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Flowering Phenology and Honeybee (*Apis Mellifera* L.) Visitation to Apple, Pear, and Plum Blossoms in Al-Abrag Region of Jabal Al Akhdar, Libya

Salma Yaseen Essa[1*], Ali A. Bataw[2]

[1]Department of Zoology, Faculty of Science (Al Guba), Derna University, Derna, Libya
[2]Department of Zoology, Faculty of Science, Omar Al Mukhtar University, Al-Bayda, Libya

توقيت التزهير وزيارة نحل العسل (*Apis Mellifera L*) لأزهار التفاح والكمثرى والعوينة في منطقة الأبرق _ الجبل الأخضر - ليبيا

سالمة ياسين عيسى, [2] علي عبد القادر بطاو [*1]

[1]قسم علم الحيوان، كلية العلوم (فرع القبة)، جامعة درنة, درنة, ليبيا
[2]قسم علم الحيوان، كلية العلوم، جامعة عمر المختار, البيضاء, ليبيا

*Corresponding author: Email: salma.yaseen@uod.edu.ly

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ABSTRACT

This study evaluated the relationship between flowering phenology and honeybee (*Apis mellifera* L.) visitation to apple (*Malus domestica*), pear (*Pyrus communis*), and plum (*Prunus domestica*) blossoms in Al-Abrag area of Jabal Al Akhdar, Libya. Branches were monitored from flower opening to senescence over nine days. Bee visitation was recorded hourly from 08:00 to 16:00 within a 1 m × 1 m observation area for 15 min each hour, while the numbers of open flowers and visiting workers were counted. Honeybee visitation varied among the three fruit-tree species and changed with flowering intensity. In plum, flowering began on 14 April 2015 and bee visitation showed the closest correspondence with flower abundance, although peak visitation did not always coincide exactly with peak bloom. In pear, flowering began on 20 April 2015, but the relationship between flower abundance and bee visitation was comparatively weak, with the highest visitation recorded at the beginning of flowering rather than at maximum flower density. A similar pattern was observed in apple, which began flowering on 23 April 2015. Peak bloom occurred on 26 April, whereas the highest bee visitation was recorded on 24 April despite a lower number of open flowers. Overall, flowering phenology was associated with temporal variation in honeybee visitation, but the strength and timing of this relationship differed among plum, pear, and apple. These findings indicate that flower abundance alone does not fully explain honeybee visitation and suggest that additional factors, including floral reward and environmental conditions, may influence visitation patterns.

الملخص :
قيّمت هذه الدراسة العلاقة بين الظواهر الموسمية للإزهار وزيارات نحل العسل *Apis mellifera L.)* لأزهار التفاح (*Malus domestica*) والكمثرى (*Pyrus communsnis)* والبرقوق (*Prunus domestica*) في منطقة الأبرق بالجبل الأخضر في ليبيا. تمت مراقبة الفروع بدءاً من تفتح الأزهار وحتى ذبولها على مدار تسعة أيام. وسُجِّلت زيارات النحل كل ساعة في الفترة من 08:00 صباحاً وحتى 16:00 مساءً ضمن مساحة مراقبة تبلغ 1 متر × 1 متر ولمدة 15 دقيقة في كل ساعة، مع عدّ الأزهار المتفتحة والنحل العامل الزائر. تفاوت زيارات نحل العسل بين أنواع أشجار الفاكهة الثلاثة وتغيرت بتغير كثافة الإزهار. ففي البرقوق بدأ الإزهار في 14 أبريل 2015، وأظهرت زيارات النحل أقوى ارتباط بوفرة الأزهار، رغم أن ذروة الزيارات لم تتطابق دائماً تماماً مع ذروة الإزهار. أما في الكمثرى، فقد بدأ الإزهار في 20 أبريل 2015، لكن العلاقة بين وفرة الأزهار وزيارات النحل كانت ضعيفة نسبياً، حيث سُجِّلت أعلى معدلات الزيارة في بداية فترة الإزهار وليس عند ذروة كثافة للأزهار. ولوحظ نمط مماثل في التفاح الذي بدأ الإزهار في 23 أبريل 2015؛ إذ حدثت ذروة الإزهار في 26 أبريل، بينما سُجِّلت أعلى معدلات زيارة النحل في 24 أبريل رغم انخفاض عدد الأزهار المتفتحة حينها. وبشكل عام، ارتبطت الظواهر الموسمية للإزهار بالتغيرات الزمنية في زيارات نحل العسل، إلا أن قوة هذه العلاقة وتوقيتها اختلفا بين البرقوق والكمثرى والتفاح. وتشير هذه النتائج إلى أن وفرة الأزهار وحدها لا تفسر بشكل كامل أنماط زيارة نحل العسل، مما تعطينا بأن هناك عوامل إضافية أخرى للنباتات والظروف البيئية التي تؤثر على هذه الأنماط.

الكلمات المفتاحية : *Apis mellifera*؛ الفينولوجيا الزهرية؛ بساتين الفاكهة؛ زيارات نحل العسل؛ بيئة التلقيح؛ الجبل الأخضر؛ ليبيا.

1. INTRODUCTION

Insect pollination is a fundamental ecosystem service that contributes directly to the reproduction of flowering plants and to the productivity and quality of many crops. Among insect pollinators, the western honeybee, *Apis mellifera* L., is one of the most widely managed species for crop pollination. Nevertheless, the contribution of pollinators to crop production depends not only on their abundance but also on the timing and frequency of their visits during flowering. Pollination limitation has been demonstrated in several economically important crops, emphasizing the importance of understanding the factors that regulate pollinator activity within agricultural landscapes (Reilly et al., 2020). Tree-fruit orchards provide abundant but highly seasonal floral resources. Apple (*Malus domestica*), pear (*Pyrus communis*), and plum (*Prunus domestica*) are mass-flowering crops whose bloom periods can attract large numbers of managed and wild bees. The temporal coincidence between flowering and pollinator activity is therefore important for effective flower visitation and subsequent pollination. Recent reviews of tree-fruit orchards have emphasized that bee abundance, species composition, floral preferences, and foraging behavior can change during the relatively short flowering period of orchard crops (Kline et al., 2023) .Flower abundance is an important component of floral resource availability, but it does not necessarily determine honeybee visitation in a simple proportional manner. Honeybee workers are selective foragers that respond to differences among plant species and to temporal changes in resource availability. Using DNA metabarcoding, Leponiemi et alhoneybee hat honeybees used only a fraction of the flowering plants available in the surrounding environment and that the time of the flowering season was one of the strongest determinants of floral-resource use. Similarly, flowering phenology, floral characteristics, time of day, and the type of resource collected can influence bee foraging patterns and pollination efficiency (Layek et al., 2022). The importance of these relationships is particularly evident in fruit orchards. Apple production is strongly dependent on insect-mediated pollination for achieving adequate fruit set and fruit quality, although the relative contributions of honeybees and wild pollinators may vary among orchards and regions (Pardo and Borges, 2020). More recent observations in apple orchards have confirmed that *A. mellifera* can be one of the most abundant visitors to apple blossoms and that visitation varies substantially among sampling dates during the flowering period (Barda et al., 2023). Honeybees can also make a substantial contribution to pear pollination. Li et al. (2022), for example, found that honeybees accounted for a large proportion of flower visits in pear orchards and that increased pollinator visitation was associated with improved fruit set and fruit quality. These observations demonstrate that quantifying flower visitation during the flowering period can provide useful information about the temporal availability and use of floral resources by pollinators. However, the number of open flowers is only one of several factors influencing honeybee activity.

Nectar quantity and quality, sugar concentration, pollen availability, floral morphology, competing floral resources, and colony requirements can influence the decisions of individual foragers. Honeybees may therefore concentrate their activity on particular floral resources even when other flowering plants are abundant. Recent research has confirmed that honeybees discriminate among available floral resources and that nectar and pollen sources can be selected differently according to their nutritional characteristics and availability (Leponiemi et al., 2023). Environmental conditions further modify these plant–pollinator relationships. Temperature, relative humidity, solar radiation, rainfall, and wind can directly affect honeybee flight and foraging activity and can simultaneously influence nectar production and concentration. A recent review by Vincze et al. (2025) concluded that honeybee flight and nectar collection are particularly sensitive to short-term weather conditions, with temperature, relative humidity, solar radiation, precipitation, and wind contributing to temporal variation in foraging activity. Despite the agricultural importance of fruit-tree pollination, information from several geographical regions remains comparatively limited. A global review of apple pollination identified substantial geographical gaps in the available literature, including limited information from African production systems (Pardo and Borges, 2020). Consequently, field observations from the Mediterranean environments of North Africa can contribute useful baseline information on the interaction between flowering dynamics and honeybee activity under local orchard conditions. The Al-Abrag area of Jabal Al Akhdar, Libya, supports orchards of several temperate fruit species, including plum, pear, and apple. Because these species differ in flowering timing and potentially in the quantity and quality of floral rewards offered to bees, their flowering periods provide an opportunity to examine whether changes in flower abundance are accompanied by corresponding changes in honeybee visitation. Such information may contribute to a better understanding of honeybee foraging patterns in Libyan fruit orchards and provide baseline data for future studies of orchard pollination and pollinator management. Therefore, the present study aimed to evaluate the relationship between flowering phenology and honeybee worker visitation in plum (*Prunus domestica*), pear (*Pyrus communis*), and apple (*Malus domestica*) under field conditions in Al-Abrag, Jabal Al Akhdar, Libya.

2. MATERIALS AND METHODS

Study Area

The study was conducted on a farm of approximately 50 ha located in the Al-Abrag region, Jabal Al Akhdar, Libya. The farm was characterized by relatively dense vegetation and included several fruit-tree species, particularly plum (*Prunus domestica*), pear (*Pyrus communis*), and apple (*Malus domestica*). The orchard contained approximately 200 apple trees, 24 pear trees, and 200 plum trees. Field observations were carried out from early April to early June 2015, corresponding to the flowering periods of the three fruit-tree species investigated.

Effect of Flowering Phenology on Honeybee Worker Activity

The activity of honeybee workers (*Apis mellifera* L.) on the flowers of the selected plant species was monitored. For each fruit-tree species, observations were conducted over nine consecutive flowering days. Bee visitation was recorded from 08:00 to 16:00 h within a 1 m observation area. Observations were conducted for 15 min during each hour, and the number of honeybee workers visiting the flowers for nectar collection was recorded.

Selected flowering branches were marked at the beginning of anthesis and monitored throughout the flowering period until flower senescence. The number of open flowers on each selected branch was recorded concurrently with honeybee visitation. A hand-held counter was used to facilitate the counting of visiting workers and open flowers.

Statistical Analysis

All collected data were statistically analyzed using Minitab software, version 16. Mean values were calculated, and regression analysis was performed to evaluate the relationship between the investigated variables, using the coefficient of determination (R^2) to determine the strength of the relationships. Graphs representing these relationships were generated using Microsoft Excel.

3. RESULT

1. Honeybee Visitation During Pear (*Pyrus communis*) Flowering

Pear (*Pyrus communis*) flowering began on 20 April 2015. On the first day of observation, the mean number of open flowers was 215.6 flowers m², while the mean number of visiting honeybee workers was 117.6 bees m². (**Figure** 1).

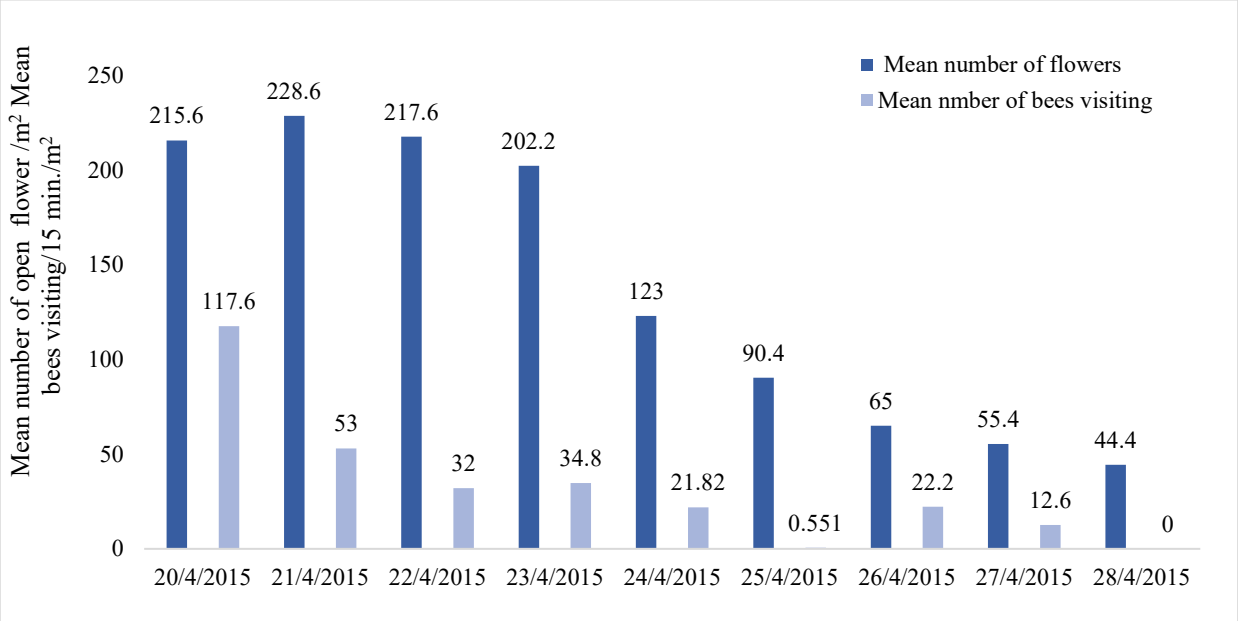


Figure 1. Mean number of *Apis mellifera* worker bees visiting *Pyrus communis* in relation to the mean number of open flowers during the study period, with observations conducted daily from 08:00 AM to 04:00 PM (Libyan Summertime).

On the second day (21 April 2015), the mean number of open flowers increased to 228.6 flowers m², whereas the mean number of visiting workers declined markedly to 53.0 bees m². On 22 April 2015, both flower abundance and bee visitation decreased, with mean values of 217.6 flowers m² and 32.0 bees m², respectively. On 23 April 2015, the mean number of open flowers decreased further to 202.2 flowers m², while the mean number of visiting workers was 34.8 bees m². During the remaining observation days (24, 25, 26, 27, and 28 April 2015), the mean number of open flowers was substantially lower than during the initial flowering period, at 123, 90.4, 65, 55.4, and 44.4 flowers m², respectively. Correspondingly, relatively low and variable numbers of honeybee visitors were recorded, averaging 21.82, 0.551, 22.2, 12.6, and 0.00 bees m², respectively **(Figure 1)**. Overall, these observations indicate that honeybee visitation generally varied with flower abundance during the flowering period; however, the lack of a consistent proportional increase in bee numbers with increasing flower abundance suggests that flower density alone did not fully explain the temporal variation in honeybee visitation. Other factors, including nectar availability, weather conditions, and time-dependent changes in floral attractiveness, may also have contributed to the observed pattern. The results indicated a positive but relatively moderate association between the number of open flowers and honeybee visitation **(Figures. 2).**

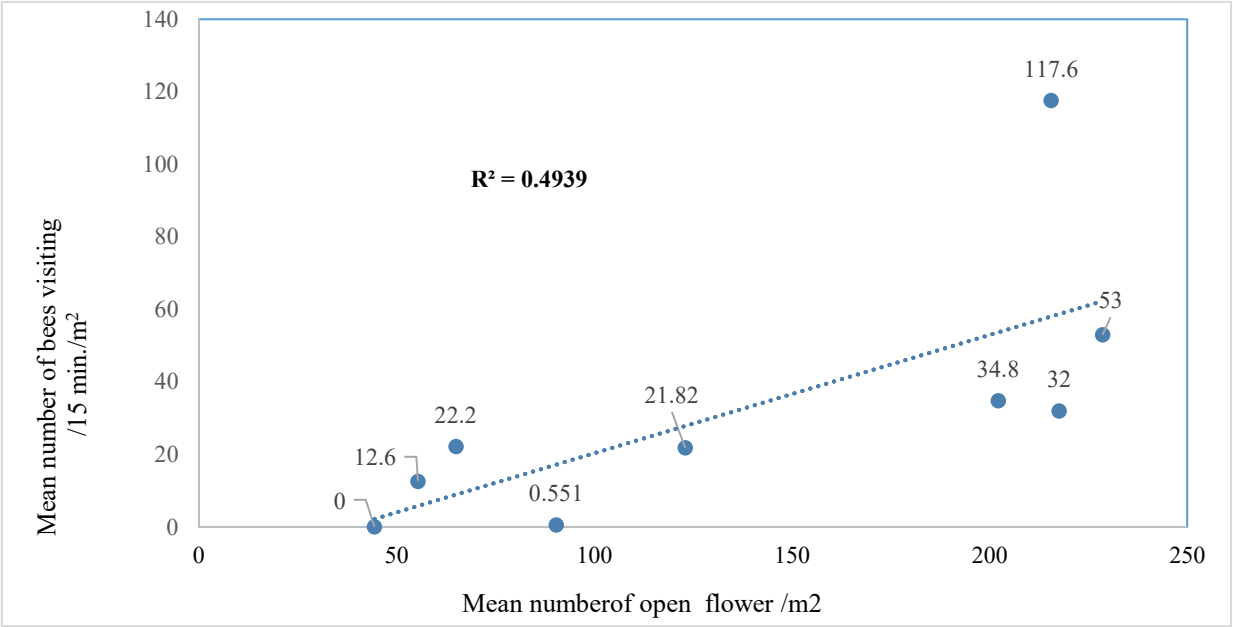


Figure 2. Relationship between the number of open flowers of *Pyrus communis* and honeybee visitation, during the flowering period from 20 to 28 April 2015; observations were conducted from 08:00 to 16:00 h local time.

2. Honeybee Visitation During Apple (*Malus domestica*) Flowering

Flowering of apple (*Malus domestica*) began in late April. On the first observation day (23 April 2015), the mean number of open flowers was 235.8 flowers m², while the mean number of visiting honeybee workers was 165.4 bees m². On 24 April 2015, the mean number of open flowers decreased to 295.2 flowers m², whereas honeybee visitation increased markedly to its highest recorded level of 225.3 bees m². On 25 and 26 April 2015, the mean number of open flowers increased to340.6 and 259.2 flowers m², respectively. However, the corresponding mean numbers of visiting workers were 21.5 and 145.0 bees m², indicating substantial temporal variation in bee visitation despite the relatively high abundance of flowers. On 27 and 28 April 2015, the mean number of open flowers were 293.4 and 103.8flowers m^{-2}, respectively, while the mean number of visiting honeybee workers was 145.2 and 115.4 bees m², respectively. On 29 April and 1 May 2015, flower abundance declined considerably to 144.2 and 0.0 flowers m², respectively, accompanied by relatively low honeybee visitation rates of 5.18 and 28.4 bees m². On 30 April 2015, both flower abundance and honeybee visitation increased relative to the preceding observation, reaching mean values of 104.4 flowers m² and 71.96 bees m², respectively **(Figure 3)**. Overall, the results suggest that honeybee visitation tended to increase with flower abundance during some stages of the flowering period. However, this pattern was not consistent across all observation days, as relatively high flower densities were sometimes accompanied by low bee visitation rates. This indicates that flower abundance alone did not fully account for variation in honeybee visitation, and that other factors, such as nectar availability, temperature, relative humidity, time of day, and changes in floral attractiveness, may also have influenced foraging activity.

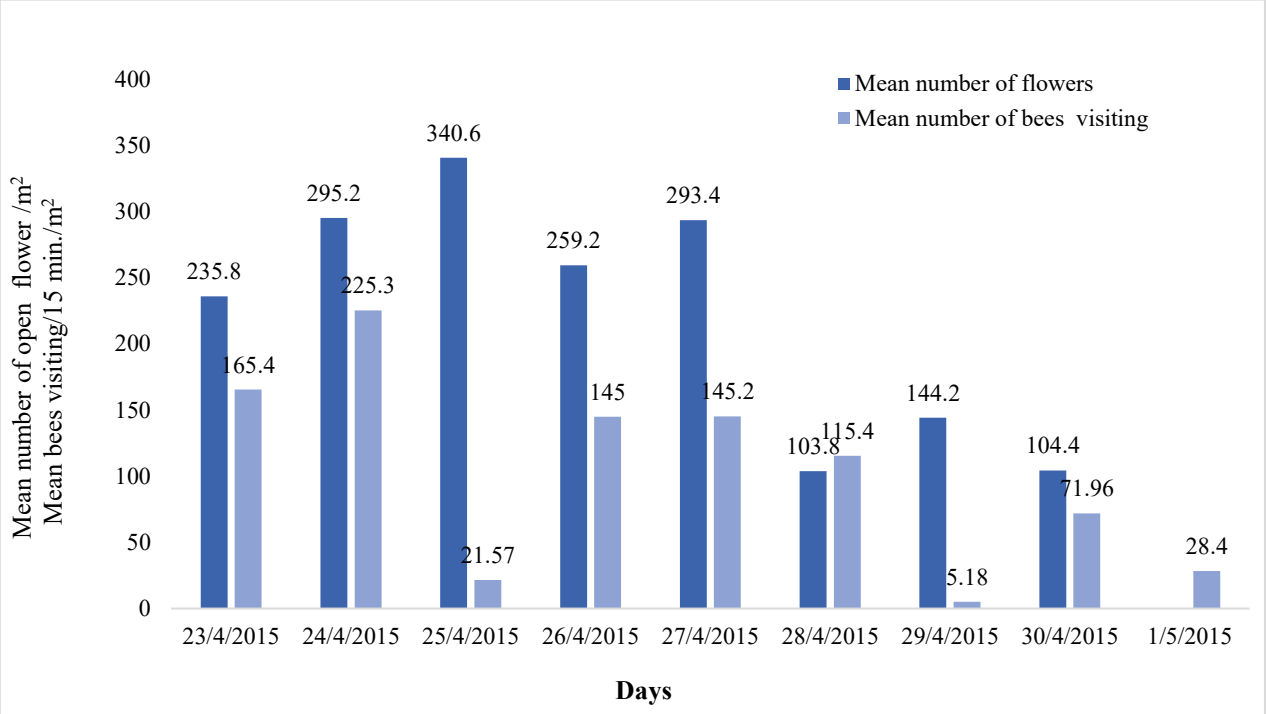


Figure 3. Mean number of *Apis mellifera* worker bees visiting *Malus domestica* and the corresponding mean number of open flowers during the study period; observations were conducted from 08:00 to 16:00 h local time.

The results showed a relationship between the number of open flowers and the number of honeybee workers visiting, although the association was relatively weak **(Figure 4).**

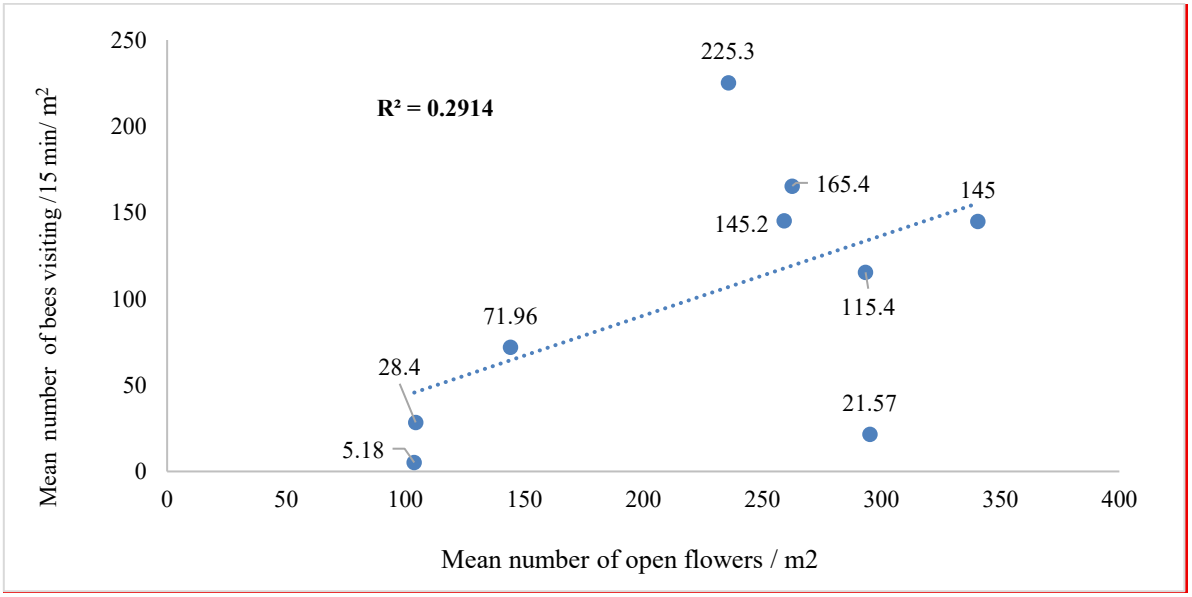


Figure 4. Relationship between the number of open flowers of *M. domestica* and honey beesvisitation, during the study period from April 23, 2015, to May 1, 2015; observations were conducted from 08:00 to 16:00 h local time.

3. HoneyBee Visitation During Plum (*Prunus domestica*) Flowering

The results obtained showed a strong positive association between the number of open flowers and the number of visiting honeybee workers **(Figure 5).** Flowering of plum (*Prunus domestica*) began in mid-April. On the first day of observation (14 April 2015), the mean number of open flowers was 288.8 flowers m², while the mean number of visiting honeybee workers was 120.6 bees m². The number of open flowers increased further during 15, 16, and 17 April 2015, with noticeable day-to-day variation in the number of bee visitors. On the third day (16 April 2015), the mean number of open flowers reached 374.6 flowers m², and this coincided with the highest recorded rate of honeybee visitation, with a mean of 225.9 bees m². On the fourth day (17 April 2015), the flowering period reached its peak, with the mean number of open flowers rising to 497.6 flowers m²; however, the mean number of visiting workers declined to 175.80 bees m², showing an inverse pattern on that day. Thereafter, the number of open flowers declined progressively during 18, 19, 20, 21, and 22 April 2015, accompanied by a clear reduction in the number of honeybee workers visiting. The lowest flowering intensity was recorded on the ninth day (22 April 2015), when the mean number of open flowers was 112 flowers m², compared with a marked decline in bee visitation to 0.20 bees m². Overall, these results indicate that an increase in the number of open flowers was generally associated with an increase in the number of visiting honeybee workers. However, on some observation days, an opposite pattern was also observed, in which higher flower abundance did not correspond to a higher number of visitors.

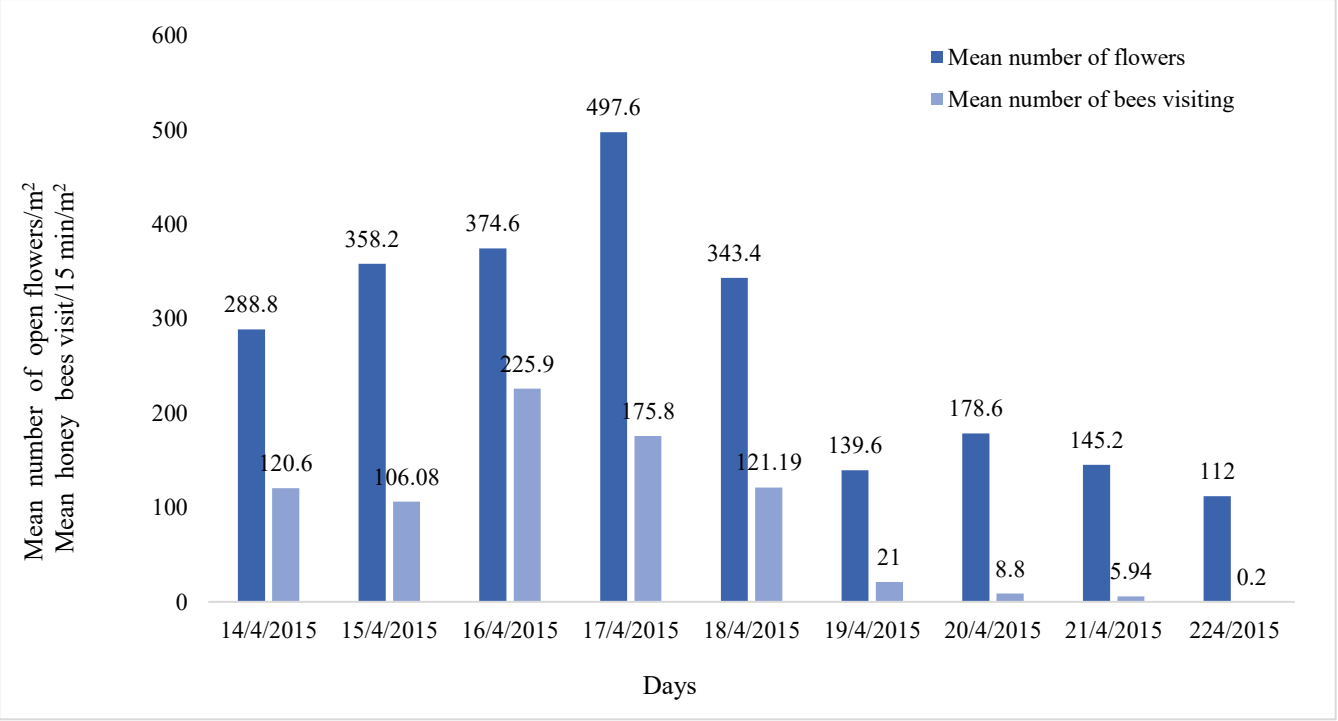


Figure (5). Mean number of *Apis mellifera* worker bees visiting *Prunus domestica* in relation to the mean number of open flowers during the study period; observations were conducted from 08:00 to 16:00 h local time.

The results obtained showed a strong positive association between the number of open flowers and the number of visiting honeybee workers **(Figure 6).**

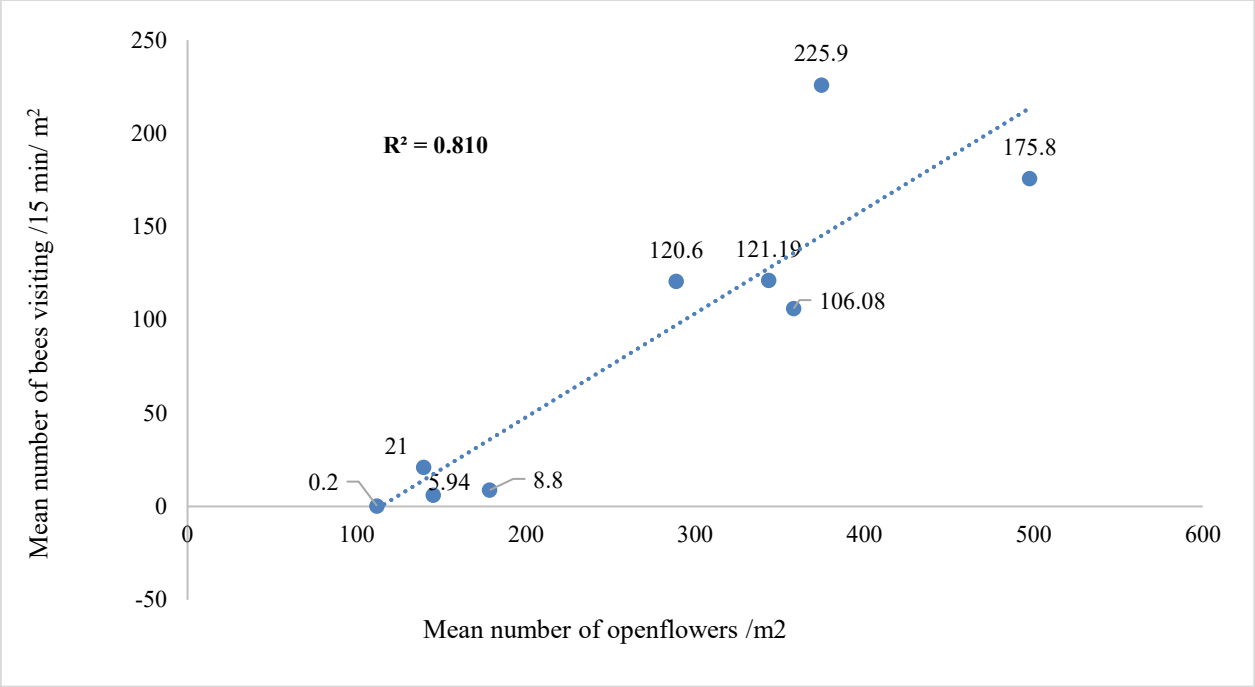


Figure 6. Relationship between the number of open flowers of *P. domestica* and honeybee visitation during the study period (April 14–22, 2015). Observations were conducted from 08:00 to 16:00 h local time.

5. DISCUSSION

The present study showed that the activity of honeybee workers (*Apis mellifera* L.) varied throughout the flowering period of the three fruit-tree species investigated. However, the correspondence between flower abundance and bee visitation differed among plum (*Prunus domestica*), pear (*Pyrus communis*), and apple (*Malus domestica*), indicating that changes in the number of open flowers alone were not sufficient to explain the temporal pattern of honeybee activity.

In plum (*P. domestica*), flower abundance and honeybee visitation showed the closest correspondence among the three fruit species. Flowering began on 14 April 2015, when relatively high numbers of both open flowers and visiting workers were recorded. Peak flowering occurred on 17 April 2015, whereas the highest honeybee visitation rate was recorded one day earlier, on 16 April 2015. Thereafter, the decline in flower abundance was generally accompanied by a reduction in bee visitation, although some day-to-day variation occurred. This overall pattern is consistent with the importance of spring-flowering fruit trees as concentrated sources of nectar and pollen for bees, while also showing that maximum floral abundance does not necessarily coincide precisely with maximum foraging activity. Recent work on early-spring floral resources has similarly demonstrated that plum, pear, and apple contribute sequential pulses of nectar and pollen availability, with pollinator use varying through this relatively short flowering period.

In pear (*P. communis*), the correspondence between flower abundance and honeybee visitation was less pronounced. Flowering began on 20 April 2015, when the highest number of visiting honeybee workers was recorded, whereas maximum flower abundance occurred on 21 April 2015, accompanied by a marked decrease in bee visitation. During the following days, flower abundance generally declined, while the number of visitors remained variable. These findings suggest that the attractiveness of pear flowers to honeybees was not determined solely by flower density. This interpretation is supported by recent research showing that pear orchards may experience relatively low pollinator visitation because pear nectar can contain lower sugar concentrations than nectar from some simultaneously flowering fruit trees and because weather during bloom can further restrict pollinator activity (Lenzi et al., 2026).

The apple (*M. domestica*) results showed a comparable pattern. Flowering began on 23 April 2015, and peak bloom occurred on 26 April 2015. Nevertheless, the highest number of honeybee visitors was recorded on 24 April 2015, when the number of open flowers was lower than at peak flowering. Consequently, peak honeybee visitation did not coincide with maximum flower abundance. Similar temporal variation has been reported in apple orchards. (Barda et al. 2023).

found that honeybee visitation changed significantly among observation dates during apple bloom and that the abundance of open apple flowers contributed to attraction, although visitation was also influenced by conditions operating at particular dates. More recent work in intensive apple orchards has likewise shown that date, time of day, and temperature are important determinants of flower-visiting insect abundance (Granata et al., 2025).

The present findings partly differ from those reported by Salem (2005) for *Arbutus pavarii*, *Marrubium vulgare*, and *Thymus capitatus* in Jabal Al Akhdar. Salem reported that the number of honeybee workers increased as the number of open flowers increased, reaching a maximum close to peak flowering, followed by a decline in visitation as flowering decreased. In the present study, this pattern was more evident in plum, whereas it was less consistent in pear and apple. Such differences among plant species are biologically plausible because honeybees do not forage simply according to the number of flowers available; rather, they make selective choices among floral resources according to their profitability and accessibility.

This interpretation is strongly supported by recent studies of honeybee foraging. (Leponiemi et al. 2023), using DNA metabarcoding, demonstrated that honeybees utilized only a fraction of the flowering plants available in the surrounding environment and that floral-resource selection changed markedly over the flowering season. Their results indicate that resource availability does not automatically translate into proportional use by honeybees and that bees exhibit considerable selectivity among available plant resources.

The quantity and quality of floral rewards may therefore explain part of the differences observed among plum, pear, and apple. Nectar represents the principal carbohydrate reward for honeybees, but its attractiveness depends not only on volume but also on sugar concentration and chemical composition. Nectar quality may vary substantially among plant species, individual flowers, and environmental conditions. (Nicolson ,2022) emphasized that nectar quality cannot be reduced to sugar concentration alone because amino acids, secondary metabolites, water content, and other chemical components may also influence pollinator behavior. Honeybees are also capable of assessing nectar quantity and sucrose concentration and incorporating these rewards into their foraging decisions (Brunet and Minahan, 2024).

This explanation is particularly relevant to the present study because previous work conducted in Jabal Al Akhdar, Libya, on the same three fruit species demonstrated differences in nectar secretion and honeybee foraging behavior among *P. domestica*, *P. communis*, and *M. domestica*.(Essa and Bataw (2020) reported temporal variation in nectar production and honeybee activity, with plum producing comparatively high nectar volume at certain observation times and pear showing much lower nectar availability at other times of the day. They also reported differences in handling and travelling times among the three fruit species. These findings provide local evidence that floral reward characteristics may contribute to the differences in visitation observed in the present study.

Therefore, a relatively large floral display may not necessarily receive the highest number of honeybee visits if individual flowers provide a poorer reward than competing floral resources. Honeybees can adjust their foraging decisions based on nectar profitability, floral signals, prior experience, and alternative resources in the surrounding landscape. Modern reviews of honeybee pollination ecology emphasize that foraging decisions operate hierarchically, from selecting a floral patch to selecting a plant species, individual plant, inflorescence, and ultimately individual flowers. Visual and olfactory cues, together with the perceived quality of the floral reward, can therefore influence whether workers continue to exploit or abandon a particular floral resource (Brunet and Minahan, 2024).

Weather conditions may provide an additional explanation for the day-to-day variation recorded in the present study. Honeybee foraging activity is highly sensitive to air temperature, relative humidity, solar radiation, rainfall, cloud cover, and wind speed. These factors can directly affect flight activity and may also indirectly modify nectar secretion, nectar concentration, and floral attractiveness. A recent comprehensive review concluded that honeybee foraging generally responds positively to suitable temperatures and solar radiation, whereas rainfall, excessive wind, and unfavorable humidity can restrict foraging. Importantly, the effects of weather vary among plant species and according to the phenological stage of flowering (Vincze et al., 2025).

The timing of observations within the day may also have contributed to the variation in visitation. Nectar and pollen availability are not constant throughout the day, and honeybees adjust their activity to the temporal pattern of floral reward production. Recent evidence indicates that pollen and nectar collection from fruit trees may peak at different times, with pollen collection often reaching maximum levels in the late morning and nectar collection later in the day. Consequently, the number of bees observed at a given time can reflect an interaction among flower abundance, resource type, nectar secretion, and prevailing weather rather than flower number alone.

Taken together, the differences observed among plum, pear, and apple are likely to result from the combined influence of flower abundance, flowering stage, nectar quantity and quality, floral attractiveness, plant species, alternative floral resources, time of day, and prevailing environmental conditions. The fact that peak flowering did not consistently coincide with peak honeybee visitation, particularly in pear and apple, supports the view that honeybee foraging activity is governed by multiple interacting factors rather than by floral abundance alone.

Future studies should therefore include multiple orchards and flowering seasons, direct measurements of floral rewards, detailed weather variables, colony characteristics, and statistical models that simultaneously evaluate the effects of flowering intensity and environmental conditions. Measurements of fruit set and fruit quality would also help establish the functional consequences of variation in honeybee visitation.

This study was conducted in a single orchard during one flowering season. The relatively short observation period and the use of a limited number of flowering days restrict the extent to which the observed relationships can be generalized across years or orchards. In addition, although temperature and relative humidity were recorded, other potentially important factors such as wind speed, solar radiation, competing floral resources, colony strength, nectar secretion, and pollen availability were not incorporated simultaneously into the statistical analysis. The results should therefore be interpreted as baseline observational evidence of temporal associations between flowering intensity and honeybee visitation rather than as evidence of direct causal effects.

Conclusion: Honeybee visitation varied markedly during the flowering periods of plum, pear, and apple in Al-Abrag, Jabal Al Akhdar. Plum showed the strongest correspondence between open-flower abundance and honeybee visitation, whereas this association was weaker and less consistent in pear and apple. Peak flowering did not necessarily coincide with peak visitation, indicating that temporal variation in honeybee use of orchard flowers cannot be attributed to flower abundance alone. Differences in floral rewards and environmental conditions may contribute to these patterns, but these factors require direct testing. The present study provides baseline information on honeybee fruit tree interactions in northeastern Libya and highlights the need for replicated, multi-season studies incorporating floral rewards, weather conditions, colony characteristics, and measures of pollination outcome.

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