

Behavioral Ecological Study of Honey Bee Workers *Apis mellifera* on Apple Flowers *Malus domestica* (L) and *Malus sylvestris* (L) during Collecting Pollen

دراسة بيئية لسلوك شغالات نحل العسل *Apis mellifera* على أزهار التفاح *Malus domestica* (L) و *Malus sylvestris* (L) أثناء جمع حبوب اللقاح

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Abstract:

This study aims to study the activity and behavior of honey bee workers during their pollen collection on apple flowers and the extent to which climatic factors affect the activity and behavior of honey bees and food search rates during their pollen collection. The results showed that there is a clear difference between the number of honeybee workers during their visit to collect pollen from *M. domestica* apple flowers with clear significant differences, as the highest worker visit was recorded at 9:00 am, where the average number of workers was (35.00 ± 2.6) workers/m². The lowest worker visit was recorded at 12:00 noon, where the average number of workers was (14.00 ± 1.7) workers/m². The numbers of bee workers on *M. sylvestris* apple flowers were also recorded during different daylight hours with significant differences. where the highest worker visit was recorded at 9:00 am with an average of (97.00 ± 3.4) workers/m². The lowest worker visit was



recorded at 10:00 am with an average of (39.00 ± 2.11) workers/m². A preference was also recorded for worker bees visit *M. sylvestris* flowers. our results also showed the foraging times of honey bees during different daylight hours on apple flowers. our results on *M. domestica* flowers indicate no significant differences in handling time. The results also indicate no significant differences in travel time. The results also showed significant differences in the residence time of worker bees on *M. sylvestris* flowers. The highest handling time was recorded at 9:00 am and 10:00 am with averages of (2.36 ± 0.06) seconds and (2.37 ± 0.1) seconds, respectively, and the lowest handling time was at 12:00 noon with an average of (1.8 ± 0.09) seconds for worker bees. Also, the travel time recorded significant differences, as the highest travel time was recorded at 9:00 am and 11:00 am, respectively, with averages of (1.6 ± 0.10) seconds and (1.4 ± 0.09) seconds, and the lowest travel time was at 10:00 am and 12:00 pm, respectively, with an average of (1.1 ± 0.05) seconds and (1.0 ± 0.03) seconds for worker bees. Also, no preference was recorded for worker bees to visit the flowers of the two apple cultivars on food search rates . our results showed that there is a clear strong correlation between climatic conditions and the extent of bee activity and also between foraging rates on the two types of apple plants.

Keywords: Apis mellifera, foraging behavior, apple flower, the handling and travel time.

الملخص

تهدف هذه الدراسة لدراسة نشاط وسلوك شغالات نحل العسل أثناء جمعها لحبوب اللقاح على أزهار أصناف، وما مدى تأثير العوامل المناخية على نشاط وسلوك نحل العسل ومعدلات البحث عن الغذاء أثناء جمعه لحبوب اللقاح. أوضحت النتائج أن هناك اختلاف واضحاً بين عدد شغالات نحل العسل أثناء زيارتها لجمع اللقاح من أزهار تفاح *M. domestica* بفروق معنوية واضحة حيث سجل أعلى زيارة لشغالة عند الساعة 9:00 صباحاً حيث بلغ عدد متوسط الشغالات (35.00 ± 2.6) شغالة/م² كذلك سجل أقل زيارة لشغالة عند الساعة 12:00 ظهراً حيث بلغ عدد متوسط الشغالات (14.00 ± 1.7) شغالة/م²، كما سجل اعداد من شغالات النحل علي صنف أزهار التفاح *M. sylvestris* خلال ساعات النهار المختلفة بفروق معنوية، حيث سجلت أعلى زيارة لشغالة عند الساعة 9:00 صباحاً بمتوسط (97.00 ± 3.4) شغالة/م². وسجل



أقل زيارة لشغالة عند الساعة 10:00 صباحا بمتوسط (39.00 ± 2.11) شغالة /م². كما سجلت تفضيلا لزيارة الشغالات النحل على أزهار نبات *M. sylvestris*. كما عرضت نتائجنا أوقات البحث عن الغذاء لشغالات نحل العسل خلال ساعات النهار المختلفة على أزهار أصناف التفاح، وتشير نتائجنا على أزهار التفاح *M. domestica* عدم وجود فروق معنوية في زمن البقاء كذلك تشير النتائج بعدم وجود فروق معنوية في زمن الانتقال، وكما عرضت على أزهار *M. sylvestris* وجود فروق معنوية في زمن بقاء الشغالات النحل حيث سجل أعلى زمن بقاء عند الساعتين 9:00 صباحا.

و10:00 صباحا بمتوسطات على التوالي (2.36 ± 0.06) ثانية و (2.37 ± 0.1) ثانية ، وأقل زمن بقاء كان عند الساعة 12:00 ظهرا كان بمتوسط شغالات النحل (1.8 ± 0.09) ثانية. كذلك زمن الانتقال سجل فروق معنوية حيث سجل أعلى زمن انتقال عند الساعتين 9:00 صباحا و11:00 صباحا على التوالي بمتوسطات (1.6 ± 0.10) ثانية و (1.4 ± 0.09) ثانية وأقل زمن انتقال كان عند الساعة 10:00 صباحا 12:00 ظهرا على التوالي بمتوسط شغالات النحل (1.1 ± 0.05) ثانية (± 0.03) 1.0) ثانية. كما لم يسجل اي تفضيلا لزيارة الشغالات النحل على أزهار صنفين التفاح في معدلات البحث. كما عرضت نتائجنا أن هناك ارتباط قوي واضح بين الظروف المناخية ومدى نشاط سلوك النحل كذلك بين معدلات البحث عن الغذاء على أزهار صنفين نبات التفاح.

الكلمات المفتاحية: *Apis mellifera* ، سلوك البحث عن الغذاء، أزهار التفاح، زمن البقاء والانتقال.

Introduction

Honey bees play a pivotal role in natural pollination, as collecting pollen is one of their primary activities to ensure plant reproduction, especially in important crops like apple trees. The quality and quantity of pollen collected depend on several environmental factors that influence bee activity, including temperature and humidity. While the effects of temperature and humidity have been widely studied, the impact of these factors on honeybee behavior specifically concerning apple trees warrants intensive study.

Among the characteristics that make honey bees some of the best pollinators is the nature of their hair-covered bodies, which helps in pollen transfer, as well as their ability to absorb nectar (Benedek et al, 1996).

(Buchmann and Nabhan ,1996) indicated that honey bee *A mellifera* is one of the most important successful pollinators. It also possesses the characteristic of constancy while visiting a flower and focusing on the same species when collecting nectar or pollen transferred between flowers. On the other hand, some scientists

have confirmed that worker bees do not leave nectar or pollen in the area they visit for other species of pollinators.

Honey bees *A.mellifera* are considered one of the most important types of pollinators because their bodies are covered with hairs to which pollen grains stick, in addition to their ability to absorb nectar, as indicated by (Stern et al. 2001).

The transfer of pollen carried on the bodies of nectar-collecting worker bees is much less than that found on the bodies of pollen-collecting workers, as indicated by (Free and Williams ,1972).

(Khanduri et al ,2002) pointed out in his study of pollen production and differentiation in the Himalayan sp plant species that anthers open periodically during the day, depending on temperature and relative humidity. The other opening process takes two days in warm conditions and three days in cooler temperatures.

(Gegear and Lavery ,2004) selected two types of bees *A. mellifera* and *Bombus* sp. during their visits to two types of flowers (yellow and blue). The study showed that honey bees exhibited high fidelity to one type of flower and took longer to move between flowers, while the standing time on flowers did not differ significantly between the two species. Additionally, the morphological structure of the bee or flower may determine the length of time spent on the flower during food gathering.

(Rust *et al*, 2003) observed variability in standing time and movement between different bee species visiting flowers of the same plant species, highlighting that flower location is important in determining bee behaviors.

Environmental factors play a significant role in the behavior of *A. mellifera* honey bees during pollen collection. (Smith,2012) conducted a study that showed elevated temperatures lead to increased honeybee activity, with more frequent flights between flowers, resulting in greater pollen collection. However, it should be noted that excessively high temperatures can cause stress to the bees and reduce their efficiency in collecting pollen.

Humidity is also a significant factor affecting honeybee behavior, as high humidity levels can make flying more difficult for the bees, especially in the early morning when flowers are covered with dew. This reduces bee effectiveness in collecting pollen during these times. Additionally, low humidity can enhance bee efficiency in the afternoon (Jones, 2015).

Ideal weather conditions moderate temperatures and low humidity increase the time bees spend foraging for pollen, leading to increased tree productivity, according to a study conducted by (Brown, 2017), which analyzed the impact of changing environmental factors on the flight time of honey bees over apple trees. Interference from environmental factors like wind, along with temperature and humidity, can add further complications to honeybee behavior. (Lee, 2019) observed that strong winds increase the challenges for bees during pollen collection, resulting in significantly reduced efficiency compared to days with less wind impact. This study aims to know the activity and behavior of honeybee workers while collecting pollen from two types of apple plants (*Malus domestica* and *Malus sylvestris*).

Research objective:

The research aims to study the activity and behavior of honeybee workers on two types of apple flowers, and the extent to which climatic factors influence their foraging rates and behaviors while collecting pollen.

Research problem:

The research problem lies in studying the extent the influence of the plant host and climatic factors on the behavior and activity of bees and on the rates of searching for food while collecting pollen from apple flowers.

Materials and Methods:

1- Study Location:

This study was conducted in the Al-Abraq area, Al-Jabal Al-Alakhdar, Libya. The farm covering 50 hectares. The farm is characterized by a dense cover of evergreen trees. The study began with the onset of blooming in April 2022 and continued for three consecutive days.

The two studied were 2.5–3 meters tall at *Maluse sylvestris* and 1.5–2.5 meters at *Maluse domestica* and plant, and their age exceeded 10 years.

2- Calculating the number of honey bee workers on apple flower varieties:

Bee activity was measured from 9 am. to 12 noon. in a restricted study area of $m^2 \times m^2$, with observations lasting for an hour each day. The behavior of worker bees visiting flowers was observed, including how they collected pollen, how they adhered to the flower, and their departure from it. Two apple species, *M. domestica* and *M. sylvestris*, were studied. All observations related to bee movement and food collection behavior were recorded.

3- Calculation Foraging time:

The time spent by a worker bee gathering pollen was calculated from the moment it touched the flower until it departed (handling time). Additionally, the time spent traveling from one flower to another (traveling time) was calculated using the same method as described by Pleasant (1981).

4-Weather Conditions :

Temperature and relative humidity were measured and recorded every 10 minutes using a temperature and humidity gauge placed near the flowers in the restricted study area.

5-Statistical Analysis:

All data collected were analyzed using the MINITAB software version 16, with variance analysis (ANOVA) conducted and the mean (M) and standard error (SE \pm) calculated. Graphs were plotted using Excel.

Results

1. Calculating the number of honey bee workers on apple flower varieties:

The results showed that there is a clear difference between the number of honeybee workers during their visit to collect pollen from *M. domestica* apple

flowers with clear significant differences ($P < 0.0001$, $df = 3$, $F = 14.24$), where the highest worker visit was recorded at 9:00 am, where the average number reached Workers (35.00 ± 2.6) workers/m². Also, the lowest visit by a worker was recorded at 12:00 noon, where the average number of workers was (14.00 ± 1.7) workers/m². Also numbers of worker bees on the apple flower variety *Malus sylvestris* during the different hours of the day with significant differences ($P < 0.0001$, $df = 3$, $F = 33.9$), where the highest worker visit was recorded at 9:00 am with an average of (97.00 ± 3.4) workers/m². The lowest worker visit was recorded at 10:00 am with an average of (39.00 ± 2.11) workers/m². Figure (1).

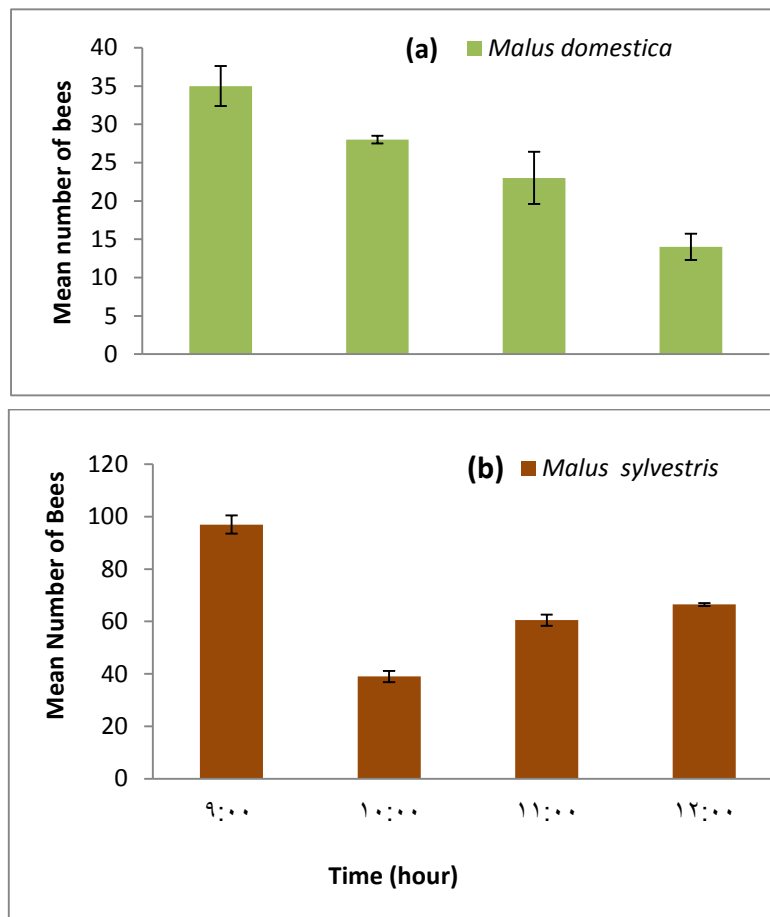


Figure (1). Mean number of worker bees *A. mellifera* ($M \pm$) on two apple varieties (a) *M. domestica* (b) *M. sylvestris* per square meter/second, during different daylight hours, starting of April for two days, 2/3–2020, starting at 9:00 am to 12:00 noon during the day.

In Table (1), indicate that there are clear significant differences ($df=1$, $F=140.7$, $P<0.005$) in the preference of honey bee workers while collecting pollen on the two apple varieties, where the highest number of visiting worker bee visits was recorded on *M.sylvestris* apple flowers. Comparing the number of workers visiting *M. domestica* flowers.

Table (1). Preference of bee *A. mellifera* on two flower Species on two apple varieties

Plant Specie	Number of bees
<i>M.domestica</i>	25.38 b
<i>M . sylvestris</i>	65.75a

The letters in the same column are no insignificant differences ($P < 0.005$)

(2). Calculation Foraging time

2.1. Calculating handling time and traveling time the rates on two apple flowers varieties:

Figure (2), shows the results of food search times for honey bee workers during different daylight hours on flowers of apple varieties. Our results on *Malus domestica* apple flowers indicate that there are no significant differences in handling time ($df = 3$, $F = 1.49$, $P = 0.224$). Also, the results indicate that there are no significant differences in traveling time ($df = 3$, $F = 0.09$, $P = 0.963$), as also shown on *Malus sylvestris* flowers with significant differences in the handling time of worker bees ($df = 3$, $F = 6.23$, $P < 0.005$), where the highest handling time was recorded at 9:00 am and 10:00 am with averages of respectively (2.36 ± 0.06) seconds and (2.37 ± 0.1) seconds. and the lowest handling time was at 12:00 noon, with an average of (1.8 ± 0.09) seconds for the worker bees. Also, traveling time recorded significant differences ($df = 3$, $F = 12.6$, $P < 0.005$), where the highest was recorded traveling time at 9:00 am and 11:00 am, respectively, with averages of (1.6 ± 0.10) seconds and (1.4 ± 0.09) seconds. The lowest travel time was at 10:00 am and 12:00 noon, respectively, with an average of (1.1 ± 0.05) seconds (1.0 ± 0.03) seconds.

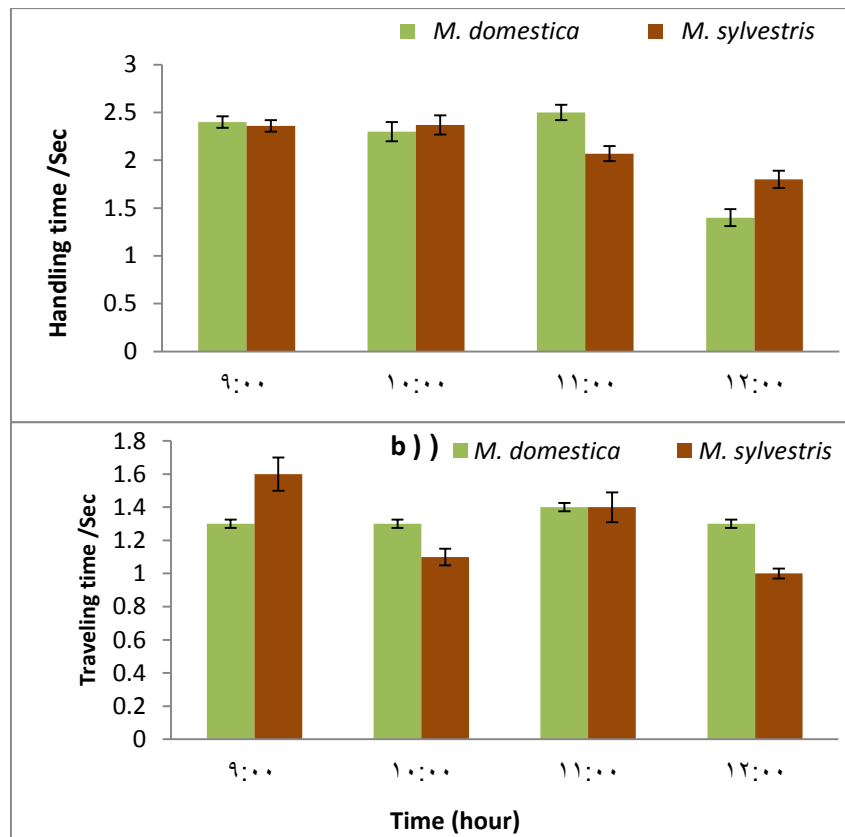


Figure (2). Comparison between the handling time and the traveling time/second of *A. mellifera* visiting two apple varieties (a) *M. domestica* (b) *M. sylvestris*. Per square meter/second, during a different daylight hour from the starting of April for two days 2/3-2020, starting from 9:00 am until 12:00 noon during the day.

The results show that there were no clear significant differences in the handling time of worker honeybees during the period of time they spent collecting pollen on the two apple varieties ($df = 1, F = 0.00, P = 0.982$). We also did not notice any significant differences ($df = 1, F = 0.00, P = 0.958$) in the traveling time between flowers for collecting pollen on two apple flower varieties, *M. sylvestris* and *M. domestica*. Table (2).

Table (2). (Mean \pm SE) of handling time and traveling time of *A. mellifera* on two flower Species apple in (Sec)



Plant Flower	Handling Time (Sec)	Traveling Time (Sec).
M.domestica	2.16 ±0.21 a	1.34±0.08 a
M . sylvestris	2.17±0.05 a	1.34±0.04 a

The letters in the same column are no insignificant differences ($P < 0.005$).

3. The effect of climate conditions on the number of worker bees and the rates of searching for food on different apple varieties:

Humidity recorded clear significant differences during the different hours of the day ($P < 0.005$, $df=3$, $F=11.74$) and also temperatures recorded clear significant differences ($P < 0.005$, $df=3$, $F=28.0$), which shows the extent to which weather conditions are related as Temperature and humidity affect the activity of honey bees during the hours of the day on the flowers of the two types of apples while collecting pollen. While the highest visits by honeybee workers in each of the two varieties were recorded at 9:00 am, where was the average number of workers with (35.0 ± 2.6) workers/m², and it was on the apple flower variety M. domestica, and it was recorded on the apple flower variety M. sylvestris with an average (97.0 ± 3.4) working/m². When recorded, the average relative humidity was 34.5% and the average temperature was 21.4 °C. also, the lowest worker visit was recorded on the M. domestica variety at 12:00 noon, where the average number of workers reached (14.00 ± 1.7) workers/m², the average relative humidity reached 22.5%, and the average temperature was 28.4°C. The lowest worker visit was recorded on the apple blossom variety M. sylvestris at 10:00 am with an average of (39.00 ± 2.11) workers/m², where the average relative humidity was 30.1% and the temperature was 22.4°C. Table (3). The results showed there are a strong relationship between relative humidity factor and worker activity ($R^2= 0.8$) on M. domestic flower plant while recorded a strong relationship on temperature factor ($R^2= 0.5$) on M. sylvestris flower plant.

Table (3). The effect of temperature and humidity on active honey bee worker *A. mellifera*, ($M \pm SE$) on two types of apple flowers during the hours of the day.

Time (hour)	Number of bees (m2) / hour		climate conditions	
	<i>M. domestic</i>	<i>M. sylvestris</i>	Humidity %	Temperature c0
9:00-10:00	35.0± 2.6 a	97.0± 3.4 a	34.5	21.4
10:00-11:00	28.0±0.5 ab	39.0±2.11 c	30.1	22.7
11:00-12:00	23.0±3.4 bc	60.0±2.18 b	28.9	23.7
12:00 -1:00	14.0±1.7 c	66.6±0.5 b	22.5	28.4

Similar lowercase letters mean no significant differences in the same column ($P < 0.001$).

Also Temperature and relative humidity recorded there are a strong relationship on two the apple flower variety during pollen collection on the handling time and traveling time of the worker bees ($R^2 = 0.5$). Table (4).

Table (4): ($M \pm SE$) of handling time and traveling time and their relationship to climatic conditions such as humidity(%) and temperature(c0) on two types of apple flowers during the hours of the day.

Plant	Foraging times/sec	Time (hour)				Weather conditions		
		9:00-10:00	10:00-11:00	11:00-12:00	12:00-1:00	Time (hour)	%	c0
<i>M. domestic</i>	Handling time	2.4 ±0.50 a	2.3 ±0.5 a	2.5 ±0.2 a	1.4±0.4 a	9:00-10:00	34.5	21.4
	Traveling time	1.37±0.6 a	1.30 ±0.5 a	1.4 ±0.7 a	1.30±0.9 a	10:00-11:00	30.1	22.7
<i>M. sylvestris</i>	Handling time	2.36±0.06 a	2.37 ±0.1 a	2.0 ±0.08 ab	1.8 ±0.09 b	11:00-12:00	28.9	23.7
	Traveling time	1.6±0.1 a	1.5 ±0.05 b	1.4 ±0.09 a	1.00±0.3 b	12:00 -1:00	22.5	28.4

Similar letters mean no significant differences between the same line ($P < 0.001$).

Discussion

Our results of the behavior of worker bees during their visits to collect pollen on the flowers of two apple varieties showed significant differences between daylight hours on the number of worker visits and activity rates of honey bee workers,



where it was recorded on *M. domestica* flowers at 9:00 am with a rate (35.00 ± 2.6) workers/m², and also it was recorded on *M. sylvestris* flowers at 9:00 am with a rate (97.00 ± 3.4) workers/m². This may be due to the effect of relative humidity, which averaged 34.5%, but the humidity factor did not hinder the honeybee workers collecting pollen. This is consistent with what (Meriti ,2003) indicated when studying some plants, including *Camalducnsis* sp., *Eucalyptus* sp., *Muricata* sp., and *Erica* sp. to collect pollen, that humidity is a very important factor in collecting pollen in tropical climates when its stimulation is linked to temperature. This is consistent with what was stated by the researcher (Percival ,1955) that the effect of the humidity factor has an impact on the effectiveness of pollen collection for worker bees, which is linked to the effect of the surrounding temperature conditions, especially if they are lower than 10°C and higher than 26°C. Also, worker bee rates decreased at 12:00 noon with an average of (14.00 ± 1.7) workers/m² on *M. domestica* flowers when the temperature reached 28.4°C compared to the decrease in humidity at this time. As for *M. sylvestris*, worker bee rates decreased at 10:00 am with an average of (39.00 ± 2.11) workers/m² due to an increase in humidity when it reached 30.1%, which affected the grazing behavior biologically. Because humidity is an influential factor in honeybee behavior high humidity can make it more difficult for bees to fly, especially in the early morning when flowers are covered with dew. This reduces the effectiveness of bees in collecting pollen at those times. In addition, low humidity may enhance the efficiency of bees in the afternoon (Jones, 2015). our results in Table (1) also recorded significant differences between the two types of flowers during the visit of worker bees behavior activity, as they were more preferred to the flowers of the *M. sylvestris* plant, with an average of 65.75 visitors, compared to the flowers of the *M. domestica* plant. The main reason for preferring to visit may be due to the nutritional components of the flower, whether protein or sugar components, or it may be due to the activity of the bee species *A. mellifera*, which is what was indicated by (Rust, 2003) that the variation in honey bee workers *A. mellifera* and *Megachile* continues to behavior activity during the period of pollen grains coming out of the anthers, but *A. Ceratina* workers forage for nectar when sugar is high

and pollen grains are low. Also, (Joshi et al. 2010) indicated that the activity of *A. mellifera* workers visiting apple flowers in a semi-tropical environment carried large quantities of pollen grains compared to *A. cerana* workers. Although they visited a small number of flowers. Researchers (Free & Williams, 1972) reported that the pollen carried on the bodies of nectar-collecting honey bees is much less than that carried on the bodies of pollen-collecting workers. This is what (Free, 1993) indicated that pollen-collecting workers are attracted to flowers with fresh pollen, while nectar-collecting workers prefer old flowers where nectar is more readily available despite the low pollen efficiency. our results also showed that the food search rates of pollen-gathering honey bees during the daytime on the flowers of two apple varieties had clear effects, as our results showed that there were no significant differences in handling time bees on the flowers of *M. domestica*, which may be due to the amount of pollen available, which reflects its role in practicing the behavior of active food search rates without any stress or fatigue, especially in the first hour of searching. our results also recorded on the same flowers of *M. domestica* no differences in the period of bees movement on the flowers due to the proximity of the flowers between the branches of the tree, and through observation, as we noticed during the flight period, it was almost non-existent, and the most used behavior was walking between the flowers. The results also showed significant differences in the handling time of *M. sylvestris* flowers, as the highest handling time was recorded at 9:00 and 10:00 am, with averages of (2.36 ± 0.06) seconds and (2.37 ± 0.1) seconds, respectively. At this time, a high activity was observed to remain on the flower due to the high relative humidity rate, which helps the flower anther to open and the flowers to be available with pollen. This is what was indicated by (Brown, 2017) according to a study he conducted that ideal climatic conditions in terms of moderate temperature and low humidity increase the time spent by bees searching for pollen, which leads to an increase in the productivity of the tree. The minimum handling time on *M. sylvestris* flowers was at 12:00 noon with an average of (1.8 ± 0.09) seconds for worker bees, temperatures reached their maximum at noon, averaging 28.4°C the reason may be that environmental factors in the behavior of honey bees *A. mellifera* play an important role during pollen collection, as indicated by researcher (Smith, 2012) in his study

that high temperatures lead to an increase in honey bee activity. but excessively high temperatures can cause stress to bees and reduce their efficiency in pollen collection. Also may be there are other reason and this is what the researcher (Herrera, 1989) indicated about the existence of a relationship between the length of the bee's mouth parts and the duration of its standing on the flower, as he found that the long-tongued species, such as the bumblebee, have a tongue length of 9 mm and a standing period on the flower of 1.3 seconds, compared to the species with a short tongue, such as the honeybee, whose tongue is 5.1 mm long and a standing period on the flower of 3.6 seconds. This indicates that the longer the bee's mouth parts are, the shorter the standing period on the flower. The researchers (Fahn & Shimony, 2001) also confirmed that the *Lasioglossum* bee showed a longer standing period on the *Ecballium* sp. plant, while *A. ceratina*, the honeybee, showed a short standing period on the same plant. The travel time also recorded significant differences on *M. sylvestris* flowers, where the highest travel time was recorded at 9:00 and 11:00 am, respectively, with averages of (1.6 ± 0.10) seconds and (1.4 ± 0.09) seconds. We noticed at this time of observation that pollen grains were captured effectively, especially in the early morning hours when humidity was high and temperature was moderate, which played a major role in the opening of the flower anthers, which affected their searching behavior. The lowest travel time on *M. sylvestris* flowers was at 10:00 am, reaching an average of (1.1 ± 0.05) seconds due to the availability of food, and their travel decreased. As for at 12:00 pm, the worker bees had an average of (1.0 ± 0.03) seconds. our results in Table (2) also showed that there was no preference during food search behavior for the period of handling or traveling time on the flowers of the two apple varieties.

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