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Diversified Ecological Roles of Insect Pollinators in the Fruits of *Coriandrum sativum* L. (Rajasthan Coriander-41) from Nadia District, West Bengal, India

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Abstract

The present research is based on entomophily, which is a type of pollination through insects like bees, butterflies, moths and beetles in the fruits of *Coriandrum sativum* L. (Rajasthan Coriander-41) studied in Nadia district, West Bengal, from January 2020 to January 2022. The study reveals a total of seven species of insects belonging to five families and three orders, all of which were collected from eight blocks of Nadia Districts, West Bengal. The maximum number of species identified were from the Hymenoptera Order and the most abundant species was *Apis cerana*. The peak behavioural activity was recorded between 10-11 AM. The effect of bagging flowers on pollination was observed and the observation was found to be remarkably greater (p<0.001) in normal pollinated flowering plants than in closed flowering plants, respectively, by 136% and 23%. Germinability of seeds increased by open-pollinated flowers at 78%.

Keywords: *Insect Pollinator; Coriandrum sativum L.; Germination*

Introduction:

The global data reveals that 75% of staple important food crops were directly or indirectly dependent on animal pollination, which includes fruits, vegetables, coffee, cocoa and almonds (Millard *et al*., 2021). The value of Crop pollination is USD 195–387 billion per year (Porto *et al.,* 2020). The most efficient pollination produces increased and improved seed and crop production. Irshad and Stephen (2014) revealed that most food grains, vegetables, edible seed oil crops, dates and nuts were mostly based on insect pollination.

The spice *Coriandrum sativum* L. belongs to the family Apiaceae. The origin of this spice was in the Mediterranean region. This spice was economically grown in the equatorial vast croplands of, India (Madhya Pradesh), Morocco, Russia, Ukraine Romania, Mexico, and Argentina. Specially mentioned that India, is the largest spice growing country in the whole world (Priyadarshi & Borse, 2014) and coriander is one of them. This special spice belongs to the family Umbelliferae/Apiaceae. This hairless, branched, slender, glabrous, aromatic, erect annual and perennial herb has an ancient history of being a delicious herb. It was an effective source of aromatic compounds with affluent essential oils and

lots of biologically active components; it holds antibacterial and antifungal properties (Mandal & Mandal, 2015). This seed is generally used as a dietary product, which might cure property-borne diseases. Msaada *et al*. (2007) opined that the essential oils from this spice undergo significant changes during ontogenesis, that might affect the aroma property of the plant. Coriander flowers draw insects, like Diptera, Coleoptera and Hymenoptera, for pollination. Among these, bees are dominant, which act as important pollinators. Khalid, Tamin and Mohammed (2008) studied *Apis* species with respect to bee pollination. The present study intended to reveal the diversified ecological roles of entomophilous insects in the fruits of coriander herbs from Nadia District, West Bengal at different times of the day, as there was no such information on the entomophilous insects' pollinators of *Coriandrum sativum* L. (Rajasthan Coriander-41), within or outside the southern part of West Bengal. The present observation also indicated the role of the pollinators with respect to the pollination ability that intends to increase the seed yield of the crop.

Methodology

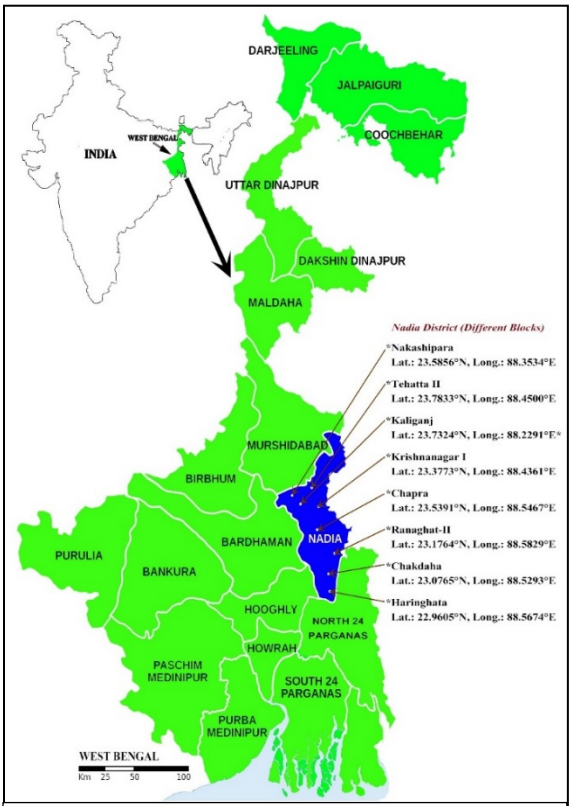

Figure 1: Map Showing the various locations of Nadia of West Bengal

The study and survey area

The observation and survey study were conducted at Nakashipara Block (23.5856˚N; 88.3534˚E) of district Nadia in the southern part of West Bengal state from January 2020 to January 2022. A triplicate study was conducted on each 1,200-square-foot plot. 'Sindhu variety', a local cultivate, was grown at the recommended spacing of 30 cm × 10 cm. The total time periods between 6 a.m. and 5 p.m. when insects visited the crop blooms, were preserved by sweeping the insect trap net (Arora, 1990). Mean weather reports like temperature (17^{o}C–23^{o}C) and relative humidity (50–65%) were studied every day for 4 consecutive months during the crop flower bloom. The statistical data analysis was done on the basis of the Shannon-Weiner diversity index for different orders of insect species (Belavadi & Ganeshaiah, 2013). *A. mellifera* and other species remained

more or less the same throughout the day, with the H value remaining constant throughout the day, as similarly reported by Belavadi (2019).

Effectiveness and efficiency Index

The maximum perennial and abundant insect visitors were studied for Pollinator Performance: Effectiveness and efficiency Index (Vithanage, 1990; Sihag & Rathi, 1994).

Examination of qualitative and quantitative variables in crop yield

In the first-year study, flowering of the crop started in the mid-week of December 2020 and in next year, bloom was in the mid-week of January 2022. To activate hermaphroditism and air pollination (preventing insect pollination), unopened floral flowers were randomly selected and insect mesh nets were enclosed. The study area covered six quadrates with 81 square meters and approximately 300 plants.

In vitro pollen viability analysis

The pollen spores were grown in a simulated sucrose solution to assess *In vitro* pollen viability and study germinating viability (Belavadi & Ganeshaiah, 2013). In different concentrations of sucrose solution, the number of pollen grains is known. Approximately 20 pollen spores were taken and placed on a groove slide. The amount of sucrose solution required for germination was pre-decided. The sucrose solution at the measurement was taken at 2%, 5%, 8%, 10%, 15%, 20%, 25%, 30%, 40% and 50%. The test repeated 18 times to get the optimum concentration for use. Test results were recorded and real pictures were captured under *Primo Vert*, 40 x inverted phase contrast microscope, Carl Zeiss.

Estimation of Grain Propagation

The result of seed propagation was measured by controlling seeds, from the two sets of pollination conditions on a poly petridish, blotting paper (double layered). Grains have been pre-soaked in distilled water for 10 hours for maximum result. The grains were split open into two parts before planting. Propagation was noted in about 1-3 weeks.

Results and Discussion

The umbel of coriander was noticed to hold 6–9 pedicels, each containing approximately 22 flowers. Each pedicel consists of three sections, like the gynandrous, the staminate and the pistilate. One thing is important: the number of staminate parts is always higher than the pistilate ones and the gynandrous parts of flowers. During the inflorescence stage, the young male part and corolla curve the male reproductive part of a flower (Stamens) remains vertically above the female part of a flower (stigma) when the

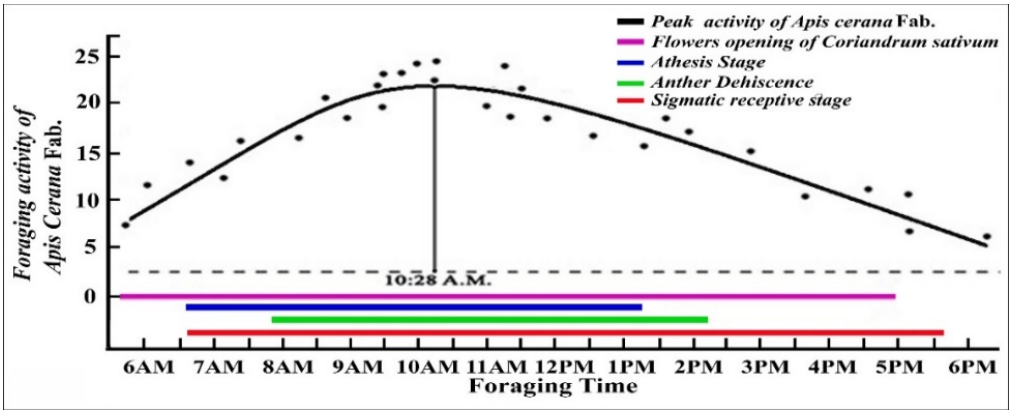

Figure 2: Inflorescence (Anthesis) and stigma activity of *Coriandrum sativum* L. (Rajasthan Coriander-41) and wandering activity of *Apis cerana* in Nadia, West Bengal

fertilizing dust is purely released and spreads fully, becoming distended after the pollen grains are discharged. It was also noticed that the fertilizing dust release starts in the late morning (from 9 a.m. to 1:30 p.m.), while the ability (receptivity) of stigma to support viable and compatible pollen to generate stigma activates in the afternoon (after 2 p.m. to 3 p.m.), with a non-occupying the same area in part among them. Therefore, they are hardly self-compatible, and the flower has to rely on the pollinators to accomplish cross pollination. Ultimately, pollinators gain the right set of circumstances for both pollen and nectar as a reward (Fig. 2).

Divergence, abundance, Pollinator Performance and Effectiveness of insect visitors in Coriandrum sativum L. (Rajasthan Coriander-41)

There are 7 insect species under 3 orders like Hymenoptera, Diptera and Coleoptera were visited on the plant *Coriandrum sativum* L. The order Hymenoptera and Diptera shared (3 species), followed by Coleoptera (1 species). Among Hymenoptera, *Apis dorsata, Apis cerana indica* and *Apis mellifera,* were both pollen and nectar acquirer, whereas 3 dipteran species like *Orthellia coerulifrons, Eristalinus arvorum* and *Chrysomya megacephala* were both nectar acquirer and normal visitors although at the same time, *Oenopia sp.* the Coleopteran was normal visitors (Table 2).

Table 2: *The pollen abundance with respect to insect visitors on the flower of Coriandrum sativum in Nadia, West Bengal*

Name of the Insect species	Family of the species	Type of Forage	Diversity Index Calculated by Shannon-Wiener	Mean scale of pollen		Hourly study of ratio of flower and insects	Index showing pollination efficiency
				Coriander Pollen	Foreign Pollen		

A. cerana Fab.	Apidae	PN	H' = -∑ $P_i(LnP_i)$ = -(-1.085) = 1.185	839	28	150:28	4494(839×150)/28 =4494
Apis dorsata Fab.	Apidae	PN		810	47	150:34	3573
Apis mellifera	Apidae	PN		729	18	150:32	3417
Orthellia coerulifrons	Muscidae	N	H' = -∑ $P_i(LnP_i)$ = -(-1.080) = 1.080	-	-	-	-
Eristalinus arvorum	Syrphidae	N		196	13	150:19	1547
Chrysomya megacephala	Calliphoridae	NV		-	-	-	-
Oenopia sp.	Coccinellidae	NV	NIL	-	-	-	-
**** PN indicates Pollen and nectar; NF indicates: Nectar foragers & NV indicates Normal Visitors***				***** Method followed by Vithanage (1990), Sihag & Rathi (1994)***			

The result from Fig. 3 shows evidence of activity during the daytime, but their highest achievement times were different. Hymenopterans and Dipterans show top performance at 10.05 am and 11.10 am, accordingly. The abundance of the maximum of Hymenopterans approx. (65.6%) followed by Dipterans (29.7%) and Coleopterans (4.6%) (Fig. 4).

After the observation and analysis of three honeybee species, Apis cerana was the most frequent (28.8%), followed by *A. dorsata* (22.4 %) and *A. mellifera* (15.2 %). Normal Foraging activity of *A. cerana* was 9.5 bees/ 81 square meter /10 min, followed by A. mellifera with 7.5 bees/81 square meter/10 min and *A. dorsata* with 2.5 bees/81 square meter /10 min. The bees consumed more time for nectar acquire (~ 14 seconds) than collection of pollen grain (~ 12 seconds). During the nectar acquisition process, the honey collector bees descend to the border of the flower clutch and perform rapid movements. For the acquisition of pollen dust, pollinators delve into the core of the cluster, performing a circular maneuver. The pollen dust acquirers comprised 60–75% of the total pollinators visiting the flower, with the rest being the nectar collectors. The Shannon-Weiner index for Hymenoptera, H' was 1.185 & 1.080 for the order Diptera (Table2). The higher diversity index of Hymenoptera specifies an equal and liberal distribution for the species of the mentioned orders. At this time, the collected mean number of pollen particles from the body bristles of the Hymenoptera and Diptera insects was figured out in Table 3. Among these, the pollination efficiency index in species *A. cerana recorded as first and* second by (*A. mellifera, A. dorsata)* and the lowest by *Eristalinus arvorum*. *Apes cerana* was founded as the best effective pollinator of *Coriandrum sativum* L. (Rajasthan Coriander-41) followed by *Apes mellifera* and *A. dorsata.*

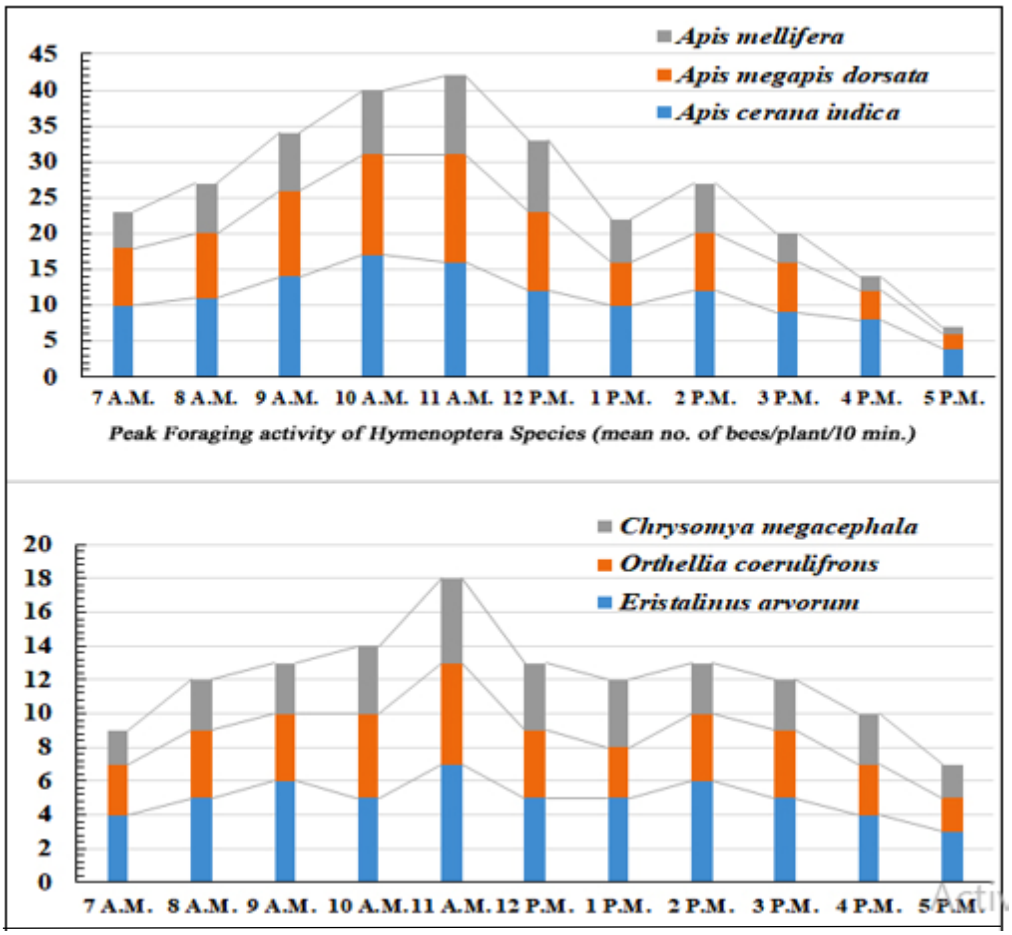

Figure 3: Peak Foraging activity. (A) Hymenoptera, (B) Dipterans, in Nadia, West Bengal

Grainy stuff (Pollen) efficacy

The quality of pollen grain is assessed in accordance with its efficacy and healthiness. The artificial germination test was the most effective test method to evaluate pollen efficacy (Belavadi & Ganeshaiah 2013). The release of pollen grains from open flowers during 9:00 a.m. to 12:30 p.m. was collected at an hourly interval between 9.00 a.m. and 1.00 p.m. in *C. sativum*. Also, pollen was accumulated from the hairy part of *Apes cerana* that give out peak bromizing activity which similar to the time of pollen indehiscence. For the development of pollen balls, the typical application of sugar fluid necessary per tube was 15–18 percent. Pollen from the insect body and an open pollinated flower. This technique was evaluated for the development of pollen channels in the required sugar fluid solution after 2.5, 4.5, 6.5, and 8.5 hours of study. In both cases, the feasibility differed from 70% to 80%. It is clear from this that both bee-collected pollen and flower-collected pollen had the same viability.

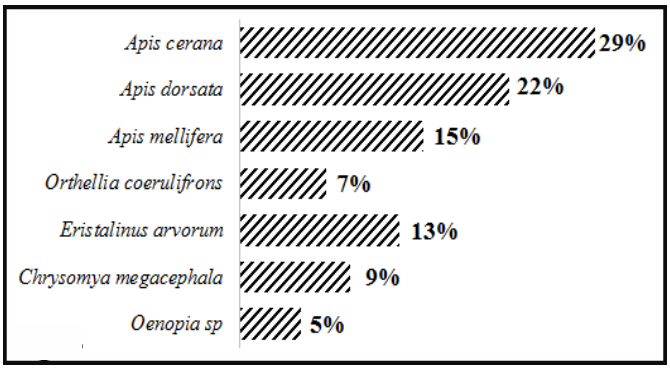

Figure 4: Relative abundance of various insect visitors on flower of Coriandrum sativum in Nadia, West Bengal

Influence of pollinators over seed and crop productivity of Coriandrum sativum

The data of seed productivity gathered (average 20/umbels), the result expressed that fruit (seed) set was 12% under insects' omission, and the data shows that it was 28.5% in unbagged pollination (136% of increase exception). The reports regarding the dominance of coriander flower visitors, except for the report from Chaudhary and Singh (2011), indicate that the Italian honeybee, *A. mellifera*, was the most dominant species, followed by *E. halteatus* and unidentified Hymenopteran species. In other crops, like onions, the observed Berger-Parker index was 0.288 (Karuppaiah, Soumia & Wagh, 2018). However, the result of increased seed yield in open pollination over the standard was 93.6%. The study revealed that the mean number of seeds was 12 and 36 per umbel, and the mean weight of 100 seeds was 2.2 gm and 2.6 gm, respectively, although in standard and natural conditions, respectively. The height of flowering peduncle was 24.9% increase in the breadth of seed was 56% in natural pollination increase (Table 3). The present study indicates that the results are validating with the outcomes observed by Kumar and Jaiswal (2012) in the case of pollinators, whose seed yield increased in *Coriandrum sativum.*

Table 3: *The influence of insect pollination on crop productivity constant of C. sativum (Rajasthan Coriander-41) in Nadia, West Bengal*

Constant	Standard (Closed inflorescence)	Free pollination	Growth in Percentage	Fischer *t*-test
Hight of flowering branch (cm)	9.98	11.8	17.9	13.8
Fruit & seed (%) production	12.06	28.51	136.22	56
Weight of 100 matured seeds in (gm)	2.2	2.6	24	11.70
Diameter of Seed (mm)	0.30	0.50	56.1	58.40
Productibility of seed (%)	47.5	85.0	78.94	71.34
Significant values are calculated against controlled and open pollination by using Fischer t-test at 18 DF and found significant at p< 0.001 in all cases.				

Germination of seed

The ability of seed germination observed from pollinated flowers under control (where the intervention of insects was excluded) and open pollinated flowers was examined. The result showed that the geitonogamy by insects improved and grow the seed productibility by 79% where unbagged flower pollination was done rather than bagged flowers (Table 3). Although the coriander plant is partially self-fertile, bees are beneficial to it. *A. cerana* indica played an important role as a pollinator of the crop, along with *A. mellifera*, *A. dorsata* and these resulted in grow the seed productivity as well as seed germinability.

Conclusion

The following observations led us to the inference that the floral visitors reported and observed were the pollinators of the aforesaid crop plants : 1) The time of visit by these visitors corresponds with the duration of pollen transfer onto the hairy stigma, 2) The visitors in a flower were seen to be profusely smeared with yellow pollen grains on the dorsal surface of their head, thorax, legs and antennae, 3) While moving within a flower, they come into contact with the dehisced anthers and the stigma. On the basis of the above observations, *Apis sp.* was found to be the most active and efficient pollinator of all four crop plants. Out of the three species of honey bees, *Apis mellifera* was found to have the highest pollination efficiency index, whereas the non-Apis bees were found to have a very low pollination efficiency index, though it was presumed that probably these non-Apis bees enhanced the foraging capability of Apis bees. Although coriander is partially self-fertile, bees proved beneficial to it, as *A. cerana* indica played an important role as a potent pollinator of the crop along with *A. mellifera* and *A. dorsata* which resulted in an increase in seed yield and germinability. Hence, the conservation and augmentation of these species' diversity are necessary for crop plant pollination and seed production.

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