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Full Length Research Article

Honey Bee Attractants (Hymenoptera- Apidae) and their Role on Increasing Crop Productivity in Coriander (*Coriandrum sativum* L.)

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Abstract

Honeybees and flowering plants are interdependent and a good example for mutualism and co-evolution. Bees are considered as most efficient pollinators in the ecosystem and utilization of bees as pollinators for various entomophilous crops. The usage of bee attractants, Bee-Q and Fruit Boost™ in the pollination of coriander was evaluated. The bee visitations to coriander flowers were observed for two weeks followed by estimation of seed yield. The different concentrations of Bee-Q and Fruit boost™ was evaluated to understand the honeybee visitation pattern of target crop for improving pollination efficiency. The observations indicate that, Bee-Q at 12.5 g/l and Fruit boost at 0.75 ml/l on coriander plots significantly attracted higher number of bee foragers than the control plots. In addition, the plots sprayed with bee attractants significantly enhanced the seed set, seed weight and germination percentage of coriander. The present investigation suggests that the bee attractants increase marginal percentage of bee visitation, seed yield and germination percentage of coriander.

Key words: *Coriandrum sativum* L., Bee-attractants*, Apis florea*, *Apis dorsata,* Bee visitation

Coriander generally blooms during September to November. an annual herb belonging to the family Apiaceae, is one of the earliest known spices. Coriander plants attain heights from 30 to 100 cm, depending upon the variety. The crop blooms in 45 to 60 days after sowing and matures in 65 to 120 days, depending upon the variety and cropping situation. The flowering phenology of coriander ensures cross-pollination. The inflorescence consists of compound umbel and usually comprises about 5 smaller umbels where main umbel first blooms, followed by lower order umbels. Each umbel contains 10 to 50 pentamerous flowers. The flowers are small, protoandrous and difficult to manipulate for controlled pollination. The corolla is made up of five petals. Flowers are both bisexual and unisexual, the latter being mostly staminate. The flower possesses five stamens and the ovary is inferior and bilocular. The fruit is globular, round and small [1]. Like other Umbelliferous plants, Coriander is also a cross-pollinated crop. The degree of cross pollination in Coriander is 50 to 60%. Coriander is partially self-fertile. Presence of honeybees during the flowering of Coriander was shown to increase its yield. Honeybees were found to be the major pollinators (80%) on Coriander [2]. Shelar and Suryanarayana [3] stated that *A. florea* was the principal pollinating insect and was found to be efficient than *A. cerana* but *A. dorsata* was not observed on Coriander. Basawana [4] reported that *A. florea* and *A. dorsata* were main visitors of coriander and fennel ecosystem and their peak activity was found between 1100 to 1400 hrs. which synchronized with peak of anthesis. They also observed 80% to 85% increase in seed set in open pollinated Coriander crop compared to caged or bagged plants. This increase in seed set was mainly due to insect pollination. Priti and Sihag [5] recorded insect visitors species to flowers of Coriander and categorized them as pollinator or non-pollinators on the basis of their foraging mode, abundance, mean activity duration and number of loose pollen grains sticking to pollinator's body. *Apisflorea* was found to be the most efficient pollinator of Coriander due to its maximum pollinating efficiency. Mane [6] reported that foraging activity of honeybees commenced at 0600 hrs. The peak activity was found at 1400 hours (2.40 bees / m^2 / min).

Nowadays the numbers of domesticated honeybee colonies in India are decreasing due to huge number of viral diseases and pests. There is a parallel interest in improving the pollinating efficacy of bees and a pollinator deficit is especially acute if neighboring crops must compete for limited pollinators [7]. Under conditions of compromised pollinator efficacy, honeybee attractants may help focus limited pollinators onto the crop of interest [8]. Of a handful of tested bee attractants (9-14), those based on queen mandibular pheromone (QMP), fruit boost and Bee-Q based on carbohydrate rich have had the most

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promising research record [15-17]. Pollination potentiality on experiments were performed and treatment response increased by the use of attractants on Ridge Gourd [18] on Guava [19], on Pumpkin [20] on Niger [21], on Pigeon pea [22], on Ridge gourd [23], on Mustard [24], on Sun flower [25], and on Water melon [26] We aimed to attract more bees towards target crop by using bee attractants and to evaluate the extent of their usefulness for increasing pollination efficiency and seed yield in coriander.

MATERIALS AND METHODS

The experiment was conducted in an agricultural farm located 20 km from Bangalore, India during 2020-2022. Coriander crop was raised in an area of one hectare by following suitable agricultural practices recommended by the Agriculture Department. Seven experimental plots, each with an area of 5x5 square meter area with row spacing of 2 meters were set up on the farm. The commercially available bee attractants- namely Bee-Q (M.S Excel Industries, Bombay, India) and Fruit boost (PherotechInc, Delta BC Canada) –were purchased for experimental applications. Attraction experiments were performed and treatment response curves were generated. In total, three concentrations of Bee-Q (10, 12.5 and 15 g/l) and three concentrations of Fruit boost (0.5, 0.75 and 1.00 ml/l) were tested. Plots without spray served as control.

Treatment assignments

From each plot we selected 10 flowering plants randomly (three plots per treatment) and were separately labeled with tags. Two colonies of *Apis cerana* were introduced to the crop area, each having eight frame populations of honeybees. (It was also noted that there were a few natural colonies of *Apis dorsata* and *Apis florae* in the vicinity of experimental site). Bee attractants were sprayed on the bloom of Coriander with a standard sprayer. Bee-Q was applied in the concentrations of 10, 12.5 and 15 g/l/ on separate (and labeled) plots. Similarly, Fruit boost was applied at concentrations of 0.5, 0.75 and 1.00 ml/l. (Different concentrations for each attractant were used to standardize for the differences in concentrations of active ingredients in the stock solutions purchased). Attractants were sprayed on flowers of Coriander during different intervals (Table 1). No bee attractant was applied to control plots. The number of honeybees visiting the coriander flowers sprayed with bee attractants was counted through visual observation. One observer was assigned to each plot and observations were synchronized to run between 08:00a.m to 04:00 pm at 2- hour intervals per day [27]. Each observer walked down each row for five minutes, recording the number of honeybee flower visits (5min x 3 replicates =15 min per plot; 7 rows x 3 replicates = 21min; 21min x 5min=105 min for all plots in 2- hour intervals). A bee landing on an open flower for about 5 to 10 seconds was considered to be a 'visit'. Observations of bee visitation were recorded on first day (08 Sept, 2022), third day (10 Sept), fifth day (12 Sept) and Seventh (14 Sept) days after spraying the attractants. This process was repeated after a second spray of attractants during the 50 percent blooming period. Post-spray bee visitation was again enumerated on the 16^{th}, 18^{th} and 20^{th} of Sept. 2022. In addition to counting total visits, observers recorded (by sight) the relative number of honeybee flower visitors from each of the following species: *Apis cerana, Apis florea* and *Apis dorsata* (Fig 1-2)

Fig 1 *Apis cerana* collecting the pollen from coriander flowers

Fig 2 *Apis florea* foraging on coriander flowers

Harvest parameters

On 22^{th} October 2022, the tagged flowering plants were harvested from each treatment, control plot and the number of seeds per plant was recorded. Dried seed-weights were also recorded from each replication and the data were statistically analyzed.

Qualitative parameters

Seeds from tagged flowering plants were collected from all the treatments and control plots. They were sun-dried and preserved for laboratory analysis.

Moisture content

The moisture content for dried seeds was estimated by periodic weighing (4hr-intervals) of samples kept in an oven (90°C) until a constant weight was recorded for three or more measurements.

Germination

100 seeds from each replication (i.e., treatment and control) were placed on moistened coarse germination paper kept in Petri plates. Plates were placed in a germination chamber at 20 °C temperature and 90% relative humidity. Germination counts were recorded. For evaluating seedling vigor, 10 rooted seedlings were selected from each replication and shoot and roots were measured 7 days after germination [28].

Climatic conditions and statistical analysis

Meteorological data including average temperature, relative humidity, wind speed and sunlight during the experimental period was obtained from the University of Agricultural Sciences Meteorological center located 2 km from the experimental station. All response variables were analyzed statistically by one-way ANOVA and a DMRT (Duncans Multiple Range Test) using SPSS (version 11.0).

RESULTS AND DISCUSSION

Bee visitation: First spray (10% flowering)

The relative abundance based on honeybee visitation (*Apis cerana, A. dorsata* and *A. florea)* to Coriander flowers on first day after first spray (1DAFS) was greatest for the Fruitboost plots treated with 0.75 ml/l and Bee-Q plots treated with 12.5 g/l (6.00 and 5.00 bees / 10 flowers/5min) were most effective at 5 percent CD. The next most effective doses were fruit boost at 1ml and Bee-Q at 10 g/l were also attracted (4.00 and 3.66 bees / 10 flowers/5min) more bees. This data and statistics are provided in (Table 1a). There was a stepwise increase in the number of honeybee flower visitors in plots treated with fruit boost at 0.75 ml/l (8.66 bees/10 flowers/5min) and Bee-Q at 12.5 g/l (5.00 bees/10 flowers/5min). On the third day after first spray (3 DAFS), visitation on fruit boost at 1 ml/l and Bee-Q at 10 g/l dosing also showed significant results over controls (5% CD). There was a significant increase in number of honeybee flower visitors in plots treated with Fruit boost at a dosage of 0.75 ml/l and Bee-Q at 12.5 g/l (7.00 and 6.00 bees/10 flowers/5min). Fruit boost at 1.00 ml/l and Bee-Q 10 g/l (5.00 bees / 10 flowers/5min) showed equal effectiveness compared to each other and a significant increase over controls (2.66 bees/10 flowers/5min) observed on fifth day after first spray (5DAFS). On the Seventh day after first spray (7 DAFS), plots treated with Fruit boost at 0.75 ml/l (7.00 bees/10 flowers/5min) and Bee-Q at 12.5 g/l (6.00 bees/10 flowers/5min) were most effective; however, Bee-Q at 15 g/l (5.33 bees / 10 flowers/5min) was also effective at 5 percent CD compared to controls (3.00 bees/10 flowers/5min).

Table 1 Bee-attractants and honeybee-visitation, showing all 7 treatments with first (10% and second (50%) spray on coriander

Treatments	Number of honeybees / 10 flowers/ 5 min						
	1a, first spray (10% flowering)				1b, second spray (50% flowering)		
	1 DAFS	3 DAFS	5 DAFS	7 DAFS	1 DASS	3 DASS	5 DASS
T_1: Bee-Q @ 10 gms/l	3.66 a	6.66 c	5.00 c	4.66 c	4.66 b	4.33 b	5.00 c
T_2: Bee-Q @ 12.5 gms/l	5.00 a	7.66 b	6.00 b	6.00 a	6.00 a	6.00 a	6.00 b
T_3: Bee-Q @ 15 gms/l	3.33 a	5.33 d	4.00 d	5.33 b	4.66 b	3.66 d	3.33 d
T_4: Fruit boost @ 0.5ml/l	3.66 a	4.66 d	4.00 d	5.00 b	4.00 c	3.00 d	2.66 e
T_5: Fruit boost @ 0.75ml/l	6.00 a	8.66 a	7.00 a	7.00 a	7.00 a	7.00 a	7.00 a
T_6: Fruit boost @ 1ml/l	4.00 c	6.66 c	5.00 c	5.00 b	5.00 b	5.33 b	5.33 b
T_7: Open pollination (control)	3.00 a	3.00 f	2.66 e	3.00 d	3.00 d	3.00 e	2.33 e
F-Value	*	*	*	*	*	*	*
SEm±	0.46	0.244	0.294	0.391	0.336	0.342	0.305
CD at 5%	NS	0.719	0.867	1.153	0.991	1.00	0.899

DAFS – Day after first Spray, DASS-Day after second spray, *Significant at 5% level, SEm± - Standard error, NS - Non significant, CD- Critical difference, Means followed by the same letter in a column do not differ significantly by DMRT

Table 2 Effect of bee attractants on the quantitative parameters in coriander

Treatments	Number of seeds / plant		1000 seed weight (gms)	
	Mean	% Increase/ decrease over OP	Mean	% Increase / Decrease over OP
T_1: Bee-Q @ 10 gms/l	479.00 b	13.15	13.95 a	29.16
T_2: Bee-Q @ 12.5 gms/l	510.33 a	20.55	15.38 a	42.40
T_3: Bee-Q @ 15 gms/l	456.33 b	7.79	12.91 b	19.53
T_4: Fruit boost @ 0.5ml/l	454.33 b	7.32	14.51 a	34.35
T_5: Fruit boost @ 0.75ml/l	520.33 a	22.91	16.98 a	57.22
T_6: Fruit boost @ 1ml/l	466.33 b	10.15	13.85 a	31.01
T_7: Open pollination (control)	423.33 c	-	10.80 b	-
F – value	*		*	
SEm±	9.716		1.101	
CD at 5%	28.652		3.247	

SEm± - Standard error, *- Significant at 5% level, CD- Critical difference
Means followed by the same letter in a column do not differ significantly by DMRT

Bee visitation: Second spray (50% flowering)

The first day after second spray (1DASS), more number of bees (7.00 and 6.00 bees/10 flowers / 5min) visited the plots that received Fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l (Table 1b). These were followed by Fruit boost at 1.00 ml/l (5.00 bees / 10 flowers/5min) was also effective at 5 percent CD, compared to controls (3.00 bees / 10 flowers/5min). There was a significant at 5 percent CD increase in number of honeybee visitors in plots treated with Fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l (7.00 and 6.00 bees / 10 flowers/5min). Fruit boost at 1.00 ml/l (5.33 bees / 10 flowers/5min) was also effective at 5 percent CD, compared to controls (3.00 bees / 10 flowers/5min) on third day after second spray (3DASS). On fifth day after second spray (5DASS), spraying of Fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l attracted more honeybees (7.00 and 6.00 bees/10 flowers/5min). Fruit boost at 1.00 ml/l (5.33 bees / 10 flowers/5min) which was effective at 5 percent CD compared to controls (2.33bees / 10 flowers/5min).

Harvest parameters

The data are provided in (Table 2). The number of seeds per plant was recorded greatest in plots treated with Fruit boost at 0.75 ml/l (520.33 seeds/ plant which representing a 22.91% increase over control). Similar results were observed for plots treated with Bee-Q at 12.5 g/l (510.33 seeds/ plant, which represents a 20.55 percent increase over control plot followed by Bee-Q at 10.00 g/l (479.00 seeds/ plant, which represents a 13.15 percent increase over control plot (423.33 seeds/ plant) at 5 percent CD. For thousand-count seed weight (TCSW), plots that received Fruit boost at 0.75 ml/l showed the greatest seed mass at 16.98 g per 1000seeds, representing a 57.22% increase over control. Plots treated with Bee-Q at 12.5 g/l also showed a significant difference in TCSW (15.38 g/1000seeds), which equated to a 42.40% increase over control. In (Table 3), growth, maturation data for coriander are provided. We found that the increase in plant germination with fruit boost treatments at 0.75 ml/l (90.33%) was significant; specifically, a 22.63% increase over control was noted. Plots treated with Bee-Q at 12.5 g/l also increased germination (88.66%), representing a 20.36% increase over control. This treatment was on par with Fruit boost at 0.5 ml/l (85.00%, representing a 15.39% increase over control. Plots treated with fruit boost at 0.75 ml/l seemed to increase root lengths (8.73 cm, which represents 38.35% increase over control. The next treatment was Bee-Q at 12.5 g/l (8.45 cm), which represents for 33.91% increase over controls (6.31 cm). However, this was not statistically significant. Spraying of fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l showed the shoot length to 9.11 and 9.03 cm, which represents a 39.93 and 38.70%, increase over controls, this was also not statistically significant. Likewise, fruit boost at 0.75ml/l and Bee-Q at 12.5 g/l appeared to enhance average shoot length in plants; however, these data not statistically significant.

Table 3 Effect of bee attractants on the qualitative parameters in coriander

Treatments	Germination percentage		Root length (cm)		Shoot length (cm)	
	Mean	% Increase / Decrease over OP	Mean	% Increase / Decrease over OP	Mean	% Increase / Decrease over OP
T_1: Bee-Q @ 10 gms/l	81.33 b	10.41	8.16 b	29.31	8.61 b	32.25
T_2: Bee-Q @ 12.5 gms/l	88.66 a	20.36	8.45 a	33.91	9.03 a	38.70
T_3: Bee-Q @ 15 gms/l	82.33 b	11.77	8.13 b	28.84	8.26 c	26.88
T_4: Fruit boost @ 0.5ml/l	85.00 b	15.39	7.90 b	25.19	8.31 b	27.64
T_5: Fruit boost @ 0.75ml/l	90.33 a	22.63	8.73 a	38.35	9.11 a	39.93
T_6: Fruit boost @ 1ml/l	81.33 b	10.41	8.03 b	27.25	8.25 c	26.72
T_7: Open pollination (control)	73.66 c	-	6.31 c	-	6.51 e	-
F - value	*		*		*	
SEm±	1.480		0.127		0.123	
CD at 5%	4.366		0.375		0.360	

SEm± - Standard error, *- Significant at 5% level, CD- Critical difference
Means followed by the same letter in a column do not differ significantly by DMRT

Table 4 Environmental conditions (average) during seven treatments conducted on coriander

Dates	Temperature (°C)	Relative humidity (%)	Cumulative wind (Km)	Sun light (Hours)
Sept-08-2022	30.0	49	270	8.6
Sept-10-2022	29.8	58	230	5.8
Sept-12-2022	27.8	98	230	1.8
Sept-14-2022	27.2	88	90	1.9
Sept-16-2022	29.2	95	270	5.5
Sept-18-2022	29.0	95	140	7.7
Sept-20-2022	29.4	91	230	6.8

Climatic conditions

The data on the climatic factors of coriander is given in (Table 4). This data showed no co-relation between the bee visitation, yield and qualitative parameters on coriander (Table 4).

These data show a general benefit in the use of honeybee attractants to promote pollination on coriander. There is evidence that fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l maximally increases the total number of honeybee flower visitations at 5DAFS. For the second spray, the data are more variable. It appears that all the days after second spray of Bee-Q at 12.5 g/l and Fruit boost at 0.75 ml/l also shows numeric significance to attract more bees, compared to control plot. This is in line with another report that showed Fruit boost at 1.00 ml/l had significant effect in attracting more pollinators on Niger [24]. Notably, there was a modest but statistically significant increase in number of seeds/plant in plots treated with Fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l sprayed plots, There was a marginal increase in TCSW on plots treated with Fruit boost at 0.75 ml/l and Bee-Q 12.5 g/l sprayed plots, which represents for 57.22 and 42.40 percent increase over control plot. Consequently, more seed and a greater TCSW are expected in cases where crops are open to all pollinators [4]. The germination percentage shows meager significance with spraying of Fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l, compared to control. The increase of germination percentage in Coriander (attributed due to frequent bee visitation) has been previously reported [29]. Neither Fruit boost nor Bee-Q was not shown a significant effect on root and shoot length. Consequently, these data suggests that Fruit boost can enhance germination and seed vigor as previously reported Niger and Mustard [24-26].

CONCLUSION

In conclusion, it appears that fruit boost at 0.75 ml/l and Bee-Q at 12.5 g/l sufficiently increased honeybee visitation on flowers of coriander to improve pollination performance when compared to untreated control plots. Increased bee visitation on this plant translated into marginal increase in yield, including the number of seeds/plant and TCSW. This is due to increase in both the forager number and inter floral pollen movement. In case of Bee-Q, which is a food attractant rich in carbohydrates; a phagostimulatory effect may also contribute to increased yield in Coriander. Over all, this study suggests that the use of bee attractants may serve as an effective management tool for improving the efficiency and consistency of pollination and productivity.

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