Chapter 48

Pollination of Strawberry by the Asian Hive Bee, *Apis cerana*

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Today, commercialisation of agriculture is being promoted on a large scale in countries of the Hindu Kush-Himalayan region. In recent years farmers in the Kathmandu valley of Nepal have started cultivating strawberry as it is one of the high payoff fruit crops. Scientific reports available from different countries show that the yield, size and shape of strawberry fruit depend upon the adequate pollination of its flowers by different insects (McGregor, 1976; Crane, 1990). Among different species of pollinating insects, domesticated species of honeybees such as *Apis cerana* and *Apis mellifera* are reported to be the principal pollinators of strawberry flower (Nye and Anderson, 1974; Singh, 1979).

So far, studies on strawberry pollination have been carried out in the European countries using *Apis mellifera*. These studies show that the honeybee (*Apis mellifera*) pollination enhances both quality and yield of strawberry fruit (Free, 1968; Moeller and Koval, 1973; Nye and Anderson, 1974; Goodman and Oldroyd, 1988). However, since very little work has been done on its pollination using the Asian hive bee, *Apis cerana* in the Hindu Kush-Himalayan region countries, therefore, we studied the foraging behaviour of *Apis cerana* and its impact on the quality and yield of strawberry fruit under the agroecological conditions of the Kathmandu valley of Nepal.

Materials and Methods

Plants of strawberry (*Fragaria ananassa* var. Nyoho) were raised on the experimental plots of ICIMOD's Trial and Demonstration Farm, Godavari, in the Kathmandu valley of Nepal (27°35'N and 85°24'E) at a plant to plant distance of 30–40 cm and row to row distance of 40–50 cm. Observations were recorded for number of flowers per plant per day, size of flowers, and total blooming period of the crop.

For the pollination studies, three sets each of three experimental groups were used: control (plants in a cage with no insect pollinators); open pollination (plants accessible to naturally occurring insect pollinators); and honeybee pollination (plants caged with *Apis cerana*). For the control plots, about 50 plants were covered with a cage to exclude all natural insect pollinators including free ranging honeybees. In open-pollinated plots observations were taken of the plants not protected by cages which permitted naturally occurring insect pollinators

to visit the flowers freely. In honeybee-pollinated plots about 200 plants were covered with a cage 12 m long, 3 m wide, and 2–2.5 m high, so that no insect pollinator could enter. Three such pollination cages were used. When strawberry started blooming, a medium-sized colony of *Apis cerana* having seven frames covered with bees and free of any sign of disease was placed in each of the three pollination cages.

Observations on foraging behaviour were recorded for the daily initiation and cessation of foraging, peak hours of foraging activity, duration of foraging trips, the individual bee's choice of nectar or pollen, the weight of pollen carried by a bee, the time spent on each flower, and the number of flowers visited per minute. Observations of the weight of pollen load, time spent on the flower, the number of flowers visited per minute by a bee and the number of pollen and nectar collectors were taken at three different times of the day i.e.09.00 (2.57 h after sun rise), 12.00 (5.57 h after sun rise) and 15.00 h (8.57 h after sun rise).

In order to differentiate between nectar and pollen collectors, returning foragers were collected with the aid of an aspirator at the hive entrance and frozen to prevent regurgitation of nectar. The frozen bees were sorted for the type of forage, following the method of Erickson *et al.* (1973). The peak hours of foraging activity were determined by counting the number of bees entering the hive in a three-minute period each hour from early morning until late evening. The weight of pollen loads were determined by anaesthetizing samples of returning bees with carbon dioxide (Frisch, 1967), removing their pollen loads, and weighing them. Duration of foraging trip was determined by marking 25 forager bees with nail polish of different colours and noting the times when each of these marked bees leaves the hive for foraging and comes back.

After ripe, the berries from control, open-pollinated, and bee-pollinated plants were picked up. Berries from each treatment were counted and weighed. Number of well-formed (perfect) as well as misshapen berries from each treatment were also counted. Changes in the quality and quantity of berries as a result of bee-pollination were assessed by comparison of the counts of number of berries, weight of berries and percent of misshapen berries. Data were analyzed statistically using analysis of variance.

Results

Strawberry plants had an average number of 3.2 ± 1.1 flowers each day. White flowers were 2.4 ± 0.3 cm in diameter (Table 1). The flowers remained open for three to four days. Strawberries started flowering during mid-February till mid-May and the total flowering period of the crop lasted for about three months.

Table 1: Floral biology of strawberry in the Kathmandu valley, Nepal. Values are mean ± s.e.

Parameter	Measurement
No. of flowers/plant/day	3.2 ± 1.1
Diameter of flower	2.4 ± 0.3 cm
Total flowering period	Three months(Mid-February to Mid-May)

Observations on the foraging behaviour of *Apis cerana* are summarised in Table 2. Worker bees of *Apis cerana* foraged on strawberry flowers for 11.27 h per day, starting at 06.59 h (56 min after sun rise) in the morning and stopping at 18.28 h (10 min after sun set) in the evening. Peak foraging occurred from 11.00 to 14.00 hours when the outside temperature was 23–27°C and relative humidity ranged between 58–77%. The average duration of each foraging trip was 18.2 ± 2.3 min. Each foraging bee made an average of 11.5 ± 1.9 trips per day and visited an average number of 157.9 ± 27.9 flowers per trip.

Each worker bee of the *Apis cerana* spent on an average 4.5, 4.3 and 8.8 s on each flower and visited an average number of 9.6, 9.9 and 6.7 flowers per minute at 09.00 (2.57 h after sun rise), 12.00 (5.57 h after sun rise), and 15.00 h (8.57 h after sun rise) respectively. At 09.00 h pollen collectors outnumbered nectar collectors (P:

Table 2: Foraging behaviour of *Apis cerana* on strawberry flowers in the Kathmandu valley, Nepal. Values are mean ± s.e. Statistical results are from analysis of variance.

Parameter	Measurement
Initiation of foraging (time of day)	06.59 ± 0.04 h (56 min after sunrise)
Cessation of foraging (time of day)	18.28 ± 0.05 h (10 min after sun set)
Duration of foraging activity (h)	11.27 ± 0.04 h
Peak foraging hours (time of day)	1100 - 1400 h
Duration of foraging trip	18.2 ± 2.3 min
Number of foraging trips per day	11.5 ± 1.9
Number of flowers visited per trip	157.9 ± 27.9
Time spent on flower	
09.00 h (2.57 h after sun rise)	4.5 ± 0.06 s
12.00 h (5.57 h after sun rise)	4.3 ± 0.03 s
15.00 h (8.57 h after sun rise)	8.8 ± 0.03 s
	F = 108.9
	df = 147
No. of flowers visited per minute	
09.00 h (2.57 h after sun rise)	9.6 ± 0.7
12.00 h (5.57 h after sun rise)	9.9 ± 0.3
15.00 h (8.57 h after sun rise)	6.7 ± 0.9
	F = 27.1
	df = 147
Weight of pollen load (mg)	
09.00 h (2.57 h after sun rise)	9.4 ± 0.9
12.00 h (5.57 h after sun rise)	11.7 ± 1.2
15.00 h (8.57 h after sun rise)	6.8 ± 2.8
	F = 21.6
	df = 27
Ratio between pollen-collectors and nectar-collectors (P: N)	
09.00 h (2.57 h after sun rise)	1.0 : 0.4
12.00 h (5.57 h after sun rise)	1.0 : 1.5
15.00 h (8.57 h after sun rise)	1.0 : 2.3

Note: Differences in the time on flower, number of flowers visited per minute and the weight of pollen loads carried between 09.00, 12.00 and 15.00 h of the day are significant at $P<0.01$

N=1.0: 0.4) whereas at 12.00 h and 15.00 h nectar collectors outnumbered pollen collectors (P: N= 1.0: 1.5 at 1200 h and P: N=1.0: 2.3 at 1500 h). Pollen loads averaged 9.4 ± 1.3 mg, 11.7 ± 1.9 mg and 6.8 ± 1.8 mg at 09.00 h, 12.00 h, and 15.00 h respectively.

The effects of *Apis cerana* pollination on the yield and quality of berries are summarised in Table 3. Bee pollination enhanced fruit set by 112.3 and 21.4%; and weight per fruit by 47.9 and 20.3% in comparison to control and open pollinated plants respectively. It reduced the percentage of misshapen fruits by 41.7 and 31.8% compared to control and open pollinated plants respectively.

Discussion

Strawberries start blooming during spring season in Kathmandu valley of Nepal. Pollination of its flowers is possible by using domesticated honeybees as well as other natural insect pollinators. But during recent years the populations of the natural insect pollinators is decreasing rapidly because of the heavy use of pesticides on agricultural and horticultural crops and the loss of habitat quality and quantity. Therefore, domesticated species of honeybee remain the most important crop pollinators. The total flowering period of crop extending upto three months suggests that this crop can be a good source of nectar and pollen to bees.

Results of the present investigation show that the duration of foraging activity of *Apis cerana* worker bees was 11.27 h per day. Our earlier studies (Partap and Verma, 1994; Verma and Partap 1993; 1994) on the foraging behaviour of *Apis cerana* on other crops flowering during early spring season in Kathmandu valley of Nepal also show that duration of foraging activity was 11.03 h on cauliflower; 12.05 h on cabbage and 11.5 h on radish. The potential for long foraging hours enables honey bees to pollinate a maximum number of flowers per day and makes them efficient pollinators.

The peak hours of foraging activity were between 11.00 to 14.00 h whereas Singh (1979) observed the maximum activity of *Apis cerana* between 09.00 and 14.00 h, with only a few bees flying after 16.00 h under the agroclimatic conditions of Uttar Pradesh hills in India. Our observation that the worker bees spent 4.5–8.8 s on each flower agrees to those of Petkov (1965) and Free (1968) who reported that *A. mellifera* worker bees (nectar collectors) averaged 7–10 s

Table 3: Effects of *Apis cerana* pollination on strawberry fruit. Values are mean ± s.e. Statistical results are from analysis of variance.

Parameter	Control	Open-pollinated	Bee-pollinated	% Increase over control	% increase over open pollinated	Values of F and degrees of freedom
Number of fruits/plant/picking	1.6 ± 0.7	2.8 ± 0.9	3.4 ± 0.4	112.3	21.4	$F = 136.3$ $df = 87$
Weight per fruit	4.8 ± 1.9	5.9 ± 1.0	7.1 ± 0.7	47.9	20.3	$F = 85.6$ $df = 57$
% misshapen fruits	64.3	22.5	12.6	-	-	$F = 97.1$ $df = 21$

per flower and that the pollen collectors spent less time on each flower. Worker bees of *Apis cerana* collected heavier pollen loads during morning and noon hours. This might be because the maximum number of pollen grains was presented by this crop during morning and noon hours. Thus, the temperature (21–25°C) and relative humidity (50–78%) during these hours are not only best suited for the peak foraging activities of worker bees but also for gathering heavier pollen loads. This is further supported by the fact that pollen collectors outnumbered nectar collectors ($P > N$) during morning hours and nectar collectors outnumbered pollen collected ($N > P$) during afternoon hours. The possible reason for this change from pollen to nectar collection during the day might be a depletion of available pollen as foragers collected it in the morning hours.

Apis cerana pollination enhanced fruit set and fruit weight compared to control and open-pollinated plants. Increase in fruit set and fruit weight as a result of bee pollination could be due to greater number of the pollinators in the plots caged with bees and the superior pollinating efficiency of honeybees. Natural insect pollinators, on the other hand, due to their lower number and lower pollinating efficiency pollinated fewer flowers which resulted in low fruit set and fruit weight. Fruit set in the plots caged without pollinating insects was due to some amount of self pollination which might have occurred by pollen blown from anthers on to the stigmas. Studies carried out in the developed countries also show that honeybee *(Apis mellifera)* pollination increased fruit set by 10–25% and fruit yield by 18–100% depending upon the cultivar (Free, 1968; Moeller and Koval, 1973; Nye and Anderson, 1974; Lackett and Burkhardt, 1979; Svensson, 1991).

Apis cerana pollination also enhanced the fruit quality by reducing the percentage of misshapen fruits. Strawberry flower has many carpels and it is necessary that all of these should contain a fertilised ovule (i.e. produce a seed) in order to produce a well-formed berry. Honeybees micromanipulated the flowers and transferred sufficient pollen grains to fertilise all the ovules in more flowers, thereby resulting in higher number of perfect berries and reducing the percentage of misshapen fruits compared to the control and open pollinated flowers. It has been already reported that honeybee (*Apis mellifera*) pollination increased the number of large and perfect fruits by 7–16% and decreased malformed fruits by 9–41% (Free, 1968; Moeller and Koval, 1973; Nye and Anderson, 1974; Goodman and Oldroyd, 1988).

Low fruit set and higher percentage of misshapen fruits in the plots caged without pollinating insects were due to insufficient pollination. Hughes (1961) also reported that plants caged without pollinating insects resulted in decreased yield and produced large percentage of malformed fruits. It has been reported that about 11–15 bee visits per flower are necessary to fertilise all the ovules (Skrebtsova, 1957; Jaycox, 1970). Skrebtsova

(1957) also reported that more than 20 visits increased the mean weight of the berries. Such a large number of visits per flower can be ensured by managing pollination through domesticated species of honeybee only.

Large attractive berries are faster to pick, thus saving the time of the farmer. Such berries also fetch higher market price compared to small, misshapen ones, thus increasing the income of the farmers. Honeybee pollination of strawberry is therefore, of great benefit to the farmers.

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