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Studies on honeybee foraging and pollination in cardamom (*Elettaria cardamomum* Maton)

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Abstract

Studies on floral biology, foraging behaviour and honeybee pollination in cardamom (*Elettaria cardamomum*) were conducted at Kadasikadavu (Idukki District, Kerala, India) during 1993 to 1995. Anthesis commenced around 0500 h and dehiscence occurred at 0600 h. The styles with receptive stigmas emerged at 0900 h and flowers withered after 12–13 h. Apoidea were the predominant flower visitors (more than 99% of all visitors), the Indian hive bee (*Apis cerana indica*) being the major visitor (95.8%) followed by *Trigona iridipennis* (2.2%). *A. cerana indica* foraging for nectar and pollen peaked from 0700 to 0900 and 0800 to 0900 h, respectively with no bee record after 1300 h. *A. cerana indica* spent more time collecting nectar (12.4 sec) than pollen (7.4 sec) and the proportion of nectar foragers was more (101.7/day) than pollen gatherers (61.6/day). The number of flower visits was minimum (6.6/min) at 0600 h which increased progressively to 14.9 min at 1100 h. The number of capsules/10 panicles, number of seeds, number of seeds/capsule, seed weight and 1000-seed weight were higher in open pollination than without insect pollination. Bee pollination resulted in better quality capsules of uniform shape and bigger size.

Key words: cardamom, *Elettaria cardamomum*, honeybee, pollination.

Introduction

Cardamom, *Elettaria cardamomum* Maton (Zingiberaceae), a highly valued spice for its aromatic seeds used in medicine and cookery, is mainly grown in Kerala, Karnataka and Tamil Nadu in India. Cardamom is a perennial herb generally cultivated in forest areas under the shade of trees. Two year old pseudostems produce slender panicles arising directly from the base of the plant which produce numerous flowers. The panicles are erect, flexuous or prostrate and each panicle bears 2-3 flowers at each node. Flowering starts from May and continues till September, with a peak during June to August. Each clump during peak flowering has 25–30 flowers every day. The flower has a characteristically large, white labellum with violet nectar guides. Three greenish, narrow and spreading corolla lobes fuse to form a nectar tube which is 23 mm long (McGregor 1976; Parameswar 1973). The flowers open singly or two or more at a time, and each flower lasts for a single day (Parameswar 1973; Belavadi *et al.* 1993).

Flowers of cardamom are bisexual and require cross pollination (McGregor 1976; Belavadi *et al.* 1993: Siddappaji & Channabasvanna 1993; Chandran *et al.* 1983). Many flower visitors have been reported to be associated with cardamom. Among them, honeybees (Indian hive bee, *Apis cerana indica* F. and rock bee, *A. dorsata* F.) are the most prominent, contributing over 98% of the total visitors (Belavadi & Parvathi 1993; Parvathi *et al* 1993). An increase of 217–486% in yield has been reported in plants having access to bee visits compared to those with no insect visits (Chandran *et al.* 1983).

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The productivity of cardamom was 128 kg/ha in India in 1996–97 which could be increased to 260–439 kg/ha (Peter 1998). Adequate planned pollination by honeybees can help in increasing productivity and export earnings to India. The present investigations were undertaken to understand the floral biology of the crop, foraging behaviour of honeybees and pollination ecology of cardamom.

Materials and methods

The investigations were carried out at the Field Observation Station, Kadasikadavu (Idukki District, Kerala, India) of Central Bee Research and Training Institute, Pune, during 1993–1995. A 15-year old 1 ha cardamom plantation (cv. Malabar) was selected in which Indian hive bee (*A. cerana indica*) colonies were kept in scattered conditions. Observations on floral biology were recorded for 5 sunny days continuously (24–28 May 1993) during peak flowering season on marked flowers (n=10) which included time of anthesis, dehiscence, style emerence, stigma receptivity, withering of flowers and life of flowers. The foraging behaviour of *A. cerana indica* was recorded on 10 tagged panicles at hourly intervals for 7 consecutive days (7-13 August 1993). The observations included time spent by honeybees on cardamom flowers, number of flowers/plants visited and foraging for pollen and/or nectar (which was confirmed by recording the presence of pollen loads on honeybee body and nectar in the honey stomach). The foraging behavior of different honeybee species to record aggressive interactions among them was also recorded visually. The number and types of insect visitors were also recorded on these tagged flowers.

The pollination experiments were conducted under two sets of conditions i e, Without Insect Pollination (WIP) and Open Pollination (OP). In WIP, 10 newly formed panicles were selected, tagged and caged individually in muslin cloth bags (60 cm x 20 cm) just before blooming, taking care that no part of it touched the muslin bags. The muslin bags were removed after completion of fruit set. In OP, 10 such panicles were randomly selected and tagged which were open to foraging by the insects. The experiment was replicated thrice in a randomized block design.

The mature capsules were periodically plucked and quantitative yield parameters including seeds/capsule, weight of seeds/capsule, seed weight and size of capsules were studied.

Results and discussion

Floral biology

Panicle initiation was recorded in February and flowers started emerging in April and continued up to September with a peak during June to August. However, during rest of the year, stray flowers were also noticed. Anthesis occurred between 0500 and 0535 h. Anther dehiscence occurred between 0600 and 0630 h. The style started emerging at 0900 h and the stigma was found to be receptive with a glistening surface and was covered with pollen by late morning. The flowers withered in the evening (from 1700 h to late in the evening). The flowers remained open for 12–13 h (Table 1). Chandran *et al.* (1983) also

Table 1. Floral biology of cardamom

Date of observation	Time (h) of			
	Flower opening	Dehiscence	Style emergence	Flower dropping
24.05.1993	5.30	6.00	9.00	17.00
25.05.1993	5.34 ± 0.02 (5.30 - 5.35)	6.00	9.00	17.00
26.05.1993	5.25 ± 0.04 (5.20 - 5.30)	6.16 ± 0.11 (6.00 - 6.30)	9.00	18.00
27.05.1993	5.22 ± 0.05 (5.15 - 5.30)	6.00	9.00	Late evening
28.05.1993	5.11 ± 0.09 (5.00 - 5.30)	6.00	9.00	Late evening

Values indicate means ± SD of 10 flowers
Figures in parentheses are ranges

recorded the time of flower opening at 0500 h; however, Parameswar (1973) observed it from 0400 h. In our studies, anther dehiscence was recorded from 0600 to 0630 h, about 1 to $1^1/_2$ h after the flowers opened whereas, Chandran *et al.* (1983) recorded synchronous flower opening and anther dehiscence while Parameswar & Venugopal (1974) reported it to be around 0700 h. Our studies are in agreement with those of Chandran *et. al.* (1983) and Parameswar (1973) regarding duration of flower opening.

Flower visitors

Among the various flower visitors, Apoidea were the most prominent, constituting more than 99% of total visitors (Fig. 1). Among the Apoidea, Indian hive bee, *A. cerana indica* giant rock bee, *A. dorsata* and stingless bee, *Trigona iridipennis* L. were the major flower visitors with a few unidentified butterflies, moths and dipteran flies with occasional visits.

Among the honey bees, *A. cerana indica* was the most prominent flower visitor constituting 95.8% of all visitors (163.3 bees/day). *A. dorsata* comprised only 2.0% (3.4 bees/day) and *T. iridipennis* 2.2% (3.7 bees) of visitors. However, Parvathi *et al.* (1993) recorded *A. cerana indica* and *A. dorsata* to be the only flower visitors at Mudigere (Karnataka), the former being dominant from beginning of May to June and again from end of August till the end of flowering. During rest of the period (mid June-August), *A. dorsata* was most predominant.

Foraging behaviour

Nectar foraging : The nectar foragers alighted on the petals and pushed their proboscis through the corolla tube to draw nectar. Due to their side working behaviour, they were rarely observed to touch the anthers and stigma. *A. cerana indica* started foraging for nectar from 0600 h and continued up to 1300 h (Fig. 2). Nectar foraging peaked from 0700 to 0900 h after which it declined with an appreciable decline after 1200 h and no bees were recorded after 1300 h.

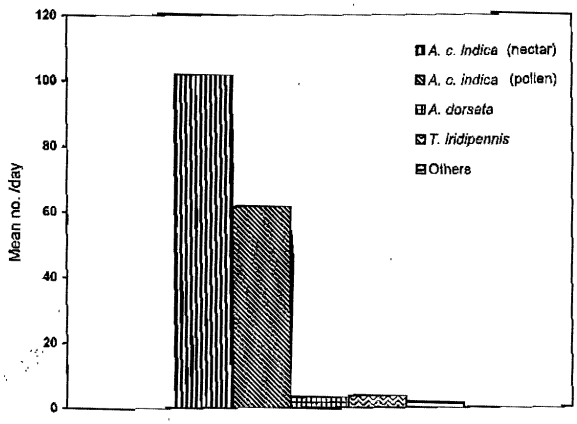

Fig. 1. Composition of various foragers on cardamom

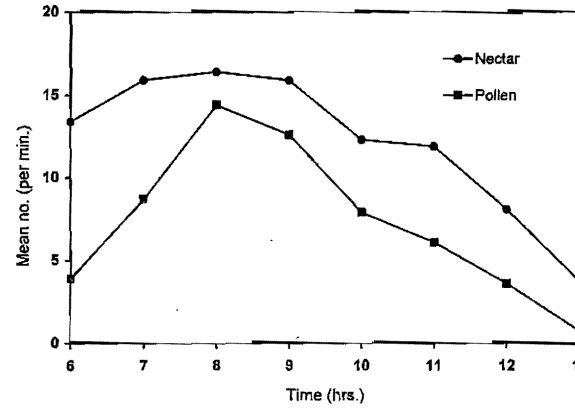

Fig. 2. Frequency of nectar and pollen foraging by *Apis cerana indica* on cardamom

Pollen foraging : Pollen foragers were mainly top workers alighting on any part of the flower and crossing over the anthers and stigma swiftly. They were also observed to nibble the anthers. During the process of pollen foraging, their mouth parts and body got covered with pollen which was packed in the carbiculae before moving to the next flower. Pollen foraging by *A. cerana indica* started little later, after commencement of nectar foraging and picked up at 0700 h and peaked from 0800 to 0900 h after which it declined steadily (Fig. 2). The number of pollen foragers were low after 1200 h (3.6) and no foragers were recorded after 1300 h.

The proportion of pollen foragers was comparatively lower (61.6/day) than nectar gathers (101.7/day). Initiation of pollen foraging activity corresponded with the time of pollen dehiscence which occurred around 0600-0630 h and peaked later. After 1300 h no foragers of *A. cerana indica* were recorded. Relative lower preference for cardamom pollen and the availability of more attractive pollen sources at that time may partially explain this behaviour. Parvathi *et al.* (1993) and Parameswar & Venugopal (1974) also recorded higher number of pollen collectors in the morning and their numbers decreased beyond 1000 h after which nectar gatherer's population increased.

Foraging time was recorded from 0600 to 1300 h

with a peak from 0800 to 0900 h only whereas, Parvathi *et al.* (1993) recorded the foraging range from 0700 to 1900 h with a peak between 1100 and 1300 h; the difference may primarily be due to climatic factors and availability of forage to the bees.

Time spent for nectar and pollen collection : *A. cerana indica* bees spent relatively more time in collecting nectar (12.4 sec) than pollen (7.4 sec). Both the frequency of nectar collection and the time spent to collect it were significantly more than these values for pollen foragers.

Number of flowers visited/plant: *A. cerana indica* foragers visited lesser number of flowers in the early hours of the day, the minimum being 6.6 flowers/min at 0600 h (Fig. 3). The frequency of visits increased progressively with the passage of time upto 1100 h when maximum flowers were visited (14.9/min) after which it started declining and after 1300 h no foragers were recorded on cardamom.

Movement of bees between plants : The number of plants visited by bees was low (0.7 plants/min) at 0600 h and this frequency increased later on (range 1.0-1.1 plants/min) up to 1300 h (Fig. 3). The number of both flowers and plants visited by *A. cerana indica* was low in the morning hours which increased progressively till 1300 h after which the bees did not visit the flowers. The bees get higher reward per visit in the morning due to higher amount and concentration of nectar. With progression of time, the depletion of nectar results

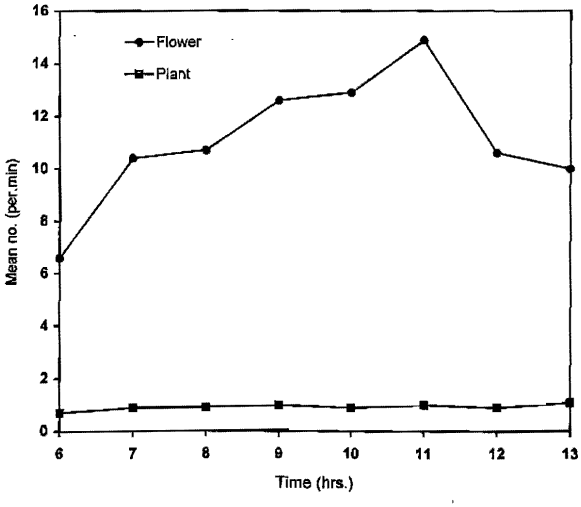

Fig. 3. Frequency of foraging by *Apis cerana indica* on cardamom flowers/plants

in both increased frequency of visits and the bees also spent more time foraging to meet their growing requirements. Similar results were also recorded by Parvathi *et al.* (1993).

Resource partitioning by honeybees: All the three species of honeybees (*A. cerana indica, A. dorsata* and *T. iridipennis*) seemed to successfully forage on cardamom without any visual aggressive interactions. Their relative foraging peaks over the entire foraging period seemed to amply suggest it. *A. cerana indica* was the most abundant visitor an cardamom flowers from 0600 to 1300 h with a peak at 0800 *A. dorsata* was observed in low numbers at 1000 h onwards with a peak at 1300 h. *T. iridipennis* was observed from 0600 to 1300h though in low numbers with peaks at 0700 h and 1300 h. The larger *A. cerana dorsata* and medium sized *A. cerana indica* both with more energy requirements foraged when nectar concentration and quantity was higher. The smaller *T. iridipennis* appeared to have the capacity to exploit depleted resources. These results are supported by the studies of Oldryod *et al.* (1992) and Goyal (1974). Our findings are in contrast to those of Koeniger & Vorwohl (1979) who reported frequent intra and inter specific interactions among these three species. The relative abundance of *A. cerana indica* over other two species may partly be explained by the presence of more such bees in the hives kept in the plantation and the probable foraging preference of *A. dorsata* and *T. iridipennis* to other sources in the near vicinity.

Pollination studies

The results of pollination experiments are presented in Table 2.

Number of capsules: In OP, the number of capsules/10 panicles was significantly higher i e, 570, compared to only 15 in WIP, an increase of 3700%.

Number of seeds: The effect of honeybee pollination on number of seeds/10 capsules was more pronounced than that of number of capsules. In OP, the number of seeds/10 panicles was 6610 compared to a mere 108 in WIP, an increase of 6020%. The number of seeds/capsule too was significantly higher in OP (11.6) compared to only 7.2 in WIP, an increase of 61%.

The studies demonstrate some degree of self pollination in Malabar cultivar of cardamom as in WIP, the panicles were enclosed in the bags

Table 2. Effect of bee pollination on yield parameters of cardamom

Treatment	Capsules/ 10 panicles	Seeds/ 10 panicles	Seeds/ capsule	Seed weight (g)		1000 seed weight (g)	Capsule size	
				With husk	Without husk		Length (cm)	Breadth (cm)
OP	570.0	6610.0	11.6	123.0	89.0	15.1	1.46	0.85
WIP	15.0	108.0	7.2	5.0	3.0	0.0	1.43	0.58
% increase over WIP	3700.0	6020.4	61.1	2360.7	2866.7	-	2.10	46.60
Sprayed	403.0	4768.0	11.8	84.0	61	14.0	0.43	0.56
Unsprayed	329.0	4097.0	12.5	80.0	58	15.0	1.49	0.58

OP = Open pollinated; WIP = Without insect pollination
Values are means of 3 replications

with no visits of the insects. The increase in number of capsules and seeds could be explained only by bee pollination as all other conditions in both the sets were similar. These studies are in contrast to that of Chandran *et al.* (1983) who reported more seeds (13.6) in self pollination compared to bee pollination (10.9).

Seed weight: Seed weight of cardamom also showed significant increase in OP over WIP, an increase of 2360 (with husk) and 2867% (without husk) respectively. Similarly, the 1000-seed weight was 15 g in OP compared to almost negligible in WIP as enough seed was not produced in these plots. Chandran *et al.* (1983) reported 217–480% increase and Puttanshetti & Prasad (1973) 500% increase in yield in bee pollination over self pollination.

Size of capsules : Capsule length was similar in both OP (1.46 cm) and WIP (1.43 cm) whereas, the breadth in OP was greater (0.85 cm) than WIP (0.58 cm), an increase of 46.6% which may probably be due to better development of ovules into seeds due to better pollination through honeybees.

The present studies clearly revealed the necessity of *A. cerana indica* bees as pollinators of cardamom as they increased all the yield parameters including number of capsules and seeds and seed weight. Planned bee pollination by estimating the pollination requirement per unit area is proposed for future studies so that beekeepers and cardamom plantation owners may maximize their gains.

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