



Research Article

Comparative Foraging Behavior of Honey Bee Species *A. cerana* (F) and *A. mellifera* (L)

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Abstract | An experiment was conducted to compare the foraging behavior of two honey bee species i.e., *A. mellifera* and *A. cerana* in Langstroth hives and *A. cerana* in traditional mud hives across eight weeks and three-time durations (T1, T2 & T3) at the Directorate of Non-Timber Forest Products (NTFP), Forest Department Khyber Pakhtunkhwa, Peshawar during spring, 2020. The highest outgoing foraging was recorded for *A. cerana* in a traditional mud hive (46.54), followed by *A. mellifera* (44.84), and the minimum outgoing foraging was recorded from *A. cerana* in a Langstroth hive (44.76). Considering outgoing, incoming and foragers returning with pollen, T1 (0700-0800 hr) was best time, whereas the foragers returning with water or nectar the most active time was T3 (1100-1200 hr). Weeks were inversely proportional to foraging behavior due to increase in temperature as predicted by returning of foragers with water and nectar. The pollen collection sources for *A. mellifera* and *A. cerana*, were 4 and 6, respectively. There was no significant difference in the ash and moisture content of the pollen of honey bee species. In contrast, the sugar concentration of *A. mellifera* pollen was higher than that of *A. cerana* in the Langstroth hive and *A. cerana* in the traditional mud hive when the three glucose-D standards were used to compare them to each other. Thus, it can be concluded that *A. cerana* in traditional mud hive shows better foraging performance as compare to *A. mellifera* and *A. cerana* in Langstroth hive.

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Keywords | Foraging behavior, *A. mellifera*, *A. cerana*, Langstroth hive, Traditional mud hive



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Introduction

Apiculture is the combination of two words Api means bees and culture means cultivation. Apiculture is the knowledge and ability of bees and beekeeping. A honey bee belongs to class insect order

hymenoptera genus *Apis*. Bees are reared for the production of Honey (Cook *et al.*, 2019). Honey is highly nutritive food consisting of a variety of proteins, sugars, minerals, free amino acids, enzymes, vitamins and trace elements. Human blood absorbs laevulose and dextrose directly from honey. Asian continent has

a variety of diverse honey bee species. A number of species of genus *Apis* are found in Asian continent are: *florae*, *dorsata*, *andreniformis*, *cerana*, *koschevnikovi*, *nuluensis*, *nigrocincta* and *laborios* *A.* Taxonomists also introduced *A. mellifera* which are now days widely used for honey production. In Pakistan there are mainly four species present which are broadly spread in the country (Nabila *et al.*, 2022).

Of the four species two species of honey bees that are Asian honey bees, the *A. cerana*, and European honey bees, the *A. mellifera*, can be domesticated in Pakistan for their by-products whereas the other two species *A. florae* and *A. dorsata* cannot be domesticated due to their wild behavior and habitation preference (Gratzer *et al.*, 2019). *A. cerana* and *A. mellifera* species resembles each other in behavior and morphology to such extent that the scientists were confused that whether they both are same species (Oldroyd and Wongsiri, 2009). While some scientists believed that *A. cerana* and *A. mellifera* belongs to the same ancestral base from last two million years (Yang, 2009).

Lately the promotion of sustainable beekeeping and training in mite supervision is being initiated under Pakistan-USDA funded project. Due to queen rearing and colony multiplication, the number of *A. mellifera* colonies has increased significantly over the past 20 years. These colonies have subsequently been dispersed among beekeepers throughout Pakistan. By 1985 there were over 3000 colonies of *A. mellifera* honey bees species in Langstroth hives but in the mountainous regions of Pakistan, people use to keep *A. cerana* species for the production of honey. *A. cerana* has been raised in Asian countries for thousands of years and has brought considerable economic benefits to the apicultural industry (Natapot *et al.*, 2023). Geographically Pakistan is blessed with diverse range of habitats from 8000 m snow-capped Himalayan peaks down to different forests and plains of the Indus and arid deserts regions found in the south of the country (Usman *et al.*, 2022).

The western honey bee (*A. mellifera* L.) provides highly valued pollination services for a wide variety of agricultural crops and ranks as the most frequent single species of pollinator for crops worldwide. A long history of domestication and intentional transport of *A. mellifera* by humans has resulted in its current cosmopolitan distribution that includes all continents except Antarctica and many oceanic islands (Hung *et*

al., 2018). As they fulfill the tasks, which are carried out of the bee hive during foraging for their colonies they bring water, pollens, nectars and resin. Many scientists have reported the significance of honey bee foraging in the pollination of plants. Russell *et al.* (2021) particularly in those plants in which honey bees primarily serves as pollinators.

The flowering plant species of a particular area can also be detected by the foraging of honey bees. Pest infestation of flowering crops or other plants from which the honey bees collect their requirements can be detected through foraging for example fruit flies (Chinkangsadarn and Kafle, 2024). All those people who are involved in Beekeeping can also take advantage of honey bee foraging by placing venom collection boards and pollen traps installed at the entrances of honey bee hives for collection purposes. Honey bees are blessed with such good qualities that they can choose better and best food source when many food sources are available in an area (El-Ghouizi *et al.*, 2023)

Foraging honeybees bring pollens that could be analyzed, which is helpful in the classification of honey. Over 250 biological components are present in bee pollens that include antioxidants, vitamins, fats, carbs, minerals and enzymes. Plant source and collection season plays important role in the composition of exact nutrients (Kieliszek *et al.*, 2018).

This experiment was conducted to identify the more effective pollinators of honey bee species and to categorize the bee flora in a certain location. Furthermore, the researcher learned about the differences in foraging among the species of honey bees.

Materials and Methods

Study area

The research was conducted at the Directorate of Non-Timber Forest Products, Khyber Pakhtunkhwa Forest Department, Peshawar during year 2020.

Honeybees (*A. mellifera*) and (*A. cerana*) colonies

Three honey bees colonies of (*A. mellifera*) Langstroth hive, (*A. cerana*) Langstroth hive and *A. cerana* in natural traditional mud hive with same number of worker bees, food and the brood comb were separated from their apiaries for the experiment. Three factor

factorial experiments in randomized complete block design were conducted.

Treatment (Honey bee species) was taken as first factor having three levels i.e., H1 = *A. mellifera* in Langstroth hive. H2 = *A. cerana* in Langstroth hive. H3 = *A. cerana* in traditional mud hive.

Time duration was considered as second factor having three levels i.e.,

T1 = 0700-0800 hours. T2 = 0900-1000 hours. T3 = 1100-1200 hours. Weeks were taken as third factor having eight levels i.e., W1, W2, W3, W4, W5, W6, W7 and W8.

Foraging behavior data collection

Foraging data was recorded as per (Cartin *et al.*, 2008) method.

Pollen classification

Pollens were collected from the surrounding area in such manner that pollens from newly emerged flowers of the surrounding area of each plant was collected in a white cloth and was brought to the laboratory, reference slides from the pollens were made. Hive entrances were equipped with pollen traps of their respective sizes to study the efficiency of pollen and foraging pattern of H1, H2 and H3. After collecting pollens from the hives through traps it was compared with the reference slides (Ramalho *et al.*, 1991).

The experiment was repeated 04 times after every 15 days. The collected pollens of H1, H2 and H3 were weighed and compared at the end.

Chemical analysis of pollen

Moisture content: The pollen samples were dried to constant weight at 70°C in an air oven and then the moisture content was estimated (Bell *et al.*, 1983). After estimating moisture content of dried samples of the pollen of each species, the comparison of moisture contents of each species was carried out.

Ash content

The ash content pollen samples of both species was estimated by heating the sample of pollen in the muffle furnace at 600 °C till it turns to grey white ash. The samples were weighed to measure the average percent of ash substance (Bell *et al.*, 1983). Results of both pollen samples were compared.

Sugar concentration

Quantification of sugar was carried out as per Brummer and Cui (2005) method. The samples were prepared in two separate mediums i.e., aqueous and acidic medium.

Aqueous medium preparation

0.2 g of pollen sample of *A. cerana* in mud and Langstroth hive and *A. mellifera* was collected in beaker. It was mixed with 50 ml distilled water. All the samples were homogenized by mixing them thoroughly in the aqueous solution.

Acidic digested medium preparation

0.1 g of each treatment pollen samples was added with 20 ml HNO₃. The samples were kept on a heating bath for 02 hours at 95°C for digestion. After the digestion, the samples were homogenized and filtered.

Standard procedure for determination of sugar content

In order to determine the total sugar content in the samples, the standard procedure was followed. The pollens were first dried and stored in a zip-lock bag. 0.2 g of each pollen sample was weighted and poured into a test-tube followed by the addition of 0.5 ml phenol. After the addition of phenol, 2.5ml concentrated H₂SO₄ was added to each of the test-tube containing samples of Honey bee species. The mixture was thoroughly combined using the vortex mixture. The color development was observed and was absorbed at 450 nm using a UV-spectrophotometer against Glucose D as standard. This procedure was followed for both the mediums and the results were then compared.

Results and Discussion

Foraging behavior of honey bee species

Out-going foragers: Honey bee species x Time intervals interaction: Honey bee species and time intervals data were recorded and depicted in Table 1. Honey bee species and time intervals were significantly different. The interaction of honey bee species and time interval revealed significant differences at 5% level of significance. Abou-Shaara *et al.* (2017) stated that *A. cerana* as compare to *A. mellifera* initiates foraging earlier and requires low thoracic temperature. Similarly, *A. cerana* foraging (departures per minute) also peaked earlier and at lower temperature than did *A. mellifera* foraging. Similar research results were

also reported by [Verma and Dulta \(2015\)](#).

Table 1: Out-going foragers Honey bee species x Time intervals mean interaction of Honey bee species in Spring, 2020.

Honey bee species	Time intervals			Mean
	T1	T2	T3	
H1	51.75 b	42.70 d	40.08 e	44.84 b
H2	51.20 b	44.25 c	38.83 f	44.76 b
H3	54.37 a	45.12 c	40.12 e	46.54 a
Mean	52.44 a	44.02 b	39.67 c	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species x Time intervals 0.8753. Critical Value for Honey bee species 0.5054. Critical Value for Time intervals 0.5054.

Honey bee species x weeks interaction

Honey bee species and weeks data were recorded and given in [Table 2](#). Honey bee species, weeks and their interaction revealed significant differences. Maximum outgoing foraging was recorded by *A. cerana* in traditional mud hive in the first week while minimum foraging was revealed by *A. cerana* in langstroth in week seven. [Blazyte-Cereskiene et al. \(2010\)](#) recorded that a strong increase in ambient temperature (43+ °C) had a negative impact on the foraging of honey bees on flowering plants. The temperature among different weeks fluctuated between 23 °C - 41 °C.

Table 2: Out-going foragers Honey bee species x Weeks mean interaction of Honey bee species in Spring, 2020.

Honey bee species	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
H1	46.77 cdef	44.33 ijkl	43.33 lm	44.22 jkl	43.55 klm	45.44 fghij	45.33 ghij	45.77 defgh	44.84 b
H2	47.11 bcd	43.66 klm	43.77 klm	44.66 hijkl	44.77 hijk	45.66 efghi	42.44 m	46.00 cdefgh	44.76 b
H3	49.44 a	48.33 ab	44.33 ijkl	46.55 cdefg	43.77 klm	47.33 bc	45.55 fghij	47.00 bcde	46.54 a
Mean	47.77 a	45.44 bc	43.81 e	45.14 cd	44.03 e	46.14 b	44.44 de	46.25 b	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species x Weeks interaction 1.4294, Critical Value for Honey bee species 0.5054, Critical Value for weeks 0.8253

Table 3: Out-going foragers Time intervals x Weeks mean interaction of Honey bee species in Spring, 2020.

Time intervals	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
T1	58.33 a	53.88 b	50.77 d	52.33 c	50.66 d	52.22 c	50.22 d	51.11 cd	52.44 a
T2	44.55 ef	42.88 gh	42.11 h	44.11 fg	42.66 h	45.66 e	45.33 ef	44.88 ef	44.02 b
T3	40.44 i	39.55 ij	38.55 jk	39.00 jk	38.77 jk	40.55 i	37.77 k	42.77 gh	39.68 c
Mean	47.77 a	45.44 bc	43.81 e	45.14 cd	44.03 e	46.14 b	44.44 de	46.25 b	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Time intervals x weeks interaction 1.4294; Critical Value for time intervals 0.5054; Critical Value for weeks 0.8253.

Time intervals x weeks interaction

It is revealed from the analysis of data that time intervals, weeks and their interaction among the out-going foragers were significant ([Table 3](#)). The maximum outgoing foraging was recorded at T1 during the W1 (58.33), while minimum value was recorded for T3 at W7 (37.77) [Verma and Dulta \(2015\)](#) argued that Peak foraging activity for *A. cerana*. Indica took place at 09.00–11.30 hrs when the temperature ranged between 15.5 and 21°C while 11.00–13.30 hrs for *A. mellifera* at temperature of 21 to 25°C. Contrary to their finding, peak time of out-going foraging activity was recorded at T1 (07.00–08.00 am). Furthermore, the difference in the foraging peak time can be due to the differences in altitude.

In-coming foragers

Honey bee species x Time intervals interaction: Significant difference among the Honey bee species, time intervals and their interaction was recorded for in-coming foragers of honey bee species ([Table 4](#)). The maximum and minimum in-coming foraging was recorded by *A. cerana* in traditional mud hive at time interval (T1) (51.79) and T3 (38.37), respectively. Our results are in similarity with [Zhang et al. \(2019\)](#), who argued that *A. cerana* has more foraging trips, higher forager proportion, less sugar consumption, and longer survival than those of *A. mellifera*.

Table 4: In-coming foragers Honey bee species $\times$ Time intervals mean interaction of Honey bee species in Spring, 2020.

Honey bee species	Time intervals			Mean
	T1	T2	T3	
H1	48.37 c	42.25 e	38.79 f	43.13 b
H2	49.41 b	42.04 e	38.70 f	43.38 b
H3	51.79 a	43.83 d	38.37 f	44.66 a
Mean	49.86 a	42.70 b	38.62 c	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species $\times$ Time intervals interaction 0.7622; Critical Value for Honey bee species 0.4400; Critical Value for time intervals 0.4400.

Honey bee species $\times$ weeks interaction

The data for incoming foragers of honey bee species revealed significant differences among Honey bee species, weeks and interaction of honey bee species by weeks (Table 5). The maximum in-coming foraging was recorded by *A. cerana* in langstroth at W1 (46.55), whereas *A. mellifera* in langstroth hive revealed minimum in-coming foraging at W2 (40.66). Li et al. (2019) stated that high temperatures can adversely affect bees. They not only affect the survival and water loss, but also stimulate oxidative stress in bees. Also, *A. cerana* was more tolerant than *A. mellifera*. These finding were in coincidence to our research work.

Table 5: In-coming foragers Honey bee species $\times$ Weeks mean interaction of Honey bee species in Spring, 2020.

Honey bee species	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
H1	44.11 cde	40.66 j	41.77 ij	43.11 efgh	42.77 fghi	43.66 def	44.55 bcd	44.44 bcd	43.13 b
H2	46.55 a	42.55 fghi	42.66 fghi	43.77 def	43.44 defg	44.33 bcde	41.55 ij	42.22 ghi	43.38 b
H3	46.22 a	44.44 bcd	43.11 efgh	46.00 a	42.11 hi	45.33 abc	44.66 bcd	45.44 ab	44.66 a
Mean	45.63 a	42.55 d	42.51 d	44.29 bc	42.77 d	44.44 b	43.59 c	44.03 bc	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species $\times$ Weeks interaction 1.2446; Critical value for Honey bee species 0.4400; Critical Value for weeks 0.7186

Table 6: In-coming foragers Time intervals $\times$ Weeks mean interaction of Honey bee species in Spring, 2020.

Time intervals	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
T1	54.00 a	46.88 e	49.44 cd	50.88 b	49.44 cd	50.55 bc	48.55 d	49.11 d	49.86 a
T2	42.00 hi	42.11 hi	40.44 jk	43.22 gh	41.44 ij	43.55 g	44.00 fg	44.88 f	42.70 b
T3	40.88 ij	38.66 lmn	37.66 mn	38.77 lm	37.44 n	39.22 kl	38.22 lmn	38.11 lmn	38.62 c
Mean	45.63 a	42.55 d	42.51 d	44.29 bc	42.77 d	44.44 b	43.59 c	44.03 bc	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Time intervals $\times$ Weeks interaction 1.2446; Critical value for time intervals 0.4400; Critical value for weeks 0.7186

Time intervals $\times$ weeks interaction

The analyzed data of in-coming foragers against time intervals and weeks data were given in Table 6. Time intervals, weeks and their interaction was significantly different at 5% level of significance. The maximum in-coming foraging of bee species was recorded at time T1 and week W1 (54.00) whereas minimum in-coming foraging was recorded at time T3 and week W5 (37.44). Week and peak hour for foraging was recorded for W1 (45.63) and T1 (49.86), contrary to our findings Verma and Dulta (2015) concluded that 1100-1330 hrs is best time for foraging. The difference in the results can be due to the altitude and environmental difference.

Foragers returned with pollens

Honey bee species $\times$ time intervals interaction

The data for honey bee species and time intervals were given in Table 7. Significant differences were recorded for honey bee species, time interval and the interaction of both. The maximum foragers returned with pollens are *A. cerana* in traditional mud hive at time T1 (33.50), whereas minimum foragers returned with pollens are *A. mellifera* in Langstroth hive at time T3 (16.62). Similar to our results, Zhang et al. (2019) stated that *A. cerana* do more foraging trips as compare to *A. mellifera*.

Table 7: Foragers returned with pollens Honey bee species $\times$ Time intervals mean interaction of Honey bee species in Spring, 2020.

Honey bee species	Time intervals			Mean
	T1	T2	T3	
H1	29.50 c	20.37 e	16.62 g	22.16 c
H2	31.70 b	20.83 e	16.83 g	23.12 b
H3	33.50 a	22.91 d	18.29 f	24.90 a
Mean	31.56 a	21.37 b	17.25 c	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species $\times$ Time intervals interaction 0.8463; Critical Value for Honey bee species 0.488; Critical value for time intervals 0.4886

Honey bee species $\times$ weeks interaction

The recorded data of honey bee species and weeks were given in Table 8. Honey bee species, weeks means and their interaction revealed significant differences. The maximum and minimum foragers returned with pollens were *A. cerana* in Langstroth hive in W1 (33.55) and *A. mellifera* in Langstroth hive at W7 (14.88). Raj *et al.* (1993) stated that the pollen load availability varies from day to day and both the species could have minor difference in their pollen trips. Same results have been recorded in our study. Zhang *et al.* (2019) also confirmed the results that *A. cerana* being higher forager species than *A. mellifera*.

Time intervals $\times$ weeks interaction

Significant differences were recorded for time intervals, weeks and interaction of time interval by weeks among the foragers returned with pollens (Table 9). The maximum foragers returned with pollens were at time T1 (0700-0800 hrs) during week W1 (40.66), whereas minimum value of 9.55 foragers were recorded at time T3 (1100-1200 hrs) and week W6. Similar to our finding, Joshi and Joshi (2010) stated that pollen availability decreases from morning to evening. Raj *et al.* (1993) also revealed that *A. mellifera* bees carried maximum average pollen loads at 1200 hrs, whereas *A. cerana* bees carried maximum average pollen load at 0900 hrs.

Foragers returned with water/nectar

Honey bee species $\times$ Time intervals interaction: The analyzed data of foragers returned with water revealed significant differences among honey bee species, time intervals and interaction of honey bee species and time interval (Table 10). The maximum foragers returned with water/nectar are *A. mellifera* in Langstroth hive at time T3 (22.16) and the minimum foragers returned with water/nectar are *A. cerana* in Langstroth hive at time T1 (17.75). Li *et al.* (2019) revealed that *A. mellifera* lost more water as compare to *A. cerana* and his finding were similar to our study. He also stated that higher temperature can adversely affect the foraging of honey bees.

Table 8: Foragers returned with pollens Honey bee species $\times$ Weeks mean interaction Honey bee species in Spring, 2020.

Honey bee species	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
H1	30.33 b	27.11 cd	25.11 ef	26.00 de	23.55 g	15.11 i	14.88 i	15.22 i	22.16 c
H2	33.55 a	27.66 c	25.88 de	26.55 cd	24.22 fg	16.22 i	15.11 i	15.77 i	23.12 b
H3	32.77 a	29.88 b	26.88 cd	29.11 b	24.66 efg	18.44 h	18.33 h	19.11 h	24.90 a
Mean	32.22 a	28.22 b	25.96 d	27.22 c	24.14 e	16.59 f	16.11 f	16.70 f	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species $\times$ Weeks interaction 1.3820; Critical Value for Honey bee species 0.4886; Critical Value for weeks 0.7979.

Table 9: Foragers returned with pollens Time intervals $\times$ Weeks mean interaction of Honey bee species in Spring, 2020.

Time intervals	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
T1	40.66 a	33.00 cd	34.33 bc	32.11 d	34.66 b	27.44 ef	25.44 h	24.88 h	31.56 a
T2	28.44 e	27.11 efg	25.88 gh	27.00 fg	24.66 h	12.77 k	12.66 k	12.44 k	21.37 b
T3	27.55 ef	24.55 h	17.66 j	22.55 i	13.11 k	9.55 l	10.22 l	12.77 k	17.25 c
Mean	32.22 a	28.22 b	25.96 d	27.22 c	24.14 e	16.59 f	16.11 f	16.70 f	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Time intervals $\times$ Weeks interaction 1.3820; Critical Value for Time intervals 0.4886; Critical Value for weeks 0.7979.

Table 10: Foragers returned with water/nectar Honey bee species $\times$ Time intervals mean interaction of Honey bee species in Spring, 2020.

Honey bee species	Time intervals			Mean
	T1	T2	T3	
H1	18.87 d	21.87 ab	22.16 a	20.97 a
H2	17.75 e	21.20 b	21.87 ab	20.27 b
H3	18.25 de	21.50 ab	20.12 c	19.95 b
Mean	18.29 b	21.52 a	21.38 a	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species $\times$ Time intervals interaction 0.8742; Critical Value for Honey bee species 0.5047; Critical Value for time intervals 0.5047.

Honey bee species $\times$ weeks interaction

The analyzed data of honey bee species and weeks were given in Table 11. Significant differences among the foragers were recorded for honey bee species, weeks interval and interaction of both. The maximum and minimum foragers returned with water/nectar were *A. mellifera* in week W7 (29.66) and *A. cerana*

in Langstroth hive in week W1 (13.11), respectively. Zhang *et al.* (2019) stated that *A. cerana* are less consumer of sugar as compare to *A. mellifera* similarly Li *et al.* (2019) stated that water loss occurs much higher in *A. mellifera* as compare to *A. cerana*.

Time intervals $\times$ weeks interaction

It is revealed from Table 12 that foragers returned with water/ nectar showed significant differences for time intervals, weeks and their interaction. The maximum foragers returned with water/nectar at time T2 during week W8 (32.44) whereas minimum foragers returned with water/nectar were at time T3 and week W1 (13.33). Our findings are in coincidence with Li *et al.* (2019) who stated that higher ambient temperature can adversely affect the foraging behavior of honey bee species. In each time interval and week, the temperature was increasing which increased the number of foragers to bring water along with them to compete environmental stress (Li *et al.*, 2018).

Table 11: Foragers returned with water/nectar Honey bee species $\times$ Weeks mean interaction of Honey bee species in Spring, 2020.

Honey bee species	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
H1	13.77 fgh	13.55 fgh	16.66 e	17.11 e	19.22 d	28.55 ab	29.66 a	29.22 ab	20.97 a
H2	13.11 h	14.88 f	16.77 e	17.22 e	19.22 d	28.11 b	26.44 c	26.44 c	20.27 b
H3	13.44 gh	14.55 fg	16.66 e	16.88 e	17.44 e	28.00 b	26.33 c	26.33 c	19.95 b
Mean	13.44 f	14.33 e	16.70 d	17.07 d	18.63 c	28.22 a	27.48 ab	27.33 b	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Honey bee species $\times$ Weeks interaction 1.4276; Critical Value for Honey bee species 0.5047; Critical Value for weeks 0.8242.

Table 12: Foragers returned with water/nectar Time intervals $\times$ Weeks mean interaction of Honey bee species in Spring, 2020.

Time intervals	Weeks								Mean
	W1	W2	W3	W4	W5	W6	W7	W8	
T1	13.44 jk	13.88 ijk	15.11 hi	18.66 f	14.77 ij	23.11 e	23.11 e	24.22 de	18.29 b
T2	13.55 jk	15.00 hi	15.00 hi	16.22 gh	16.77 g	31.88 a	31.33 a	32.44 a	21.52 a
T3	13.33 k	14.11 ijk	20.00 f	16.33 gh	24.33 de	29.66	28.00 c	25.33 d	21.38 a
Mean	13.44 f	14.33 e	16.70 d	17.07 d	18.63 c	28.22 a	27.48 ab	27.33 b	

Mean followed by same letters are not significantly different at 5% level of significance (LSD test). Critical Value for Time intervals $\times$ Weeks interaction 1.4276; Critical value for time intervals 0.5047; Critical Value for weeks 0.8242.

Table 13: Pollen source preferences of Honey bee species in Spring, 2020.

S. No.	<i>A. mellifera</i> (H1)	<i>A. cerana</i> (Langstroth hive) (H2)	<i>A. cerana</i> (Traditional mud hive) (H3)
1	<i>Eucalyptus camaldulensis</i>	<i>Eucalyptus camaldulensis</i>	<i>Eucalyptus camaldulensis</i>
2	<i>Amaryllis belladonna</i>	<i>Amaryllis belladonna</i>	<i>Amaryllis belladonna</i>
3	<i>Brassica napus</i>	<i>Brassica napus</i>	<i>Brassica napus</i>
4	<i>Taraxacum japonicum</i>	<i>Taraxacum japonicum</i>	<i>Taraxacum japonicum</i>
5	--	<i>Rumex dentatus</i>	<i>Rumex dentatus</i>
6	--	<i>Althaea officinalis</i>	<i>Althaea officinalis</i>

Pollen source preference of honey bee species

Different honey bee species have different pollen preferences. Reddy *et al.* (2015) stated that *A. cerana* and *A. mellifera* may have slight difference in their pollen sources due to their own preference. *A. cerana* prefer tall trees while *A. mellifera* prefer short herbs in Japan. Hu and Wu (2019) argued that the pollen composition in between *A. cerana* and *A. mellifera* may differ. Yang *et al.* (2020) stated that *A. mellifera* are more likely to bring pollens from the near sources as compare to *A. cerana*. Current study shows resemblance with the previous studies (Table 13).

Ahmad *et al.* (2017) stated that *A. mellifera* carries much heavy pollen loads having more pollen grains and uni-floral pollen loads as compare to *A. cerana*. Hu and Wu (2019) stated that *A. mellifera* carries much pollens per individual than *A. cerana*. Similar results were also recorded in current study, where *A. mellifera* (H1) brought more pollens by weight than *A. cerana* in Langstroth hive (H2) and *A. cerana* in traditional mud hive (H3) (Table 14).

Table 14: Pollen difference by weight of Honey bee species.

Honey bee spp	<i>A. mellifera</i> (H1)	<i>A. cerana</i> (Langstroth hive) (H2)	<i>A. cerana</i> (Traditional mud hive) (H3)
R1	12.004 g	07.065 g	07.923 g
R2	11.028 g	06.569 g	07.004 g
R3	10.438 g	04.313 g	04.812 g
R4	06.383 g	03.002 g	03.991 g
Total	39.853 g	20.949 g	23.730 g

Chemical analysis of honey

Ash content: Margaoan *et al.* (2012) stated that ash content of honey bee pollens may vary from 1.75-3.25% whose results are in accordance with the current study (Figure 1).

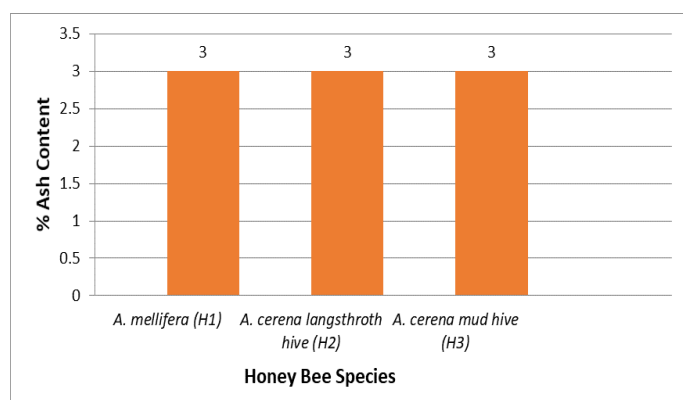


Figure 1: Ash Content of different honey bee pollen samples.

Moisture content: Margaoan *et al.* (2012) stated that the moisture content of honey bee pollens may vary from 17.59-29.55%. Thakur and Nanda (2020) stated that fresh bee pollens moisture content may vary from 7-30%. These results show similarity with the current results (Figure 2).

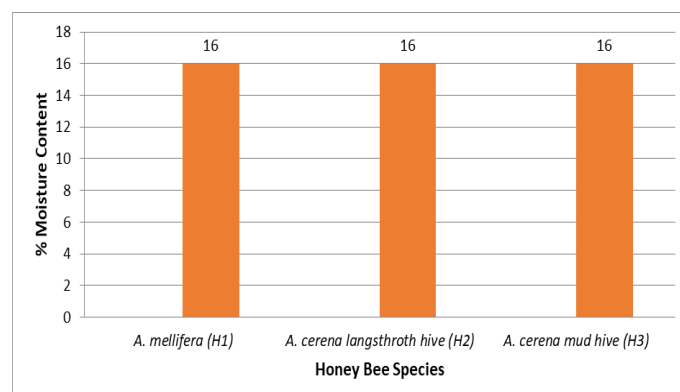


Figure 2: Moisture Content of different honey bee pollen samples.

Total sugar content: Aqueous medium: The sugar analysis was carried out in aqueous medium through spectrophotometer by passing each sample from 450 nm light. It was concluded that the pollens brought by the honey bee species *A. mellifera* (H1), *A. cerana* in Langstroth hive (H2) and *A. cerana* in traditional mud hive (H3) were having 2.07%, 1.30% and 1.31% absorbance of 450 nm light, respectively. While the standard glucose 1%, 3% and 5% was having total sugar absorbance of 0.85%, 1.75% and 2.08% respectively. H1 was having significant sugar content results to 5% glucose standard while H2 and H3 were lying below 3% glucose results (Figures 3, 4, 5).

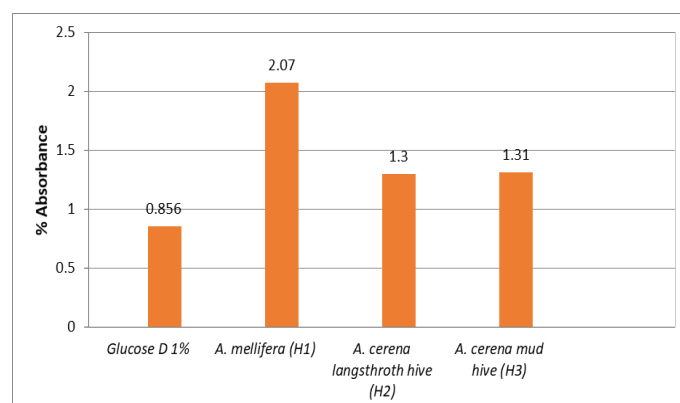


Figure 3: Quantification of samples in 1% Glucose D aqueous medium of different honey bee pollen samples.

Acidic medium: In acidic medium the same method was applied apart from medium, the pollens of H1, H2 and H3 absorbed 450 nm light at 2.863%, 1.953% and 1.958%, respectively. In acidic medium H1 was having higher (2.867%) absorbance at 450 nm light

than 5% glucose standard (2.08 %) whereas H2 and H3 were having 1.953% and 1.958% absorbance, respectively. This value was lower as compare to 5% glucose D % absorbance but higher than 3% glucose D % absorbance (1.75%) (Figures 6, 7, 8).

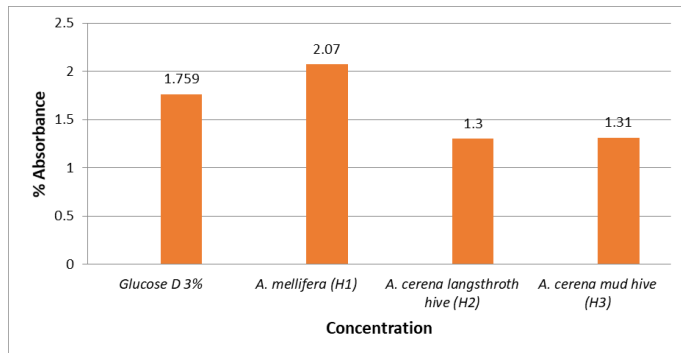


Figure 4: Quantification of samples in 3% Glucose D aqueous medium of different honey bee pollen samples.

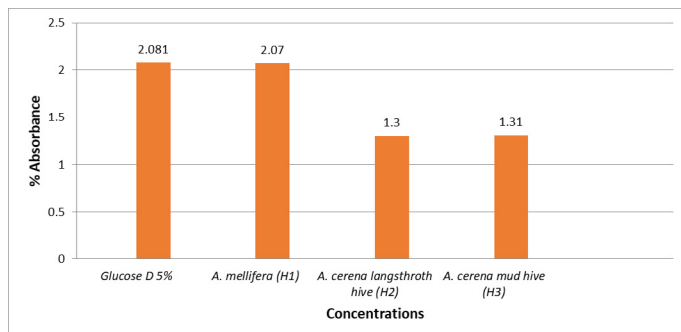


Figure 5: Quantification of samples in 5% glucose D aqueous medium of different honey bee pollen samples.

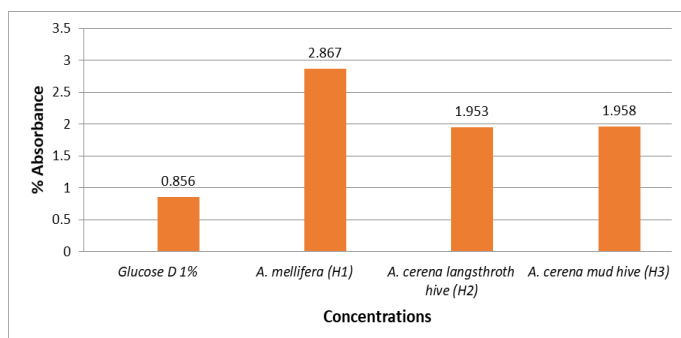


Figure 6: Quantification of samples in 1% glucose D acidic medium of different honey bee pollen samples.

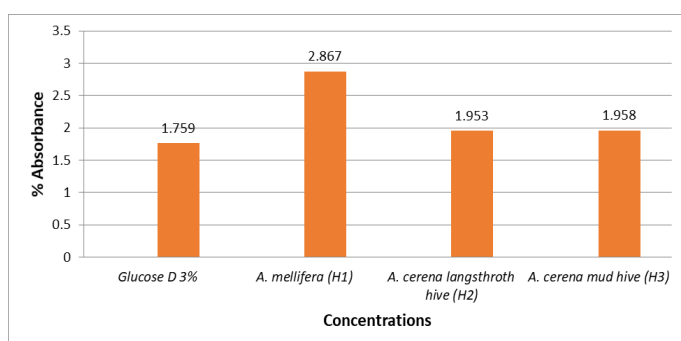


Figure 7: Quantification of samples in 3% Glucose D acidic medium of different honey bee pollen samples.

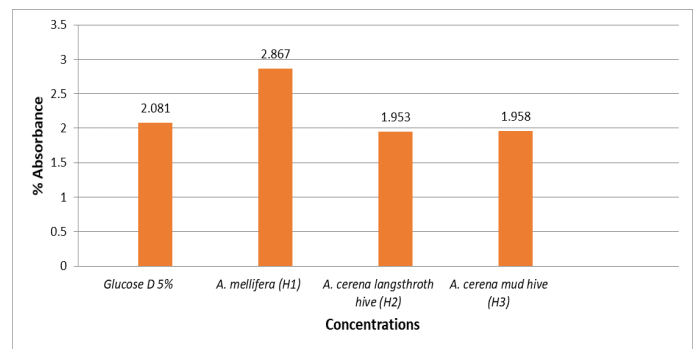


Figure 8: Quantification of samples in 5% glucose D acidic medium of different honey bee pollen samples.

Conclusions and Recommendations

It has been concluded that *A. cerana* in traditional mud hive (H3) shows better foraging performance as compare to *A. mellifera* (H1) and *A. cerana* in Langstroth hive (H2). T1 (07:00-08:00 am) was recorded as peak foraging performance time. The ratio of foragers returning with pollens and water is affected by high temperature as foragers returning with water increases with increase in temperature. *A. cerana* brought pollens from six sources while *A. mellifera* brought pollens from four sources, this revealed that *A. cerana* is more diverse than *A. mellifera*. The ash and moisture content of all the three Honey bee species was 3% and 16%, respectively, whereas the total sugar content results obtained through spectrophotometer in aqueous medium were 2.07% for *A. mellifera*, 1.30% for *A. cerana* in Langstroth hive and 1.31% for *A. cerana* in traditional mud hive.

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Novelty Statement

This study is helpful in understanding the foraging behavior and peak foraging performance of honey bees as it is reported for the first time in Peshawar. This will also help the farmers to move their colony as per preference of the honey bees.

Author's Contribution

Hamza Iftikhar: Carried out research, data collection, analysis and write-up

Ranra Jalal: Helped in data analysis

Mansoor Ali Shah: Helped in data collection

Syed Anas Shah Bacha: Helped in write-up

Amjid Ali: Helped in editing and graphs designing

Syed Majid Rasheed: Helped in proofreading and editing

Conflict of interest

The authors have declared no conflict of interest.

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