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Effect of Indigenous Bee Attractants on Bee Visitation and Seed Production of Sesame (*Sesamum indicum* Linnaeus)

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ABSTRACT

An experiment to determine the effect of various bee attractants on bee visitation and quantitative parameters in sesame crops was conducted during the *kharif* season in Amritsar, Punjab. The 10% concentration of each bee attractant (honey solution, jaggary solution, sugar solution, sugar+jaggary solution, and glucon-D+milk powder) was sprayed twice at 10 and 50% flowering of the crop, and bee visitation (no. of bees/5 minutes/m^2 area) was recorded three times a day at 0800, 1100 and 1400 hrs. After the first spray, a gradual increase in bee visitation was recorded from 1st to 5th day of observation, whereas after the second spray, bee visitation increased till 2nd day followed by a steady decline afterwards. The bee species, including *Apis mellifera*, *Apis cerana*, *Apis dorsata* and *Megachile lanata*, were observed at a maximum on plots sprayed with honey solution (4.49±0.49, 3.91±0.39, 3.17±0.28, 3.59±0.25 bees/m^2/5 min, respectively), followed by jaggary solution, sugar solution, sugar+jaggary solution, and glucon-D+milk powder. Among the quantitative parameters, the maximum number of capsules per plant (141.86±0.93), seeds per capsule (68.80±0.15), test weight (4.22±0.12 g), and seed yield (5.99 q/ha) were recorded with honey solution.

Keywords Sesame, Bee attractants, Honey solution, Bee visitation, Quantitative parameters.

INTRODUCTION

Sesame, a primary oilseed crop, grows in tropical and subtropical regions worldwide (Joshi *et al.* 1961). It carries up an honorable label of 'queen of oilseeds' (Biswas *et al.* 2018) because of its high oil content, delicious nutty aroma, and flavor (Myint *et al.* 2020). It is a mixed-pollination crop, where cross-pollination enhances yield by 22-33% over self-pollination (Panda *et al.* 1988). A large number of insect pollinators belonging to different orders, such as Coleoptera, Diptera, Lepidoptera, and Hymenoptera, contribute to pollination (Rao *et al.* 2021). Among hymenopteran insects, bees are mainly responsible for 80% of total insect pollination (Thapa 2006). Application of various bee attractants can increase the visitation of bees, which can ensure pollination, resulting in a higher yield. Both commercial and indigenous bee attractants

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are widely used to attract bees (Naik *et al.* 2005 and 2007). Although commercial bee attractants are costly and non-feasible, indigenous bee attractants such as honey solution, sugar solution, jaggery solution, sugarcane juice, and molasses can be used to boost the activity of bees (Gothi *et al.* 2022). These local bee attractants are cheaper, non-toxic, and eco-friendly and can be used in the organic production of crops to enhance yield. In India, research related to this topic is lacking, especially in Punjab (where no such research has been conducted to date). Therefore, the present study was conducted with the objective of investigating the influence of indigenous bee attractants on bee visitation and quantitative parameters of sesame crops.

MATERIALS AND METHODS

This study was conducted on sesame during the *kharif* season in 2022 in the fields of Khalsa College, Amritsar. The experimental details are listed in Table 1. The treatments namely Honey solution, sugar+jaggary solution, jaggary solution, glucon-D+milk, and sugar solution at 10% concentration and two controls (self-pollination and open pollination) were selected. Control plants were not sprayed with attractants, while plants belonging to the control (self-pollination) were caged in ultrafine mesh nets. From each plot, the number of bees visiting flowers in five minutes on a randomly selected area of one m^2 was recorded three times a day from 0800 to 1400 hrs at three-hour interval on the day before and on the 1st, 2nd, 3rd, and 5th day after the first and second spray. For the quantitative parameters, ten plants were selected from each treatment to estimate the number of capsules per plant. Similarly, ten capsules were used to count the number of seeds. The crop was harvested separately based on treatment, and seeds were weighed to evaluate the test weight (g) and seed yield (g/plot); later, the seed yield was converted into q/ha. Bee visitation data and quantitative parameters were analyzed using ANOVA in the CPCS software and ICAR WASP 2.0 software, respectively.

Table 1. List of the experimental details.

Name of cultivar	:	Punjab til no. 2
Procurement of seeds	:	Punjab agricultural university
Number of treatments	:	7
Number of replications	:	3
Time of planting	:	9th of July, 2022
Plot size	:	4 × 4 m^2
Spacing	:	30 × 15 cm
Time of spraying	:	10 and 50% flowering
Design	:	Randomized Block Design

RESULTS AND DISCUSSION

Throughout the study period, four bee species (*Apis mellifera*, *Apis cerana, Apis dorsata* and *Megachile lanata*) visited the sesame flowers. Bee visitation was found to be almost uniform in all plots a day before the first and second spray of attractants. After the first spraying, a gradual increase in bee visitation was observed from the first to the fifth day of spraying, whereas after the second spraying, bee visitation increased from the first to the second day of spraying, and a continuous decrease in bee visitation was observed afterwards. Among the bee attractants evaluated, the plots sprayed with honey solution recorded the highest number of *A. mellifera, A. cerana, M. lanata* and *A. dorsata* with 4.49±0.49, 3.91±0.39, 3.59±0.25 and 3.17±0.28 bees/m^2/5 min, respectively followed by jaggary solution, sugar solution, sugar+jaggary solution and glucon-D+milk powder while least number of bees were recorded on untreated plots (Tables 2–5).

The present study concluded that honey solution entices the maximum number of bees, which might be due to the presence of a potent aroma, air-diffusing properties, or phago-stimulatory effect, and the presence of carbohydrates (glucose and fructose) in honey. A similar trend in the visitation of bees on plants after spraying with bee attractants was observed by Manhare and Painkra (2018) on buckwheat and Manchare *et al.* (2019) on bitter gourd. Our findings are in line with those of Hitesh *et al.* (2021), who also reported an increase in the visitation of bees on sesame up to 7th days after the first spray and 3rd day after the second spray.

The various quantitative parameters, such as capsules/plant (141.86±0.93), seeds/capsule (68.80±0.15), test weight (4.22±0.12 g), and seed yield (5.99 q/ha), were significantly higher in plants sprayed with honey solution followed by jaggary

Table 2. Effect of bee attractants on the visitation of *Apis mellifera* on sesame. LSD (p≤0.05), Days (D)-0.19, Treatment (T)-0.15, DxT-0.48, Values are mean±SE of three replications, Figures in parentheses are means of square root transformation, DBS- Day before spraying, DAS- Day after spraying.

Treatments	Bee visitation/m²/5 min									
	First spray (10% flowering)					Second spray (50% flowering)				
	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	Mean
Control	1.11±0.09 (1.45)	0.77±0.09 (1.33)	1.11±0.18 (1.44)	2.11±0.09 (1.76)	2.44±0.09 (1.85)	2.00±0.15 (1.73)	2.33±0.24 (1.82)	2.66±0.09 (1.91)	2.44±0.18 (1.85)	1.44±0.09 (1.56)	**1.91±0.25**
Honey solution (10%)	1.00±0.15 (1.41)	2.11±0.09 (1.76)	3.22±0.09 (2.05)	3.88±0.09 (2.21)	4.66±0.15 (2.37)	3.11±0.09 (2.02)	5.55±0.09 (2.55)	6.22±0.09 (2.68)	5.77±0.09 (2.60)	4.55±0.09 (2.35)	**4.49±0.49**
Sugar+ jaggary solution (10%)	0.77±0.09 (1.33)	1.22±0.09 (1.48)	2.11±0.09 (1.76)	2.88±0.09 (1.97)	3.55±0.18 (2.13)	2.55±0.09 (1.88)	4.44±0.15 (2.33)	5.11±0.09 (2.47)	5.11±0.18 (2.47)	3.44±0.09 (2.10)	**3.48±0.49**
Jaggary solution (10%)	0.44±0.09 (1.20)	1.77±0.09 (1.66)	2.66±0.15 (1.91)	3.44±0.18 (2.10)	4.33±0.15 (2.30)	2.44±0.09 (1.85)	5.00±0.00 (2.44)	5.88±0.32 (2.62)	5.33±0.18 (2.51)	3.66±0.09 (2.16)	**3.94±0.46**
Glucon-D+milk powder (10%)	0.55±0.09 (1.24)	0.88±0.09 (1.37)	2.00±0.15 (1.73)	3.00±0.18 (1.99)	3.22±0.18 (2.05)	2.33±0.15 (1.82)	4.66±0.15 (2.38)	4.88±0.18 (2.42)	4.11±0.15 (2.25)	2.88±0 (1.97)	**3.20±0.47**
Sugar solution (10%)	0.66±0 (1.29)	1.44±0.09 (1.56)	2.88±0.15 (1.97)	2.66±0.31 (1.90)	4.00±0.15 (2.23)	2.33±0.15 (1.82)	4.77±0.09 (2.40)	6.11±0.09 (2.66)	4.88±0.18 (2.42)	3.44±0.09 (2.10)	**3.77±0.52**
Mean	**0.75±0.09**	**1.37±0.19**	**2.33±0.28**	**3.00±0.23**	**3.70±0.30**	**2.46±0.13**	**4.46±0.41**	**5.14±0.48**	**4.61±0.44**	**3.00±0.38**	

Table 3. Effect of bee attractants on the visitation of *Apis cerana* on sesame. LSD (p≤0.05), Days (D)-0.17, Treatment (T)-0.13; D×T-0.42, Values are mean±SE of three replications, Figures in parentheses are means of square root transformation. DBS- Day before spraying, DAS- Day after spraying.

Treatments	Bee visitation/m²/5 min									
	First spray (10% flowering)					Second spray (50% flowering)				
	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	Mean
Control	0.44±0.09 (1.20)	0.88±0.09 (1.37)	1.22±0.09 (1.48)	1.22±0.09 (1.48)	1.00±0.15 (1.41)	1.11±0.09 (1.45)	1.55±0.09 (1.59)	1.88±0.24 (1.69)	1.77±0.09 (1.66)	1.77±0.09 (1.66)	**1.41±0.13**
Honey solution (10%)	0.44±0.09 (1.20)	1.88±0.09 (1.69)	3.11±0.18 (2.02)	3.44±0.09 (2.10)	3.55±0.09 (2.13)	2.11±0.09 (1.76)	4.55±0.09 (2.35)	5.22±0.09 (2.49)	5.00±0.15 (2.44)	4.55±0.18 (2.35)	**3.91±0.39**
Sugar+ jaggary solution (10%)	0.55±0.09 (1.24)	1.33±0.00 (1.52)	2.88±0.09 (1.96)	2.55±0.09 (1.88)	2.44±0.09 (1.85)	1.66±0.00 (1.63)	3.66±0.15 (2.15)	4.33±0.15 (2.30)	3.88±0.09 (2.21)	3.44±0.09 (2.10)	**3.06±0.34**
Jaggary solution (10%)	0.44±0.09 (1.2)	1.55±0.09 (1.59)	2.66±0.24 (1.91)	3.11±0.09 (2.02)	3.22±0.09 (2.05)	1.88±0.09 (1.69)	4.22±0.09 (2.28)	4.77±0.18 (2.40)	4.55±0.09 (2.35)	4.22±0.09 (2.28)	**3.53±0.39**
Glucon-D+milk powder (10%)	0.55±0.09 (1.24)	1.55±0.09 (1.59)	2.11±0.15 (1.76)	2.22±0.09 (1.79)	2.22±0.09 (1.79)	1.55±0.09 (1.59)	4.00±0.15 (2.23)	4.22±0.24 (2.28)	3.77±0.09 (2.18)	3.22±0.09 (2.05)	**2.91±0.35**

Table 3. Continued.

Treatments	Bee visitation/m²/5 min									
	First spray (10% flowering)					Second spray (50% flowering)				
	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	Mean
Sugar solution (10%)	0.44±0.09 (1.20)	1.44±0.18 (1.56)	2.44±0.18 (1.85)	2.88±0.09 (1.97)	2.77±0.09 (1.94)	1.77±0.09 (1.66)	4.00±0.15 (2.23)	5.00±0.15 (2.44)	4.22±0.09 (2.28)	4.00±0.15 (2.23)	**3.34±0.41**
Mean	**0.48±0.02**	**1.44±0.12**	**2.40±0.25**	**2.57±0.29**	**2.53±0.33**	**1.68±0.12**	**3.66±0.40**	**4.24±0.45**	**3.87±0.41**	**3.53±0.37**	

Table 4. Effect of bee attractants on the visitation of *Apis dorsta* on sesame. LSD (p≤0.05), Days (D)-0.21, Treatment (T)-0.16, D×T-0.53, Values are mean±SE of three replications, Figures in parentheses are means of square root transformation, DBS- Day before spraying, DAS- Day after spraying.

Treatments	Bee visitation/m²/5 min									
	First spray (10% flowering)					Second spray (50% flowering)				
	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	Mean
Control	0.44±0.09 (1.20)	0.66±0.15 (1.28)	1.00±0.15 (1.41)	1.22±0.24 (1.48)	1.44±0.24 (1.55)	1.22±0.09 (1.48)	1.22±0.09 (1.48)	1.66±0.15 (1.63)	1.55±0.09 (1.59)	0.88±0.09 (1.24)	**1.20±0.12**
Honey solution (10%)	0.55±0.09 (1.24)	2.42±0.07 (1.84)	2.77±0.09 (1.94)	3.33±0.15 (2.08)	3.77±0.18 (2.18)	2.22±0.24 (1.79)	3.66±0.15 (2.15)	4.44±0.09 (2.33)	4.33±0.15 (2.30)	4.33±0.15 (2.23)	**3.59±0.25**
Sugar+ jaggary solution (10%)	0.55±0.09 (1.24)	1.77±0.18 (1.66)	2.11±0.09 (1.76)	2.77±0.09 (1.94)	3.00±0.27 (1.99)	1.88±0.09 (1.69)	2.88±0.09 (1.97)	3.88±0.09 (2.21)	3.33±0.27 (2.07)	3.00±0.15 (1.99)	**2.84±0.23**
Jaggary solution (10%)	0.44±0.09 (1.20)	2.11±0.09 (1.76)	2.44±0.09 (1.85)	3.00±0.15 (1.99)	3.55±0.09 (2.13)	2.22±0.24 (1.79)	3.44±0.09 (2.10)	4.22±0.09 (2.28)	4.00±0.15 (2.23)	3.66±0.15 (2.15)	**3.30±0.26**
Glucon-D+milk powder (10%)	0.44±0.09 (1.20)	1.55±0.09 (1.59)	1.88±0.18 (1.69)	2.66±0.15 (1.91)	2.88±0.18 (1.97)	1.77±0.09 (1.66)	1.77±0.09 (1.88)	3.66±0.31 (2.15)	3.22±0.09 (2.05)	2.66±0.15 (1.91)	**2.63±0.24**
Sugar solution (10%)	0.44±0.09 (1.20)	1.88±0.18 (1.69)	2.44±0.09 (1.85)	2.88±0.09 (1.97)	3.44±0.24 (2.10)	2.22±0.18 (1.79)	3.22±0.18 (2.05)	4.22±0.24 (2.28)	3.88±0.09 (2.21)	3.33±0.15 (2.08)	**3.16±0.26**
Mean	**0.48±0.02**	**1.73±0.22**	**2.11±0.23**	**2.64±0.27**	**3.01±0.31**	**1.92±0.14**	**2.83±0.32**	**3.68±0.38**	**2.38±0.37**	**2.92±0.41**	

Table 5. Effect of bee attractants on the visitation of *Megachile lanata* on sesame. LSD (p≤0.05), Days (D)-0.22, Treatment (T)-0.17, D×T-0.55, Values are mean±SE of three replications, Figures in parentheses are means of square root transformation, DBS- Day before spraying, DAS- Day after spraying.

Treatments	Bee visitation/m²/5 min									
	First spray (10% flowering)					Second spray (50% flowering)				
	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	Mean
Control	0.66±0.15 (1.28)	0.55±0.09 (1.24)	0.77±0.09 (1.33)	1.33±0.15 (1.52)	1.22±0.18 (1.48)	1.33±0.15 (1.52)	1.22±0.09 (1.48)	1.44±0.24 (1.55)	0.77±0.09 (1.33)	1.33±0.41 (1.38)	**1.07±0.11**
Honey solution (10%)	0.77±0.09 (1.33)	1.77±0.24 (1.66)	2.22±0.09 (1.79)	3.44±0.24 (2.10)	3.77±0.09 (2.18)	1.66±0.15 (1.63)	3.44±0.09 (2.10)	4.22±0.09 (2.28)	3.44±0.18 (2.10)	3.11±0.09 (2.02)	**3.17±0.28**
Sugar+ jaggary solution (10%)	0.77±0.09 (1.33)	1.44±0.18 (1.56)	2.11±0.09 (1.76)	2.44±0.09 (1.85)	2.66±0.15 (1.91)	1.44±0.09 (1.56)	2.55±0.09 (1.88)	3.44±0.09 (2.10)	2.22±0.24 (1.79)	2.11±0.09 (1.76)	**2.37±0.20**

Table 5. Continued.

Treatments	Bee visitation/m²/5 min										
	First spray (10% flowering)					Second spray (50% flowering)					
	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	DBS	1st DAS	2nd DAS	3rd DAS	5th DAS	Mean
Jaggary solution (10%)	0.44±0.09 (1.20)	1.55±0.09 (1.59)	1.88±0.09 (1.69)	3.33±0.27 (2.07)	3.44±0.18 (2.10)	1.55±0.09 (1.59)	3.00±0.15 (1.99)	4.00±0.15 (2.23)	2.77±0.18 (1.94)	2.77±0.09 (1.94)	**2.84±0.28**
Glucon-D+milk powder (10%)	0.88±0.18 (1.36)	1.22±0.32 (1.47)	1.33±0.15 (1.52)	2.55±0.09 (1.88)	2.22±0.09 (1.79)	1.44±0.09 (1.56)	2.55±0.24 (1.88)	3.22±0.09 (2.05)	1.88±0.24 (1.69)	1.33±0.27 (1.52)	**2.03±0.25**
Sugar solution (10%)	0.66±0.00 (1.29)	1.55±0.09 (1.59)	1.88±0.09 (1.69)	3.22±0.09 (2.05)	3.33±0.15 (2.08)	1.66±0.15 (1.63)	2.77±0.09 (1.94)	3.66±0.27 (2.15)	2.44±0.18 (1.85)	2.11±0.09 (1.76)	**2.62±0.26**
Mean	**0.70±0.05**	**1.35±0.16**	**1.70±0.20**	**2.72±0.20**	**2.77±0.35**	**1.51±0.04**	**2.59±0.28**	**3.33±0.37**	**2.25±0.33**	**2.07±0.27**	

Table 6. Effect of bee attractants on quantitative parameters of sesame crop.Values are mean±SE of three replications, CD- Critical difference, variables (a, b, c…...) significantly different from each other at 5% level of significance, OP- Open pollination, SP- Self pollination.

Treatments	Capsules/ plant	Percent increase over		Seeds/ capsule	Percent increase over		Test weight (g)	Percent increase over		Seed yield (g/plot)	Percent increase over		Converted yield (q/ha)
		OP	SP		OP	SP		OP	SP		OP	SP	
Control (Open pollination)	96.30^{f}±1.61	--	27.16	61.16^{e}±0.12	--	11.54	3.53^{e}±0.01	--	3.51	722.66^{e}±8.20	--	3.51	4.52
Control (Self-pollination)	75.73^{g}±0.99	--	--	54.83^{f}±0.44	--	--	3.41^{f}±0.04	--	--	640^{f} ±7.64	--	--	4.00
Honey solution (10%)	141.86^{a}±0.93	47.31	87.32	68.80^{a}±0.15	12.49	25.47	4.22^{a}±0.06	19.54	23.75	959.33^{a}±6.39	19.54	23.75	5.99
Sugar+jaggary solution (10%)	127.56^{d}±0.44	32.46	68.44	64.16^{c}±0.08	4.90	17.01	3.84^{c}±0.01	8.78	12.61	849.33^{d}±8.97	8.78	12.61	5.30
Jaggary solution (10%)	138.13^{b}±0.17	42.39	81.07	66.46^{b}±0.57	8.66	21.21	3.99^{b}±0.01	13.03	17.00	931.66^{b}±11.47	13.03	17.00	5.82
Glucon-D+ milk powder (10%)	119.43^{e}±0.63	24.01	57.70	62.76^{d}±0.71	2.61	14.46	3.70^{d}±0.01	4.81	8.50	843^{d} ±9.30	4.81	8.50	5.26
Sugar solution (10%)	132.73^{c}±0.92	37.82	75.26	66.13^{b}±0.08	8.12	20.60	3.90^{bc}±0.04	10.48	14.36	893.66^{c}±8.22	10.48	14.36	5.58
CD (p≤0.05)	2.77		--	1.27		--	0.11		--	27.50		--	--

solution, sugar solution, sugar+jaggary solution, glucon-D+milk powder, and control (open pollination), whereas the minimum was observed in the control (self-pollination) (Table 6).

The results revealed that the application of honey solution boosted all quantitative parameters, which may be due to the increased number of bee visitations that resulted in uniform pollen dispersion on flowers at the ideal moment when the stigma was receptive, which eventually led to efficient cross-pollination and improved seed set. The current findings are in close agreement with those of researchers who reported similar results in cucumber (Wankhede *et al.* 2018), coriander (Khandibagur *et al.* 2019) and onion (More *et al.* 2020).

CONCLUSION

Based on the findings of the experiment, it can be said that spraying indigenous bee attractants onto flowers can help pollinate sesame by enticing more bees to the blooms. Spraying honey solution at 10% and 50% flowering has proven to be the most successful treatment since it enhanced bee visits to the treated flowers and markedly improved the number of capsules, seeds per capsule, test weight, and crop yield.

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