



Foraging Behaviour of *Apis mellifera* Responses to the Position of Apple Flowers (*Malus domestica*)

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Abstract

This study was conducted to investigate the effect of flower height on the number of worker bees, *Apis mellifera*, and its effect on the foraging behavior during its visit to the flowers of *Malus domestica*. The flowering region of the tree was divided into two equal heights, and the number of honey bee visitors and foraging behavior during the first hours of the day were monitored and calculated. The two regions showed apparent significant differences in the average number of nectar collections at 11:00 am, the highest number of visitors was recorded in the upper region 96.0 ± 6.0 workers/m², and the lower region of nectar with an average of 84.0 ± 3.3 workers/m², and the lowest rates were recorded in the upper region of nectar, with an average of 73.3 ± 63.3 workers/m² at 12 noon. At 9:00 am, the lower region of nectar was recorded with an average of 36.6 ± 4.6 workers/m². The two regions had the highest average number of pollen collectors. At 9 am, the upper region recorded 25.3 ± 0.4 workers /m², and the lower region recorded 13.3 ± 0.77 workers/m². The lowest rates were recorded in the upper region 7.00 ± 0.9 workers/m² at 11:00 am. At noon, the average area recorded 3.6 ± 0.1 workers /m². The result revealed no significant differences in the handling time in the two regions during the nectar collection. However, differences were recorded in the traveling time in the lower region only for nectar collectors; we conclude that the tree's height affected the behavior of the honey bee workers during the search for food and pollen collection.

Keywords: *Apis Mellifera*, The Upper And Lower Region. Foraging Behavior Apple Flower.

INTRODUCTION

The most common insect pollinator of apple is the honey bee (*Apis mellifera*); however, it is not the most efficient one; the study of the Behavior of *Apis mellifera* honey bee workers is one of the most important ancient and modern studies through which it is possible to understand the relationship between flowers and insects. They are among the most important pollinating insects found in orchards and modern agricultural systems (Morse & Calderone, 2000; Sharm et al., 2004). This indicated by (lau et al., 2019) that climatic conditions greatly affect the activity of bees while collecting pollen. as a study indicated (Silva & Dean, 2000) about concentration of sugar in the nectar, also mentioned the climatic conditions affect the number of *A. mellifera* worker bees visiting the flowers of *M. domestica*, *P. communis*, and *P. domestic.a*. It increases with high temperature and low humidity.



ty (Essa & Bataw, 2020), as the researchers pointed out (Shareef et al., 2022) when studying it on the *Sinapisabla* plant, *Pelargonium radula*, *Stachy stournefortii*, and *Malva parviflora*. temperature factor has a direct effect on the plant, When the temperature increases, the number of honey bee workers increases, and the humidity has the opposite impact on the number of visitors to the honey bee workers. The lower the humidity, the greater the number of visitors to *A. mellifera*. As (Khanduri & Sharma,2002),indicated about the production and dispersal of pollen grains in the Himalayan sp plants, the opening of the mycelium sacs occurs periodically during the day, which is related to the temperature and relative Humidity. As indicated by (Benedek et al, 2000), the reason may be due to the quantity and quality of nectar, which has changed since its production and is affected by weather conditions. Recent studies also indicated that the variation in the time spent searching for food and foraging during the day is affected by many factors, which reflects their role in the rate of bee visitors, as it was recorded (Bataw & Sharref, 2018) that *A.mellifera* honey bee workers spent a longer handling time on the *Stachy stournefortii* plant of up to 8.6 seconds. Moreover, the least handling time on a plant that reached *Malva parviflora* was 7.2 seconds.

The reason is that the bees collect pollen and nectar simultaneously from the first plant, which takes longer, while the second collects pollen only (Gegear& Laverty, 2004). During their visit to two kinds of flowers yellow and blue flowers, the study showed that honey bees recorded high stability on one type of flower and took longer to move between flowers. In contrast, the duration of handling time on flowers did not differ much between the two types. Also, (Rust et al, 2003) noted a difference in the time of handling and traveling between the different species of bees visiting the flowers of *Ecballium* sp plant. The effect of different elevation zones on tree branches for apple blossom indicated that honey bee workers were recorded to prefer the middle zone more than the upper zone. (Joshi et al, 2010).

This study aims to identify the effect of the location of apple blossoms on the tree on the activity of the honey bee and its association with foraging behavior.

MATERIALS AND METHODS

Study area

The study was conducted in the Al-Abraq area of Al-Jabal Al-Akhdar (32° 46' 02"N 22° 00' 08"E, 677m) during the Apple bloom period of the season 2022 on a farm of 50 hectares. The study began during the peak flowering time of the apple *Malus domestica*; three days were chosen, 23-25/April. The trees were 10 –17 years old, with heights ranging from 1.5–2.5 m and an average crown size of 2.1 m × 2.0 m. Pesticides were not applied. The experiment was started when about 15-20% of the flowering took place so that bees would not forage outside the orchard on the other floral resources. The observations were made continuously for the different foraging parameters for 3 days.

The activity of honey bee workers

To assess the effect of altitude area on the number of worker honey bees visitors during their collecting nectar and pollen, the flowering area of the apple tree was divided into two equal heights, the upper and the lower region, where each region was studied separately with the recording of the surrounding climatic conditions, the number of visits of worker honey bees collecting nectar and pollen was from 9:00 am until 1:00 pm in an area. The observations were calculated for the visitors of the honey bee workers in the densely flowering branches with a length of 1 meter by following up the movements of the visiting workers of honey bees flowers, where the visiting workers of the flowers are monitored from the moment they enter the determined area and all their behaviors in collecting and pollen and how they stick to the flower and leave during the visit were recorded.

Foraging behavior

The time the worker spent collecting nectar or pollen from the flower was calculated, and the time began to be calculated until she left the flower (Handling time). Likewise, the time started to be calculated as soon as the worker stood on the flower and touched its parts. The time she moving from one flower to another (Traveling time) was calculated using the same method (Pleasant, 1981), where the period of handling and traveling time is calculated in both the upper and down regions, taking into account measurements of climatic conditions.

Weather

Temperature and relative Humidity were recorded by a psychomotor and a thermometer a every 10 minutes near the flowers of Apple flowers.

Statistical analysis

Statistical analysis of all data was carried out using the program (Minitab) version (16), analysis of variance (ANOVA), and calculation of (mean \pm SE).

RESULTS

1. The foraging activity of *Apis mellifera* on flowers

a. The effect of flowers' position on the nectar collectors

The results showed significant differences in the number of visits by worker bees in each of the specific flowering regions on the apple tree during the day. In the upper region, significant differences were recorded in the number of workers who visited during the daytime (One-way ANOVA,, $F = 9.53$, $df = 3$, $P < 0.0001$). The highest rate of visiting a worker was recorded at 11:00 am, where the average number of workers was 96.00 ± 6.0 workers/m². The lowest rate of female worker visits was recorded at noon, where the average number of female workers was 73.3 ± 2.61 female workers / m². The lower region, also recorded significant differences (One-way ANOVA) ($F = 25.55$, $df = 3$, $P < 0.0001$) where the highest rate of a visit by a worker was recorded at 11:00 am, with an average number of 84.00 ± 3.3 worker/m². The lowest rate of female worker visits was recorded at 9:00 am, with an average number of 3.6 ± 0.1 workers/m². (Table 1a).

Table (1a). Mean (\pm SE) number of honey bee's nectar collectors during day times from the two flowering height categories during the peak season (23-25 / April / 2022).

Day time	Mean No. of nectar collectors (\pm SE)	
	Upper region	lower region
9:00-10:00	83.3 ± 1.9 ^{ab}	36.6 ± 4.6 ^c
10:00-11:00	73.6 ± 0.8 ^b	66.6 ± 3.5 ^b
11:00-12:00	96.0 ± 6.0 ^a	84.0 ± 3.3 ^a
12:00 -1:00	73.3 ± 2.6 ^b	63.6 ± 3.8 ^b

Similar lowercase letters mean no significant differences in the same column.

b. The effect of flowers' position on the pollen collectors

Our results revealed a significant difference between the number of honey bee workers collecting pollen throughout the day in both flowering region (Table 1b). The upper region recorded a substantial difference in the number of bees collecting pollen through the daytime (One-way ANOVA) ($F = 159.1$, $df = 3$, $P < 0.0001$). The highest rate of visiting a worker was recorded at 9:00 am, where the mean number of 25.3 ± 0.4 worker / m² was reached. while the lowest rate of a visit by a worker was recorded at noon when the average number of workers was 3.6 ± 0.4 worker/m². The lower region also recorded significant differences (One-way ANOVA), ($F=34.15$, $df=3$, $P < 0.0001$), the highest rate of visiting a worker was recorded at 9:00 am, where the average number of workers

was 13.3 ± 0.77 worker/m². The lowest rate of a visit by a worker was recorded at noon when the average number of workers was 3.6 ± 0.1 worker/m².

Table (1b). Mean (\pm SE) number of honey bee's pollen grain collectors during day times /from the two flowering height categories during the peak season. (23-25 / April / 2022).

Day time	Mean No. of pollen collectors (\pm SE)	
	Upper region	lower region
9:00-10:00	25.3 ± 0.4^a	13.3 ± 0.77^a
10:00-11:00	13.6 ± 0.1^b	11.6 ± 0.4^a
11:00-12:00	7.00 ± 0.9^c	6.3 ± 0.76^b
12:00 -1:00	3.6 ± 0.4^d	3.6 ± 0.1^c

Similar lowercase letters mean no significant differences between the same column.

The results showed a clear difference between the number of honey bee workers in the upper and lower regions during their visit to collect nectar and pollen during different hours of the day, where the highest preference for visiting honey bee workers during their collection of nectar was recorded in the upper region (81.6 ± 1.9) worker/m² the compared to the lower region. P-Value = 0.001, df = 223, T-Value = 6.05. Also, the highest preference recorded for visiting honey bee workers during pollen collection was recorded in the upper region compared to the lower region, with an average of 11.4 ± 0.8 worker/m², P-Value = 0.005, df = 212, T-Value = 2.85 (Table 1c). From our results, we find an apparent effect of height on the behavior of worker bees, especially in the upper region during food gathering.

Table (1c). The comparison of the mean number (\pm SE) of workers collecting nectar and pollen during a day time/m² from the two flowering height categories during the peak season (23-25 / April / 2022).

No. worker (flower/hr.)	Collecting Nectar	Collecting Pollen
Upper region	81.6 ± 1.9^a	11.4 ± 0.8^a
lower region	62.8 ± 2.5^b	8.5 ± 0.5^b

The letters different in the column are meant to find significant differences.

2. The effect of flower position on handling and traveling time

a. effect on the rate of nectar collection

The results show the handling and traveling times of honey bee workers on flowers during daylight hours in each of the two flowering regions while collecting nectar and pollen, (Table. 2a). in the upper region, we did not record significant differences during handling time for workers (df = 3, F = 1.07, P>0.363). Also, the handling time for the lower region shows no significant differences (df = 3, F = 1.06, P>0.369). The traveling time between the flowers in the upper region shows a significant difference (df=3, F=3.21, P<0.02), where the highest traveling time was recorded at 11:00 am with an average of (2.0 ± 0.05) sec., while the lowest traveling time between flowers was at 12 noon with an average of (1.5 ± 0.17) sec. in the upper region. In contrast, the traveling time between the flowers in the lower region shows no significant differences through day hours (df=3, F=0.47, P>0.701).

Table (2a). The Mean (SE \pm) handling and traveling time of *Apis mellifera* collecting the nectar of apple flowers *Malus domestica* during different days.

Height		Foraging times/second			
		9:00-10:00	10:00-11:00	11:00-12:00	12:00-1:00
Handling time	Upper region	1.9 ± 0.15^a	1.8 ± 0.8^a	2.2 ± 0.15^a	1.9 ± 0.2^a
	lower region	1.9 ± 0.27^a	1.6 ± 0.1^a	2.12 ± 0.2^a	2.1 ± 0.21^a
Traveling time	Upper region	1.7 ± 0.11^{ab}	1.7 ± 0.1^{ab}	2.0 ± 0.05^a	1.5 ± 0.17^b
	lower region	1.6 ± 0.18^a	1.3 ± 0.1^a	1.5 ± 0.07^a	2.0 ± 0.07^a

Similar letters mean no significant differences between the same line.

b. Effect on the rate of pollen collection

Our results in Table (2b) show the times of foraging rate of honey bee workers on flowers during daylight hours in each region while collecting pollen, where significant differences were recorded in the upper region for the handling time ($df=3$, $F= 9.78$, $P<0.0001$). Where the highest handling time was recorded at 10:00 am with an average of (2.50 ± 0.3) sec. and the lowest handling time was recorded in the same area at 12 noon with an average of (0.4 ± 0.2) sec.). When recorded lower region during collection pollen significant differences (One-way ANOVA, $df=3$, $F=8.62$, $P<0.0001$) when was highest handling time at 10:00 am recorded with an average (2.5 ± 0.45) seconds, as well as at 12:00 noon recorded the lowest handling time was with an average of (0.3 ± 0.1) seconds, at the same time, as it was recorded in two regions traveling time, where the upper region recorded apparent significant differences ($df=3$, $F= 31.28$, $P<0.0001$). The highest traveling time was at 10:00 am with a mean of (1.6 ± 0.1) sec.) and recorded between 11:00 am and 12:00 noon; the lowest traveling time recorded was at 12:00 with an average of (0.2 ± 0.1) sec.. also the lower region recorded a significant difference ($df=3$, $F=12.26$, $P<0.0001$). The highest traveling time of a worker was at 10:00 am with an average of (1.3 ± 0.12) sec., and the lowest traveling time was at noon with an average of (0.4 ± 0.11) seconds, (Table 2b).

Table (2b). The Mean (SE \pm) handling and traveling time of *Apis mellifera* collecting.

Foraging Behaviour		Times(second) / day time			
		9:00-10:00	10:00-11:00	11:00-12:00	12:00-1:00
Handling time	Upper region	1.9 \pm 0.15 ^{ab}	2.5 \pm 0.3 ^a	0.8 \pm 0.36 ^{bc}	0.4 \pm 0.2 ^c
	Lower region	2.1 \pm 0.27 ^{ab}	2.5 \pm 0.45 ^a	1.3 \pm 0.4 ^{bc}	0.3 \pm 0.1 ^c
Traveling time	Upper region	1.1 \pm 0.05 ^b	1.6 \pm 0.11 ^a	0.4 \pm 0.13 ^c	0.2 \pm 0.1 ^c
	Lower region	1.1 \pm 0.06 ^b	1.3 \pm 0.12 ^a	0.7 \pm 0.16 ^{bc}	0.4 \pm 0.11 ^c

Similar letters mean no significant differences between the same line.

The results revealed that no significant differences were recorded between the upper and lower regions in the handling time of honey bee workers while collecting nectar $df = 229$, P-Value = 0.801, T-Value = - 0.25. Also, our results did not record significant differences in the two regions for the handling time during the pollen collection, $df = 232$. T-Value = -0.31, P-Value = 0.753. As for the traveling time, no differences were recorded between the two regions during the nectar collection. $df = 145$. T-Value = 0.61, P-Value = 0.542, while the traveling time recorded significant differences between the two regions, where the pollen-collecting honey bee workers recorded the most preference for traveling. It was in the upper region with an average of (1.0 ± 0.07) seconds, $df = 238$. T-Value = 2.35, P-Value = 0.020 (Table.2c)

Table (2c). The mean duration of the visit of *Apis mellifera* on apple flowers during the blossom season in both upper and lower regions.

Foraging region	Handling time (sec.)		Travelling time (sec.)	
	Nectar	Pollen	Nectar	Pollen
Upper region	1.92 \pm 0.08 ^a	1.6 \pm 0.1 ^a	1.7 \pm 0.06 ^a	1.0 \pm 0.07 ^a
Lower region	1.96 \pm 0.1 ^a	1.7 \pm 0.2 ^a	1.6 \pm 0.1 ^a	0.7 \pm 0.06 ^b

Similar letters mean that there are no significant differences between (in) the same column.

3. Weather conditions during the hours of the day

Temperatures recorded significant differences between the different daylight hours during the two regions (One-way ANOVA, $P<0.0001$ $df= 3$, $F= 29.35$), and humidity levels recorded significant differences between the different daylight hours (One-way ANOVA) $F= 30.62$, $df=3$, $P < 0.0001$), Where at 9:00 am the temperature was recorded at an average of 21.5°C and the average humidity

was 36.6%. Also, at 10:00 am, the temperature was recorded at an average of 23.4C°, and the average humidity was 31.0%. at 11:00 am, the average temperature was 24.5C°, and the average humidity was 26.2%. at 12:00 noon the average temperature was 27.5C°, and the average humidity was 22.1%.

DISCUSSION

The results showed apparent significant differences in the number of bee visits between day hours in the upper and lower region of the flowers during their foraging on nectar, the highest activity rates was on the upper region at 11:00 am (96.0 ± 6.0 bees / m²), and (84.0 ± 3.3) bees / m² on lower region due to the raise gradually of temperatures, which reach of 24 C°. The low rates of honey bee workers collecting nectar were recorded in the upper region at 12:00 pm, with an average of 73.3 ± 2.6 bees/ m², at the temperature reached of 27 C°, while at 9:00 am the lower region with an average 36.6 ± 4.6 bees / m² the reason may be due to the humidity factor which reached 36.6%. The results showed apparent significant differences in collecting pollen between day hours during their visit to the upper and lower regions, the highest rates were 25.3 ± 0.4 bees / m², in the upper regions, and 13.3 ± 0.77 bees / m² on the lower region at 9:00 am were the humidity was 36.6%, and this is consistent with (Essa & Bataw, 2020) who investigated the influence of higher temperatures increase the number of worker bees collecting nectar compared to decrease of humidity, and also agreed with what was indicated by (Meriti, 2003) when studying the activity of bees flowers of *Camalducensis* sp, *Eucalyptus* sp, *Muricata* sp, *Erica* sp. during their pollen collection. The lowest number of visiting rates of bees collecting pollen in the upper region were recorded at 11:00 am (7.00 ± 0.9 bees/m²), as well as at 12:00 pm at lower region, when the rise in temperatures was recorded (3.6 ± 0.1 bees / m²) and this results indicated by (Brown and Paxton, 2009) who consider the climate conditions as the important influences that play a decisive role in controlling the life and activity of insects, and changes these conditions are capable of affecting behavior, and addition to the effect of the humidity factor and its effect on the anthers of this plant, and this is consistent with what was indicated by (Malerbo et al., 2004) that honey bees collect pollen from *Citrus sinensis* in the early morning hours. The preference activity of bees was recorded the highest rates in the upper region during collect nectar (81.6 ± 1.9) worker/m² and pollen (11.5 ± 0.8) worker/m² and this is what is consistent with (Mattu,2012) that the effect of the difference in heights depends on the start of the timing of the foraging activity. The strategic positioning of flowers plays a vital role in guiding bees' approach flights and landings. By optimizing these routes, bees can conserve energy and time, which is essential for maximizing their foraging success and ensuring effective pollination by (wang et al., 2014).

Our results recorded an effect of the handling and travelling time rate on honey bee workers collecting nectar and pollen during daylight hours. No significant differences in the handling time in the upper and lower region when collecting nectar. As a result of the availability pollen and nectar, which allows bees to obtain it without fatigue and hardship, especially in the first hour of bee activity because the nature of the plant nectar changes in quantity and composition during the day (Corbet, 1978). The results recorded apparent significant differences in travelling time between flowers at the upper region during the day time, at 11:00 am, the highest rate of travelling time was recorded, with an average of (2.0 ± 0.05 sec.). and the lowest travelling time was at 12:00 noon, with an average of (1.5 ± 0.17 sec.),the high concentration and available of nectar at this time could be one of the reasons (Willmer et al, 1994 Bataw ,1996).

The handling and travelling time of the bee visit in both regions recorded the highest rates of at 10:00 am and the lowest handling and travelling time at 12 noon during collecting pollen., as result

of decrease production of new pollen grains at this time, where the apple blossoms produced pollen grains at 9:00 in the morning, and the effectiveness of the activity was high, which affected the handling time at the hour 10 am while collecting pollen at this time. and the variation in honey bee workers *A.mellifera* and *Megachile* sp continues to forage during the period of pollen release from the anthers, but *A.ceratina* forage for nectar when sugar rises and pollen decreases (Rust et al , 2003).efficient flower arrangements not only reduce handling time but also enhance the overall foraging success of bees. By minimizing the time handling on each flower, bees can visit more flowers, increasing their nectar and pollen collection, which is vital for their handlined and ecological role This strategic positioning ensures consistent pollinator movement and maximizes pollination success (Jordan et al.,2016).

The results indicated that the flower area did not affect the period of handling time in both regions during the visit of the bees to collect nectar or pollen, also the results revealed the effect of the flowers height on travelling time in the lower region during the collection of pollen. These results conclude that the behavioral activity of honey bees is determined by several factors, such as food preference or suitability of climatic conditions within the foraging flowers, which in turn reflects on the effect of tree height, and the flower position on the tree.

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