Chapter 52

# Comparative Foraging Behaviour of *Apis cerana* and *Apis mellifera* in Pollinating Peach and Plum Flowers in Kathmandu Valley, Nepal

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Peaches and plums are widely planted in the middle hills of Nepal. Varieties of plum are self-incompatible and require cross-pollination to produce fruits. Peach varieties are self-compatible; however, cross-pollination has been reported to increase yield and improve fruit quality (Free, 1993). Cross-pollination of peach and plum 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 peach or plum under the agroclimatic conditions of the Kathmandu valley of Nepal. Therefore, in the present investigation the foraging behaviour of two honeybee species – the native bee, *Apis cerana,* and the exotic bee, *A. mellifera* – on peach and plum 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 Kathmandu valley where *A. mellifera* has been recently introduced from India.

## Material and Methods

Foraging behaviour of *A. cerana* and *A. mellifera* on plum (*Prunus domestica* var. Maithili) flowers was studied during the last week of February 1996 and on peach (*Prunus persica* var. Perigreen) flowers during mid-March 1996 at HMG Horticultural Farm, Godavari (27°35' N and 85°24' E) in the Kathmandu valley of Nepal. 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 centre 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 behaviour of the bees on plum and peach 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, per centage 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 behaviour 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' and 'side worker' 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 3-min 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 a fine camel-hair 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 colours and observations of the individual marked bee were recorded. Contents of pollen loads were determined by preparing glycerin jelly slides (Erdtman, 1969) and studying the slides microscopically. Data were analysed statistically using 't' tests or one-way analysis of variance.

## Results

Observations on the foraging behaviour of *A. cerana* and *A. mellifera* on peach and plum 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 TW and SW for the time spent per flower and the number of flowers visited per minute.

*Apis cerana* workers bees began foraging earlier in the morning (07.31 h on peach and 08.12 h on plum flower) compared to *A. mellifera* worker bees that started foraging at 08.01 h on

**Table 1:** Foraging behaviour of *Apis cerana* and *Apis mellifera* on peach and plum flowers during February/March in the Kathmandu Valley, Nepal. Values are mean ± SE

| Parameter | Peach | | Plum | |
|---|---|---|---|---|
| | *A. cerana* | *A. mellifera* | *A. cerana* | *A. mellifera* |
| Initiation of foraging (time of day) | 07.31 ± 0.7 | 08.01 ± 0.4 | 08.12 ± 0.4 | 08.37 ± 0.6 |
| Cessation of foraging (time of day) | 18.06 ± 0.36 | 17.35 ± 0.7 | 17.51 ± 0.6 | 17.02 ± 0.3 |
| Duration of foraging activity (h) | 10.35 ± 0.92 | 9.34 ± 0.88 | 9.39 ± 0.5 | 8.25 ± 0.57 |
| Peak foraging hours (time of day) | 11.00–14.00 | 11.30–13.30 | 11.00–13.30 | 11.30–13.00 |
| Duration of foraging trip (min) | 20.3 ± 0.22 | 25.9 ± 0.2 | 21.4 ± 0.2 | 25.1 ± 0.7 |
| Time spent on flower (s) | TW 4.8 ± 0.2 | 5.4 ± 1.5 | 3.8 ± 0.9 | 4.6 ± 1.8 |
| | SW 12.6 ± 1.3 | 16.4 ± 1.7 | 9.1 ± 0.8 | 13.3 ± 1.7 |
| Number of flowers visited per min. | TW 9.7 ± 0.9 | 8.9 ± 1.5 | 14.8 ± 1.2 | 13.7 ± 2.2 |
| | SW 4.1 ± 1.6 | 3.1 ± 1.0 | 9.7 ± 1.1 | 7.9 ± 1.9 |
| Pollen loads (mg) | | | | |
| 1000h | 12.5 ± 0.9 | 18.9 ± 2.4 | 13.3 ± 1.7 | 17.1 ± 1.4 |
| 1200h | 14.3 ± 1.6 | 16.8 ± 1.9 | 12.2 ± 1.2 | 16.7 ± 1.7 |
| 1400h | 6.7 ± 2.2 | 9.3 ± 2.3 | 5.9 ± 1.7 | 8.7 ± 2.7 |

peach and 08.37 h on plum. In the evening *A. mellifera* stopped earlier (17.35 h on peach and 17.02 h on plum) than *Apis cerana* (18.06 h on peach and 17.51 h on plum). The duration of foraging activity for *A. cerana* was significantly longer (10.35 h per day on peach and 9.39 h per day on plum) than *A. mellifera* for which foraging activity was 9.34 h per day on peach and 8.25 h per day on plum. Differences in all three parameters were significant at $P < 0.01$. On both peach and plum, foraging activity of *A. mellifera* diminished greatly with only few bees foraging after 15.30 h whereas that of *A. cerana* continued until 17.00 h.

The peak of foraging activity for *A. cerana* (mean number of incoming bees/three minutes) occurred earlier and was longer (11.00–14.00 h on peach and 11.00–13.30 h on plum) than for *A. mellifera* (11.30–13.30 h on peach and 11.30–13.00 h on plum). The duration of an individual foraging trip by *A. cerana* (20.3 min on peach and 21.4 min on plum) was significantly shorter ($P < 0.01$) than for *A. mellifera* (25.9 min on peach and 25.1 min on plum).

A forager of *A. cerana* averaged significantly less time (4.8 s by TW and 12.6 s by SW on peach, and 3.8 s by TW and 9.1 s by SW on plum flower) than *A. mellifera* that, on average, spent 5.4 s for TW and 16.4 s for SW on peach, and 4.6 s for TW and 13.3 s for SW on plum flower. *Apis cerana* foragers averaged significantly more flowers per minute (9.7 by TW and 4.1 by SW on peach; 14.8 by TW and 9.7 by SW on plum) than *A. mellifera* that averaged 8.9 peach flowers by TW and 3.1 by SW; and 13.7 plum 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 *A. cerana* $P > N$ throughout the day ($P < 0.01$) on both peach and plum whereas for *A. mellifera* $P > N$ ($P = 0.01$) 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 *A. cerana* than *A. mellifera* throughout the day on both peach and plum (Table 2).

Number of top or side worker foragers showed fluctuations at different hours of the day (Table 3). For *A. cerana*, more bees worked from top position (TW>SW) throughout the day whereas for *A. mellifera* more bees worked from the 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 peach and plum. Proportion of the top workers was more for *A. cerana* than for *A. mellifera*.

Worker bees of *A. mellifera* carried significantly heavier pollen loads from both peach and plum flowers than those of *A. cerana* (Table 1). Both

**Table 2.** Per centage of *A. cerana* and *A. mellifera* honeybees collecting pollen (P) and nectar (N) from peach and plum flowers during different hours of the day in Feb/March in the Kathmandu Valley, Nepal. n=number of observations, NS= not significant.

| | 1000h | | 1200h | | 1400h | |
|---|---|---|---|---|---|---|
| | *A. cerana* | *A. mellifera* | *A. cerana* | *A. Mellifera* | *A. cerana* | *A. Mellifera* |
| **Peach** | | | | | | |
| $P(n = 100)$ | 78 | 61 | 72 | 44 | 59 | 38 |
| $N(n = 100)$ | 22 | 39 | 29 | 66 | 41 | 62 |
| $P : N$ | 3.5: 1.0 | 1.6: 1.0 | 2.5: 1.0 | 0.7: 1.0 | 1.4: 1.0 | 0.6: 1.0 |
| **Plum** | | | | | | |
| $P(n = 100)$ | 89 | 71 | 78 | 50 | 57 | 43 |
| $N(n = 100)$ | 11 | 29 | 22 | 50 | 43 | 67 |
| $P : N$ | 8.1: 1.0 | 2.5: 1.0 | 3.5: 1.0 | 1.0: 1.0 | 1.3: 1.0 | 0.6: 1.0 |

For *A. cerana* $P > N$ at 10.00 h, 12.00 h, and 14.00 h on both peach and plum ($P < 0.01$). For *A. mellifera* $P > N$ at 10.00h and $N > P$ at 12.00h and 14.00h on peach ($P < 0.01$); and on plum $P > N$ at 10.00h and N>P at 14.00h (P<0.01), $P = N$ at 12.00h (NS).

**Table 3.** Per centage of top workers (TW) and side workers (SW) visiting peach and plum flowers; and per centage of unifloral (UF) and multifloral (MF) pollen loads carried by honeybees at different hours of the day. Data for *Apis mellifera* are given in parentheses; n =number of observations; NS = not significant

| Parameter | Time of the day | | |
|---|---|---|---|
| | 1000h | 1200h | 1400h |
| **Peach** | | | |
| TW ($n$ = 150) | 82.9 (68.3) | 79.1 (51.6) | 51.1 (29.2) |
| SW ($n$ = 150) | 17.1 (31.7) | 20.9 (48.4) | 48.9 (70.8) |
| 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) |
| **Plum** | | | |
| TW ($n$ = 150) | 91.0 (77.3) | 80.7 (53.2) | 68.2 (37.4) |
| SW ($n$ = 150) | 9.0 (22.7) | 19.3 (46.8) | 31.8 (62.6) |
| 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) |
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| MF ($n$ = 50) | 1.9 (2.1) | 2.5 (2.8) | 3.2 (4.3) |

For *A. cerana* TW > SW at 10.00h, 12.00 h and 14.00 h on both peach and plum ($P < 0.01$). For *A. mellifera* 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 peach and plum. On peach and plum UF > MF for both *A. cerana* and *A. mellifera* ($P < 0.01$).

species showed the same floral fidelity during pollination; foragers on both peach and plum collected pollen loads that were more than 95 % unifloral (Table 3).

More bees of both *A. cerana* and *A. mellifera* were observed foraging near the hive; the number decreased with the distance ($P < 0.01$). In the peach orchard, the number of foragers of *A. cerana* and *A. mellifera* per 1000 flowers per 10 min was 11.2 and 12.5 respectively at a distance of 50 m; and 6.4 and 6.9 respectively at 150 m. In the plum orchard, the number of *A. cerana* and *A. mellifera* 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 4.** Effect of distance on the foraging of *A. cerana* and *A. mellifera* on peach and plum flowers. Values are mean ± SE of 21 observations

| Crop | Honeybee species | Number of bees per 1000 flowers/10 minutes | |
|---|---|---|---|
| | | 50 m | 150 m |
| Peach | *A. cerana* | 11.2 ± 2.4 | 6.4 ± 1.1 |
| | *A. mellifera* | 12.5 ± 1.9 | 6.9 ± 2.9 |
| Plum | *A. cerana* | 13.1 ± 2.9 | 5.5 ± 0.9 |
| | *A. mellifera* | 12.9 ± 1.7 | 7.2 ± 1.0 |

## Discussion

Since plum and peach bloom during early spring in the Kathmandu valley, the hive bees, *A. cerana* and *A. mellifera*, 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-behaviour data suggest that worker bees of *A. cerana* started foraging activities earlier in the morning and ceased later in the evening that *A. mellifera* workers. The total duration of foraging activity of *A. cerana* worker bees is significantly more than those of *A. mellifera*. This enables *A. cerana* worker bees to forage and pollinate flowers for extended periods of time compared to *A. mellifera*. Moreover, the duration of peak foraging activity was longer for *A. cerana*. Verma and Partap (1994) observed that duration of foraging activities of

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*A. cerana* was 12.1 h on cabbage and 11.03 h on cauliflower during March. 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 findings on the duration of peak foraging differ from those of Verma and Dulta (1986) who reported that under the agroecological conditions of high-mountain areas, the peak of foraging activities of *A. mellifera* on apple flower begins after the peak foraging activity of *A. 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 *A. mellifera* than *A. 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 *A. cerana* (Dulta and Verma, 1989).

The number of flowers visited per minute by a TW and a SW *A. cerana* worker bee was greater compared to an *A. mellifera* worker bee; however, this difference was not statistically significant. However, more foragers of *A. cerana* worked flowers as top workers and collected mainly pollen whereas *A. mellifera* bees worked mostly as side workers and collected nectar from both peach and plum flowers. Top workers collecting pollen are considered to be better pollinators than side workers collecting nectar. Our observations on high floral fidelity exhibited by both the species agree with those of Verma and Rana (1994) who found only 2-7 % of pollen loads were mixed.

The heavier pollen loads carried by *A. mellifera* compared to that carried by *A. cerana* may be related to the larger size of body parts for the former species (Mattu and Verma, 1980; 1983; 1984 a, b, c). Free (1960) and Kendall and Solomon (1973) observed that insects with smaller body parts carry little pollen compared to larger, hairy-bodied insects. 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 *A. cerana*, pollen collectors outnumbered nectar collectors throughout the day on both peach and plum whereas for *A. mellifera* pollen collectors outnumbered nectar collectors in the morning and in the afternoon nectar collectors outnumbered pollen collectors on both peach and plum. P: N ratio was significantly higher for *A. cerana* throughout the day than *A. mellifera*. This may be because flowers of both peach and plum 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) showed that *A. cerana* when visiting cauliflower and cabbage collected either pollen or nectar but never both on an individual foraging trip. Similar observations were recorded by Free (1960) for *A. mellifera*.

Observations that the number of forager bees of both species was greater near the hive agree with earlier observations of Eckert (1933) and Lavin (1959) who reported that if sufficient forage is available, bees prefer to work close to their hives. Based on the observations discussed above, it can be concluded that *A. cerana* is a better pollinator than *A. mellifera* of peach and plum in the Kathmandu valley of Nepal.

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