



Effect of Imidacloprid on Foraging Behaviour of Wild Bee Species on Coriander

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Abstract: The experiment was carried out at Beekeeping Unit, TCA, Dholi (Muzaffarpur) during 'rabi 2021-22' on c.v. of coriander 'Rajendra Dhanisa-2'. Foraging behaviour of rock bee and little bee such as duration of foraging, foraging speed and rate was studied under two conditions i.e. with and without insecticide application. In untreated area duration of foraging was maximum in *Apis dorsata* (7.16 second) and minimum in *Apis florea* (3.51 second). Foraging rate was highest in *A. florea* (11.66 flowers) followed by *A. dorsata* (6.64 flowers). Application of insecticide imidacloprid @ 25 gm a.i./ha completely ceased the activity of honey bee species on flowers of coriander for three days. Effect of insecticide on foraging behaviour was observed for a period of 4 to 5 days in wild bee species. Insecticide application caused 20 to 25 % reduction in foraging activity of both wild species during complete flowering period.

Keywords: *Apis dorsata*, *Apis florea*, Foraging activity, Imidacloprid 17.8 % SL, Deviation

India is considered as the home of spices due to largest production, consumption and export of seed spices. Coriander (*Coriandrum sativum* L.) is an important tropical spice crop of family Apiaceae (Umbelliferae). Although it is a native to eastern Mediterranean region, India has the production share of more than 70 per cent to the total world output (Coskuner and Karababa 2007). Spices are highly cross pollinated and around 75 per cent are dependent on the animals for pollination while the only 28 crop spices crops depend on wind or self-pollination (Klein et al 2007). The flowering phenology of coriander i.e., protandrous condition is responsible for cross pollination in it. Around 11 to 14 insect pollinators were documented as the important agents responsible for pollinating coriander (Devi et al 2015, Thakur et al 2022). Genus *Apis* is the most studied because of their fascinating and complex lifestyle, communication systems, role as keystone and the valuable hive products that they produce (Giri et al 2018). Bees, in particular, excel as pollinators due to their pollen-collecting behavior driven by nutritional needs. Over 80 percent of a honey bee body is adorned with pollen-attracting hairs that utilize electrostatic forces to draw in pollen grains. Their remarkable loyalty to a single plant until it ceases flowering enhances pollination efficiency, making them highly favored for effective pollination. *Apis dorsata* (Fabricius) and *A. florea* (Fabricius), as wild species, cannot be kept in bee boxes, yet their role as

primary pollinators becomes indispensable in the absence of domesticated species. Despite their lower honey yields compared to domesticated counterparts, they play a pivotal role in the pollination process.

Given coriander's reliance on honey bees for cross-pollination, the impact of insecticide on these vital pollinators becomes a pressing concern. The perils associated with insecticidal application encompass not only direct mortality but also indirect consequences such as fumigative effects, repellency, and the toxicity of residues found in nectar and on various floral parts (Desneux et al 2007). Consequently, investigating the effect of imidacloprid on the foraging behavior of wild bees holds paramount significance in preserving the pollination dynamics of coriander and other cross-pollinated crops. This research aims to investigate the impact of imidacloprid on the foraging behavior of wild bee species, *A. dorsata* and *A. florea* within the context of coriander pollination.

MATERIAL AND METHODS

The foraging pattern of the wild species of honey bee on coriander was observed at Beekeeping Unit, TCA, Dholi (Muzaffarpur) during 'rabi 2021-22'. The observations were recorded on duration of foraging, foraging speed and foraging rate. This objective was studied under two different conditions i.e. with insecticidal application and without insecticidal

application. Imidacloprid spraying was carried out on March 6, 2022 in 3 plots with imidacloprid 17.8% SL @ 25gm a.i/ha. Initiation time of foraging for bee pollinators was recorded in morning and cessation time in the evening .The duration of foraging (minute) was calculated. The time spent in seconds by honey bee species on individual flower is foraging speed. The number of flowers visited by honey bee species per minute is called foraging rate and was calculated by visual observations. Observations were recorded from 07:00 at 2 hour interval till 17:00 hours from 3 different spots from each plot on alternate day from March 3 to March 17, 2022

RESULTS AND DISCUSSION:

Foraging duration: In the untreated area duration of foraging was maximum in *A. dorsata* (10:37 hours) than *A. florea* (09:42 hours) under normal condition (Fig. 1). Earliest foraging activity was started by *A. dorsata* i.e. 06:46 AM and stopped at 17:25 PM. *A. florea* started foraging activity very late i.e. 07:15 AM and ceased at 16:56 PM. Maximum foraging period was observed on March 17,2022 i.e.11:12 hours in *A. dorsata*, whereas in *A. florea* it was observed on March 13,

2022 i.e. 10:09 hours. Chandel et al (2002) observed that maximum foraging period by *A. dorsata* i.e. 6.30 AM-6.50 PM. Negi et al (2020) observed that foraging period of *A. dorsata* was 6.30 AM to 6.55 PM, which was maximum among all other species. Kumar and Giri (2020) also observed that duration of foraging was maximum in *A. dorsata*. Duration of foraging was low during initial days of flowering when day length was shorter but increased with increase in day length. Duration of foraging increased with increase in pollen-nectar availability, temperature and day length. Requirement of floral resources was higher in *A. dorsata* due to bigger body size which resulted in maximum foraging duration.

In insecticide treated area before the date of insecticide application, the foraging activity was same as in the untreated plot for both bee species. After insecticide treatment the foraging activity was ceased completely for 3 days in all species (Table 1). Though foraging activity was restarted after 4 days in both bee species, foraging duration was lesser than the normal. Effect of insecticide on foraging behaviour was observed for 4 to 5 days in wild bee species. Giri et al (2022) also observed that neonicotinoid causes

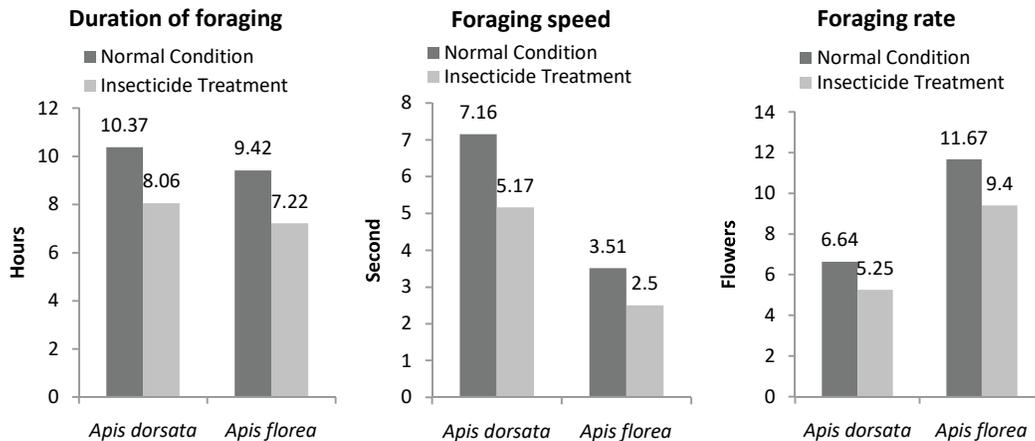


Fig. 1. Deviation in mean foraging activity due to imidacloprid treatment

Table 1. Foraging activity period of honey bee species on coriander bloom in untreated and imidacloprid treated area

Dates of observation (2022)	Untreated						Imidacloprid treated					
	<i>A. dorsata</i>			<i>A. florea</i>			<i>A. dorsata</i>			<i>A. florea</i>		
	I	C	D	I	C	D	I	C	D	I	C	D
March 3	07:02	17.10	10:08	07:50	17:00	09:10	07:02	17:09	10:07	07:52	17:01	09:09
March 5	06:54	17:22	10:28	07:35	17:03	09:28	06:55	17:23	10:28	07:35	17:04	09:29
March 9	06:50	17:25	10:35	07:00	17:04	10:04	00:00	00:00	00:00	00:00	00:00	00:00
March 13	06:40	17:29	10:49	06:57	17:06	10:09	06:40	17:28	10:48	06:55	17:08	10:13
March 17	06:28	17:40	11:12	06:53	16:30	09:37	06:27	17:42	11:15	06:50	04:32	09:42
Mean	06:46	17:25	10:38	07:15	16:56	09:41	06:46	17:25	08:31	07:18	13:56	07:42

I - Initiation time (AM), C - Cessation time (PM), D - Duration of foraging (Hrs)

mortality of bee species under semi-field conditions which caused reduction in foraging duration. Honey bees avoided to visit the field due to toxic and strong smell of insecticide.

Foraging speed: In untreated area mean foraging speed (time spent on individual flower) was highest in *A. dorsata* (7.16 sec.) followed by *A. florea* (3.51 sec.) (Fig. 1). Foraging speed of *A. florea* was highest during early flowering, whereas at peak flowering stage *A. dorsata* showed highest foraging speed. *A. dorsata* showed high foraging speed during late afternoon hours i.e. 8.21 sec. *A. florea* (5.01 sec) spent more time during early morning hours (Table 2, 3). Devi (2011) also reported similar trend. *A. dorsata* spent more time on umbel followed by *A. florea*. Das et al (2019) observed that foraging speed of *A. florea* was maximum during morning hours (9:00 to 11:00 AM) and decreased as temperature started to increase. Mishra and Kumar (2018) reported that time spent on individual flower was maximum in *A. dorsata* and least observed in *A. florea*. Foraging speed of *A. florea* was maximum in morning while minimum in evening. *A. dorsata* spent more time on individual flower due to high floral resource requirement. Only small sized bee (*A. florea*) can enter the partially opened flowers in morning hours, which was the main reason behind high foraging speed of little bee during early morning.

In insecticide treated area after insecticide spraying, foraging activity ceased for 3 days. Effect of insecticide was prominent up to 5 to 6 days on foraging speed of *A. florea* and *A. dorsata* (Table 2, 3). Foraging activity restarted on 4th day, still the foraging speed was lower than the normal. Mean foraging speed in insecticidal treatment was highest in *A. dorsata* (5.17 sec) followed by *A. florea* (2.50 sec) (Fig. 1). Giri et al (2018) also reported that thiamethoxam had negative impact on foraging speed of honey bee.

Foraging rate: In untreated area mean foraging rate was highest in *A. florea* (11.67 flowers) followed by *A. dorsata* (6.64 flowers) (Fig. 1). *A. dorsata* (7.20 flowers) showed (maximum foraging rate during early morning period (Table 4, 5). *A. florea* visited maximum flowers (14.58 flowers) during late afternoon period and minimum foraging rate was of *A. dorsata* (5.56 flowers) during late flowering period. *A. florea* (8.22 flowers) showed less foraging rate at initial stage of flowering. *A. dorsata* visited fewer flowers when pollen-nectar availability of flower got increased i.e. up to peak period of flowering and again increased near to seed maturity. Chaudhary and Singh (2007) reported that lowest foraging rate in *A. dorsata* (6.61 flowers/minute). Devi (2011) reported that *A. dorsata* spent more time on onion umbel followed by *A. florea*. Foraging rate of *A. dorsata* was low

Table 2. Foraging speed of *A. dorsata* visiting coriander flowers in untreated and imidacloprid treated area

Dates of observation (2022)	Time spent on flowers (in sec.)							
	09:00		11:00		13:00		15:00	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
March 3	6.12	6.10	6.75	6.70	6.90	6.95	6.45	6.40
March 5	6.88	6.92	7.89	7.80	7.12	7.20	8.88	8.90
March 9	7.86	0.00	7.77	0.00	8.05	0.00	8.56	0.00
March 13	7.35	7.3	8.24	8.20	8.89	8.88	9.04	9.06
March 17	6.89	6.88	6.88	6.90	7.34	7.30	8.12	8.14
Mean ± SD	7.02±0.64	5.44±3.07	7.51±0.66	5.92±3.37	7.66±0.81	6.07±3.48	8.21±1.04	6.50±3.78

Table 3. Foraging speed of *A. florea* visiting coriander flowers in untreated and imidacloprid treated plot

Dates of observation (2022)	Time spent on flowers (in sec.)							
	09:00		11:00		13:00		15:00	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
March 3	5.75	5.76	5.04	5.08	4.12	4.11	3.77	3.78
March 5	6.12	6.15	5.78	5.70	4.52	4.45	4.25	4.18
March 9	4.78	0.00	4.89	0.00	3.78	0.00	3.25	0.00
March 13	4.69	4.66	3.84	3.85	3.50	3.56	3.10	3.12
March 17	3.72	3.75	3.45	3.46	3.02	3.05	3.03	3.02
Mean ± SD	5.01±0.95	4.06±2.46	4.60±0.94	3.62±2.22	3.79±0.57	3.03±1.78	3.48±0.52	2.82±1.65

Table 4. Foraging rate of *A. dorsata* visiting coriander flowers in untreated and imidacloprid treated plot

Dates of observation (2022)	Number of flowers visited in one minute							
	09:00		11:00		13:00		15:00	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
March 3	8.22	8.22	7.44	7.45	7.22	7.11	7.67	7.67
March 5	7.56	7.45	6.44	6.45	7.11	7.00	5.67	5.67
March 9	6.33	0.00	6.44	0.00	6.33	0.00	6.00	0.00
March 13	6.67	7.00	6.11	6.22	5.67	5.67	5.56	5.67
March 17	7.22	7.33	7.33	7.33	6.67	7.00	6.22	6.22
Mean ± SD	7.20±0.74	6.00±3.38	6.75±0.59	5.49±3.12	6.60±0.63	5.36±3.05	6.22±0.85	5.05±2.94

Table 5. Foraging rate of *A. florea* visiting coriander flowers in untreated and imidacloprid treated plot

Dates of observation (2022)	Number of flowers visited in one minute							
	09:00		11:00		13:00		15:00	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
March 3	8.67	8.67	10.00	9.67	12.11	12.22	13.22	13.11
March 5	8.22	8.10	8.67	8.67	11.00	11.11	11.67	11.56
March 9	10.45	0.00	10.22	0.00	13.22	0.00	15.33	0.00
March 13	10.67	10.67	13.00	13.00	14.33	14.22	16.11	16.00
March 17	13.44	13.33	14.56	14.45	16.56	16.45	16.56	16.56
Mean ± SD	10.29±2.06	8.15±5.00	11.29±2.41	9.16±5.64	13.44±2.14	10.80±6.37	14.58±2.07	11.45±6.72

Table 6. Per cent deviation in insecticide treated plots from normal condition

Parameters	<i>A. dorsata</i>	<i>A. florea</i>
Foraging duration	- 22.28	- 23.35
Foraging speed	- 27.79	- 28.77
Foraging rate	- 20.93	- 19.45

‘-’ indicates reduction in percentage

during peak flowering period as the more floral resource was available on individual flower. Due to partially opened flowers *A. dorsata* visited more flowers to collect the floral resources. In insecticide treated area after insecticide spraying, foraging activity ceased for 3 days. Effect of insecticide was prominent up to 5 to 6 days on foraging rate of *A. dorsata* and *A. florea*. Foraging activity restarted on 4th day and foraging rate suddenly increased to higher range. Mean foraging rate in insecticidal treatment was highest in *A. florea* (9.40 flowers) followed by *A. dorsata* (5.25 flowers).

Deviation in foraging activity: Foraging duration of *A. dorsata* and *A. florea* reduced by 22.28 and 23.35 %, respectively due to insecticide application during flowering period (Table 6). Foraging speed of *A. dorsata* (27.79 %) and *A. florea* (28.77 %) was also reduced due to insecticide treatment. Decrease in foraging rate due to insecticidal application was observed in *A. dorsata* (20.93 %) and *A.*

florea (19.45 %).

CONCLUSION

Under untreated environmental conditions, *A. dorsata* forages extensively due to larger size and higher nutritional needs, resulting in prolonged foraging sessions. Foraging duration is linked to daylight hours, not the flowering period. *A. dorsata*, despite its slower pace, efficiently collects floral resources from individual blossoms. *A. florea*, faster but less resource-efficient, displays the highest foraging rate but fails to fully exploit available resources, indicating reduced efficiency. Food scarcity increases foraging rates but decreases speed. Insecticide use halts honey bee activity on coriander flowers for three days and affects *A. florea* and *A. dorsata* for five to six days, harming pollination. Wild bee species are more resilient than domestic ones but still suffer reduced pollination for up to a week. Insecticides disrupt foraging behavior, potentially harming coriander crop yields. Economic assessments are crucial before pesticide use in cross-pollinated crops like coriander.

AUTHOR CONTRIBUTION

The author MVT and NK conceptualized the idea. MVT and GSG designed the work. MVT and RDV collected data from field. RDV performed tabulation of the data, while NK

and GSG analysed the data. MVT and SSM interpreted the result. SSM wrote the manuscript. MVT, NK and GSG reviewed and finalized the manuscript.

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Received 22 January, 2024; Accepted 10 June, 2024