Chapter 2

The Asian Hive Bee, *Apis cerana*, as a Pollinator of Vegetable Crops

Vegetable seed production offers an opportunity for the commercialisation of agriculture. Sufficient or adequate pollination of vegetable crops is essential for the production of good quality seeds. Many of these vegetable crops are completely or partially self-incompatible and incapable of pollinating themselves, therefore, the cross-pollination of their flowers by insects, especially honeybees, is essential.

Under the USAID/ADB-funded beekeeping research and development programme at ICIMOD, detailed investigations have been conducted on the use of the native Asian hive bee, *Apis cerana,* to enhance yields and improve the seed quality of important vegetable crops grown in the Kathmandu Valley. The results of these investigations are summarised below.

Cauliflower

The cauliflower is an important vegetable crop widely grown in temperate and sub-tropical regions. Since most of its cultivars are self-incompatible, cross-pollination of its flowers is essential for seed production. Cross-pollination of the cauliflower is mostly carried out by insect pollinators, especially honeybees which are the most efficient

pollinators, because they can be managed in sufficient number and exhibit flower constancy.

Cauliflower

The floral biology of the plant, the foraging behaviour of honeybees in relation to pollination, and the qualitative and quantitative effects of *Apis cerana* pollination on cauliflower seed production have been researched at ICIMOD. For this, cauliflower plants (*Brassica oleracea*, var. *botrytis*, sub-var Kathmandu Local) were raised on experimental plots at the HMG/FAO Vegetable Seed Production Farm, Khumaltar, during August 1991. (See plate above). The plant to plant distance was 50-60cm and the row to row distance was 80-90cm. Three sets of experiments were performed when the cauliflower crop started blooming in the first week of March, 1992 (1) control (no insect pollinators), (2) open-pollinated (only natural insect pollinators), and (3) bee-pollinated.

Data on the floral biology of cauliflower plants are given in Table 2.1. The results suggest that the average number of branches per plant was seven and that each branch contained an average of 600 flowers. The average diameter of each flower was 15mm and the buds were about

Table 2.1: Floral Biology of Cauliflower, Cabbage, Radish, and Lettuce Plants Grown in the Kathmandu Valley, Nepal

Parameter	Cauliflower	Cabbage	Radish	Lettuce
No. of flowers per branch	M 600 RV 500-700	M 94 RV 84-106	M 153 RV 104-201	M 75 RV 15-175
No. of flowers per plant	M 4,000 RV 3,000-5,000	M 1,128 RV 900-1,500	M 1,500 RV 1,000-2,000	M 1,500 RV 1,000-2,300
Time of flower opening	Opens in the morning and remains open for about 2-3 days	Same as in Cauliflower	Same as in Cauliflower	M 0822h RV 0800-0900h
Time of flower closing				M 1,135 RV 1,100-1,200
Diameter of flower/head* (mm)	M 15 RV 12-16	M 14 RV 12-15	M 14 RV 12-16	M 15 RV 12-16
Length of bud (mm)	M 9 RV 8-10	M 8 RV 7-9	M 11 RV 10-12	M 7 RV 6-9
Total flowering period	One month (mid Feb to mid Mar)	One month (mid March to mid April)	One month (1st week of March to the last week)	One month (mid June to mid July)

* In Lettuce small flowers cluster in the form of a head (or capitulum) surrounded by an involucre of bracts. Each head contains 15-25 small flowers (or florets).

M = Mean
RV = Range of variation

9mm long. The flowers opened in the morning and remained open for about two to three days. The total blooming period of the crop lasted for about one month.

Observations on the foraging behaviour of *Apis cerana* on this plant are given in Table 2.2. The results suggest that *Apis cerana* started foraging at 0702 h in the morning and ceased their foraging activity at 1805 hours in the evening. The total duration of foraging activity was

Table 2.2: Foraging Behaviour of *Apis cerana* on Cauliflower, Cabbage, Radish, and Lettuce Plants in Kathmandu Valley, Nepal
(Values are mean ± S.E.)

Parameter	Cauliflower	Cabbage	Radish	Lettuce*
Initiation of foraging (time of day)	0702 ± 0.02	0630 ± 0.02	0640 ± 0.02	0830 ± 0.05
Cessation of foraging (time of day)	1805 ± 0.02	1835 ± 0.03	1830 ± 0.02	1130 ± 0.05
Duration of foraging activity (h)	11.03 ± 0.03	12.05 ± 0.05	11.50 ± 0.04	3.00 ± 0.05
Peak foraging hours (time of day)	1100 - 1300	1100 - 1300	1100 - 1300	0900 - 1100
Duration of foraging trip (min)	26.87 ± 0.81	23.87 ± 0.42	22.13 ± 0.03	15.66 ± 0.04
Time on flower (sec) at				
0900 h	5.83 ± 0.3	4.33 ± 0.21	4.34 ± 0.06	
1200 h	6.69 ± 0.5	4.63 ± 0.32	5.31 ± 0.03	3.84 ± 0.02
1500 h	5.14 ± 0.2	6.90 ± 0.24	12.79 ± 0.03	
Time taken to shift from flower to flower (sec) at				
0900 h	2.51 ± 0.1	3.33 ± 0.50	3.08 ± 0.10	
1200 h	3.35 ± 0.3	3.63 ± 0.30	2.83 ± 0.30	2.69 ± 0.07
1500 h	2.15 ± 0.1	3.43 ± 0.30	3.31 ± 0.80	
Distance covered from flower to flower (cm) at				
0900 h	9.43 ± 2.0	09.80 ± 2.25	20.97 ± 1.20	9.86 ± 2.21
1200 h	9.25 ± 1.1	21.83 ± 1.50	21.56 ± 0.90	
1500 h	9.04 ± 1.5	22.00 ± 3.02	20.47 ± 1.90	
No. of flowers visited per min at				
0900 h	7.0 ± 0.5	7.00 ± 0.40	8.00 ± 0.50	
1200 h	6.0 ± 1.0	7.00 ± 0.50	9.00 ± 0.40	13.00 ± 1.00
1500 h	8.0 ± 0.5	5.00 ± 0.50	5.00 ± 0.50	
Pollen load (mg) at				
0900 h	7.0 ± 0.5	08.00 ± 0.03	11.00 ± 0.20	
1200 h	9.0 ± 0.3	10.00 ± 0.01	10.00 ± 0.50	8.00 ± 0.10
1500 h	5.0 ± 0.5	08.00 ± 0.49	7.00 ± 0.50	
Ratio between pollen collectors and nectar collectors (P:N) at				
0900 h	7:3	6:4	6:4	Bees collect
1200 h	5:5	5:5	5:5	only pollen
1500 h	3:7	4:6	3:7	
Top vs side workers at				
0900 h	6:4	9:1	9:1	No side
1200 h	5:5	7:3	6:4	worker
1500 h	4:6	4:6	2:8	observed
No. of bees per plant at				
0900 h	9	3	5	4
1200 h	8	4	9	
1500 h	4	3	4	
Non-*cerana* pollinators	Insects such as *Eristalis*, stingless bees, butterflies, ladybird beetles, etc.	Insects such as *Eristalis*, stingless bees, butterflies, ladybird beetles, etc.	Insects such as *Eristalis*, stingless bees, butterflies, ladybird beetles, etc.	Insects such as *Eristalis*, stingless bees, butterflies, ladybird beetles, etc.
Pollen+Nectar collectors (P+N) at				
0900 h	nil	nil	4%	nil
1200 h	nil	nil	7%	
1500 h	nil	nil	nil	

* In lettuce, flowers open in the morning for three to four hours only (i.e., from 0822 h to 1135 h). Observations on foraging behaviour were recorded during these hours only.

11.03 hours and peak foraging activity occurred between 1100-1300 hours (Fig.2.1). The duration of each foraging trip was 26.87 min. Each worker bee spent an average time of five to seven seconds on a flower, visited an average of six to eight flowers per minute, carried an average pollen load of five to eight miligramme per trip, and the number of bees per plant varied from four to nine during different times of the day. An interesting aspect of their behaviour was that, at 0900 hours, pollen collectors outnumbered nectar collectors. This ratio was equal at 1200 hours and at 1500 hours nectar collectors outnumbered pollen collectors. *Apis cerana* collected either pollen or nectar but not both during a single foraging trip.

The qualitative and quantitative effects of honeybee pollination on seed production are given in Table 2.3. These results suggest that bee pollination significantly increased fruit set by 57 and 20 per cent compared to control and open-pollinated plants. Similarly, the number of seeds per siliqua increased by 500 and 33.8 per cent compared to control and open-pollinated plants. *Apis cerana* pollination increased the seed weight increase by 62.9 and 37.4 per cent and enhanced seed germination by 16 and 12 per cent compared to control and open-pollinated plants.

Cabbage

Like cauliflower, many varieties of this crop are self-incompatible and require cross-pollination of their flowers for seed production. In order to study the effects of *Apis cerana* pollination on cabbage seed production, cabbage plants (*Brassica oleracea*, var *capitata*, subvar. Pride of India) were raised on experimental plots in HMG/FAO Vegetable Seed Production Farm, Khumaltar, during the second week of September, 1991, in the same way as the cauliflower plants. (See plate, page 17). The crop started blooming during mid-March 1992 and, at that time, three sets of experiments, similar to those in the case of cauliflower plants, were performed -(1) control, (2) open-pollinated, and (3) bee-pollinated.

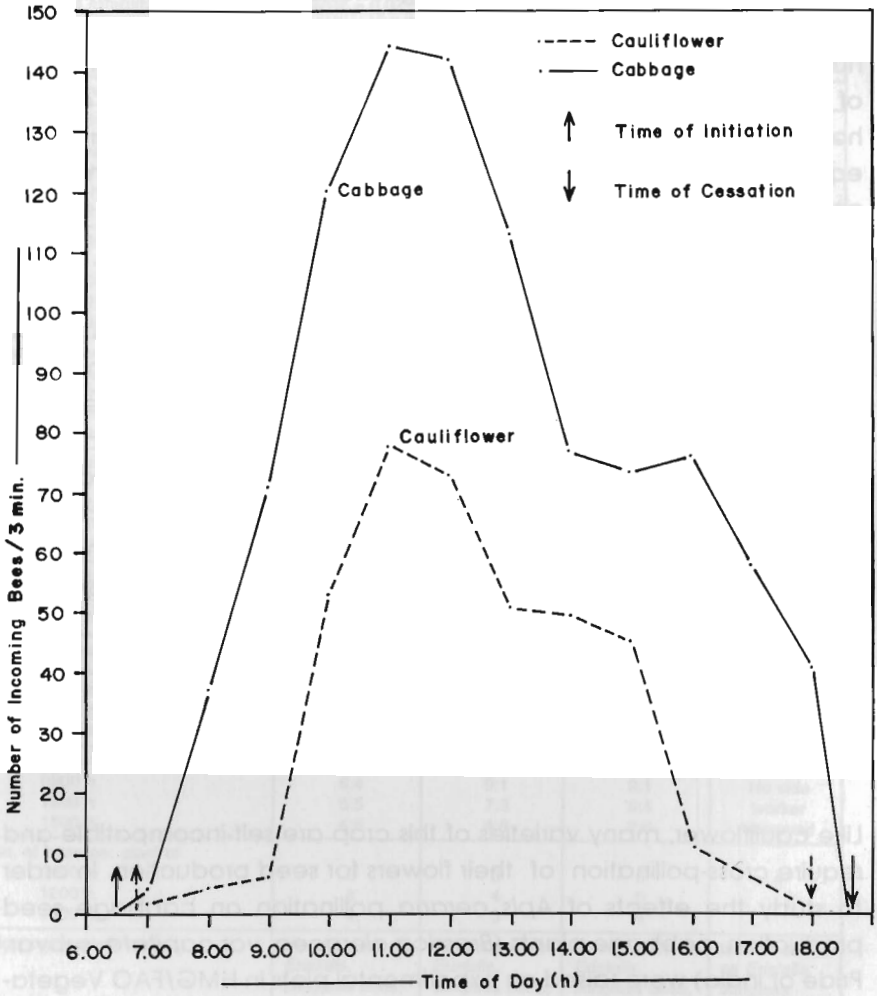

Fig. 2.1: Peak hours of foraging activity (number of incoming bees/3 min.) of *Apis cerana* on cauliflower and cabbage plants in Kathmandu Valley

Cabbage

Table 2.3: Quantitative and Qualitative Effects of *Apis cerana* Pollination on Cauliflower Seeds

(Values are mean ± S.E.)

Parameter	Control	Open-pollinated	Bee-pollinated	Per cent Increase[1]	Per cent Increase[2]
Per cent fruit set	21.0	58.0	78.0	57.0	20.0
No. of seeds per siliqua	3.3 ± 1.4	14.8 ± 0.6	19.8 ± 0.5	500**	33.8**
100 seed weight (mg)	264 ± 7	313 ± 8	430 ± 12	62.9**	37.4**
Per cent germination	80.0	84.0	96.0	16.0	12.0

1. Increase compared to control
2. Increase compared to open-pollinated

** Significant (P = 0.01)

Observations on the floral biology of cabbage plants are recorded in Table 2.1. The results show that each plant had an average of 13 branches and each branch bore an average of 94 flowers. Each flower was 14mm in diameter and its bud was eight milimetres long. Flowers opened in the morning and remained open for about three days like those of cauliflower. The total blooming period of the crop lasted for about a month, i.e., mid-March to mid-April.

Data on foraging behaviour (Table 2.2) suggest that *Apis cerana* worker bees began foraging at 0630 hours in the morning and ceased their foraging activities at 1835 h in the evening; thus the total duration of foraging activity was 12.05 hours. Peak foraging activity was observed between 1000-1300 hours, and the duration of each foraging trip was 23.87 min. Each bee made an average of 10 foraging trips per day (Fig. 2.1).

Apis cerana worker bees either collected pollen or nectar but never both during the same foraging trip. During morning hours (at 0900 hours), pollen collectors outnumbered nectar collectors (P:N=6:4). This ratio was equal at 1200 hours (P:N=5:5) and, at 1500 hours, nectar collectors outnumbered pollen collectors (P:N = 4:6). Each worker bee spent an average of four to seven seconds on a flower and collected eight to 10mg of pollen load during different hours of the day.

The qualitative and quantitative effects of *Apis cerana* pollination (Table 2.4) suggest that bee pollination significantly enhanced the fruit and seed set by 27 and 52.9 per cent respectively compared to open-pollinated plants. Control plants did not set any fruit indicating that the crop is self-incompatible and required cross-pollination. Bee pollination significantly increased the weight of the seeds by 51 per cent and germination by 28 per cent compared to open-pollinated plants. It also decreased the time required for the initiation of germination.

Radish

Radish is also an important vegetable and salad crop. Many varieties of radish are self-incompatible and almost entirely cross-pollinated.

Table 2.4: Quantitative and Qualitative Effects of *Apis cerana* Pollination on Cabbage Seeds

(Values are Mean ± S.E.)

Parameter	Control	Open-pollinated	Bee-pollinated	Per cent Increase
Per cent fruit set	No Fruit Set	52.0	79.0	27.0
No. of seeds per siliqua	-	18.5 ± 0.1	28.3 ± 0.7	52.9**
100 seed weight (mg)	-	278.0 ± 4.0	420.0 ± 3.0	51.1**
Per cent germination	-	56.0	84.0	28.0

** Significant (P = 0.01)

Cross-pollination of its flowers by honeybees and other natural insect pollinators is, therefore, of great significance in seed production. In order to study the effect of bee pollination on radish seed production, some field experiments were carried out. Radish plants (*Raphanus sativus*, var Meno Early) were raised at the HMG/FAO Vegetable Seed Production Farm, Khumaltar, during the last week of September (see plate, page 20). The plant to plant distance was 50cm and the row to row distance was 75cm. Three sets of experiments were performed, similar to those in the case of cauliflower plants, when the crop started blooming in the first week of March - (1) control, (2) open-pollinated, and (3) bee-pollinated.

Table 2.1 shows the floral biology of the crop. Each radish plant had an average of 10 branches and each branch bore an average of 155 flowers which opened in the morning and remained open for about three days. Each bud was 11mm long and each flower was 15mm in diameter. The crop started blooming from the first week of March until the last week of March, thus the total flowering period of the crop was one month.

Observations on the foraging behaviour of *Apis cerana* are summarised in Table 2.2. *Apis cerana* worker bees started foraging

early in the morning at 0640 h and ceased their foraging activities at 1830 hours in the evening. Thus the total duration of foraging activity was 11.50 hours per day. Peak foraging activity was observed between 1100-1300 hours. Each bee made an average of nine trips in a day and the duration of each foraging trip was 22.13min.

Radish

Each bee spent four to 12 seconds on a flower and carried seven to 11mg of pollen load during different hours of the day. Most of the bees collected either pollen or nectar during a single foraging trip but a few bees (4% during the morning and 7% during the noon hours) collected both pollen as well as nectar during the same foraging trip. Pollen collectors outnumbered nectar collectors at 0900 hours (P:N=6:4), the ratio was equal (P:N = 5:5) at noon and during the afternoon at 1500h, nectar collectors outnumbered pollen collectors (P:N=3:7).

The effects of *Apis cerana* pollination on the quality and quantity of radish seeds are summarised in Table 2.5. It shows that bee pollination significantly enhanced fruit set by 23 per cent compared to open-pollinated plants. Bee pollination also significantly increased the number of seeds per siliqua by 42.3 per cent and seed weight by 44.5

Table 2.5: Quantitative and Qualitative Effects of *Apis cerana* Pollination on Radish Seeds

(Values are Mean ± S.E.)

Parameter	Control	Open-pollinated	Bee-pollinated	Per cent Increase
Per cent fruit set	No Fruit Set	51.0	74.0	23.0
No. of seeds per siliqua	-	5.2 ± 0.4	7.4 ± 0.3	42.3**
100 seed weight (mg)	-	1276.0 ± 4.0	1844.0 ± 7.0	44.5**
Per cent germination	-	44.0	76.0	32.0

** Significant (P = 0.01)

per cent compared to open-pollinated plants. Control branches did not set any fruit indicating that the crop was self-incompatible and required cross-pollination. Bee pollination enhanced seed germination by 32 per cent and decreased the time required for initiation of germination compared to open-pollinated plants.

Lettuce

Lettuce is grown for its succulent leaves which are used in salads and also as a vegetable. The lettuce flower, however, is usually self-pollinated and the plants are self-compatible. Cross-pollination has also been observed. The plants are cross-pollinated by insect pollinators which visit lettuce flowers for pollen, and honeybees are the chief pollinators of this flower.

To study the effect of *Apis cerana* pollination on lettuce seed production, lettuce plants (*Lactuca sativa var Atlanta*) were raised during the first week of February 1992 (see plate, page 22). The crop came into bloom during mid-June 1992. Three sets of experiments similar to those for the other three crops (i.e., cauliflower, cabbage, and radish) were per-formed - (1) control, (2) open-pollinated, and (3) bee-pollinated.

Lettuce

Observations on the floral biology of lettuce plants are summarised in Table 2.1. Each lettuce plant had 20 (15-25) branches and each branch bore 75 yellow flowering heads (capitula). Each head was about 15mm in diameter. It opened at 08.22 hours in the morning (i.e., between 0800-0900 hours depending upon the weather) and closed at 11.35 hours (i.e., between 1100-1200 hours depending upon weather conditions), thus it remained open for 3.13 hours only.

Each head was surrounded by a series of overlapping bracts (involucre). On an average it contained 22 (20-25) florets that developed simultaneously. The total flowering period of the crop was one month, i.e., from mid-June to mid-July.

Table 2.2 shows the foraging behaviour of honeybees on lettuce flowers. The bees started foraging on lettuce soon after the flowering heads opened, i.e., at 0830 hours, and ceased their activity only when the heads closed, i.e., at 1130 hours. Peak foraging activity was observed between 0900-1100 hours and the average duration of each foraging trip was 15.66 minutes. Each bee spent an average time of 3.84 seconds on a flower, collected 8.0mg of pollen load, and visited 13.0 flowers per minute. The number of bees per plant was four. Bees collected only pollen because the plant did not secrete nectar.

The qualitative and quantitative effects of *Apis cerana* pollination on lettuce are given in Table 2.6. This table shows that bee pollination significantly increased the number of seeds per capitulum (flowering head) by 31.8 and 21.05 per cent compared to control and open-pollinated plants respectively. Seed weight also increased by 16.03 per cent due to bee-pollination compared to control plants and 15.15 per cent compared to open pollinated plants. Bee pollination also increased the seed length by 23.88 and 11.26 per cent and breadth by 13.25 and 3.29 per cent respectively in comparison to control and open-pollinated plants. Germination of seeds was enhanced by 20 per cent compared to control plants and 12.83 per cent compared to open-pollinated plants. Moreover, seeds from bee-pollinated plants also showed resistance to fungal attack.

Table 2.6: Quantitative and Qualitative Effects of *Apis cerana* Pollination on Lettuce Seeds

(Values are Mean ± S.E.)

Parameter	Control	Open-pollinated	Bee-pollinated	Per cent Increase	Per cent Increase[2]
No. of seeds per capitulum	15.70 ± 0.63	17.10 ± 0.30	20.70 ± 0.75	31.80**	21.05**
100 seed weight	109.57 ± 0.46	110.41 ± 0.39	127.14 ± 0.85	16.03**	15.15**
Size of seeds (mm) Length Breadth	3.35 ± 0.10 0.83 ± 0.06	3.73 ± 0.09 0.91 ± 0.05	4.15 ± 0.10 0.94 ± 0.02	23.88** 13.25	11.26* 3.29
Per cent germination	76.66	83.33	96.66	20.20	12.83
Resistance to fungal attack	Susceptible (6 out of 25 seeds were attacked by fungus)	Less resistant (2 out of 25 seeds were attacked by fungus)	More resistant (none of the seeds were attacked by fungus)	-	-

* = Significant (P = 0.05)
** = Significant (P = 0.01)
1. = Increase compared to control
2. = Increase compared to open-pollinated