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Diversity of different pollinators/visitors on coriander flowers

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Abstract
Studies on the diversity of pollinators/visitors on coriander flowers was undertaken during the Rabi 2018-19 total 10 species of insects were observed visiting on coriander crop. The *Apis cerana indica* was found dominant bee species among other main pollinators like *Apis dorsata, Apis mellifera* and *Apis florae.* Some other pollinators/visitors were also recorded like *Eristalis* sp., *Musca domestica, Danaus chrysippis, Dysdercus cingulatus, Coccinalla septumpuntata, and Chrysomya beziana* visiting on coriander flowers. Coriander flowers were visited by ten species of insect pollinators, of which eight species of insect pollinators belong to order Hymenoptera, four species to Diptera, three species to Lepidoptera, Hemiptera and Coleoptera, one species and Hemiptera. Honeybee species *viz., A. c. indica A. dorsata A. mellifera, and A. florea* constituted about 88.17 percent of the total insect pollinators visiting coriander compared to 11.83 percent of other insect pollinators.

Keywords: Coriander flowers, diversity, pollinators/visitors, succession

Introduction
Coriander (*Coriandrum sativum* Linn.) belongs to the family *Apiaceae* (*Umbelliferae*) as an annual herbaceous crop. In the Sanskrit literature, it is referred to as' dhanayaka' or' kusthumbari.' The Coriandrum genus includes plant grown *C. sativum* and Wild species *C. tordylium*. It is cultivated as an annual summer or winter plant. The plant can attain heights of between 0.20 and 1.40 m at the flowering stage. In India, coriander cultivation area was estimated to be 4.7 lakh hectares with 37 lakh tons of output and an average 789 kg/ha of productivity. The export of coriander powder from India was 2246 metric tons (2003-04) and 8318 metric tons (2003-04) as curry powder including coriander in the mixture (Anonymous, 2006) [1].

Coriander (*Coriandrum sativum* L.) is an annual herb belonging to the family Umbelliferae. It is originated from East Mediterranean and South Europe. It is mainly cultivated for its leaves and seeds as a summer or winter crop. At flowering, the plant can reach an height between 60 cm. The germination is epigaeal and the plant has a tap root. The stem is more or less erect and sympodial, monochasial-branched, sometime with several side branches at the basal node. Each branch finishes with an inflorescence. The stem of the plant is hollow and the leaves are alternate and the first ones are often gathered in a rosette form. The basal leaves are usually either undivided with three lobes or tripinnatifid. The higher leaves are inserted and more pinnate. The leaves are green or light green and underside of the leaves are often shiny and waxy. During flowering period, the leaves sometimes turn to red or violet. They wither before the first fruits are ripe, starting from the basal leave (Axel Diederichsen, 1996) [6].

The inflorescence is a compound umbel with one or two linear bracts is a compound. The umbel has two to eight primary rays grouped in such a way that the umbellets are at the same point, having different sizes. Flowering starts with the primary umbel, and peripheral umbellets are found in every umbel, and peripheral flowers are the first to bloom in each umbellet. Protandro are the flowers. The flowers have five petals and pale pink or white is the shade of the petals. It takes about 5-7 days to complete the single umbel flowering cycle (Luzina, 1953) [15].

The seeds are globular form, beaked, finely ribbed, yellowish brown, 6mm in diameter with five longitudinal ridges which are separable into two halves (mericarps), each of which is concave internally and shows two broad, longitudinal oil cells (vittae). The seeds are aromatic, when crushed and possess characteristic odour. All parts of the plant consists of schizogenic channels, which contain essential oils, thereby give a characteristic smell, which is similar to

that of bugs. The oil content ranges from 0.10 to 1.00 percent in dry seeds, which is pale yellow or colourless. The seeds also consists of 5 percent of ash and also malic acid, tannin and some fatty matter (Axel Diederichsen, 1996) [6].

In the world, India has traditionally been known as the "home of spices." India is the world's largest seed spice manufacturer, consumer and exporter. Seed spices are an important agricultural product community and play a very important role in our national economy. Seed spices are essential commodities oriented towards exports and about 10% of our production is exported as raw and also as value-added products, realizing 206,25 rupees per annum in foreign exchange. The estimated global seed spice demand is 90,000 tons, of which our country is currently capable of exporting around 46,000 tons annually, which is around 51 percent of total demand. In India, fourteen seed spices are cultivated commercially. Among them, coriander is one of the most popular seed spices and accounted for 25% of total seed spices export with 13% earnings during 2000-01.It is the only seed spice included in the National Crop Projection System (Sivaraman *et al*, 2001) [28].

Bee pollination not only increases yield rates, but also increases hybrid vigor, generates variability and preserves the gene flow in the eco system, while maintaining the diversity of plant varieties. The above claim that efficient use of pollinators can significantly increase the yield rate has been verified by experiments (Melinichenko, 1977) [16].

The name ' coriander ' originates from the Greek word ' kopis, ' meaning ' worm. 'In Europe, Northern Africa, Southeast, Central and South Asia, Coriander is an essential seed spice. Coriander was mentioned and is known in the Holy Bible since the Middle Ages.

The cultivation of coriander has increased slightly over a period of time in India (from 1980 to 1990 between 2,80 and 3,34 lakh hectares). At present, however, it is cultivated in an area of 5. 46 lakh hectares with a total output of 2.90 tons and an average output of 531 kg per hectare. Rajasthan, Andhra Pradesh, Tamil Nadu, Gujarat, Madhya Pradesh and Karnataka. In Karnataka, coriander is grown in an area of 17,300 hectares with a total output of 2,900 tons and an average output of 168 kg / ha compared to the national average of 531 kg / ha (Sivaraman *et al*, 2001) [28]. Karnataka's low coriander productivity is primarily due to poor production technologies, lack of improved varieties, management of nutrients, and adequate pollination.are the big rising coriander states.

In India it is being cultivated in an area of 583 thousand hectares with an annual production of 784 thousand tonnes (Anonymous, 2019) [2, 3]. In India, Madhya Pradesh, Rajasthan, Gujarat, Tamil Nadu, U.P. are the major producing states. In India the domestic marketing centers of coriander are Jodhpur.

Coriander is the important vegetable, spice crop of the Chhattisgarh state with area of 20069 hectare an annual production 94730 metric tonnes (Anonymous, 2019) [2, 3].

Coriander's flowering phenology allows better cross-pollination. The inflorescence consists of a compound umbel, where the primary umbel is to bloom first, followed by the umbels of lower order. Therefore, pollination depends largely on various pollinating agents, including insects, especially honeybees, which are the cheapest and most environmentally friendly inputs to maximize yield in most cross-pollinated crops. Various insects such as honeybees (*Apis florea Apis cerana Trigona iridipennis* Smith.), solitary bees, butterflies and flies carry out cross pollination in coriander. Honey bees are among them the main coriander pollinators (80.30 percent). The bee pollination raised the yield in coriander by 49.86% (Anonymous, 2000) [4].

Bee pollination not only helps to increase yield, but also improves the quality of different seed spices including uniformly mature coriander and early crop harvest. The provision of bee colonies during the crop's flowering cycle is very important for increasing coriander productivity. Coriander is a rich source of pollen and nectar, attracting many insect pollution species. A nationally organized bee pollination system contributes significantly to meeting global demand and foreign exchange even at the existing land-use level for coriander crop cultivation.

Materials and Methods

The experiment was undertaken at Raj Mohini Devi College Agriculture and Research Station, Ajirma Farm, Ambikapur, District, Surguja (C.G.), during 2018-19 to It was upland single plot size 2x2 m, variety Chhattisgarh dhaniya-1 study the diversity of pollinators/visitors umbels for pollen or nectar collection and or both under open and caged conditions was recorded in one square meter area for 5 minutes at 2 hourly intervals from 0900-1000, 1000-1300, 1500-1700 hours at 5 days interval initial peak flowering period. Three spots were chosen in the crop field, each spot with a square meter for recording the diversity of pollinator/visitors

Results and Discussion

Diversity of pollinators/visitors on coriander flower

The data on average population of insect visitors (Table 1) revealed that the coriander flowers were visited by 10 insect species belonging to different orders and families recorded from initiation of flowering.

Among the insect visitors, four species were from Hymenoptera viz. *Apis cerena indica*, *Apis dorsata*, *Apis mellifera*, *Apis florae* of Apidae family. Three species were from Diptera viz. *Eristlis* sp. of Syrphidae, *Musca domestica* of Muscidae family, and *Chrysomya beziana* of Calliphoridae family; one species of Lepidoptera viz. *Euploea core* of Nymphalidae family; one species of Hemiptera viz. *Dysdercus cingulatus* of Pyrrhocoride family and one species of Coleoptera viz. *coccinella septumpunctata* of Coccinellidae family were recorded in the coriander crop. About 88.17 percent of the insect pollinators/visitors visited on the flowers of the coriander crop were from the order Hymenoptera (*Apis cerena indica. Apis dorsata*., *Apis mellifera.* and *Apis florae*) while the non-Hymenoptera insect pollinators/visitors constituted 11.85 percent . The most active and dominant insect contributing about 28.16 percent among insect pollinators/visitors was *Apis cerena indica* followed by *Apis dorsata* (26.92 percent), *Apis mellifera* (22.30 percent), *Apis florae* (10.79 percent), *Chrysomya beziana* (2.68 percent), *Musca domestica* (2.37 percent) while others contributed 6.8 percent of the insect pollinators /visitors.

The present findings are in close agreement with those stated by Jagdish *et al*. (2003) [13] for the honeybee species, *A. dorsata* was the dominant sunflower visitor, and while Kumar and Singh (2005) [14] recorded the highest population of *A. mellifera* was followed by *A. cerena indica, A. dorsata* and the lowest of the *A.* florea on the sunflower. Pashte *et al*. (2013) [23] observed that during the flowering period of sesame, the dominant visitor was the honey bee species (77.67 %) compared to other insect pollinators (6.79 %).

Among the honey bees, the dominant visitor was *Apis cerana*, followed by *A. florae* and *A. dorsata*.

Succession of pollinators diversity on coriander flower

The successions of specific insect pollinators were recorded on coriander crop variety of Chhattisgarh dhaniya-1 during the Rabi season 2018-19. Foraging behavior of various pollinators/visitors were observed at 0900-1100hrs, 1100-1300hrs, 1500-1700hrs, for five minute period of the day on randomly selected plants in an area of one meter square at five days intervals on different dates (Table 2).

Indian honey bee (*Apis cerana indica*)

The diversity of Indian honey bee *Apis cerena indca* was first appeared from January, 14th 2019 with population (2.33 bees/5min/m^2) and continued at February, 18th 2019 with (1.68 bees/5min/m^2). The peak period of activity was recorded on January, 29th 2019 with average population of (6.00 bees/5min^2). After that the average activity of Indian honey bee started declining and least Indian honey bee activity was observed on February, 08th 2019 (1.66 bees/5min/m^2). The overall mean population of Indian bee was recorded as (2.79 bees/5min/m^2).

These findings corroborated with the results of Painkra and Shaw (2016) [19, 20] observed that the foraging activity of *Apis cerana indica* in niger flowers was recorded highest in the first week of November 2011 and the second week of December 2012 (33.83 bees/5min/m^2). The maximum visitation was observed at 1100hrs (66.06 bees/5min/m^2). The highest foraging activity of *Apis dorsata* was recorded at 1100hrs (11.75 bees/5min/m^2), while the lowest was recorded at 1700hrs (0.50 bees/5min/m^2). The maximum foraging behaviour of *Apis florea* was observed at 1300hrs (4.00 bees/5min/m^2) and was noticed lowest at 0900hrs (0.56 bees/5min/m^2).

Rock bee (*Apis dorsata*)

The rock bee *Apis dorsata* was recorded as second important pollinator, that activity was noticed from January, 14th 2019 (2.30 bees/5min/m^2), to continued at February, 18th 2019 (1.55 bees/5min/m^2). The highest activity of rock bee was recorded during January, 29th 2019 (with 5.00 bees/5min/m^2) on coriander flower and minimum visitation was observed during February, 8th 2019 with population of 1.51 bees/5min/m^2. The overall average population was found (2.65 bee/5min/m^2).

These findings are consistent with the previous findings of Chaudhary (2001) [8]. He recorded little bee, *A. florea* as the most abundant species (42.8%) in rapeseed followed by rock bee *A. dorsata* (16.6 %). Guruprasad (2001) [11] recorded *A. dorsata* (27.35 %) as the most influential pollinator in niger crop among the pollinators followed by *A. mellifera* (10.81%), *A. florea* (4.88 %) and *A. cerena indica* (4.17 %). Painkra (2016) [19, 20] who recorded the rock bee visiting on lajwanti flowers.

Italian bee (*Apis mellifera*)

The first appearance of *Apis mellifera* was observed from January, 14th 2019 (1.00 bees/5min/m^2), the peak period of Italian bee activity was recorded during January, 29th 2019 (4.32 bees/5min m^2) and started decline during February, 3rd (1.25 bees/5min/m^2) and minimum activity was observed during February, 18th 2019 (0.22 bees/5min/m^2). The overall mean population of Italian bee was observed (1.63 bees/5min/m^2).

In support of the above findings, it was found that Chandel *et al*. (2004) [7]. observed *A. dorsata* recoded highest foraging activity (06.30-18.55 h) and *A. Mellifera* recorded least foraging period (07.25-18.20 h) on onion seed crop. Similarly, the visit amount of onion flowers per minute by honeybee species was observed to be maximum (15.40 flowers/min) at 9 a.m. and minimum (0.93 /min) at 7 a.m. *A. Mellifera*, while for *A. dorsata* was maximum (11.46/min) at 3 p.m. and minimum (5.26/min) at 9 a.m. and was absolutely missing at 7 a.m. Furthermore, the comparison of the behaviour and the rate of visit of the onion flowers by the two species indicate that *A. Mellifera* visited more number of flowers (8.85flowers/min) than *A. dorsata* visiting 7.60 flowers/min. Painkra (2019) [22] and Painkra (2020) [21] recorded the foraging activity of Italian honey bee,A*pis mellifera* in marigold and in broccoli flowers.

Little bee (*Apis florea*)

The diversity of *Apis florea* was first recorded during January, 14th 2019 (2.00 bees/5min/m^2), thereafter the population of little bee increased and reached its peak period during January, 24th 2019 (2.11 bee/5min/m^2). Further, it started declining during January, 29th 2019 (1.98 bee/5min/m^2) and least little bee activity was noticed during February, 18th 2019 (0.39 bees/5min/m^2). The overall mean population of little bee was found as 1.22 bees/5min/m^2.

The results are corroborated by the early findings of the Nidagundi and Sattagi (2005) [17]. They observed *Apis florea* (43.00 percent) as the most dominant species in bitter gourd followed by *Apis cerana* (26.00 percent) and *A. Darsata* (13.00 percent). Saeed *et al*. (2012) [25] also recorded *Apis florea* and *A. dorsata* also reported highest visiting periods and frequency in bitter gourd.

Syrphid fly (*Eristalis sp.*)

The syrphid flies were first observed during January, 14th 2019 (1.00 syrphid flies/5min/m^2). The population of syrphid flies increased to its peak period during January, 24th 2019 (3.00 syrphid flies/5min/m^2). Further, syrphid flies population was started declining during January, 29th 2019 (2.98 syrphid flies/5min/m^2). The lowest syrphid flies population was recorded on February, 18th 2019 (0.59 syrphid flies/5min/m^2). The overall mean population of syrphid flies was noticed 1.46 syrphid flies/5min/m^2.

The findings are in conformity with the reports of Atmowidi *et al.* (2007) [5] recorded high abundance of syrphid flies (2.07 percent), *Apis cerana* (43.11%), *ceratin sp*. (36.98%) and *A. dorsata* (8.36%) on mustard crop.

House fly (*Musca domestica*)

The first appearance of house flies was recorded during January, 14th 2019 (1.96 house fly/5min/m^2) and the highest population was noticed during January, 24th 2019 (2.61 house fly/5min/m^2). After, it began decreasing January, 29th 2019 (1.44 house fly/5min/m^2). The lowest population of house fly was recorded on February, 18th 2019 (0.40 house fly/5min/m^2). The overall average population was recorded as 1.26 house flies/5min/m^2.

The results are in close compliance with the works of Saeed *et al.* (2008) [26] who observed *Apis dorsata* and *A. Florea* bee species as onion pollinators which were dominant over *Episyrphus balteatus, Musca domestica,* true flies , *Eupeodes sp. and Eristalinus aeneus*.

Common crow (Black) (*Euploea core*)

The diversity of the common crow *Euploea core* was first revealed from January, 14th 2019 (0.47 common crow/5min/m^2). The population reached its peak period during February, 8th 2019 (1.89 common crow/5min/m^2) and the minimum population of common crow was recorded during February, 18th 2019 (0.13 common crow/5min/m^2). The overall average population was recorded 0.79 common crow/5min/m^2.

The results are consistent with the findings of Dhakal and Pandev (2003) [9] reported that the niger flowers were visited by butterflies during the blooming period. Dhurve (2008) [10] reported *Danaus chrysippus* (15.71 percent) followed by *Apis dorsata* (37.23 percent), *A. Florea* (28.74 percent) and *A. Cerena indica* (18.32 percent) pollinating on niger flower. Nath and Viraktamath (2010) [18] reported eight species of sunflower pollinators, of which five were Hymenoptera and three were Lepidoptera species. *Danuas chrysippus, Pieris sp*. and *Papilio demoleus* was recorded as the major pollinators.

Red cotton bug (*Dysdercus singulatus*)

The first appearance of the red cotton bug was observed on January, 14th 2019 (0.48 red cotton bug/5min/m^2) and after that red cotton bug population reached to its maximum on January, 29th 2019 (1.51 red cotton bug/5min/m^2). The minimum population was recorded on February, 18th 2019 (0.20 red cotton bug/5min/m^2). The overall average population was noticed 0.79 red cotton bug/5min/m^2.

Thapa (2006) [29] observed the red cotton bug visiting on flowers of radish blooms.

Lady bird beetle (*Coccinella septumpunctata*)

Lady bird beetle first incidence was recorded during January 14th 2019 (0.98 lady bird beetle/5min/m^2). Further, it started decreasing during January, 19th 2019 (0.48 lady bird beetle/5min/m^2) and again lady bird beetle population was observed highest during January 8th 2019 (1.96 lady bird beetle/5min/m^2) and lowest population of lady bird beetle was recorded on February, 18th 2019 (0.25 lady bird beetle/5min/m^2). The overall average populations were noticed as 0.90 lady bird beetle/5min/m^2.

Results are in close agreement with Jadhav *et al.* (2010) [12] reported ladybird beetle visiting on sunflower crop. Wahab and Ebadah (2011) [30] also recorded a visit of *Coccinella undecipunctata* to black cumin.

Blow fly (*Chrysomiya bezziana*)

The first occurrence of blow fly was observed during January, 14th 2019 (1.04 blow fly/5min/m^2) and the highest population of blow fly was recorded in January, 24th 2019 (1.89 blow fly/5min/m^2). The population of blow fly started declining in January, 29th 2019 (0.61 blow fly/5min/m^2) and reached its lowest level during February, 18th 2019 (0.33 blowfly/5min/m^2). The overall mean population was found 0.85 blow fly/5min/m^2.

The present results are consistent with Priti *et al.* (2001) [24] reported that *Apis dorsata A. florea*, *A. mellifera*, *Halictus sp*., *Gasterophilus sp.*, *Chrysomya bezziana* and *sarcophagus sp.* as pollinators on radish flowers. Sajjad *et al*. (2008) [27] observed various onion bloom pollinators comprising about 72% of syrphid flies and 28% of non-syrphid flies, *i.e. Domestic musca*, *Calliphoridae sp*. and *Sarcophagus sp.*

Table 1: Diversity of pollinators/visitors on coriander flower during 2018-19

S.N.	Pollinator /Visitors	Scientific Name	Order	Family	(visits/5min/m^2) hours of the day			Mean	Percent contribution of insect pollinators/ visitors (%)	Total percentage
					900-1100hrs	1100-1300hrs	1500-1700hrs			
1	Indian honey bee	*Apis cerena indica*	Hymenoptera	Apidae	2.39	3.66	2.16	2.74	28.16	88.17
2	Rock bee	*Apis dorsata*	Hymenoptera	Apidae	2.37	3.61	1.88	2.62	26.92	
3	Italian bee	*Apis melifera*	Hymenoptera	Apidae	1.50	3.47	1.55	2.17	22.30	
4	Little bee	*Apis florea*	Hymenoptera	Apidae	1.00	1.35	0.80	1.05	10.79	
5	syrphid fly	*Eristalis sp.*	Diptera	Syphidae	0.20	0.40	0.19	0.26	2.68	7.00
6	House fly	*Musca domestica*	Diptera	Muscidae	0.23	0.26	0.20	0.23	2.37	
7	Blow fly	*Chrysomya beziana*	Diptera	Calliphoridae	0.17	0.25	0.14	0.19	1.95	
8	Common crow (black)	*Euploea core*	Lepidoptera	Nymphalidae	0.16	0.22	0.13	0.17	1.74	4.83
9	Red cotton bug	*Dysdercus cingulatus*	Hemiptera	Pyrrhocoridae	0.15	0.21	0.12	0.16	1.65	
10	Lady bird beetle	*Coccinalla septumpuntata*	Coleoptera	Coccinellidae	0.14	0.18	0.10	0.14	1.44	
	Total				8.31	13.61	7.27	9.73	100.00	

Table 2: Succession of pollinators diversity on coriander flower during Rabi 2018-19

Date of observation	Mean number of visitors/5min/m^2									
	Indian honey bee	Rock bee	Italian bee	Little bee	Syrphid fly	House fly	Common crow (Black)	Red cotton bug	Lady bird beetle	Blow fly
14.01.2019	2.33	2.66	1.00	2.00	1.00	1.96	0.47	0.48	0.98	1.04
19.01.2019	3.13	3.10	3.50	1.23	2.00	1.20	0.33	1.04	0.48	0.61
24.01.2019	3.22	3.30	2.02	2.11	3.00	2.61	1.08	1.10	1.00	1.89
29.01.2019	6.00	5.07	4.32	1.98	2.98	1.44	1.01	1.51	0.90	1.06
03.02.2019	2.21	2.13	1.25	0.97	0.74	0.87	1.21	0.55	1.08	0.87
08.02.2019	1.66	1.89	0.41	0.61	0.53	0.83	1.89	0.39	1.96	0.52
13.02.2019	2.10	1.51	0.33	0.44	0.85	0.80	0.20	0.29	0.58	0.48
18.02.2019	1.68	1.55	0.22	0.39	0.59	0.40	0.13	0.20	0.25	0.33
Total	22.33	21.21	13.05	9.73	11.69	10.11	6.32	5.56	7.23	6.80
Overall mean	2.79	2.65	1.63	1.22	1.46	1.26	0.79	0.70	0.90	0.85

A view of Different pollinators/visitors visiting on coriander flowers

Plate 1: Indian Honey Bee

Plate 2: Rock Bee

Plate 3: Italian Bee Plate

Plate 4: Syrphid Fly

Plate 5: Common Crow (Black)

Plate 6: Red Cotton Bug

Plate 7: Lady Bird Beetle

Plate 8: Blow Fly

Conclusion

Coriander flowers attracted different kinds of pollinators/visitors due to its pollen and nectars sources i.e. *Apis dorsata, Apis mellifera* and *Apis florae.* Some other pollinators/visitors were also recorded like *Eristalis* sp., *Musca domestica, Danaus chrysippis, Dysdercus cingulatus, Coccinalla septumpuntata,* and *Chrysomya beziana* visiting on coriander flowers. All the above insects were contributed for yield enhancement of coriander crop.

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