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Beekeeping in the Desert: Foraging Activities of Honey Bee during Major Honeyflow in a Hot-Arid Ecosystem

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Abstract: This study investigated the outgoing and pollen-gathering foraging activities of *Apis mellifera jemenitica* (*AMJ*) and *Apis mellifera carnica* (*AMC*) under a hot-arid environment in the presence of nectar-rich melliferous *Ziziphus nummularia* flora. The data revealed the differential effects of weather conditions and *Z. nummularia* flora on the foraging activities of the studied honey bee subspecies in the Rawdat-Khuraim oasis in central Saudi Arabia. *Z. nummularia* exhibited two flowering seasons, from June–July (season I) and August–October (season II), with a significantly higher mean flowering density observed during season II (404 flowers/m^2) than during season I (235 flowers/m^2). *AMJ* showed significantly higher foraging activities (outgoing and pollen-gathering) than *AMC* (exotic bees) during all months in each flowering season. The mean outgoing and pollen-gathering foraging rates of *AMJ* (32.40 ± 0.67 and 4.88 ± 0.40 workers/colony/min, respectively) were significantly higher than those of *AMC* (15.93 ± 1.20 and 2.39 ± 0.23 workers/colony/min, respectively). The outgoing and pollen-gathering foraging activities of the two subspecies fluctuated throughout the different times of day. Foraging activities were considerably high at sunrise (SR) and low at noon (N) during both flowering seasons. We also observed seasonal variations in the foraging activities of both bee subspecies. The mean foraging activities (outgoing and pollen-gathering) were slightly higher in season I (27.43 ± 1.21 and 4.46 ± 0.45 workers/colony/min, respectively) than in season II (21.71 ± 0.86 and 3.02 ± 0.22 workers/colony/min, respectively). The thermal window analysis revealed a significant difference between the flight activities (bees exiting and returning to the nest throughout the day) of *AMJ* and *AMC*; *AMJ* had a higher temperature threshold than *AMC*. The outgoing and pollen-gathering foraging activities within each bee subspecies were positively correlated. The present study can help researchers understand the performances of honeybees and the association of their performances with weather and nectar-rich flora conditions.

Keywords: arid environment; bee subspecies; flight activity; foraging; flowering season; *Ziziphus nummularia*; *Apis mellifera*

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1. Introduction

Beekeeping in the tropics and subtropics is challenged by shortage of rich nectar floral resources with variations in the dates of honeyflow occurrence [1]. *Ziziphus nummularia* (Burm. f.) is among the major melliferous plant species prevailing in the ecosystems of central Arabia, including Saudi Arabia [2,3]. This plant is well adapted to harsh conditions, such as drought, high temperatures, and high salinity [4,5], and is abundant in the desert oases of Saudi Arabia. It is important for the preservation of wild fauna, as it represents a high-potential honey source and plays roles in facilitating insect diversity and pollination [2,6,7].

Approximately 170 native species of the *Ziziphus* genus have been reported in tropical and subtropical regions of the world [8]. These species provide multipurpose benefits, such as conserving soil, stabilizing dunes, favoring the presence of perennial grasses, and serving as forage for livestock [5,9]. Plants of this genus are also used as fuel and construction materials; their edible fruits are eaten by humans; and the plants are used as medicine for some human and animal diseases due to their potent antimicrobial and analgesic properties [5,10–15]. These trees have the ability to tolerate and withstand harsh conditions such as heat, drought, and salinity [4,13].

The Rawdat-Khuraim oasis is located in central Saudi Arabia and represents a unique ecosystem within an arid desert. This oasis is a model nature preserve, providing an excellent and unique habitat for biodiverse animal and plant species. The floral diversity of this ecosystem harbors as many as 153 plant species of 32 families [16], and the region is an optimal area for potential studies of pollinator communities, including honey bees, due to its rich plant flora [16–18]. Pollinator diversity is crucial for reproduction processes of plants [19,20].

The foraging and production activities of honey bees are greatly influenced by the climatic conditions, the nature of flowering plants (the forage materials of bees), and the quantity of secreted nectar [7,21–23]. Nectar secretion is directly related to visitation by pollinators and weather conditions [24–27]. Honey bees show seasonal foraging activity patterns depending on the prevailing weather conditions [28]. A hot-dry environment exhibits differential effects on various honey bee species and subspecies [29,30].

The main objectives of this study were to investigate the foraging activities (outgoing and pollen-gathering activities) of two honey bee subspecies in the hot-dry environment of central Saudi Arabia during the abundant presence of *Z. nummularia* flora and to compare the activity patterns of the studied honey bee subspecies in relation to the weather conditions. The results of this study enhance our understanding of the flowering dynamics of bee plants in desert ecosystems and provide data for further studies aiming to improve beekeeping and honey production in arid environments.

2. Materials and Methods

2.1. Experimental Area and Plant Species

The field investigations were conducted at Rawdat-Khuraim, an oasis located 120 km northeast of Riyadh city, Saudi Arabia (25°30′–25″ N and 47°46′–30″ E at an elevation of 1817 feet) [3,22]. This oasis is approximately 18 km long and 1–2.5 km wide; during the flowering seasons of local flora, the climate is characterized as extremely dry (5–21% RH) and hot (23–52 °C) [21]. The oasis is enriched with diverse plants dominated by populations of plant species associated with bee flora, such as *Z. nummularia* and *Acacia gerrardii* [17].

Z. nummularia (Burm. f.) is a melliferous plant that is widespread in the arid and semiarid regions of Saudi Arabia. *Z. nummularia* populations occur within other plant communities in the Rawdat-Khuraim oasis, and this species is mainly dependent on water from the estuaries in surrounding areas during winter, autumn and spring [16]. The high-value honey extracted from *Ziziphus* spp. is locally called "Sidr honey" [31]. This research was carried out during the two flowering seasons of *Z. nummularia*, one from June–July (season I) and another from August–October (season II), over two years (2013–2015). Five trees (*Z. nummularia*) of the same reproductive age were randomly selected in the experimental area, and their trunks were tagged. These trees were freely accessible by honey bees, and potential floral visits by the bees were recorded during the two flowering seasons of *Z. nummularia*.

2.2. Flowering Density

The flowering density of *Z. nummularia* was measured at weekly intervals during the months from June–July (flowering Season I) and from August–October (flowering season II). The numbers of flowers on the five randomly selected *Z. nummularia* trees of the same reproductive age were counted, and the mean flowering density was calculated to show the flowering abundances and flowering density trends in the two seasons.

2.3. Honey Bee Subspecies

Two honey bee subspecies were targeted to evaluate their field activities during *Z. nummularia* flowering. These subspecies were *Apis mellifera jemenitica* (*AMJ*; an indigenous subspecies of Saudi Arabia) and *Apis mellifera carnica* (*AMC*; an exotic subspecies often imported from Egypt). These species are well adapted environmentally and are domesticated in Saudi Arabia [32]. Five equal-strength colonies (five frames/colony) of each subspecies per season were randomly used in this study in each flowering season in 2013 and 2015. Modern wooden Langstroth hives were used to rear the selected colonies, and the colonies were kept sheltered under a sunshade in the Rawdat-Khuraim oasis for one month prior to the onset of each *Z. nummularia* flowering season in each year of study.

2.4. Foraging (Outgoing and Incoming Pollen-Gathering) Activities of Honey Bees

The total numbers of foraging (outgoing bees) and pollen-gathering (incoming bees loaded with pollen pellets) worker bees were counted over periods of one min/week in each tested colony throughout the flowering seasons of *Z. nummularia* trees using a counter and a stopwatch. The data were collected at five fixed times throughout the day for each tested colony according to Arabia Standard Time (AST). The five targeted times were labeled as sunrise (SR), forenoon (FN), noon (N), afternoon (AN) and sunset (SS) and took place at 5:30 h, 8:30 h, 11:30 h, 14:30 h and 17:30 h, respectively [32–36].

2.5. Collection of Meteorological Data

Temperature (°C) and relative humidity (RH) data were hypothesized to affect the foraging activities of the studied honey bees. These meteorological factor data were monitored in parallel to the collection of outgoing and pollen-gathering forager data. The meteorological data characterizing each year of study were obtained from a nearby weather station at King Khaled International Airport, and monthly and seasonal means were calculated.

2.6. Thermal Window for Flight Activity

The thermal windows for the flight activities of outgoing and pollen-gathering honey bees were calculated by counting the numbers of bees exiting and returning from the five colonies during the day at consistent ambient temperatures throughout the flowering season [37,38]. The thermal temperature ranges associated with the flight activities of the two honey bee subspecies (*AMJ* and *AMC*) were evaluated and compared.

2.7. Statistical Analysis

In the data analysis, the data were calculated and presented as means followed by standard errors. The data were processed for normality and homogeneity using the Kolmogorov–Smirnov and Levene tests, respectively, and compared by means of two-way ANOVA followed by Duncan's test using SPSS-22® statistical software. Statistical significance was indicated at $p < 0.05$, $p < 0.01$ and $p < 0.001$.

3. Results

3.1. Meteorological Data

Temperature (°C), relative humidity (%) and wind speed (km/h) observations were recorded during the flowering seasons of *Z. nummularia* from June–July (season I) and from August–October (season II). The observations revealed hot temperatures (with means of 38 and 36 °C and ranges of 26–46 °C and 21–44 °C in seasons I and II, respectively) and dry weather (with mean RH values of 9% and 11% and ranges of 4–20% and 4–30% in seasons I and II, respectively), with mean wind speeds of 13 and 10 km/h (ranging from 0–28 km/h and from 0–30 km/h) during flowering seasons I and II, respectively (Figure 1A).

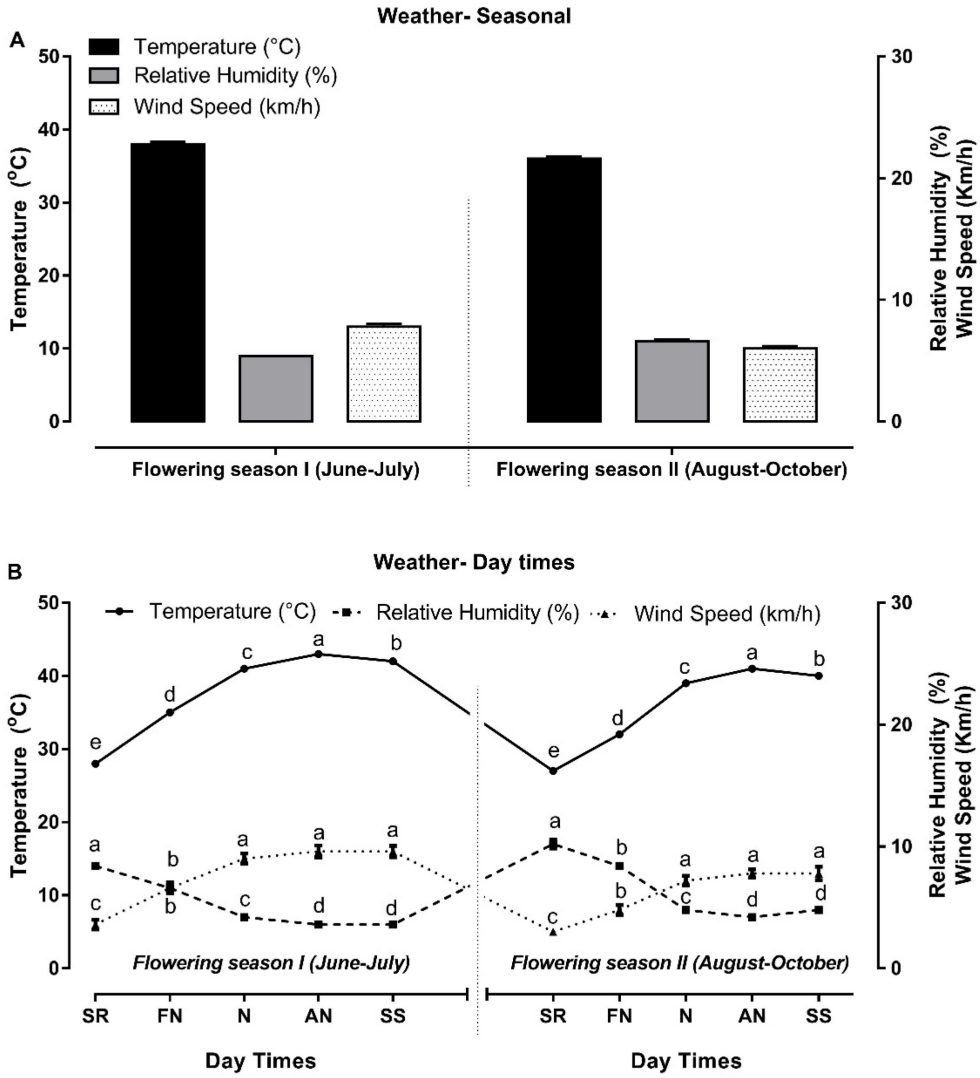

Figure 1. Meteorological temperature (°C), relative humidity (%) and wind speed (km/h) data recorded during the flowering seasons of *Z. nummularia* in central Arabia. (**A**) Seasonal patterns of weather factors (mean ± SEM) in each flowering season (season I and season II). (**B**) Daily patterns of weather factors (mean ± SEM) registered at different times of day (SR: sunrise, FN: forenoon, N: noon, AN: afternoon, and SS: sunset). Different letters indicate significant differences among the mean values of a single weather factor at different times of day at $p < 0.05$. SEM: standard error of the mean. Flowering season I was from June–July, and flowing season II was from August–October.

The hourly weather pattern revealed that the temperatures were significantly higher at noon (N), afternoon (AN) and sunset (SS) than at sunrise (SR) and forenoon (FN) during both flowering seasons. In both flowering seasons, the highest temperatures were recorded at the AN time and the lowest temperatures were recorded at the SR time. The relative humidity (RH) was significantly high at SR and gradually decreased to the lowest level later in the day during both seasons. The wind speed was significantly higher at N, AN and SS than at SR and FN during both flowering seasons (Figure 1B).

The monthly pattern of weather revealed that temperature was equally high during June, July, and August but was significantly lower during September and October (Figure 2A). RH was equally low during June, July, and August but significantly higher during September and October. The wind speed was significantly higher during July and August than during June, September and October (Figure 2A). Figure 2B shows the seasonal patterns of temperature, RH and wind speed in each month of the studied flowering seasons.

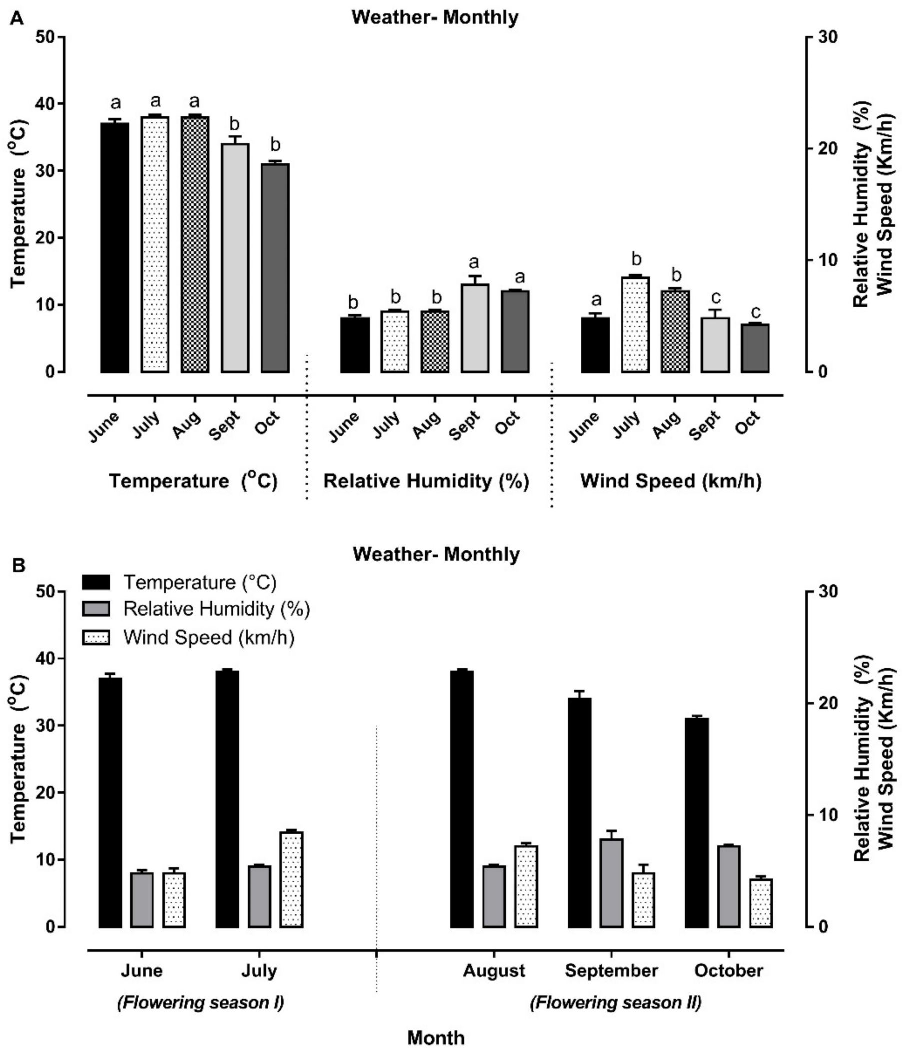

Figure 2. Monthly pattern of meteorological temperature (°C), relative humidity (%) and wind speed (km/h) data recorded during the flowering seasons of *Z. nummularia* in central Arabia. (**A**) Monthly patterns of weather factors (mean ± SEM). (**B**) Comparison of weather factors among different months (mean ± SEM). Different letters indicate significant differences among monthly weather data within a group of single weather factors at $p < 0.05$. SEM: standard error of the mean. Flowering season I was from June–July, and flowing season II was from August–October.

3.2. Flowering Density of *Z. nummularia*

The flowering density data (flowers/m^2) revealed two *Z. nummularia* flowering seasons: June–July (flowering season I) and August–October (flowering season II). Figure 3 clearly shows the flower abundance patterns of *Z. nummularia* in the two flowering seasons at weekly intervals during each month. The mean flowering density was significantly higher (404 flowers/m^2) during season II than during season I (235 flowers/m^2). During Season I, the flowering density (25 flowers/m^2) began increasing in June, reached a maximum (355 flowers/m^2) in mid-July and gradually declined throughout August (174 flowers/m^2) into the next flowering season. During Season II, the flowering density began increasing at the end of August, reached a maximum (877 flowers/m^2) in September and then gradually declined to a minimum of 32 flowers/m^2 in October. The highest mean flowering densities recorded in a month were measured in July (at 282 flowers/m^2) and September (546 flowers/m^2) for seasons I and II, respectively.

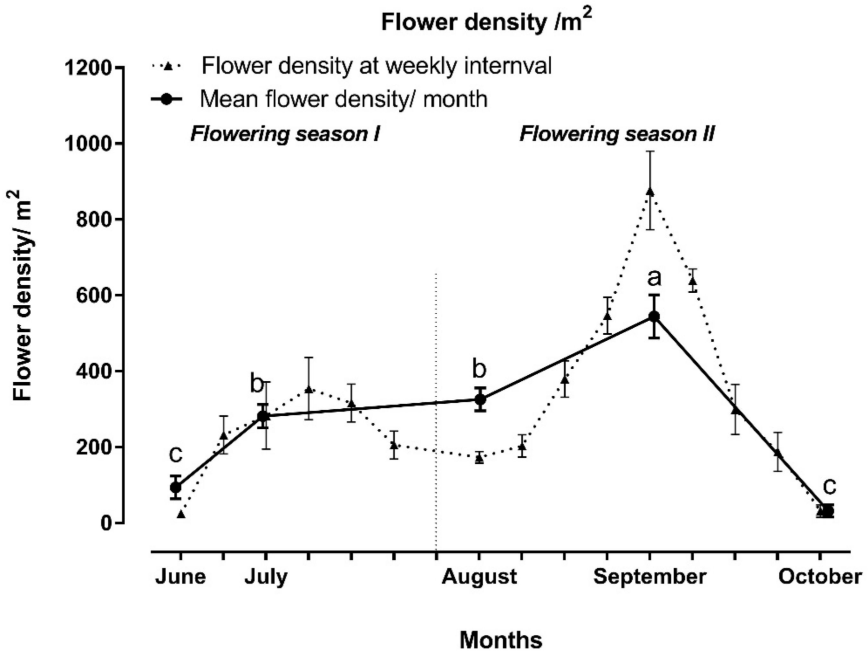

Figure 3. Flowering density (mean ± SEM) of *Z. nummularia* during June–July (season I) and August–October (season II) in central Arabia. The mean flowering density/month was measured using flowering density values recorded at weekly intervals. Different letters indicate significant differences among the flower densities measured during different months at $p < 0.05$.

3.3. Foraging Activities

The mean number of outgoing foragers and incoming pollen-gathering foragers of the two Apis subspecies were determined during the two *Z. nummularia* flowering seasons.

3.3.1. Outgoing Foraging

The outgoing foraging of native bees (*AMJ)* and exotic bees (*AMC*) showed significant variations among different times throughout the day (SR, FN, N, AN and SS) during the flowering seasons of *Z. nummularia*. The outgoing foraging activities of both subspecies reached peak levels at SR and lowest levels at N during both flowering seasons (Figure 4A). The outgoing foraging activity of *AMJ* was significantly higher than that of *AMC* during the daytime (SR and FN) in season I and during the daytime (SR, FN, AN and SS) in season II (Figure 4A). Taken together, *AMJ* exhibited significantly elevated outgoing foraging activity compared to *AMC*. The combined mean outgoing foraging activity (workers/colony/min) measured in the two flowering seasons revealed significantly higher outgoing foraging activity by *AMJ* (32.40 ± 0.67 workers/colony/min) than by *AMC* (15.93 workers/colony/min ± 1.20) (Figure 6A).

The monthly foraging activity of *AMJ* was significantly greater than that of *AMC* throughout the months in the two *Z. nummularia* flowering seasons (Figure 4B). The monthly foraging activity increased gradually beginning in June, peaked during July and August, and declined steadily in September until reaching a minimum level in October (Figure 4B). The cumulative mean numbers of outgoing foraging workers of both bee subspecies were significantly higher in season I (27.43 ± 1.21 workers/colony/min) than in season II (21.71 ± 0.86 workers/colony/min) (Figure 6B).

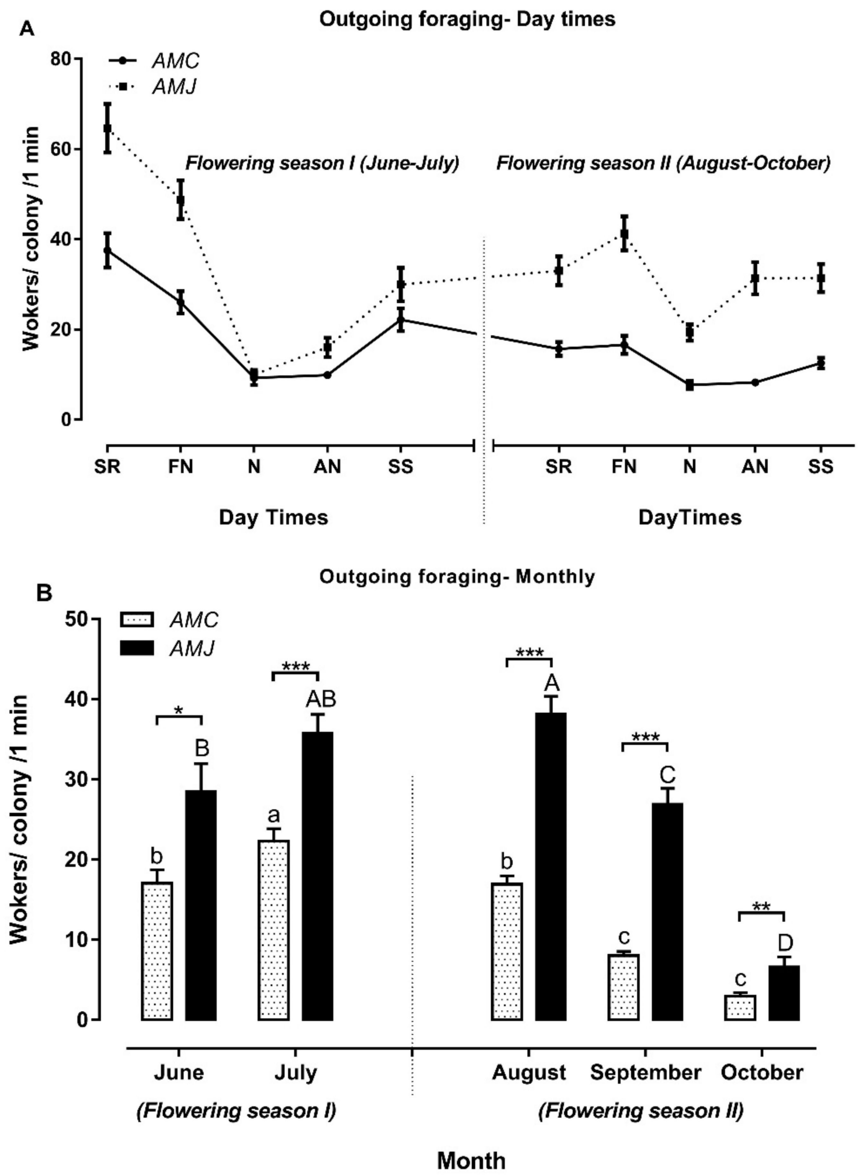

Figure 4. Outgoing foraging activities of two honey bee subspecies during the two flowering seasons of *Z. nummularia* in central Arabia. (**A**) Outgoing foraging activities (mean ± SEM) of *AMJ* and *AMC* recorded at different times of day (SR: sunrise, FN: forenoon, N: noon, AN: afternoon, and SS: sunset). (**B**) Monthly values (mean ± SEM) of the outgoing foraging activities of *AMJ* and *AMC* during the two flowering seasons (season I and season II). SEM: standard error of the mean. Flowering season I lasted from June–July, and flowering season II lasted from August–October. Different letters indicate significant differences among the foraging activities within each subspecies given in different columns at $p < 0.05$. The asterisks indicate significant differences between the foraging activities of the two subspecies in a single month (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$).

3.3.2. Pollen-Gathering Foraging

The native bees (*AMJ*) were more active in pollen-gathering than the exotic bees (*AMC*) at all tested times of day (SR, FN, N, AN and SS) during both flowering seasons (season I and season II) of *Z. nummularia*. The pollen-gathering activities of both subspecies of honey bees (*AMJ* and *AMC*) were high at SR and low at SS during both flowering seasons (Figure 5A). The pollen-gathering foraging activities were much higher at SR during season I than at SR during season II for both honey bee subspecies (Figure 5A). The combined mean outgoing pollen-gathering activities in the two flowering seasons (workers/colony/min) were significantly higher for *AMJ* (4.88 ± 0.40) than for *AMC* (2.39 ± 0.23) (Figure 6A).

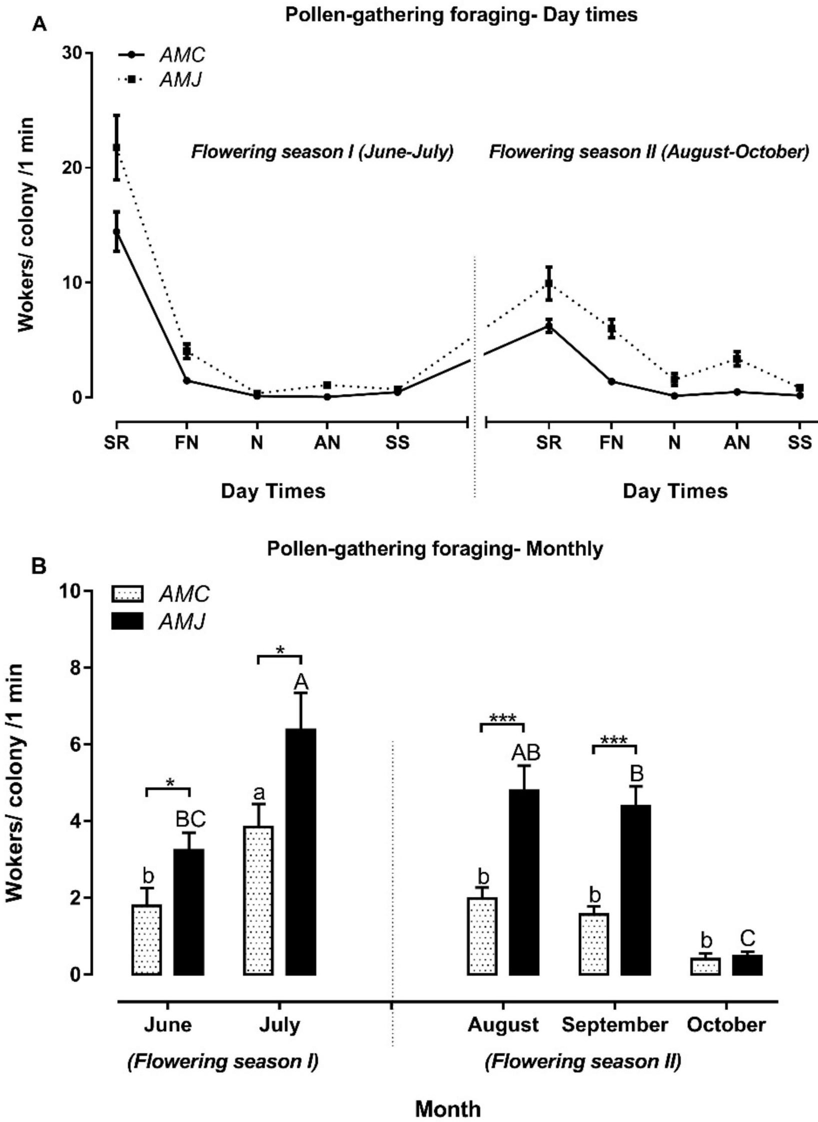

Figure 5. Pollen-gathering activities of the two honey bee subspecies during the two flowering seasons of *Z. nummularia* in central Arabia. (**A**) Pollen gathering activities (mean ± SEM) of *AMJ* and *AMC* recorded at different times of day (SR: sunrise, FN: forenoon, N: noon, AN: afternoon, and SS: sunset). (**B**) Monthly values (mean ± SEM) of the pollen-gathering activities of *AMJ* and *AMC* during the two flowering seasons (season I and season II). SEM: standard error of the mean. Flowering season I lasted from June–July, and flowering season II lasted from August–October. Different letters indicate significant differences between the foraging activities of each subspecies given in different columns at $p < 0.05$. The asterisks indicate significant differences between the two columns in each graph (* $p < 0.05$; *** $p < 0.001$).

The monthly pattern revealed significantly higher pollen gathering by *AMJ* compared to that by *AMC* throughout the months in both flowering season I and flowering season II of *Z. nummularia* (Figure 5B). The monthly pollen-gathering activity increased gradually beginning in June, reached a peak in July, and declined steadily from August-September until reaching a minimum level in October (Figure 5B). The cumulative mean pollen-gathering foraging activities of both subspecies during the flowering seasons of *Z. nummularia* were higher (4.46 ± 0.45 workers/colony/min) during season I than during season II (3.02 ± 0.22 workers/colony/min) (Figure 6B).

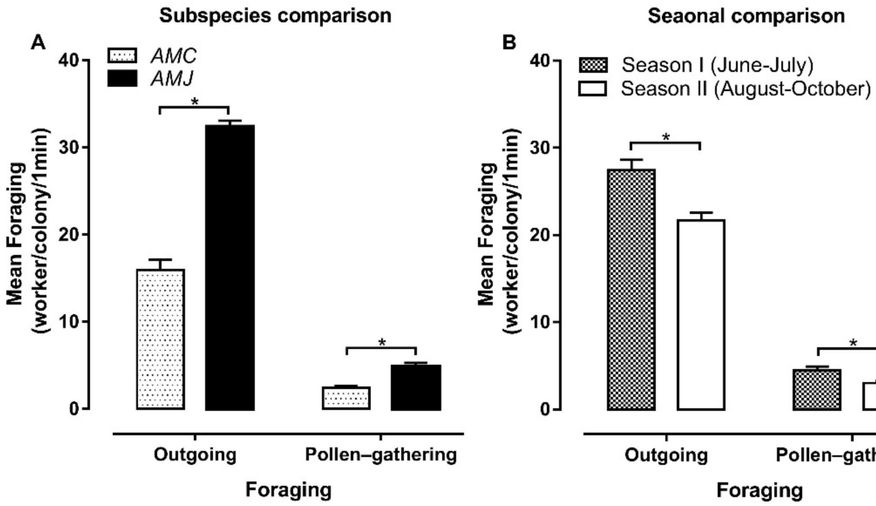

Figure 6. Comparison between the foraging activities (cumulative means for the two combined flowering seasons) of the two studied honey bee subspecies (*AMJ* and *AMC*) and the cumulative foraging activities of the subspecies combined during the two flowering seasons of *Z. nummularia*. (**A**) Foraging activities (mean ± SEM) of *AMJ* and *AMC*, regardless of season. (**B**) Seasonal comparison of foraging activities (mean ± SEM) during the two flowering seasons (season I and season II) of *Z. nummularia* regardless of subspecies. SEM: standard error of the mean. Flowering season I lasted from June–July, and flowering season II lasted from August–October. The asterisks indicate significant differences between the two columns in each graph at $p < 0.05$.

3.4. Correlation Analysis

Table 1 presents the correlation analysis among the outgoing foraging activities, pollen-gathering foraging activities and weather factors such as temperature (Temp.), relative humidity (RH) and wind speed (WS) observations. Temperature has a significant negative correlation with RH (−7.993) and a significant positive correlation with the WS (0.5412). RH shows a significant negative correlation (−0.3786) with the WS. Temperature is significantly correlated with the outgoing and pollen-gathering foraging activities of *AMJ* (0.0760 and −0.1307, respectively) and *AMC* (−0.0793 and −0.1665, respectively). The two foraging activities (outgoing and pollen-gathering activities) of each bee subspecies were significantly positively correlated (0.5120 and 0.5039 for *AMC* and *AMJ*, respectively) with each other. Subsequently, the overall means calculated for the two subspecies also revealed a significant positive correlation (0.523) between these foraging activities.

Table 1. Pearson correlation coefficients among weather factors (temperature, relative humidity, and wind speed) and foraging activities (outgoing foraging and pollen gathering activities) of *AMJ* and *AMC*. The general means of the two subspecies revealed a positive significant correlation (0.523***) between outgoing foraging and pollen-gathering activities. The asterisks indicate significant correlations (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). [a] Temperature; [b] relative humidity; [c] Wind speed.

Subspecies	Foraging Activity	Correlation Coefficient (r) and Significance			
		Temp. [a]	RH [b]	WS [c]	Outgoing
AMC	Outgoing	−0.0793 **	0.1105 **	0.1032 **	-
	Pollen-gathering	−0.1665 ***	0.1661 **	−0.0442	0.5120 **
AMJ	Outgoing	0.0760 **	−0.0662	0.0748 *	-
	Pollen-gathering	−0.1307 **	0.1303 **	−0.0629	0.5039 **
Weather factors	Temp. [a]		−7.993 **	0.5412 **	
	RH [b]	−7.993 **		−0.3786 **	
	WS [c]	0.5412 **	−0.3786 **		

3.5. Thermal Windows of Flight Activity

Due to the adaptations of the studied honey bee subspecies to different climate zones, the thermal windows of foraging flight activities (bee exiting and returning to hives during the day) differed between *AMJ* and *AMC*. Considering the numbers of bees leaving the nests (outgoing foraging bees) at a given ambient temperature, we found overlapping thermal windows (defined as the temperature range in which 90% of flight activities occur) for the two honey bee subspecies (Figure 7). High numbers of individual *AMJ* (22,677) and *AMC* (11,150) bees were observed, and both subspecies were found to be active in the temperature range of 27–43 °C with mean peak activities at 35.5 and 35.3 °C, respectively. Despite the overlapping patterns with similar values, due to the high number of bees that were evaluated, there was a significant difference (*t*-test: $t = 2.8$; $df = 33{,}825$; $p = 0.005$) between the honey bee subspecies regarding their outgoing foraging thermal windows.

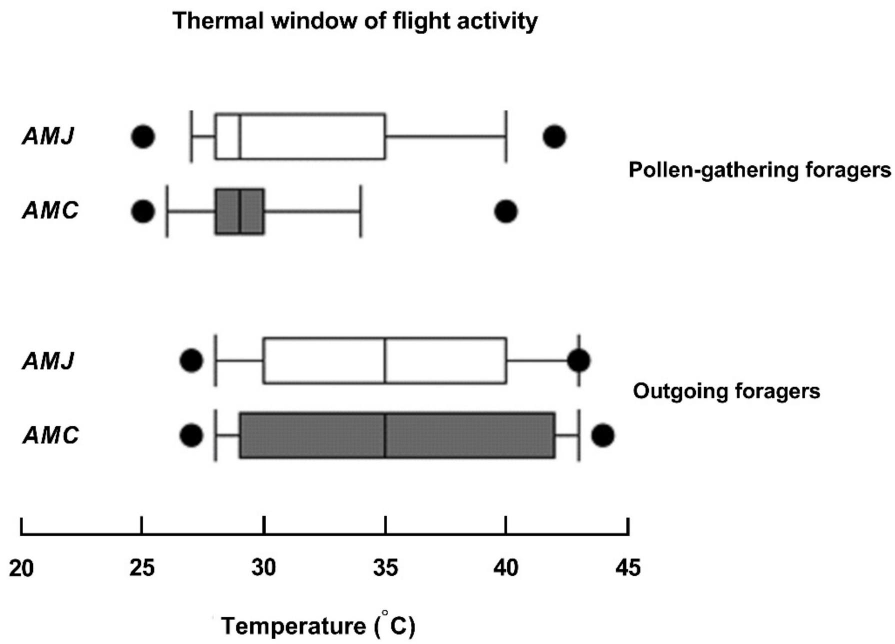

Figure 7. Thermal windows of the foraging flight activities of *AMJ* and *AMC* during the flowering seasons of *Z. nummularia* under hot-arid environmental conditions. The lower panel represents the number of foragers leaving the nests (outgoing foragers), and the upper panel represents the pollen-gathering foragers returning to the nests. The boxes represent the temperature range in which 50% of the foraging activities occurred, and the whiskers indicate the 80% range, while the outliers show the 90% range.

The thermal windows of the flight activities of returning foragers (pollen-gathering foragers) were between 25 and 42 °C (peak activity: 31.4 °C) for *AMJ* and between 25 and 40 °C (peak activity: 29.6 °C) for *AMC* (Figure 7). The main pollen-foraging activities (50% of individuals) of *AMC* bees occurred in a narrow range between 28 and 30 °C, while the main activities of *AMJ* bees occurred between 28 and 30 °C. A significant difference (*t*-test: $t = 12.5$; $df = 5090$; $p = 0.001$) was found between the honey bee subspecies regarding their pollen foraging activity thermal windows.

4. Discussion

Z. nummularia is a dominant bee-forage plant in the Rawdat-Khuraim oasis in Saudi Arabia, in addition to other plants, especially *Acacia* spp. [17,22,39]. The experimental oasis was surrounded by a hot and dry environment during the *Z. nummularia* flowering seasons [3].

4.1. Flowering Density

In the present study, the flowering density of *Z. nummularia* reflected two flowering seasons that were categorized into two seasons: season I (from June to July) and season II (from August to October). This was in agreement with the findings of Hassan, et al. [3], who also reported the onset of flowering from June to October in two seasons. The flowering density was higher during flowering season II than during flowering season I. The longevity of *Z. nummularia* flowers was found to be two days, with 83% nectar secretion occurring on the first day and 17% occurring on the second day of the blooming period [2]. Thus, *Z. nummularia* can produce sufficient flowers even under harsh climatic conditions [3,7].

4.2. Foraging Activities

The foraging activities (outgoing foraging and pollen-gathering activities) of the two studied honey bee species (*AMJ* and *AMC*) revealed that both species performed foraging activities well in hot, dry, and windy environments in the presence of abundant *Z. nummularia* flora. These subspecies also performed well under identical weather conditions in the presence of abundant *Acacia* flora [22]. Honey bees are able to survive and produce honey even under harsh climatic factors when encouraged by the flowering of rich nectar sources [40], and peak worker visitation takes place when ample food sources are available [41].

We observed that *AMJ*, a native bee of Saudi Arabia, exhibited significantly higher foraging activities (outgoing and pollen-gathering activities) than the exotic European bee (*AMC*) in the presence of abundant *Zizyphus* flowers during the flowering seasons of the studied plant species (June–October). Frequent foraging activities on *Z. nummularia* flowers by *AMJ* were reported from August–October compared with those of *AMC* [2], and the foraging rate of *AMJ* was previously found to be greater than that of *AMC* on *Acacia* flowers [22]. The variations in the levels of foraging activity between these two subspecies may be explained by considering the adaptation levels and morphological and physiological traits of these subspecies. *AMJ* is well adapted to the local climatic conditions of Saudi Arabia, while *AMC* is well known for its adaptation to the temperate climate of central Europe [22,29,42].

Other potential factors inducing differential foraging between honey bee subspecies include the higher population density (strength) of the *AMJ* colonies than that of the *AMC* colonies; consequently, a larger number of *AMJ* bees were at foraging age at the time of this study. It was further assumed that if the population densities of the two subspecies were considered identical, then these findings may indicate that a larger proportion of *AMC* workers may have been engaged in other activities inside their nests, such as thermoregulation or brood care, or were simply inactive. *AMJ* bees are well adapted to harsh native environmental conditions and have better tolerance to high temperatures than *AMC* bees, as the *AMC* subspecies has a lower temperature threshold [29,34,43]. Therefore, the increased thermoregulation of *AMC* compared to that of *AMJ* may induce differences in the optimal brood temperature within the nests. To avoid fatal body overheating, *AMC* bees reduce their activity levels and, consequently, their production of metabolic heat. This also explains the adaptation of the morphological and physiological traits of the native bee subspecies to [29,44].

4.3. Effect of Weather on Foraging

4.3.1. Foraging and Time of Day

The different honey bee subspecies examined in this study countered hot and dry weather conditions differently during the abundant flowering season [3]. We found that weather conditions exerted a significant effect on the foraging and pollen-gathering activities of both bee subspecies in abundant *Z. nummularia* flora. This resulted in variations in honey bee foraging patterns hourly (time of day), monthly and seasonal levels. The outgoing and pollen-gathering foraging activities of *AMJ* bees were significantly higher than those of *AMC* bees during each month (June–October) in the flowering seasons. The daily patterns concerning the numbers of bees leaving the nests differed between the two seasons. The daytime fluctuations in the outgoing and pollen-gathering foraging activities of *AMJ* and *AMC* during the flowering seasons of *Z. nummularia* were comparable with the daytime fluctuations in nectar and pollen-gathering foraging activities observed during the flowering of *Acacia* spp. [22]. The outgoing and pollen-gathering foraging activities of both honey bee subspecies were higher at sunrise (SR) than at other times of day during both flowering seasons. Flower-opening in *Z. nummularia* has been reported to start just before SR and continue until SS [2], which could explain the reason for the higher foraging activity observations at SR. A reasonable quantity of nectar attracts more floral pollinators [27], and it is presumed that the opening of more flowers offers more nectar at SR, resulting in high foraging activities at SR. In addition, the role of weather conditions (such as temperature and humidity) cannot be ignored at the onset of foraging activities because weather factors significantly affect the nectar quantity [25,45].

4.3.2. Foraging and Flowering Season

Given the elevated foraging availability and high flowering density of melliferous *Z. nummularia* in season II, it was hypothesized that foraging (outgoing and pollen-gathering) activities may increase from flowering season I (June–July) to flowering season II (August–October). However, this was not the case; we found no evidence of any increased foraging activities during season II. Surprisingly, the foraging activity was considerably high in season I (June–July). Hassan, et al. [3] reported peak nectar production of *Z. nummularia* during July, which might explain the high foraging activity trend observed in season I. This trend reflected that the observed foraging activity across flowering seasons might not be explained only by the availability of sufficient food. A plausible explanation for the observed differences in the seasonal foraging patterns could include the differences in foraging fauna and temperatures between the flowering two seasons. In addition, the elevated pollen intake during season I might have caused an increase in brood production. Thus, more workers might have been engaged in brood rearing in season II than in season I. An alternative explanation could be a general reduction in the bee populations from season I to season II. It is believed that under the extreme weather conditions of oases with high temperature and low humidity values, the noticeable foraging activities of *AMJ* and *AMC* were only possible due the abundance of nectar-rich *Z. nummularia* plants in the experimental area. The differential foraging trends observed during each month (June to October) could have been associated with the fluctuating monthly nectar secretion rate of the flowering plants [22,46].

4.4. Correlation and Thermal Activity

The correlations between the outgoing and pollen-gathering foraging activities of the two bee subspecies were significantly positive. The correlations between the temperature and RH (negative), between the temperature and WS was significant (positive), and between RH and the WS (negative) were significant. These findings are in agreement with those of Alqarni [22], who reported comparable correlations between weather parameters and the foraging of bees on Acacia nectar. Although the tested honey bee subspecies exhibited overlapping flight activity thermal windows, the thermal windows of *AMJ* and *AMC* differed for outgoing and pollen-gathering foraging activities (the subspecies had thermal ranges of 27–43 °C and 25–42 °C, respectively). This shows that foragers are able to survive and forage at high temperatures. Previous studies on the thermal tolerance of honey bees have shown that the *AMJ* and *AMC* subspecies were able to tolerate very high temperatures exceeding 50 °C [29]; temperatures this high were never reached in the present study. The present research helps to understand the performance of honey bees and their association with weather conditions and nectar-rich flora. More studies are needed to explore the responses of bee foragers to *Ziziphus* flowers and the potential of these honey bee subspecies colonies to produce honey during *Ziziphus* flowering.

5. Conclusions

We conclude that weather has a substantial influence on the outgoing and pollen-gathering foraging activities of honey bees. The foraging of honey bees was found to be variable at different times of day, with high foraging observed at sunrise. *Z. nummularia*, a melliferous plant, has a high flowering density from August–October. *AMJ* was showed higher outgoing and pollen-gathering foraging activities than *AMC* during each month of the flowering seasons of *Z. nummularia*. The thermal windows for the foraging flight activities of the two honey bee subspecies were significantly different. The outgoing and pollen-gathering foraging activities of each bee species were positively correlated with each other. These outcomes will help researchers understand the relationships among bee foraging, weather conditions and the abundance of nectar-rich flora.

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