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Effect of bee attractants on activity of stingless bee, *Tetragonula* "nr." *pagdeni*, and its significance in pollination of coriander

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ABSTRACT: Coriander (*Coriandrum sativum* L.) is an important seed spice crop that depends largely on insect-mediated pollination for optimum seed production. A field experiment was conducted at Devihosur, Karnataka, to evaluate the efficacy of different bee attractants in enhancing pollination by stingless bees (*Tetragonula* "nr" *pagdeni*) and improving coriander productivity. Seven treatments comprising jaggery (15%), jaggery + lime juice (15%), enriched jaggery (15%), ocimum oil (0.1%), menthol oil (0.1%), ajwain oil (0.1%), and an untreated control were evaluated in a randomized design. Among the treatments, ocimum oil (0.1%) recorded the highest seed yield (14.46 q ha^{-1}), followed by jaggery (15%) (12.91 q ha^{-1}), both of which were significantly superior to the untreated control (9.15 q ha^{-1}). The higher seed yield obtained with ocimum oil was associated with increased stingless bee visitation, resulting in improved pollination efficiency. Enhanced pollination also positively influenced seed quality, with ocimum oil recording the highest seed germination (82.67%), seedling length (12.23 cm), seedling vigour index (1011), and seedling dry weight (0.013 mg) compared with the control. Although ocimum oil produced the maximum yield and superior seed quality, jaggery (15%) resulted in the highest benefit ratio owing to its low input cost. The findings demonstrate that bee attractants can effectively enhance stingless bee activity and coriander productivity, with ocimum oil being the most effective for maximizing yield and seed quality, while jaggery (15%) offers a simple, economical, and farmer-friendly option for profitable coriander seed production.

Keywords: Bee attractants, *Coriandrum sativum*, Enriched jaggery, Ocimum oil, Seed Yield

INTRODUCTION

India is the world's leading producer, consumer, and exporter of seed spices and is widely recognized as the "Home of Spices." Seed spices are economically important, export-oriented crops that contribute substantially to the country's agricultural economy. Among these, coriander (*Coriandrum sativum* L.), an annual herb belonging to the family Apiaceae (Umbelliferae), is one of the most important seed spice crops cultivated in India. It originated in the eastern Mediterranean region and southern Europe and was subsequently introduced into India (Gal *et al.,* 2010). The crop is predominantly cultivated during the rabi season and is valued for its aromatic seeds and fresh leaves, which are widely used in culinary, pharmaceutical, and traditional medicinal applications. Owing to its diverse uses and increasing global demand, coriander has emerged as an important domestic and export commodity (Mane, 2003).

Despite its economic importance, coriander productivity is often constrained by poor seed set resulting from inadequate pollination. Although the flowers are hermaphroditic, coriander is predominantly cross-pollinated because of its protandrous nature, wherein pollen dehiscence generally precedes stigma receptivity (Blade, 2008). Consequently, successful seed production depends largely on insect-mediated pollination, and the absence or low abundance of pollinators during the flowering period is considered one of the major factors limiting yield (Mane, 2003).

A diverse assemblage of insects, including honey bees (*Apis florea* Fabricius, *Apis cerana* Fabricius, and *Tetragonula "nr" pagdeni*), solitary bees, butterflies, and flies, visit coriander flowers for nectar and pollen. Among these, honey bees constitute the dominant pollinator group, accounting for nearly 80.3% of all floral visitors (Ricciardelli *et al.,* 1979). Their high foraging efficiency and abundance make them the principal

pollinators of coriander, contributing significantly to improved pollination, seed set, crop productivity, and overall agricultural sustainability.

The population of managed honey bee colonies in India has declined in recent decades owing to the incidence of pests and diseases, while natural pollinator populations have also been adversely affected by changes in land-use patterns, habitat degradation, and agricultural intensification (Delaplane and Mayer, 2000). The reduced availability of pollinators during the flowering period limits effective pollination and consequently affects seed yield in insect-pollinated crops such as coriander. Therefore, approaches that enhance pollinator visitation to crop flowers are of considerable practical importance.

Honey bees rely predominantly on olfactory cues for locating and selecting floral resources, making bee attractants a promising strategy for improving pollinator activity in crop fields (Doull, 1974; Seeley, 1999). Bee attractants are chemical cues that modify bee foraging behaviour and increase visitation to target crops, thereby enhancing pollination efficiency (Elli and Delaplane, 2009). Previous studies have demonstrated the effectiveness of bee attractants in coriander. Choudhary and Singh (2007) reported that spraying the commercial bee attractant Bee-Q increased pollinator visitation by 20.7%, with an average of 5.2 visitors min^{-1} compared with 4.3 visitors min^{-1} under open pollination. Likewise, Narendra (2014) observed that application of the bee attractant Cacambe (10%) significantly improved yield attributes and seed yield in coriander.

Although commercial bee attractants have shown promising results, their widespread adoption under Indian farming conditions is constrained by their high cost and dependence on synthetic compounds that mimic honey bee pheromones. In contrast, indigenous plant-based attractants are inexpensive, biodegradable, non-toxic, and environmentally friendly, making them well suited for sustainable and organic crop production. However, information on the efficacy of such plant-derived bee attractants for enhancing pollination and seed production in coriander is limited. Therefore, the present study was undertaken to evaluate indigenous plant-based bee attractants for enhancing stingless bee visitation, pollination efficiency, seed yield, and seed quality in coriander.

MATERIAL AND METHODS

The present study was carried out at Horticulture Research and Extension Center (HREC), Devihosur during Rabi season of 2018-19. It is situated in the northern transitional agro-climatic zone (Zone-VIII) of Karnataka with 75° 21' East longitude, 14°47' North latitude and at an altitude of 563 meters above mean sea level (MSL). The experiment was carried out using coriander variety DCC-46 (Devihosur Coriander Cultivar) also known as Varadevi-1. The crop was raised as per package of practice recommended by UHS, Bagalkot. The experiment was carried out in randomized complete block design (RCBD) involving seven treatments each replicated thrice (plot size of 4 m × 4 m area) (Fig.1). Between the treatments one meter distance was maintained as a buffer zone. The treatments included were *viz.*, T_1- jaggery (15%), T_2- jaggery + lime juice (15%), T_3- enriched jaggery (15%), T_4- Ocimum oil (0.1%), T_5- menthol oil (0.1%), T_6- ajwan oil (0.1%) and T_7- control. Three attractants namely jaggery at 15%, jaggery+lime at 15% (Dissolved equal concentrations of jaggery and lime juice (*i.e.* 7.5% + 7.5%) and enriched jaggery at 15% (Two vitamin tablets dissolved in one litre of water) were prepared and three plant based commercial bee attractants *viz.,* concentrated Ocimum oil, menthol oil, and ajwan oil were procured from the online market.

To evaluate the effect of bee attractants on the foraging activity of the stingless bee *Tetragonula* "nr" *pagdeni*, a single colony containing an optimum population of approximately 2,500–3,000 bees was placed at the centre of the experimental field when the crop reached 10% flowering. The colony was maintained in the field until the completion of the flowering period. The colony required for the study was purchased from commercial bee keeper from Brahmavara (Udupi). In each replicated plot (one square meter area), five plants were randomly tagged to record observations (Bee visitation as well as quantitative and qualitative yield parameters). Later, attractants were sprayed two times, first at 10 per cent of flowering and second at 50 per cent of flowering stages. Observations on bee visitation were recorded from five tagged plants per plot on a day before the spray of bee attractants and one, three, five and seven days after each spray at 10:00 to 12:00 h and 15:00 to 17:00 h of the day. Further, the seed quantity parameters like number of umbels per plant, number of seeds per umbel and seed yield were recorded from the tagged plants and mean data was taken for statistical analysis. Similarly, seed quality parameters like Thousand seed weight (Test weight) (g), Per cent seed germination (%), Seedling length (cm), Seedling dry weight (mg), were recorded

after the harvest of umbels. The recorded observations were analyzed using WASP2 software and means were ranked by Duncan's Multiple Range Test (DMRT). Later the bee visitation was correlated with yield attributes of coriander crop and their relationship was determined.

RESULTS AND DISCUSSION

Stingless bee, *T. pagdeni* were found visiting flowers of coriander throughout the study period, but observations were recorded at 10 and 50% flowering. A day before the first spray of attractants, the stingless bee visitation was uniform in all the treatments and varied from 0.73 to 1.00 bee/plant/min and during second spray 0.87 to 1.00 bee/plant/min (Table 1). Following the first spray at 10% flowering, bee attractants significantly influenced the foraging activity of *T. pagdeni*. Among the treatments, ocimum oil (0.1%) recorded the highest overall mean bee visitation (2.49 bees plant^{-1} min^{-1}). This was followed by jaggery (15%), enriched jaggery (15%), and jaggery + lime juice (15%), which attracted 1.85, 1.76, and 1.68 bees plant^{-1} min^{-1}, respectively. Comparatively lower bee visitation was observed with ajwain oil (0.1%) and menthol oil (0.1%), recording 1.45 and 1.40 bees plant^{-1} min^{-1}, respectively. The untreated control recorded the lowest bee visitation (0.83 bee plant^{-1} min^{-1}), indicating that the application of bee attractants substantially enhanced stingless bee activity in coriander.

Following the second spray at 50% flowering, the mean bee visitation recorded over seven days differed significantly among the treatments. Ocimum oil (0.1%) attracted the highest number of stingless bees, recording a mean visitation of 2.44 bees plant^{-1} min^{-1}. The next most effective treatment was jaggery (15%), with a mean visitation of 1.87 bees plant^{-1} min^{-1}, followed by enriched jaggery (15%) and jaggery + lime juice (15%), which recorded 1.77 and 1.70 bees plant^{-1} min^{-1}, respectively. Lastly, untreated control plot recorded least number of bees *i.e.* 0.88 bees/plant/minute (Table 1). The present findings are in line with Abrol *et al*. (2017) who

Table 1: Influence of bee attractants on stingless bee, *Tetragonula "nr" pagdeni* visitation on coriander

Treatment	Number of bees visited / plant / min											
	First spray at 10 per cent flowering						Second spray at 50 per cent flowering					
	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	MEAN	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	MEAN
Jaggery 15%	0.87 (0.90)^{a}	2.20 (1.48)^{b}	2.87 (1.69)^{ab}	2.40 (1.54)^{b}	0.93 (0.97)^{a}	1.85 (1.36)^{b}	0.93 (0.97)^{a}	2.20 (1.48)^{b}	2.80 (1.66)^{b}	2.67 (1.62)^{ab}	0.87 (0.93)^{a}	1.87 (1.37)^{b}
Jaggery + lime juice 15 %	0.87 (0.92)^{a}	1.87 (1.33)^{bcd}	2.47 (1.56)^{b}	2.33 (1.52)^{b}	0.87 (0.93)^{a}	1.68 (1.29)^{bc}	1.00 (1.00)^{a}	2.13 (1.45)^{b}	2.40 (1.55)^{b}	2.20 (1.48)^{bc}	0.87 (0.92)^{a}	1.70 (1.31)^{bc}
Enriched jaggery 15%	0.80 (0.89)^{a}	2.07 (1.43)^{bc}	2.73 (1.65)^{ab}	2.40 (1.55)^{b}	0.80 (0.89)^{a}	1.76 (1.32)^{bc}	0.93 (0.96)^{a}	2.07 (1.48)^{b}	2.60 (1.60)^{b}	2.33 (1.53)^{abc}	0.93 (0.96)^{a}	1.77 (1.34)^{b}
Ocimum oil 0.1%	1.00 (0.97)^{a}	3.47 (1.86)^{a}	3.73 (1.93)^{a}	3.20 (1.79)^{a}	1.07 (1.03)^{a}	2.49 (1.58)^{a}	1.00 (0.99)^{a}	3.20 (1.79)^{a}	3.93 (1.98)^{a}	3.00 (1.71)^{a}	1.07 (1.01)^{a}	2.44 (1.55)^{a}
Menthol oil 0.1%	0.87 (0.93)^{a}	1.27 (1.13)^{de}	2.07 (1.43)^{b}	1.87 (1.36)^{b}	0.93 (0.97)^{a}	1.40 (1.19)^{c}	0.87 (0.93)^{a}	1.40 (1.18)^{c}	2.07 (1.43)^{b}	1.87 (1.36)^{c}	0.87 (0.93)^{a}	1.41 (1.19)^{d}
Ajwan oil 0.1%	0.73 (0.84)^{a}	1.40 (1.17)^{cde}	2.33 (1.52)^{b}	1.93 (1.38)^{b}	0.87 (0.93)^{a}	1.45 (1.19)^{c}	0.87 (0.93)^{a}	1.67 (1.28)^{bc}	2.13 (1.45)^{b}	1.93 (1.38)^{c}	0.80 (0.89)^{a}	1.48 (1.21)^{cd}
Control*	0.73 (0.84)^{a}	0.87 (0.93)^{e}	0.93 (0.94)^{c}	0.87 (0.93)^{c}	0.73 (0.85)^{a}	0.83 (0.91)^{d}	0.93 (0.97)^{a}	0.87 (0.93)^{d}	0.93 (0.96)^{c}	0.93 (0.97)^{d}	0.73 (0.85)^{a}	0.88 (0.94)^{e}
S.Em ±	0.08	0.08	0.10	0.07	0.06	0.04	0.07	0.07	0.09	0.08	0.09	0.03
C.D. at 5%	NS	0.26	0.34	0.20	NS	0.14	NS	0.24	0.26	0.24	NS	0.12

DBS- Days Before Spray DAS-Days After Spray

Figures in the parentheses are $\sqrt{x} + 0.5$ transformed values

In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT

*Without any bee attractants spray

investigated and reported that Basil crop when grown around agricultural crops attracted more flower visitors which illustrate the importance of basil as a pollinator reservoir. Another research reported by Pereira *et al.* (2015) revealed that intercropping with Basil, *Ocimum basilicum* increased bee abundance and richness in the area and enhanced bell pepper fruit and seed production (*Capsicum annuum*). Thus, it is confirmed that plant-based products enticed more bees towards the crop. Similar findings are also reported by Gallert *et al.* (1985), who stated that honey bees were attracted to the Lucerne plots sprayed with a crude extract of dried fruit of lavender, *Evodia hupehensis*. The present findings also confirmed the results of Dinesh (2003), who reported that spraying of cacambe 10 per cent and jaggery 10 per cent had significantly attracted a greater number of pollinators on cucumber bloom. Further, Patil *et al*. (2010) reported that Bee-Q at 15g per litre was significantly superior in attracting maximum number of *Tetragonula* sp. in onion as compared to sugar syrup at 5 per cent and molasses at 10 per cent on first day after first spray and their efficacy lasted up to five days.

Application of bee attractants significantly increased the number of seeds per umbel. The highest number of seeds per umbel was recorded with ocimum oil (0.1%) (16.00), followed by jaggery (15%) (15.33). The enhanced seed set observed in these treatments can be attributed to increased stingless bee visitation and improved pollination efficiency. These findings are consistent with those of Kalmath and Sattigi (2005), who reported that a 10% jaggery solution exerted a phagostimulatory effect in onion, attracting a greater number of pollinators following both the first and second sprays. However, both bee visitations were uniform on the seventh day after each spray in all bee attractant sprayed plots. The findings are also in line with Kalmath and Sattigi (2002) who documented that cacambe (10%) had significant influence on number of seeds per umbel (968.96) followed by jaggery solution (10%) in onion. Bee pollination also resulted in increased number of fruits in cucumber (Dinesh, 2003). The highest seed yield was recorded in the crop treated with ocimum oil (0.1%) (14.46 q ha^{-1}), followed by jaggery (15%) (13.75 q ha^{-1}) (Fig. 2; Table 2). These treatments increased

Table 2: Influence of bee attractants on seed quality and quantity parameters of coriander

Treatments	Seed quality parameters						Seed quantity parameters			
	1000 seed weight (g)	Per cent seed germination	Increase over control (%)	Seedling length (cm)	Seedling vigour index	Seedling dry weight (mg)	No. of umbels/ plant	No. of seeds/ umbel	Yield (q/ha)	Increase over control (%)
Jaggery 15%	15.80^{a}	79.67^{ab}	18.32	11.15^{b}	889^{b}	0.013^{a}	26.67^{a}	15.33^{a}	13.75^{ab}	50.29
Jaggery + lime juice 15 %	15.83^{a}	76.33^{bc}	13.37	9.17^{c}	700^{c}	0.012^{ab}	26.73^{a}	13.00^{abc}	12.41^{abc}	35.64
Enriched jaggery 15%	16.03^{a}	77.67^{b}	15.35	10.47^{b}	813^{b}	0.012^{ab}	26.73^{a}	14.67^{ab}	12.91^{abc}	41.11
Ocimum oil 0.1%	16.57^{a}	82.67^{a}	22.77	12.23^{a}	1011^{a}	0.013^{a}	27.00^{a}	16.00^{a}	14.46^{a}	58.05
Menthol oil 0.1%	15.47^{a}	71.33^{de}	5.94	8.98^{c}	641^{c}	0.011^{bc}	26.33^{a}	11.00^{cd}	11.17^{bcd}	22.16
Ajwan oil 0.1%	15.27^{a}	72.67^{cd}	7.92	9.05^{c}	658^{c}	0.011^{bc}	25.73^{a}	11.33^{bcd}	11.32^{cd}	23.72
Control*	15.03^{a}	67.33^{e}		6.97^{d}	470^{d}	0.010^{c}	26.13^{a}	9.67^{d}	9.15^{d}	
S.Em ±	0.13	0.09		0.04	0.56	0.003	0.16	0.15	0.13	
C.D. at 5%	NS	0.29		0.15	1.70	0.01	NS	0.48	0.37	

In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT
*Without any bee attractant spray

seed yield by 58.05% and 50.29%, respectively, over the untreated control, demonstrating the positive effect of bee attractants on coriander productivity. The higher seed yield may be attributed to increased stingless bee visitation, which enhanced pollen transfer during the period of stigma receptivity, resulting in improved cross-pollination, better fertilization, and consequently higher seed set. The increased bee visitation in plots treated with Ocimum oil was mainly due the presence of volatile compounds such as ocimene, thymol and linalool. The attractant capacity of the jaggery could be attributed to the presence of fructose and glucose sugars. Similarly, Kalmath and Sattigi (2002) also recorded higher seed yield from cacambe (10%) and jaggery solution (10%) sprayed plots in onion. In addition Narendra (2014), documented that highest seed yield per hectare (994.51 kg/ha) was recorded in jaggery solution (10%) sprayed plot as against open pollination (602.08 kg/ha) in onion.

The number of umbels per plant did not differ significantly among the bee attractant treatments and the untreated control, ranging from 25.73 to 27.00 umbels per plant. The absence of a treatment effect suggests that umbel production is primarily governed by the genetic potential of the crop and is not influenced by pollinator visitation. Although the 1,000-seed weight ranged from 15.03 g in the untreated control to 16.57 g in the ocimum oil (0.1%) treatment, the differences among treatments were not statistically significant, indicating that bee attractants had no appreciable effect on seed weight. The present findings are in line with findings of Srikanta (2008), who reported that bee pollination had no impact on test weight in sunflower. Contrarily, Viraktamath and Patil (1999), stated that maximum test weight was recorded from crop sprayed with Bee-Q at 15 g per litre in mustard. Per cent germination was highest, when sprayed with Ocimum (82.67%) which accounted for 22.77 per cent increase over control (Table 2 and Fig. 3). The present findings are in line with reports of Kumar *et al.* (2021), who documented that seeds from attractant-treated plots of Egyptian clover (*Trifolium alexandrinum* L.) recorded highest germination percentage (sugar-92.67; jaggery-92.33) when compared with caged (79.33) and hand pollinated (82) plots. Similarly, Kalmath and Sattigi (2005), opined that spray of bee attractant, cacambe enhanced germination percentage of onion.

Significantly highest seedling length, seedling vigour index and dry weight were recorded in Ocimum sprayed plot (12.23 cm, 1011 and 0.013 mg, respectively) followed by jaggery 15% (18.32 cm, 11.15 and 0.013 mg, respectively) Table 2, Fig.4. The present reports confirm the findings of Kalmath and Sattigi (2005), who opined that increased seedling length were obtained from cacambe treated onion plot. Similarly, Chandravathi and Gurumurthy (2016) reported that Bee-Q spray recorded highest seedling vigour index (2627) in pigeon pea.

Table 3: Cost economics of different bee attractants with respect to coriander yield

Treatments	Yield (q/ ha)	Cost of bee attractants (Rs./ha)	Other cost production (Rs./ha)	Total cost of production (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C Ratio
T_1 - Jaggery at 15%	13.75^{ab}	2,850	32,697	35,547	1,64,960	1,29,413	4.64
T_2 - Jaggery + lime juice at 15 %	12.41^{abc}	3,750	32,697	36,447	1,48,880	1,12,433	4.08
T_3 - Enriched jaggery at 15%	12.91^{abc}	4,650	32,697	37,347	1,54,880	1,17,533	4.15
T_4 - Ocimum oil at 0.1%	14.46^{a}	19,950	32,697	52,647	1,73,480	1,20,833	3.30
T_5 - Menthol oil at 0.1%	11.17^{bcd}	7,650	32,697	40,347	1,34,080	93,733	3.32
T_6 - Ajwan oil at 0.1%	11.32^{cd}	10,950	32,697	43,647	1,35,800	92,153	3.11
T_7 – Control*	9.15^{d}	0	31,697	31,697	1,09,760	78,063	3.46
S. Em ±	0.13						
C.D. at 5%	0.37						

Present market price: Rs 120/kg Seed
Net return = Gross return- Total cost
*Without any bee attractant spray
Gross return=Yield × Market price
B: C ratio=Gross return / Total cost
**Spraying cost of Rs. 1000 excluded

However, cost economics of different bee attractant treatment indicated that even though Ocimum oil at 0.1 per cent recorded maximum yield, which has failed to be the best treatment, due to higher cost of production. However, jaggery at 15 per cent registered maximum B:C ratio of 4.64 with net returns, Rs. 1,29,413 per hectare signifying that jaggery at 15 per cent proved as most feasible, ecofriendly and cost-effective treatment from the farmers point of view (Table 3). Therefore, it is confirmed that application of bee attractants enhanced both quantitative and qualitative yield parameters of coriander (Vanitha et al., 2025).

Fig. 1. Stingless bee *Tetragonula* "nr" *pagdeni* foraging on the umbel of coriander flower

CONCLUSION

The present study demonstrated that the application of bee attractants enhanced the foraging activity of the stingless bee *Tetragonula "*nr*" *pagdeni*, resulting in improved pollination and increased seed yield in coriander. Among the treatments evaluated, ocimum oil (0.1%) recorded the highest bee visitation and seed yield, whereas jaggery solution (15%) proved to be the most economical option, with the highest benefit: cost ratio. The increased pollinator activity facilitated more effective pollen transfer and seed set, thereby improving crop productivity. Considering its low cost, ease of availability, and effectiveness in attracting pollinators, jaggery solution (15%) can be recommended as a practical and farmer-friendly bee attractant for enhancing coriander seed production under field conditions.

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AUTHORS CONTRIBUTION

Formal analysis, investigation, writing- original draft, writing- review & editing (V.K., V.M.M., G.J.B.); Conceptualization, supervision, methodology, review and editing (V.B.B.P., M.S.S.).

CONFLICT OF INTEREST STATEMENT

Authors don't have conflict of interest to express

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