Chapter 47

Foraging Behaviour of *Apis cerana* on Sweet Orange (*Citrus sinensis* var. Red Junar) and its Impact on Fruit Production

Uma Partap
International Centre for Integrated Mountain Development (ICIMOD)
PO Box 3226, Kathmandu, Nepal

The sweet oranges (*Citrus sinensis* var. Red Junar) have been widely planted under the middle hill region of Nepal. They bloom during March–April and produce plenty of nectar and pollen. Flowers are usually self-compatible but benefit to a great deal from cross-pollination by honeybees. Honeybees collect lots of honey from citrus flowers.

The pollination requirements of the different kinds of citrus vary from almost complete self-sterility in some cultivars to complete self-fertility in others. While in the self-sterile cultivars pollen must be transferred from those of another compatible varieties for maximum fruit production, in self-fertile cultivars the plant is benefited if pollen is moved from flower to flower within the cultivar or within the species. In addition, there are varying degrees of parthenocarpic development of the fruit, for example, 'Washington Navel' oranges have the ability to set parthenocarpic fruit (Webber *et al*, 1943). Therefore, studies on foraging behaviour of *Apis cerana* on the commonly planted sweet orange (*Citrus sinensis*, a local variety called Red Junar) flower and its impact on the quality and yield in the middle hill areas were carried out.

Materials and Methods

Foraging behaviour of *Apis cerana* on the flowers of a local variety of sweet orange (*Citrus sinensis* var. Red Junar) and its impact on fruit production was studied at HMG's Horticulture Farm, Kirtipur, in the Kathmandu valley of Nepal. Observations on floral biology included the number of flowers per plant per day, size of flowers, and total blooming period of the crop. Observations on the foraging behaviour of the bees were made on the daily time of initiation and cessation of foraging, total duration of foraging activity, peak foraging hours, time spent on the flower, number of flowers visited per minute, number of foragers per 1,000 flowers per 10 minutes, 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.

For the pollination studies, three treatments were applied as follows: 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 details of the experimental design, please see Chapter 46 on "Pollination of peach and plum by *Apis cerana* (Partap *et al*, 1999 a) of this book. Data were analyzed statistically using analysis of variance.

Results

Flowering started in the spring (late March to early April). The flowers were whitish in colour, had a pleasant fragrance and were highly attractive to the bees. The size of flowers varied from 2.0–2.5 cm. They open primarily from 9 a.m. to 4 p.m. with the peak period about noon. The flowers never close; the petals shed a few days later. Each flower had five oblong, glossy petals, ten stamens consisting of upright white filaments, united into three groups at the base, with yellow anthers on the tip and a greenish multilocular overy with 9–13 locules, a style and a globose yellowish stigma that terminated the style. A nectariferous disc was situated at the base of the ovary.

Apis cerana started their foraging activities early in the morning at 0600 h and ceased late in the evening at 1835 h. The total duration of foraging activity was 12.05 hours and the average duration of a foraging trip 22.6 minutes. Peak foraging activity was observed between 1000–1200 h. A nectar collector spent an average of 9.3 seconds and a pollen collector spent 4.1 seconds per flower, and visited an average number of 5.5 and 8.2 flowers per minute respectively. A pollen collector on an average collected 6.5 mg of pollen load (Table 1).

Apis cerana enhanced fruit set by 24.2 per cent and nine per cent, and reduced fruit drop by 45.9 and 2.98 per cent as compared to control and open pollinated respectively. Bee pollination also enhanced the fruit quality by enhancing the fruit size, fruit weight, amount of fruit juice and the amount of sugars in the fruit juice. It increased the fruit length by 8.9 and 2.5 per cent, and fruit diameter by 34.8 and 9.8 per cent as compared to control and open pollinated respectively. Bee pollination enhanced the amount of fruit juice by 67.7 and 44.4 per cent, and fruit sugar by 39.1 and 25.5 per cent as compared to control and open pollinated respectively. It also increased the number of seeds per fruit. Bee pollination reduced the citric acid content by 29.2 per cent compared to control, there was no difference in the citric acid content in the fruits from bee-pollinated and open-pollinated plants (Table 2).

Table 1. Foraging behaviour of *Apis cerana* on sweet orange bloom

Parameter	Measurement
Initiation of foraging activity (time of day)	06.30 ± 0.2
Cessation of foraging activity (time of day)	18.35 ± 0.3
Total duration of foraging activity (h)	12.05 ± 5
Peak foraging hours (time of day)	10.00 - 12.00
Time spent per flower by a bee (s)	
i. Pollen collector	4.1 ± 0.8
ii. Nectar collector	9.3 ± 1.3
Number of flowers visited per minute by a bee	
i. Pollen collector	8.2 ± 1.3
ii. Nectar collector	5.5 ± 1.2
Number of bees per 1000 flowers per 10 minutes	6.1 ± 1.2
Weight of pollen load	6.5 ± 1.7

Discussion

Sweet orange blooms during spring in the Kathmandu valley. Its flowers are visited by a number of different kinds of insects for their abundant nectar and pollen. But honeybees are important for pollination. They collect both pollen and nectar from citrus. The flower is so constructed that if the bee has visited a previous pollen-producing flower, some pollen is likely to be transferred to the next stigma visited, thus

Table 2. Effect of *Apis cerana* pollination on quality and yield of sweet orange

Parameter	Control	Open Pollinated	Bee Pollinated	% Increase over Control	% Increase over Open Pollinated
Initial Fruit set (%)	15.5±5.7	30.7±4.9	39.7±2.6	24.2	9.0
% Fruit drop	50	12.1	4.06	-45.9	-2.98
Final fruit set (%)	7.5±7.5	26.9±6.7	38.09±4.4	30.6	11.8
Weight per fruit (g)	146	157.5	170	35.04	7.9
Fruit length (mm)	60.6	64.4	66.0	8.9	2.5
Fruit diameter (mm)	54.9	67.4	74.0	34.8	9.8
Peel thickness (mm)	6.6	5.9	4.4	-33.3	-25.2
Juice per fruit (g)	155	180	260	67.7	44.4
% Citric acid	2.4	1.7	1.7	-29.2	No difference
% Sugar in juice	9.2	10.8	12.8	39.1	25.5

affecting pollination. Thus, honeybee is unquestionably the primary pollinating agent of citrus, other pollinating insects are minor they are not present in abundance in nature and can not be managed for pollination. Wind and gravity can not affect pollination in citrus (Free 1993, McGregor, 1976)

Our observation on the foraging behaviour that the pollen collectors spent comparatively less time and visited more number of flowers than nectar collectors agree to that of Hassanein and Ibrahim (1959) who reported that the nectar collectors spent 15-20 s per flower compared to 5-8 s by the pollen collectors. *A. cerana* mostly worked flowers from top and collected mainly pollen indicating its greater efficiency in fruit-crop pollination. Top workers collecting pollen are considered to be better pollinators than side workers collecting nectar. Nectar collectors, on the other hand alight on the petals and collect nectar without touching the anthers. Similar results were reported by Hassanein and Ibrahim (1959) for citrus and Partap *et al.* (1999 b) for peach and plum.

Apis cerana pollination enhanced fruit set and fruit weight, and increased both length and diameter of fruits as compared to control and open-pollinated plants. However, it also increased the number of seeds per fruit, which can be considered as a negative impact on quality of fruit in citrus. Thus one has a choice of managing bee pollination for having higher fruit set and fruits with more juice of higher sugar content or lower fruit set with less number of seeds with relatively less juice and lower sugar content. Increase in fruit set and fruit weight as a result of bee pollination could be because of greater numbers of pollinators in the plots caged with bees and the superior pollinating efficiency of honeybees. Natural insect pollinators, on the other hand, because of their lower numbers and lower pollinating efficiency resulted in lower fruit set and fruit weight. Any fruit set in plots caged without pollinating insects resulted from a limited amount of self-pollination that might have occurred by pollen blown from anthers on to stigmas. However, on the basis of available literature, McGregor (1976) analyzed that the results of bee pollination in citrus depend upon the cultivars.

Our results agree with those of Glukhov (1955) who reported that orange trees (cultivar not mentioned) pollinated by bees produced four times as much fruit as trees isolated from bees. Similarly, Zavrashvili (1966) reported that the orange crop in cages without bees was 54.4 per cent lower than that on trees in the open. The cultivar was not identified nor was there a measure of cage effect on the plant other than pollination effect. Wafa and Ibrahim (1963) obtained 31 per cent increase in set of fruit on the 'Elfelaha' orange, 22 per cent increase in fruit weight, 33 per cent more juice, and 36 per cent more seeds from fruits on trees visited by bees than on trees from which bees were excluded. Hassanein and Ibrahim (1959) reported a set of 2.6 per cent of flowers of the 'Khalili' orange where insects were excluded, 10.4 per cent set where honeybees were present, and 7.4 per cent on open blooms. Although the results of tests are meager, some beneficial effects of pollination on oranges are indicated.

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