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Comparative foraging behavior of eastern honeybee, (*Apis cerana* F) and western honeybee, (*Apis mellifera carnica*) in pollinating pear and apricot flowers in Taleghan, Iran

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Abstract

The Eastern honeybee, (*Apis cerana*), is indigenous to Asia and is an important pollinator for Asian ecosystems; the Western honeybee, (*Apis mellifera*), has been introduced to Asia because of its high honey yields. European honeybee, (*Apis mellifera carnica*) is native to the Iranian continent and is adopting apiaries by the beekeepers in Iran. The results shown that for times of initiation; cessation and duration of foraging activity, duration of foraging trip; and weights of pollen loads, differences between the two honeybee species are significant ($P<0.01$). The total duration of foraging activity of (*Apis cerana* F) worker bees is significantly more than those of (*Apis mellifera carnica*). *Apis ceranais* a better pollinator than (*Apis mellifera carnica*) of pear and apricot. For (*Apis cerana* F), pollen collectors outnumbered nectar collectors throughout the day on both pear and apricot, whereas for (*Apis mellifera carnica*) pollen collectors outnumbered nectar collectors in the morning and in the afternoon nectar collectors outnumbered pollen collectors on both pear and apricot. (*P:N*) ratio was significantly higher for (*Apis cerana* F) throughout the day than (*Apis mellifera carnica*). Therefore, *Apis cerana* could strongly influence plant pollination in study area. Results obtained from foraging behavior indicate the top talent of this species for rearing compared with (*Apis mellifera carnica*) species in this context. Also pear and apricot are among plants that well pollinate with these bees. Thus, we propose that (*Apis cerana* F) can contribute to the colony pollination service and could be used in apiaries in Taleghan region.

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Introduction

The limited pollination efficiency of honey bees (*Apidae; Apis*) for certain crop plants and, more recently, their global decline fostered commercial development of further bee species to complement crop pollination in agricultural systems. Pollination is an essential ecosystem service and insect pollination is both an ecosystem service and a major contributor to crop production all over the world. Honeybees are an extremely important part of the natural ecosystem because they help to maintain biodiversity and enhance agricultural productivity by providing valuable pollination services, based on the ecological principal of mutual interactions between pollinated plants and pollinators. Many fruit, nut, vegetable, legume, and seed crops depend on pollination. Pollination services are provided both by wild, free-living organisms (mainly bees, but also to name a few many butterflies, moths and flies), and by commercially managed bee species. Bees are the predominant and most economically important group of pollinators in most geographical regions. Insect pollination is both an ecosystem service and a major contributor to crop production all over the world. Indeed, around 80 % of flowering plants are entomophilous, i.e., dependent on insect pollination to reproduce, and it is estimated that half of the pollinators of tropical plants are bees (Bradbear, 2009). The pollinating efficiency of honey bees in agricultural landscapes is due to their large numbers, their anatomy and their foraging behavior on only one plant species at one time (Bradbear, 2009). However, the abundance and diversity of wild bees are now declining (Biesmeijer *et al.*, 2006). This could dramatically affect world food safety since the agricultural dependence on pollinators is continuously increasing (Aizen and Harder, 2009). The honeybee is managed for both honey production and pollination services (Morse and Calderone, 2000). Division of labor among worker honeybees is an evolutionary phenomenon as 2 or 3 weeks old worker bees go out forage. Forager honeybees collect pollen, nectar, water and propolis. Many factors such as genetics and physiology of forager bee and also environmental conditions, effect on their foraging behavior and its efficiency. Pears and apricots are native plant in the Alborz province of Iran. Varieties of pear are self-incompatible and require cross-pollination to produce fruits. Apricot varieties are self-compatible; however, cross-pollination has been reported to increase yield and improve fruit quality (Free, 1993). Cross-pollination of pear and apricot is brought about by insect pollinators that visit their flowers for pollen and nectar. Among pollinating insects, honeybees in particular are attracted to these crops and are reported to be of great benefit (Choi and Lee, 1988, Free, 1993, Mann and Singh, 1983). Practically no work has been done on the pollination of either pear or apricot under the agro climatic conditions of the Alborz province in Taleghan region of Iran. Therefore, in the present investigation the foraging behavior of two exotic honeybee species; the native bees, (*Apis mellifera carnica*) and (*Apis cerana* F) on pear and apricot flowers have been compared in order to assess their role as pollinators of these fruit crops. Such studies assume great importance under the local ecological conditions of Alborz province where (*Apis mellifera carnica*) has been recently introduced from Iran. The pollen is the only source of protein for the breeding of broods and adult honeybees. According to previous research has shown that different colonies with different genotype, have different foraging behavior and pollen collection (Kimiaei *et al.*, 2014). Although there are more than 3000 pollinators other than honeybees, but among them honeybee are ranked first. These insects use pollen just in their larval stage of their life, but the honeybees throughout their life time utilize the nectar and pollen to feed themselves and their larva, and during collecting these sources cause pollination and fertilization of flowers and it has to be emphasized that a honeybees colony utilize 400 million flowers in a year. Now a days in most of the countries (except Iran) attention to honeybees at first is due to its role in economical return through pollinating and increasing of agricultural crops. The results of surveys in other countries showed that, role of honeybees in increasing of the agricultural crop was about 69 to

143 times of their direct production. Address to surveys in Iran, it is clear that the value of honeybees in increasing agriculture crop are 90 times of their direct production and that is equal 4 per cent of GNP (Ghaderzadeh and Fattahi, 2014).

Pollination of flowering plants by animal pollinators is an essential ecosystem function (Sargent and Ackerly, 2008). *Apis mellifera* and *Apis cerana* have evolved in distinct ecologies; their social organization as well as mating behavior has been successfully shaped by their respective ecosystems. The Eastern honeybee, (*Apis cerana*), is indigenous to Asia and is an important pollinator for Asian ecosystems; the Western honeybee, (*Apis mellifera*), has been introduced to Asia because of its high honey yields. These two species are now sympatric and share a similar environment (Yang, 2005). According to (Admassu, 2003) *Apis mellifera* is native to Europe and Africa, while the rest are native to the Asian continent. Pollination is vital to our ecosystems and to human societies. The health and wellbeing of pollinating insects are crucial to life, be it in sustaining natural habitats or contributing to local and global economies (Fig. 1).

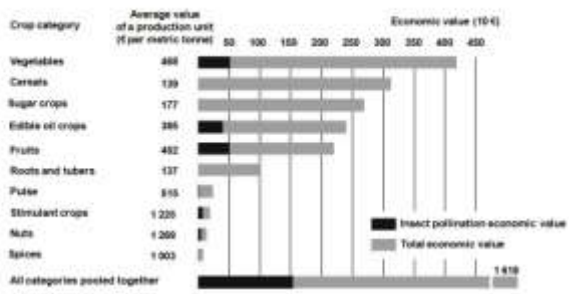

Fig. 1. Economic impact of insect pollination on agricultural production used directly for human food worldwide.

The contribution of pollinators to the production of crops used directly for human food has been estimated at €153 billion globally, which is about 9.5% of the total value of human food production worldwide (Simon, 2006, Gallai *et al.*, 2008). The contribution of a pollinator visit to fruit or seed *set also* varies considerably between pollinator species and is affected by diverse aspects such as pollinator morphology, size and foraging behavior on the focal plant (Sahli and Conner, 2007). According to (Blüthgen and Klein, 2011, Hoehn *et al.*, 2008, Brittain *et al.*, 2012) the combination of several pollinator species may increase crop yields compared to those obtained with a single commercial pollinator species, due to spatiotemporal and behavioral complementarity between pollinator species in their foraging activity. Social insects, including the Western Honey Bee, *Apis mellifera* L, protect and regulate their colony environment to rear brood and store food. The two principal food sources, pollen and nectar, are brought into the colony by foragers that may specialize on one of these resources or collect both (Fewell and Page, 1993). In contrast to stored nectar or honey (Fewell and Winston, 1996), the amount of pollen in the honey bee hive is tightly regulated (Fewell and Winston, 1992, Dreller *et al.*, 1999).

Artificial selection has repeatedly demonstrated a substantial genetic component for the amount of pollen stored, or pollen hoarding (Page and Fondrk, 1995, Hellmich *et al.*, 1985). Pollen hoarding is a complex social trait because the amount of pollen stored in the hive is a function of available space, pollen collection, and consumption, and the active regulation occurs by adjusting the level of pollen collection by the foragers (Dreller and Tarpy, 2000). Therefore, it is not surprising to find artificial selection for pollen hoarding associated with corresponding changes in the probability of individual forager to collect pollen and their pollen load sizes (Pankiw, 2003, Page *et al.*, 2000). Consistently, workers from the strain selected for high-pollen hoarding performed more recruitment dances for pollen sources and also follow such dances more (Waddington *et al.*, 1998). The Carniolan bee is the honeybee of the temperate central European climate region, ranging from the Alps to the Carpaths (Ruttner, 1992). Honeybees, mainly *Apis mellifera*, remain the most economically valuable pollinators of crop monocultures worldwide (Mcgregor, 1976), and yields of some fruit, seed and nut crops decrease by more than 90 % without these pollinators (Southwick and Southwick, 1992). According to (Kevan *et al.*, 1990) stated that underestimation of the pivotal role played by managed and native insect pollinators are a key constraint to the sustainability of contemporary agricultural practices. The economic value of such insects to pollination, seed set, and fruit formation greatly outweighs that suggested by more conventional indices, such as the value of honey and wax produced by honey bees.

Material and methods

Fieldwork was conducted in Taleghan region in Alborz province, Iran. The research was carried out in (2012-2014) in the Taleghan District, located between (36.5:36.21° North latitude and 50.24:51.14° East longitude in the Alborz province of Iran. All data were collected on standardized weather condition (sunny day, wind velocity <8m/s, temperature > 20 °C).Observations on the foraging behavior of the bees on apricot and pear flowers were recorded for the daily time of initiation and cessation of foraging, total duration of foraging activity, time spent on the flower, number of flowers visited per minute, individual bee's choice of pollen and nectar, percentage of *'top worker'* (TW) and *'side worker'* (SW) bees, and the weight of pollen load carried by an individual bee. Observations of time spent on flower, number of flowers visited per minute, pollen loads collected and pollen vs. nectar collectors were recorded at 1000, 1200 and 1400 h. We repeated our observation in January 2014 and between the end of February and mid of March 2014.

Description of the Study Area / Altitude and Climate

The study was conducted in the Taleghan district in Alborz province, Iran (Fig.2). Alborz province is one of the 31 provinces of Iran. Alborz province was formed by division of Tehran province into two provinces. After the Parliamentary approval on June 23, 2010, and was introduced as 31st province of Iran. In 2014 it was placed in Region. Alborz province is surrounded by Mazandaran in the north, Markazi in the south westand Qazvin in the west and Tehran in east. Situated south east of Tehran, the province of Alborz has 4 counties, Karaj, Savojbolagh, Taleghan and Nazarabad. Alborz province is situated 20 km west of Tehran, at the foothills of the Alborz Mountains, and is Iran smallest province in area. Apart from arable crops, and livestock production in the area, (*Milliferous flora)* is common in the area under study. There are a lot of weeds climbers and ornamentals which are plants visited by the honeybees, the common tree plants include *Medicago sativa*, Yellow sweet clover *(Melilotus officinalis)*, *Robinia pseudoacacia*, Mountain Cornflower *(Centaurea Montana)*, Garden cress *(Lepidium sativum)*, Bladder campion *(Silene vulgaris)*, garden grass *(Dactylus glomerata)*, pinto peanut *(Arachis pintoi)*, chickweed *(Stellaria spp)*, Thymus vulgaris *(Labiatae)*, *Astragalus brachycalyx, Astragalus susianus (Tamarix gallica)* and etc; apart from these, fruit trees like apple, pear, fig, apricot, Cherry, peach, grape and common vegetables like sunflower, Tomato, cabbage, lettuce, carrot, cucumber, forage corn, and nectar plants, etc. Are scattered around the area which provide good flora for bees (Kishani Farahani *et al.,* 2010). The state of Taleghan (36.5:36.21°N; 50.24:51.14°E) represents one of the most important beekeeping area in Iran (Fig 2). Taleghan district altitude is 1857 m, with annual average temperatures of 18°C, and the average annual rainfall is 500 mm (Anonymous, 2014).

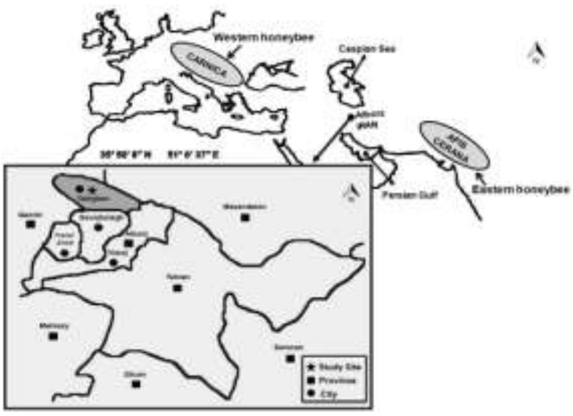

Fig. 2. Map of Iran and the study area of Taleghan district in Alborz province.

Foraging behavior of (*Apis cerana* F) and (*Apis mellifera carnica*) on apricot (*Prunus- armeniaca* Lvar. KBSR7) flowers was studied during the last week of February 2014 and on pear (*Pyrus communis* L var. Sebri) flowers during mid-March 2014 at Taleghan region (pear and apricot orchards, Kajiran (36°19ˀN and 50°86ˀE) in Taleghan region of Alborz province in Iran. Two colonies (one colony of each species containing almost the same number of worker bees and free of any sign of disease) were placed in the center of each orchard at 5-10% flowering to ensure that bees foraged only on the flowers of the crop under investigation and ignored alternative forage in the vicinity. Bees were kept in the field until the end of flowering.

Observations on the foraging behavior of the bees on apricot and pear flowers were recorded for the daily time of initiation and cessation of foraging, total duration of foraging activity, time spent on the flower, number of flowers visited per minute, individual bee's choice of pollen and nectar, percentage of *'top worker'* (TW) and *'side worker'*(SW) bees, and the weight of pollen load carried by an individual bee. For other logistics of foraging behavior studies, methods given by (Partap and Verma, 1994) and (Verma and Partap, 1994) were followed. Observations of time spent on flower, number of flowers visited per minute, pollen loads collected and pollen vs. nectar collectors were recorded at 1000, 1200 and 1400 h.

Proportions of *'top worker'* (TW) and *'side worker'* (SW) bees were determined as follows: worker bees alighting upright on stamens to collect pollen or nectar were considered as top workers and those alighting on petals and collecting nectar were considered as side workers (Verma and Rana, 1994). In order to check whether a returning forager has collected nectar, it was caught at the hive entrance and its abdomen pressed to regurgitate nectar. Peak hours of foraging activity were determined by counting the number of bees entering the hive in a 3min period each hour from early morning until late afternoon. Weight of pollen loads was determined by catching returning pollen collectors at the hive entrance, removing their pollen loads with bee brush and weighing the loads. In order to determine the number and duration of foraging trip, 20 bees were marked with nail polish of different colors and observations of the individual marked bee were recorded (Fig.3). Contents of pollen loads were determined by preparing glycerin jelly slides (Erdtman, 1969) and studying the slides microscopically. Data were analyzed statistically using 'T' tests or one-way analysis of variance.

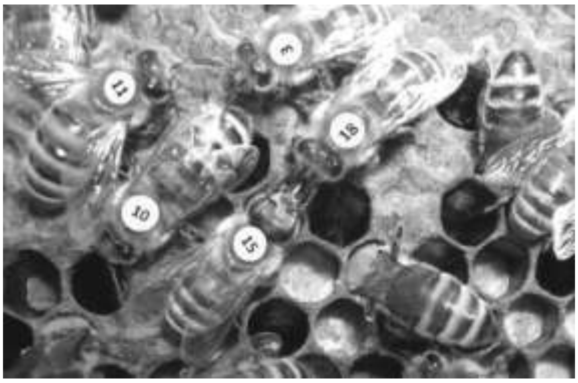

Fig. 3. Honey bees label with different numbers and marked with nail polish of different colors and observation of individual marked bee were recorded.

According to (Westrich, 1989, Radmacher and Strohm, 2010) foraging behavior often shows relatively high pollen constancy as these bees tend to prefer certain pollen sources provided these are abundant near their nesting site. This trait is advantageous for commercial fruit tree pollination in orchards. According to (Hermann, 2010) their limited flight radius and their preference for *Rosacea* pollen leads to distinct fruit tree flower fidelity in orchard environments (Schindler and Peters, 2011, Torchio, 1976, Marquez *et al.*, 1994, Bosch *et al.*, 2000, Sheffield *et al.*, 2008b). According to (Hosseini *et al.*, 2014) foraging behavior of honey bees (*Apis mellifera*), the results showed that the worker bees leaving the hive, were significantly different ($P<0.01$) at 11 am and 17 pm and the number of bees with pollen were also significantly different ($P<0.01$) at 11 am. There was a relationship between each trait and mean ambient temperature, relative humidity and the time of visit. It was found that there was an indirect significant difference (P<0.01) between humidity and the time of visit, for the bee entering with pollen. Bees with nectar showed direct relationship with temperature, humidity and time of visit, the bees leaving the hive, showed a direct relationship with temperature (P<0.01). It was also shown an indirect relationship between bees entering with pollen with humidity and time of visit. Correlation between the number of bees with nectar, pollen and workers leaving the hive, with temperature was positive and significantly different (P<0.01). Bees with pollen and leaving the hive with observation hours and humidity was negative and significantly different (P<0.01) and Correlation between bees carrying nectar and humidity was negative and significantly different (P<0.01).The rate foraging activity and the number of worker bees entering the hive with nectar and pollen and those leaving in at 9 am to 13 pm of the day were at the highest rate.

According to (Tahmasbi *et al*., 2011) foraging and pollen collecting behavior of worker bees (the traits connected to honey production) in high and low production honeybee colonies, The Obtained data were showed the returned bees with pollen load (P≤0.05) in high production colonies were more than low production colonies. In the other hand but the number of bees that going out of colonies have not significant differentness. The result showed that the number of forager in the morning were more than afternoon in the some days. The number of foragers' bees have positive correlation with honey production in the honeybee colonies.

Statistical analysis

All analyses were performed using SPSS Statistics 20 and Data were analyzed statistically using 'T' tests or one-way analysis of variance.

Result

Observation on the foraging behavior of (*Apis cerana* F) and (*Apis mellifera carnica*) on pear and apricot flowers are presented in (Table 1). For times of initiation; cessation and duration of foraging activity, duration of foraging trip; and weights of pollen loads, differences between the two honeybee species are significant (*P<0.01*). Differences are also significant between the bee species and between *'top worker'* (TW) and *'side worker'* (SW) for the time spent per flower and the number of flowers visited per minute. (*Apis cerana* F) workers bees began foraging earlier in the morning (07.31h on pear and 08.12 h on apricot flower) compared to (*Apis melliferacarnica*) worker bees that started foraging at 08.01h on pear and 08.37 h on apricot. In the evening (*Apis mellifera carnica*) stopped earlier (17.35 h on pear and 17.02 h on apricot) than *Apis cerana*(18.06 h on pear and 17.51 h on apricot). The duration of foraging activity for (*Apis cerana*)was significantly longer (10.35 h per day on pear and 9.39 h per day on apricot) than (*Apis mellifera carnica*) for which foraging activity was 9.34 h per day on pear and 8.25 h per day on apricot. Differences in all three parameters were significant at (P<0.01). On both pear and apricot, foraging activity of (*Apis mellifera carnica*) diminished greatly with only few bees foraging after 15.30 h whereas that of (*Apis cerana* F) continued until 17.00 h.

Table 1. Foraging behavior of (*Apis cerana* F) and (*Apis mellifera carnina*) on pear and apricot flowers during February / March in the Alborz province in Iran.

S. No.	Indicators	Foraging behavior			
		Pear		Apricot	
		***Apis cerana* F**	***Apis mellifera carnica***	***Apis cerana* F**	***Apis mellifera carnica***
1.	Initiation of foraging (time of day)	07.31± 0.7	08.01 ± 0.4	08.12 ± 0.4	08.37 ± 0.6
2.	Cessation of foraging (time of day)	18.06 ± 0.36	17.35 ± 0.7	17.51 ± 0.6	17.02 ± 0.3
3.	Duration of foraging activity (h)	10.35 ± 0.92	9.34 ± 0.88	9.35 ± 0.5	8.25 ± 0.57
4.	Peak foraging hours (time of day)	11.00 – 14.00	11.30 – 13.30	11.00 – 13.30	11.30 – 13.00
5.	Duration of foraging trip (min)	20.3 ± 0.22	25.9 ± 0.2	21.4 ± 0.2	25.1± 0.7

S. No.	Indicators	Foraging behavior			
		Pear		Apricot	
		***Apis cerana* F**	***Apis mellifera carnica***	***Apis cerana* F**	***Apis mellifera carnica***
a.		**Time spent on flower (s)**			
	Top worker (TW)	4.8 ± 0.2	5.4 ± 1.5	3.8 ± 0.9	4.6 ± 1.8
	Side worker (SW)	12.6 ± 1.3	16.4 ± 1.7	9.1± 0.8	13.3 ± 1.7
b.		**Number of flowers visited per min**			
	Top worker (TW)	9.7 ± 0.9	8.9 ± 1.5	14.8 ± 1.2	13.7 ± 2.2
	Side worker (SW)	4.1 ± 1.6	3.1 ± 1.0	9.7 ± 1.1	7.9 ± 1.9
c.		**Pollen loads (mg)**			
	1000 h	12.5 ± 0.9	18.9 ± 2.4	13.3 ± 1.7	17.1 ± 1.4
	1200 h	14.3 ± 1.6	16.8 ± 1.9	12.2 ± 1.2	16.7 ± 1.7
	1400 h	6.7 ± 2.2	9.3 ± 2.3	5.9 ± 1.7	8.7 ± 2.7

Note: Values are mean ± SE
Source: Field survey, 2014

The peak of foraging activity for *Apis cerana F* (mean number of incoming bees / three minutes) occurred earlier and was longer (11.00 – 14.00 h on pear and 11.00 – 13.30 h on apricot) than for *Apis mellifera carnica* (11.30 – 13.30 h on pear and 11.30 – 13.00 h on apricot). The duration of an individual foraging trip by *Apis cerana F* (20.3 min on pear and 21.4 min on apricot) was significantly shorter (*P<0.01*) than for *Apis mellifera carnica* (25.9 min on pear and 25.1min on apricot). A forager of (*Apis cerana F*) averaged significantly less time (4.8 s by TW and 12.6 s by SW on pear, and 3.8 s by TW and 9.1 s by SW on apricot flower) than (*Apis mellifera carnica*) that, on average, spent 5.4 s for TW and 16.4s for SW on pear, and 4.6s for TW and 13.3s for SW on apricot flower. (*Apis cerana F*) foragers averaged significantly more flowers per minute (9.7 by TW and 4.1 by SW on pear; 14.8 by TW and 9.7 by SW on apricot) than (*Apis mellifera carnica*) that averaged 8.9 pear flowers by TW and 3.1 by SW; and 13.7 apricot flowers by TW and 7.9 by SW in one minute.

Bees of both the species collected either nectar or pollen during a single foraging trip. For (*Apis cerana F*)*P>N* throughout the day (*P<0.01*) on both pear and apricot whereas for (*Apismellifera carnica*)*P>N* (*P=0.01*) in the morning at 10.00 h, (*N=P*) at 12.00 h and (*N>P*) at 14.00 h (*P:N*) ratios were significantly higher for (*Apis cerana F*) than (*Apis mellifera carnica*) throughout the day on both pear and apricot (Table 2). Number of *'top worker'* (TW) or *'side worker'*(SW) foragers showed fluctuations at different hours of the day (Table 3). For (*Apis*ceranaF), more bees worked from top position (*TW>SW*) during the morning (10.00 h) but from the side position (*SW>TW*) during the afternoon (14.00 h) on both pear and apricot. Proportion of the top workers was more for (*Apis cerana F*) than for (*Apis mellifera carnica*).

Table 2. Percentage of (*Apis cerana* F) and (*Apis mellifera carnica*) honeybees collecting pollen (*P*) and nectar (*N*) from pear and apricot flowers during different hours of the day in February / March in the Alborz province in Iran.

Indicators	Time of the day		
	1000h	**1200h**	**1400h**
Pear			
TW (n = 150)	85.9 (71.3)	82.1 (54.6)	54.1 (32.2)
SW (n = 150)	14.1 (28.7)	17.9 (45.4)	45.9 (67.8)
TW : SW	4.8:1.0 (2.2:1.0)	3.4:1.0 (1.1:1.0)	1.04:1.0 (0.4:1.0)
UF (n = 50)	98.5 (98.3)	97.7 (97.0)	97.1 (95.2)
MF (n = 50)	1.5 (1.7)	2.3 (3.0)	2.9 (4.8)
apricot			
TW (n = 150)	93.0 (80.3)	83.7 (56.2)	71.2 (40.4)
SW (n = 150)	7.0 (19.7)	16.3 (43.8)	28.8 (59.6)

Indicators	Time of the day		
	1000h	1200h	1400h
TW : SW	10.1:1.0 (3.4:1.0)	4.2:1.0 (1.1:1.0)	2.1:1.0 (0.6:1.0)
UF (n = 50)	98.1 (97.9)	97.5 (97.2)	96.8 (95.7)
MF (n = 50)	1.9 (2.1)	2.5 (2.8)	3.2 (4.3)

Note: For (*A. cerana* F) TW>SW at 10.00 h, 12.00 h and 14.00 h on both pear and apricot (P<0.01). For (*A. mellifera carnica*) TW>SW at 10.00 h (P<0.01), TW>SW at 12.00 h (NS) and SW>TW at 14.00 h (P<0.01) on both pear and apricot. On pear and apricot UF>MF for both (*A. cerana* F*)* and (*A. mellifera carnica*) (P<0.01). Date for (*Apis mellifera carnica*) are given in parentheses; (n) is number of observations and (NS) is not significant.

Worker bees of (*Apis mellifera carnica*) carried significantly heavier pollen loads from both pear and apricot flowers than those of *Apis cerana F*(Table 1). Both species showed the same floral fidelity during pollination; foragers on both pear and apricot collected pollen loads that were more than 95% unifloral (Table 3). More bees of both (*Apis cerana* F) and (*Apis mellifera carnica*) were observed foraging near the hive; the number decreased with the distance (*P<0.01*). In the pear orchard, the number of foragers of (*Apis cerana* F) and (*Apis mellifera carnica*) per 1000 flowers per 10 min was 11.2 and 12.5 respectively at 150 m. In the apricot orchard, the number of (*Apis cerana F*) and (*Apis mellifera carnica*) bees was 13.1 and 12.9 respectively at 50 m; and 5.5 and 7.2 at 250 m(Table 4). At 50 m number of foragers of both the species are more (P<0.01) than at 250 m.

Table 3. Percentage of top workers (TW) and side workers (SW) visiting pear and apricot flowers; and percentage of unifloral(UF) and multi-floral (MF) pollen loads carried by honeybees at different hours of the day.

Time	1000 h		1200 h		1400 h	
	(*A. cerana* F)	**(*A. mellifera*)**	**(*A. cerana* F)**	**(*A. mellifera*)**	**(*A. cerana* F)**	**(*A. mellifera*)**
Pear						
P (n = 100)	76	63	68	66	60	34
N (n = 100)	24	37	32	44	40	66
P : N	3.5:1.0	1.6:1.0	2.5:1.0	0.7:1.0	1.4:1.0	0.6:1.0
apricot						
P (n = 100)	90	71	79	50	58	47
N (n = 100)	10	29	21	50	42	63
P : N	8.1:1.0	2.5:1.0	3.5:1.0	1.0:1.0	1.3:1.0	0.6:1.0

Note: For (*Apis cerana* F) *P>N* at 10.00 h, 12.00 h, and 14.00 h on both pear and apricot (*P<0.01*). For (*Apis mellifera carnica*) *P>N* at 10.00h and *N>P* at 12.00 h and 14.00 h on pear (*P<0.01*); and on apricot *P>N* at 10.00h and *N>P* at 14.00h (*P<0.01*), *P=N* at 12.00 h (*NS*).
(*n*): Is number of observation and (*NS*) is not significant.

Table 4. Effect of distance on the foraging of (*Apis cerana* F) and (*Apis mellifera carnica*) on pear and apricot flowers.

Crop	Honeybee species	Number of bees per 1000 flowers per 10 minutes	
		50 m	150 m
Pear	(*Apis cerana* F)	11.2 ± 2.4	6.4 ± 1.1
	(*Apis mellifera carnica*)	12.5 ± 1.9	6.9 ± 2.0
Apricot	(*Apis cerana* F)	13.1 ± 2.9	5.5 ± 0.9
	(*Apis mellifera carnica*)	12.9 ± 1.7	7.2 ± 1.0

Note: Value are mean ± SE of 21 observation.

Discussion

Since pear and apricot bloom during early spring in the Alborz province, the hive bees, (*Apis cerana* F) and (*Apis mellifera carnica*), are important for their pollination because natural insect pollinators are present in much smaller numbers during this period owing to low temperatures. The flowers of these crops are attractive to both species of honeybee and provide good amounts of pollen and nectar for about two weeks.

Comparative foraging behavior data suggest that worker bees of (*Apiscerana* F) started foraging activities earlier in the morning and ceased later in the evening that (*Apis mellifera carnica*) workers. The total duration of foraging activity of (*Apiscerana* F) worker bees is significantly more than those of (*Apis mellifera carnica*). This enables (*Apiscerana* F) worker bees to forage and pollinate flowers for extended periods of time compared to (*Apis mellifera carnica*). Therefore foraging behavior and collecting behavior of worker bees of honeybee colonies can help the beekeepers and research to select the best colonies to establish the next generations.Moreover, the duration of peak foraging activity was longer for (*Apiscerana* F). According to (Verma and Partap, 1994) observed that duration of foraging activities of (*Apiscerana* F) was 12.1h on cabbage and 11.03 h on cauliflower during March.

According to (Partap *et al.*, 1996) the duration of foraging activity for *Apis cerana* (10.35 h per day on peach and 9.39 h per day on plum) than (*Apis mellifera*) for which foraging activity was 9.34h per day on peach and 8.25 h per day on plum during February/March and differences in all three parameters were significant at ($P<0.01$).Worker bees of (*Apis mellifera*) carried significantly heavier pollen loads from both tree peach and plum. Total duration of foraging activity of (*Apis cerana*) worker bees is significantly more than those of (*Apis mellifera*).

The differences that were observed between the species with respect to the time of initiation and peak hours of foraging activity agree with those of (Verma and Dulta, 1986). These differences in foraging preferences may have reflected the differences in temperature and relative humidity preferences. The present finding on the duration of peak foraging differ from those of (Verma and Dulta, 1986) who reported that under the agro-ecological conditions of high-mountain areas, the peak of foraging activities of (*Apis mellifera*) on apple flower begins after the peak foraging activity of (*Apis cerana*) decreases.These workers, therefore, suggested that both these bee species are complimentary in apple pollination. The mean duration of an individual foraging trip was significantly longer for (*Apis mellifera*) than (*Apis cerana*). These differences might be attributable to a difference in foraging efficiency and glycogen supply (energy) to flight muscles. (*Apis mellifera*) has more glycogen for fuel than *Apis cerana* (Dulta and Verma, 1989).

The number of flowers visited per minute by a TW and a SW (*Apiscerana* F) worker bee was greater compared to an (*Apis mellifera carnica*) worker bee; however, this difference was not statistically significant. However, more foragers of (*Apiscerana* F) worked flowers as *'top workers'* and collected nectar from both pear and apricot. According to (Verma and Rana, 1994, Partap *et al.*, 1996) top workers collecting pollen are considered to be better pollinators than side workers collecting nectar.

Fig. 4. The hind leg of the worker is an ingenious anatomical adaptation for gathering pollen.

The heavier pollen loads carried by (*Apis mellifera*) compared to that carried by (*Apis cerana*) may be related to the larger size of body parts for the former species (Mattu and Verma, 1980, Mattu and Verma, 1983, Mattu and Verma, 1984a, b, c). According to (Free, 1960) and (Kendall and Solomon, 1973) and (Thorp, 1979) observed that insects with smaller body parts carry little pollen compared to larger, hairy-bodied insects and their body to collect pollen in their pollen baskets on the tibia (Fig. 4). Foragers of both species collected significantly heavier pollen loads during morning hours than afternoon hours. This may be because bees collect most of the available pollen during the morning hours, therefore the amount of pollen available during afternoon is less.

For (*Apiscerana* F), pollen collectors outnumbered nectar collectors throughout the day on both pear and apricot whereas for (*Apis mellifera carnica*) pollen collectors outnumbered nectar collectors in the morning and in the afternoon nectar collectors outnumbered pollen collectors on both pear and apricot. (*P:N*) ratio was significantly higher for (*Apiscerana* F) throughout the day than (*Apis mellifera carnica*). This may be because flowers of both pear and apricot presented pollen in the morning and nectar in afternoon. In the present investigation, worker bees of both species collected either pollen or nectar but not both during a single foraging trip. This may be because in this crop nectar and pollen are not equally attractive to a forager at the same time. Earlier studies (Verma and Partap, 1994) shown that (*Apis cerana*) when visiting cauliflower and cabbage collected either pollen or nectar but never both on an individual foraging trip and similar observations were recorded by (Free, 1960) for (*Apismellifera*). Observations that the number of forager bees of both species was greater near the hive agree with earlier observation of (Eckert, 1993, Lavin, 1959, Partap *et al.*, 1996, Hosseini *et al.*, 2014) who reported that if sufficient forage is available, bees prefer to work close to their hives. Based on the observations discussed above, (*Apiscerana* F) is a better pollinator than (*Apis mellifera carnica*) of pear and apricot in Taleghan Region in the Alborz province of Iran.

Conclusion

In conclusion, our data suggests that (*Apis cerana* F) it is foraging behaviorally well equipped to substantially contribute to pollination. In light of the extended population-level flight ranges and different flower choices compared to workers bee (*Apis mellifera carnica*), they may well complement the pollination activities and hence expand the pollination service of the *Apis cerana* colony as a whole. Comparative foraging behavior data suggest that worker bees of (*Apiscerana* F) started foraging activities earlier in the morning and ceased later in the evening that (*Apis mellifera carnica*) workers. The total duration of foraging activity of (*Apiscerana* F) worker bees is significantly more than those of (*Apis mellifera carnica*). This enables (*Apiscerana* F) worker bees to forage and pollinate flowers for extended periods of time compared to (*Apis mellifera carnica*).Therefore foraging behavior and collecting behavior of worker bees of honeybee colonies can help the beekeepers and research to select the best colonies to establish the next generations.Moreover, the duration of peak foraging activity was longer for (*Apiscerana* F).

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