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Diurnal foraging activity of flower visiting insects on some seed spices under terai agroclimatic zone of West Bengal

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Abstract
A field experiment was carried out at the instructional farm of the varsity, Uttar Banga Krishi Viswa Vidyalaya, at terai agro-climatic zone of West Bengal (India) during Rabi season of 2015 and 2016 to monitor the foraging activity of different flower visiting insects on some seed spices like fennel, black cumin and coriander. Local varieties of fennel and black cumin along with coriander variety Debcor-88 were considered for the study and foraging time of different insects were recorded during the blossoming period of the spice crops. This is the first ever work in this area. Results revealed that a total of 18 species of insects belonging to 5 orders visited coriander flowers while 25 insect species from 5 orders were recorded from fennel flowers. In case of black cumin, the number of flower visiting insects was 11 under 4 orders. Maximum of the Hymenopteran pollinators were found to visit the flowers between 12.00 hrs to 13.00 hrs followed by 9.00- 10.00 hrs in the morning and 15.00- 16.00 hrs in the afternoon. Dipteran visitors were highly active during morning between 9.00 - 10.00 hrs. Their abundance noticeably reduced during 15.00-16.00 hrs in the afternoon and lowest activity was observed during 12.00-13.00 hrs in the noon. Lepidopteran insects had shown highest foraging activity during 12.00-13.00 hrs. The foraging activity of the Coleopteran insects was the highest during the morning from 9.00-10.00 hrs and their activity decreased during the noon from 12.00-13.00 hrs and increased again during the afternoon hours.

Keywords: Pollinators, seed spices, foraging activity of insects, honeybee

Introduction
Seed spices are the most indispensible component of Indian cuisine for their aroma and test and are used in preparation of countless dishes all over the Indian sub-continent. India is the land of spices and among the different spices grown in the country, 20 spices are considered as seed spices. Most important seed spices includes coriander (*Coriandrum sativum* L.), cumin (*Cuminum cyminum* L.), fennel (*Foeniculum vulgare* Mill.), fenugreek (*Trigonella foenum-graecum* L.), Ajwain (*Trachyspermum ammi* L.), celery (*Apium graveolens* L.), dill (*Anethum sowa* Roxb., *A. graveolens*), Nigella (*Nigella sativa* L.) (Free, 1993) [1]. Majority of the seed spice crops like coriander (Deodikar and Suryanarayana, 1977; Baswana, 1984 and Sihag, 1986) [2, 3, 4], fennel (Baswana, 1984) and cumin (Sihag, 1986) are cross pollinated in nature. Insects and other arthropods play an important role in boosting their production by significantly increasing the yield through visiting flowers and helping in pollination. These seed crops are also known as pollinator inviting plants and some of them (Fennel, Coriander and Black cumin) are recommended as pollination enhancing tools under the concept of ecological engineering in AESA based IPM.
The present experiment was conducted with an objective of documentation of different insect visitors visiting the flowers of three important spice crops *viz.* Fennel, Black cumin, Coriander and also to study their foraging activities during different hours of the day.

Materials and methods
The studies were carried out during Rabi season of 2014-15 and 2015-16 at the instructional farm of Uttar Banga Krishi Viswavidhayalaya, Pundibari ($26^0$19' 86" N latitude and 89^0 23' 53" E longitude), Cooch Behar, West Bengal. The elevation of the place is 43 meters above mean sea level. The area lies under the Terai agro climatic region of West Bengal.
Local varieties of fennel and black cumin along with coriander variety Debcor-88 were considered for the study on insect foraging. N, P and K were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP) respectively @ 60: 30:30.

First irrigation was given after 5 DAS and the subsequent 5 irrigations were given at 10 days interval. Plot size was 4m×3m and spacing was 10 cm (plant to plant) and 30 cm (row to row).

The records on the flower visiting insects were taken during the entire flowering period of the crops and recording of insects were accomplished by sweep netting conducted three times a day at two hours interval starting from 09.00 to 10.00 hrs. 12.00 noon to 13.00 hrs. and 15.00 to 16.00 hrs. through three minutes left and right netting in each plot. The experiment was laid out in RBD with three replications. The data thus collected was statiscally analysed by using standard analysis of variance (ANOVA).

Results and discussion

It is evident from the experiment that 18 species of insects visited coriander flowers, 25 species visited fennel while 11 insects species were recorded from black cumin flowers. The result of the present study is in conformity with various previous works. Chaudhary and Singh (2007) [5] reported 34 species of insects belonging 18 families under 8 orders from the coriander flowers from Karnal while Meena *et al.* (2015) [6] recorded 25 insect visitors. Sihag (1986) noted honeybees and some dipterans as the most dominant visitors of coriander, whereas Koul (1989) [7] recorded honeybees as the main pollinator of coriander. Chaudhary (2006) [8] recorded 39 species of insects from fennel flowers and among the honeybees. *A.mellifera* was the prominent one while the others were *A. dorsata, A cerena, A. flora*. Similarly 16 insects species were recorded by Shilpa *et al*. (2014) [9] and Meena *et al.* (2015) reported 24 floral visitors from fennel group and honeybees were the primary pollinators. Mukherjee *et al.* (2013) [10] recorded one species of honeybee (*Apis dorsata*), coccinellid beetles, ladybugs, butterflies and wasp from flowers of black cumin. Kant *et al.* (2018) [11] observed bees as the main pollinators of black cumin and *A. flora* was the dominant one along with the presence of *A dorsata* and *A mellifera.* Abrar *et al.* (2017) [12] recorded nine species of insects from three orders namely dipteral, hymenoptera and lepidoptera from black cumin in Pakistan and syrphid flies among the dipteral, honeybees (*Apis dorsata* and *A florea*) among hymenoptera, cabbage butterfly (*Pieris brassicae*) and Monarch butterfly among lepidoptera were dominant.

Occurrence of 18, 25 and 11 species of insects in coriander, fennel and black cumin respectively signifies the existence of rich biodiversity in this zone and different species of honeybees and wild bees are already present and actively participate in the process of pollination of various crops. Variation in the number of species may be accounted for the location of the study. Among dipteran insects, syrphid fly constituted a major proportion of the pollinators which implies that they might play some important role in keeping the various pests of the spice crops under control during their immature stage and later thrive on the pollen and nectar of the three spice crops viz coriander, fennel and black cumin.

Foraging activity of insect visitors on three spice crops showed almost a definite pattern in different crops. Except the ant species, all other Hymenopteran insects had maximum activity during 12:00 to 13:00 hrs. The ant species was mostly active in the morning hours during 9:00 to10:00 hrs. Similarly, all the dipteran flower visitors had their highest foraging activity during the morning hours (9:00 to 10:00 hrs) and they also showed high activity during afternoon hours while their activity was lowest during noon hours. During the entire course of study, the foraging activity of lepidoptera, hemiptera and coleoptera were very highly active during the morning hours i.e 9:00-10:00 hrs.

It is known from the behavioural studies that honeybee species viz *A. dorsata*, *A florea* and *A. indica* begins their activity at 9:00 -10:00 hrs and their activity becomes peak at 12:30-14:00 hrs and ceases by 17:00 hrs (Kapil *et al.*, 1971[13]). Bhalla *et al.* (1983) [14] also had similar finding. Prasad *et al*. (1989) [15] observed that foraging activity of honeybees started at 8:00 hrs and reached a peak between 11:00-12:00 hrs and ceased towards evening. Thus the result of the present study lends support from the above mentioned result. However it is contradicted by Mohar and Jay (1988) [16] who reported the highest activity of honeybee species during 9:00 hrs. The ants remained active during morning hours probably for the reason that they cannot tolerate higher temperature during noon and afternoon hours. They frequently visit the flowers for pollen and nectar. Hence the result is in conformity with this work.

Most of the dipteran flower visitors remained active during morning hours. The natural enemie syrphid fly (*E. Balteatus*, *Meliscaeva auricollis*, *Sphaeropheria scripta*) prey on the tiny soft bodied insects and during early morning hours all the soft bodied insects remain less active due to wetting of their bodies with dew precipitation on the leaves or flowers. Shivashankara *et al.* (2016) [17] observed early morning activity of syrphid flies (8:23 hrs) on coriander which is much early than the honeybees (10:30 hrs). Abrar *et al.* (2017) [12] found higher activity of syrphid flies on black cumin during morning hours from 9:30-10.30am and lower activity was noted during 2:30-3:30pm. Thus the results are in agreement with the above mentioned works.

Foraging activity of lepidopteran insects were more during 12:00-1:00 hrs. Similar results was obtained by Abrar *et al.* (2017) [12] who noticed that relative abundance of *P. brassicae* and *D. chryssipus* were more at 2:30-3:30 pm than morning hours at 9:30-10:30 pm. Munawar *et al.* (2009) [18] also recorded honeybees, Syrphid flies and butterflies in pollination activity in black cumin. Mukherjee *et al.* (2013) [10] noted honeybees and butterflies a pollinators of black cumin while Shivashankara *et al.* (2016) [17] recorded three species of Lepidoptera from coriander flowers.

Foraging activity of coleopteran insects were very high during morning hours (9:00-10:00 hrs). Most of the workers put emphasis on the foraging activity of the hymenopteran and dipteran insects which constitute the major share of the pollinating insects. Shivashankara *et al.* (2016) [17] recorded two species of coccinellidae from coriander flower and they observed the initiation of activity of all pollinating insects at the morning hours and peak activity during 12:00-3:00 pm except the syrphid flies.

Thus the result of the present study is similar with the above except the period of activity which may be due to the difference in geographical location and climatic condition.

Table 1: Foraging activity of flower visiting insects in Coriander during 2015-16

Sl. No.	Insect visitors	Mean population of insects visitor m-^{2} on 3 minute sweep netting in Coriander during different day hours											
		2015				2016				Pooled			
		09:00-10:00	12:00-13:00	15:00-16:00	Mean	09:00-10:00	12:00-13:00	15:00-16:00	Mean	09:00-10:00	12:00-13:00	15:00-16:00	Mean
1.	*Apis cerana*	5.29	10.90	6.29	7.49	4.10	9.33	5.05	6.16	4.70	10.12	5.67	6.83
2.	*Apis dorsata*	4.57	8.86	4.10	5.84	3.19	7.19	2.67	4.35	3.88	8.03	3.39	5.10
3.	*Apis melifera*	9.86	19.00	10.33	13.06	7.81	16.29	8.24	10.78	8.84	17.65	9.29	11.92
4.	*Halictus* sp.	5.19	8.81	3.33	5.78	3.67	6.52	1.57	3.92	4.43	7.67	2.45	4.85
5.	*Camponotus* sp.	18.52	9.10	14.43	14.02	19.24	9.24	14.76	14.41	18.88	9.17	14.60	14.22
6.	*Episyrphus balteatus*	30.90	16.19	24.38	23.83	33.81	17.24	26.71	25.92	32.36	16.72	25.55	24.88
7.	*Meliscaeva auricollis*	24.10	13.48	19.62	19.06	26.90	13.76	21.57	20.75	25.50	13.62	20.60	19.91
8.	*Prosena* sp.	8.57	3.67	6.52	6.25	9.43	4.00	7.29	6.90	9.00	3.84	6.91	6.58
9.	*Sphaerophoria scripta*	23.76	12.52	19.00	18.43	26.14	12.76	20.76	19.89	24.95	12.64	19.88	19.16
10.	*Sphaerophoria taeniatta*	17.14	8.29	13.57	13.00	18.52	8.86	14.57	13.98	17.83	8.58	14.07	13.49
11.	*Musca* sp.1	29.67	15.29	22.95	22.63	32.86	16.33	25.62	24.94	31.27	15.81	24.29	23.79
12.	*Musca* sp.2	18.95	10.10	16.14	15.06	21.43	10.52	17.57	16.51	20.19	10.31	16.86	15.79
13.	*Amata phegea*	1.76	4.48	0.48	2.24	1.57	3.90	0.48	1.98	1.67	4.19	0.48	2.11
14.	*Lampides boeticus*	1.14	4.14	0.33	1.87	1.14	3.52	0.29	1.65	1.14	3.83	0.31	1.76
15.	*Palomena prasina*	3.38	2.43	2.86	2.89	3.90	2.71	3.05	3.22	3.64	2.57	2.96	3.06
16.	*Coccinella septempunctata*	7.33	4.62	5.67	5.87	9.14	5.71	7.43	7.43	8.24	5.17	6.55	6.65
17.	*Coccinella transversalis*	4.29	2.62	3.95	3.62	5.57	3.33	4.90	4.60	4.93	2.98	4.43	4.11
18.	*Micraspis discolour*	4.81	3.19	4.24	4.08	5.95	4.05	5.76	5.25	5.38	3.62	5.00	4.67
19.	Unidentified Spider	6.19	3.62	5.14	4.98	7.24	3.95	5.95	5.71	6.72	3.79	5.55	5.35
	Mean	11.86	8.49	9.65		12.72	8.38	10.22		12.29	8.44	9.94	
	SD	9.71	5.07	7.70		10.91	4.89	8.61		10.31	4.98	8.16	

Table 2: Foraging activity of flower visiting insects in fennel during 2015-16

Sl. No.	Insect visitors	Mean population of insects visitor m-^{2} on 3 minute sweep netting in Fennel during different day hours											
		2015				2016				Pooled			
		09:00-10:00	12:00-13:00	15:00-16:00	Mean	09:00-10:00	12:00-13:00	15:00-16:00	Mean	09:00-10:00	12:00-13:00	15:00-16:00	Mean
1.	*Apis dorsata*	4.57	8.38	4.05	5.67	3.05	6.52	2.52	4.03	3.81	7.45	3.29	4.85
2.	*Apis cerana*	5.10	9.52	3.81	6.14	3.48	8.10	2.48	4.69	4.29	8.81	3.15	5.42
3.	*Apis mellifera*	8.24	14.33	7.33	9.97	5.90	12.39	5.10	7.80	7.07	13.36	6.22	8.89
5.	*Polistes*	1.14	3.48	0.33	1.65	0.90	2.99	0.14	1.35	1.02	3.24	0.24	1.50
6.	*Scolia dubia*	0.19	1.52	0.00	0.57	0.19	1.35	0.00	0.51	0.19	1.44	0.00	0.54
7.	*Vespa orientalis*	0.43	1.86	0.10	0.79	0.19	1.00	0.10	0.43	0.31	1.43	0.10	0.61
8.	*Camponotus* sp.	26.05	15.71	22.24	21.33	26.38	16.32	22.81	21.84	26.22	16.02	22.53	21.59
9.	*Mesembrius bengalensis*	5.76	2.76	4.71	4.41	6.57	3.17	5.48	5.07	6.17	2.97	5.10	4.74
10.	*Meliscaeva auricollis*	10.19	5.43	8.71	8.11	11.33	6.47	9.86	9.22	10.76	5.95	9.29	8.67
11.	*Eristalis arvorum*	4.05	0.95	2.48	2.49	4.33	0.98	2.71	2.68	4.19	0.97	2.60	2.59
12.	*Chysomyia bezziana*	2.57	0.62	2.24	1.81	2.52	0.63	2.19	1.78	2.55	0.63	2.22	1.80
13.	*Episyrphus balteatus*	22.38	11.67	19.14	17.73	25.19	13.59	21.14	19.97	23.79	12.63	20.14	18.85
14.	*Musca* sp.1	22.14	11.76	18.62	17.51	24.33	13.68	20.43	19.48	23.24	12.72	19.53	18.50
15.	*Musca* sp.2	11.62	5.57	9.76	8.98	12.86	6.52	10.67	10.02	12.24	6.05	10.22	9.50
16.	*Sphaerophoria scripta*	7.52	3.29	5.71	5.51	8.48	3.94	6.38	6.27	8.00	3.62	6.05	5.89
17.	*Sphaerophoria taeniata*	4.14	1.29	3.38	2.94	4.62	1.51	3.71	3.28	4.38	1.40	3.55	3.11
18.	*Amata phegea*	0.90	1.86	0.24	1.00	0.81	1.51	0.29	0.87	0.86	1.69	0.27	0.94
19.	*Danaus chrysippus*	0.10	0.86	0.00	0.32	0.00	0.31	0.00	0.10	0.05	0.59	0.00	0.21
20.	*Lampides boeticus*	0.29	1.43	0.10	0.60	0.19	0.98	0.10	0.42	0.24	1.21	0.10	0.51
21.	*Leptocoris algar*	2.81	1.43	2.24	2.16	2.67	1.43	2.19	2.10	2.74	1.43	2.22	2.13
22.	*Palomena prasina*	1.24	0.38	1.14	0.92	1.14	0.44	1.14	0.91	1.19	0.41	1.14	0.92
23.	*Coccinella septempunctata*	9.00	4.76	7.76	7.17	10.81	6.00	9.38	8.73	9.91	5.38	8.57	7.95
24.	*Coccinella*	4.95	2.62	4.33	3.97	5.48	3.03	4.95	4.49	5.22	2.83	4.64	4.23

	transversalis												
25.	*Micraspis discolour*	4.05	2.33	3.71	3.37	4.81	2.95	4.43	4.06	4.43	2.64	4.07	3.72
26.	Unidentified Spider	6.52	3.76	5.71	5.33	7.62	4.42	6.81	6.28	7.07	4.09	6.26	5.81
	Mean	6.23	4.63	5.22		6.46	4.69	5.41		6.35	4.66	5.32	
	SD	6.87	4.51	5.91		7.51	4.61	6.42		7.19	4.56	6.17	

Table 3: Foraging activity of flower visiting insects in Black Cumin during 2015-16

Sl. No.	**Insect visitors**	**Mean population of insects visitor m-^{2} on 3 minute sweep netting in Black Cumin during different day hours**											
		2015				**2016**				**Pooled**			
		09.00-10.00	**12.00-13.00**	**15.00-16.00**	**Mean**	**09.00-10.00**	**12.00-13.00**	**15.00-16.00**	**Mean**	**9.00-10.00**	**12.00-13.00**	**15.00-16.00**	**Mean**
1.	*Apis dorsata*	3.10	7.33	2.48	4.30	2.33	6.76	1.33	3.48	2.72	7.05	1.91	3.89
2.	*Apis mellifera*	7.95	15.24	7.14	10.11	6.57	13.24	4.43	8.08	7.26	14.24	5.79	9.10
3.	*Halictus* sp.	3.29	5.81	1.86	3.65	3.05	5.52	0.90	3.16	3.17	5.67	1.38	3.41
4.	*Musca* sp.2	22.38	10.05	16.19	16.21	26.33	10.71	18.48	18.51	24.36	10.38	17.34	17.36
5.	*Prosena* sp.	3.76	4.05	1.24	3.02	4.14	4.43	1.19	3.25	3.95	4.24	1.22	3.14
6.	*Episyrphus balteatus*	24.62	11.76	18.14	18.17	27.19	11.86	18.81	19.29	25.91	11.81	18.48	18.73
7.	*Sphaerophoria scripta*	19.24	8.81	15.48	14.51	20.48	8.81	15.19	14.83	19.86	8.81	15.34	14.67
8.	*Amata phegea*	1.67	2.33	0.14	1.38	1.62	2.14	0.14	1.30	1.65	2.24	0.14	1.34
9.	*Coccinella septempunctata*	3.14	1.81	2.48	2.48	4.33	2.29	2.90	3.17	3.74	2.05	2.69	2.83
10.	*Coccinella transversalis*	1.76	0.90	1.52	1.40	2.19	0.90	1.90	1.67	1.98	0.90	1.71	1.54
11.	*Micraspis discolour*	2.76	1.86	2.29	2.30	3.52	1.86	2.62	2.67	3.14	1.86	2.46	2.49
12.	Unidentified Spider	3.71	2.48	3.29	3.16	4.14	2.62	3.43	3.40	3.93	2.55	3.36	3.28
	Mean	8.12	6.04	6.02		8.83	5.93	5.94		8.48	5.99	5.98	
	SD	8.28	4.43	6.34		9.76	4.30	7.11		9.02	4.37	6.73	

Conclusion

This two years study revealed that in all the three seed spices, i.e, Coriander, Fennel and Black Cumin, major proportion of visiting insects were from the order Diptera. The dipterans were highly active during the morning hours during 9.00-10.00 hrs and their abundance reduced during afternoon hours from 15.00-16.00 hrs and their activity was lowest during 12.00-13.00 hrs. Hymenoptera constitute the second largest foraging group and their activity was highest during mid-day period i.e. from 12.00 to 13.00 hrs. Equal extent of low activity of hymenopteran insects was noted during 9.00-10.00 hrs in the morning and also during 15.00-16.00 hrs in the afternoon. On the other hand an exception was noticed in the foraging activity of the ant species, *Camponotus* sp. Their activity was highest during morning hours from 09.00 to 10.00 hrs followed by afternoon hours from 15.00 to 16.00 hrs and lowest activity was noted during mid-day from 12.00 to 13.00 hrs.

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