S.D. of head types = 181.6 L.S.D. of interaction = 248.2

d. Mean percentage of seed setting (%)

Sunflower variety	Sunflower head type		Mean
	Unbagged	Bagged	
Coban (hybrid) variety	88.1	81.4	84.7
Sinn al-Theeb (open pollinated) variety	79.8	10.1	45.0
Mean	83.9	45.8	

L.S.D. of varieties = 16.17 L.S.D. of head types = 8.54 L.S.D. of interaction = 12.86

e. Mean weight of filled seeds per head (g)

Sunflower variety	Sunflower head type		Mean
	Unbagged	Bagged	
Coban (hybrid) variety	35.5	30.7	33.1
Sinn al-Theeb (open pollinated) variety	63.9	07.3	35.6
Mean	49.7	19.0	

L.S.D. of varieties = n.s. L.S.D. of head types = 25.43 L.S.D. of interaction = 26.31

f. Mean weight of a single filled seed (g)

Sunflower variety	Sunflower head type		Mean
	Unbagged	Bagged	
Coban (hybrid) variety	0.0511	0.0513	0.0512
Sinn al-Theeb (open pollinated) variety	0.1014	0.1132	0.1073
Mean	0.0763	0.0823	

L.S.D. of varieties = 0.0244 L.S.D. of head types = n.s. L.S.D. of interaction = n.s.

*** (1) Each variety was represented by 72 heads at the ratio of 1:1 of unbagged and bagged heads.**

(2) P<0.05.

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