*<u>**Original Research Article**</u>*

Effect of bee attractants on foraging behaviour of honey bees(species…………….) and seed yield of Aster(botanical name…………….) flowers

ABSTRACT

Aims: Aster (*Callistephuschinensis* L.) is a seed-propagated annual flower crop widely used in floral arrangements, garlands and landscaping, making it increasingly popular among small-scale farmers. Despite this growing interest, challenges like poor seed quality and low seed set have made it difficult to meet the demand for high-quality Aster seeds in market. As a cross-pollinated crop, Aster depends heavily on pollinators, particularly honeybees, to ensure effective seed production. By enhancing cross-pollination, bee attractants can help boost seed yield. Thus, our aim to identify suitable local, bee attractants and evaluate their effectiveness in improving Aster seed yield.

Place and Duration of Study: The experiment was conducted over two years (2021-22 and 2022-23) at the ICAR-Directorate of Floricultural Research, Pune.

Methodology: Experiment is conducted with seven treatments and three replications. Bee attractant sprays were applied twice to the crop during its flowering period, first taken at 20 per cent flowering and the second spray was applied at 70 per cent flowering. Observations were recorded on abundance of bee visitors and seed yield parameters.

Results: The results showed that sugar solution (10%) was significantly superior in attracting in *Apisflorea* (35.08 bees/ m^2 /5 min) and *Apisceranaindica*(17.44 bees/ m^2 /5 min), which was statistically on par with jaggery solution (15%) (30.85 and 15.08 bees/ m^2 /5 min, respectively). Seed yield parameters including number of seeds per flower, weight of seed/flower, seed yield (kg/ha), and test weight of seeds recorded highest in plots treated with sugar solution (10%) (171.63, 0.40g, 291.33 kg/ha and 2.79g, respectively) which was statistically on par with jaggery solution (15%) (159.63, 0.39g, 281.74kg/ha and 2.57g, respectively).

Conclusion: The study concluded that both sugar solution (10%) and jaggery solution (15%) are effective in increasing bee activity, which in turn helps boost seed production in cross-pollinated crops like Aster. This research offers valuable insights into potential of affordable and accessible attractants for marginal and smallholder farmers which aims to enhance pollination and seed production in Aster.

Keywords: Aster, bee attractant, bees, abundance, seed yield

1. INTRODUCTION

Aster (*Callistephuschinensis* L.) is a seed propagated annual flower crop from the Asteraceae family known for its aesthetic value. Due to its beautiful and colourful flowers, Aster is in high demand for use in floral arrangements, garlands and landscape gardening. In India, Aster continued gaining popularity among small and marginal farmers due its high market potential and relatively easy cultivation requirements. Now it's become a third most popular flowering annual plant in India, reflecting its continued growth in popularity (Chakraborty *et al*., 2019).

As the popularity of Aster flowers increases, the demand for high-quality seeds also rises. However, their demand is unattainable, primarily because of poor seed quality and inadequate seed set. There is still limited information available on high quality seed production in Aster. However, seed setting studies are often neglected because it's time-consuming and labour-intensive nature. Though some growers try to produce seeds, they often face challenges with low quality and inadequate seed sets.

In Aster, single and semi-double varieties are primarily cross pollinated (Strube, 1965; Janakiram, 1997), meaning they rely primarily on pollinators for effective seed production. Cross pollination can be significantly enhanced by utilizing pollinators particularly honeybees, which are known to be one of the most efficient, cheap and eco-friendly way for increasing the seed yield of many crops (Free, 1970). Research has shown that honeybee activity directly correlates with better seed set, and fewer bee visits are often associated with lower yields (Long and Morandin, 2011).

In fact, many studies have demonstrated that proper pollinator management can significantly maximize seed yields in a wide range of crops by up to 43 per cent in sunflower, sesame and niger and as much as 100-150 per cent in cucurbits (Melnichenko and Khalifman, 1960). However, presence of bees in the vicinity is not enough for successful pollination. For the pollination management, one of the key challenges is attracting honeybees to the target crops away from more attractive competing flowers in that vicinity (Free, 1968). Furthermore, the ability to divert bees from other compatible pollen sources towards the target crop is crucial to ensure efficient cross-pollination and in turn, seed yield (Malerbo-Souza *et al*., 2004).

This is where bee attractants play an important role. These attractants act as a powerful tool to boost honeybee activity towards specific crop of interest (Viraktamath and Anagoudar, 2002). In fact seed yield is a highly complex aspect, significantly influenced by the external application of insect attractants (Maynard *et al*., 1992). Commercial bee attractants like Bee-Q and Bee Scent are commonly used in various crops worldwide to enhance pollination and improve yields (Viraktamath and Patil, 2002). However, given the high cost and limited availability of commercial bee attractants, indigenous and locally available alternatives can offer a more affordable and practical solution for small and marginal farmers in India.

Previous studies have shown that indigenous bee attractants like jaggery solution, sugar solution, citral and geraniol are highly effective in drawing honeybees. This, in turn, helps improve pollination and crop yields in crops that rely on cross-pollination (Waller, 1970; Malerbo-Souza et al., 2004; Dwarka *et al.,* 2024).

There is a lack of research regarding potential of such easily available, local bee attractants to improve seed yield of commercial flower crops like Aster. This study, therefore, aims to evaluate the impact of indigenous bee attractants on native pollinators, particularly honeybees, and assess how these attractants influence seed yield of aster. By identifying affordable and sustainable methods for improving pollination, this research could offer valuable insights for farmers seeking to enhance aster seed production in India.

2. MATERIAL AND METHODS

2.1 Location

The current studies were undertaken during two consecutive years 2021-22 and 2022-23 at research farm of the ICAR-Directorate of Floricultural Research, Pune (18°31'26.6"N and 73°57'27.7"E).

2.2Preparation of plots

The Aster *cv.* Phule Ganesh Pink was raised by following all recommended agronomic practices and special care has been taken to avoid or minimize use of pesticide in the field.The experiment was laid out in a randomized block design (RBD) with seven treatments and three replications. Each block was 5 m x 5 m with 45cm x 60cm spacing between plants. A total of two bee attractant sprays were applied to the crop during its flowering period, first taken at 20 per cent flowering and the second spray was applied at 70 per cent flowering respectively. The details of the treatments are presented in Table 1.

Table 1: Treatment details of bee attractants

Tr. No.	Treatments	Concentration (%)
	T_1-Citral	0.1
	T_2-Geraniol	0.1
	T_3-Lemongrass oil	0.1
	T_4-Sugar solution	10
	T_5-Jaggery solution	15
	T_6-Control (water spray)	-
	T_7-Control (without water spray)	-

2.3Observations recorded

Observations were recorded on *Apisflorea* and *Apisceranaindica* bees which was observed as dominant and frequent visitors of Aster. Observations were recorded by counting the number of bees visited to flowers per m^2 area for five minute at a three hour interval from 9.00 hrs to 18.00 hrs. These observations were recorded day before the first and second spray and later on the 1^{st}, 3^{rd}, 5^{th} and 7^{th} days after the first and second sprays. After harvest, quantitative parameters like number of seeds per flower, seed weight per flower (g), seed yield (kg/ha), test weight of 1000 seeds (g) were compared among treatments.

2.4Statistical analysis

Using analysis of variance for a randomized block design, all the data regarding abundance and yield parameters were statistically analysed after appropriate transformations where necessary (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1 Effectofbeeattractantonbeevisitationonasterflowers

The data presented in Table 2 on Aster flowers showed that a day before spraying in case of *Apisflorea*visiting Aster flowers, the number of bees ranged from 11.03-11.64 bees/ m^2 /5 min which did not differ significantly among the treatments. However, 1DAFS sugar solution (10%) attracted higher number of bees which was statistically similar with the treatment jaggery solution (15%) (46.53 and 39.69 bees/ m^2 /5 min, respectively). The control (water spray) which was statistically on par with control (without water spray) were least effective in attracting bees towards aster flowers. The other treatments were in between them. Thereafter the bee visit started declining in all the imposed treatments. However even after 3DAFS, 5DAFS and 7DAFS, sugar solution (10%) attracted higher number of bees which was statistically similar with the treatment jaggery solution (15%) attracted large number of bees as compared to other attractants but all these treatments was superior to control (water spray) and control (without water spray) which was statistically on par with each other. A similar trend was observed during second spray. Considering the mean of two sprays, it reveals that the sugar solution (10%) attracted higher number of bees which was statistically similar with the treatment jaggery solution (15%) (35.08 and 30.85 bees/ m^2 /5 min) and significantly superior over the control (water spray) and control (without water spray) which was statistically similar with each other. In the current study, both the attractants are equally effective in attracting *Apisflorea* bees.

In case of *Apisceranaindica*(Table 3), the initial population 1DBFSranged between 4.07-4.57 bees/ m^2 /5 min which was non-significant among the treatments.However, 1DAFS sugar solution (10%) attracted higher number of bees which was at par with the treatment jaggery solution (15%) (16.72 and 15.03 bees/ m^2 /5 min, respectively). The control (water spray) which was statistically on par with control (without water spray) were least effective in attracting bees towards aster flowers. The other treatments were in between them. Afterward, the number of bee visits gradually decreased in all the treatments. However even after 3DAFS, 5DAFS and 7DAFS, sugar solution (10%) attracted higher number of bees which was statistically similar with the treatment jaggery solution (15%) attracted large number of bees as compared to other attractants but all these treatments was superior to control (water spray) and control (without water spray) which was statistically on par with each other. A similar trend was observed during second spray. Considering the mean of two sprays, it reveals that the sugar solution (10%) attracted higher number of bees which was statistically on par with the treatment jaggery solution (15%) (17.44 and 15.08 bees/ m^2 /5 min) and significantly superior over the control (without water spray) and control (water spray) which was statistically similar with each other. In this study, both attractants were found to be equally effective in drawing *Apisceranaindica* bees.

Several researchers cited that spraying attractants like sugar and jaggery solutions can significantly boost pollinator activity in crops like, onion (Naik *et al.,* 2019), cucumber (Wankhede *et al.,* 2019), sesame (Hitesh *et al.,* 2021)) and Niger (Dwarka *et al.,* 2024). Although both attractants have been shown to benefit a variety of crops, there is a lack of research specifically on aster. Therefore, we've used data from other crops as a point of reference for comparison.

Sugar solutions are almost entirely sucrose (about 90%), while jaggery solutions contain about 50% sucrose. This high sucrose content seems attributed to phago stimulatory effect in bees which stimulates the bees' feeding behaviour, encouraging them to visit the aster flowers more frequently. These solutions not only provide the bees with an immediate source of energy but also help to sustain their health by supplying essential fats and proteins (Jayaramappa*et al*., 2011; Naik, 2019).

Our results also support earlier research showing that certain essential oils, like citral, geraniol and lemongrass oil, are effective in attracting bees though their effectiveness was generally lower compared to sugar and jaggery solution. These findings are in line with studies by Waller (1970), Malerbo-Souza *et al.* (2004), Naik (2010) and Pashte*et al*. (2015). Pheromones play a key role in guiding bee foraging behaviour. The Nasonov pheromone, produced by worker bees, contains citral and geraniol, both of which are found in various plants. These compounds are effective at attracting bees individually, though their effectiveness can vary depending on concentration and other factors (Williams *et al*., 1981). Lemongrass oil, shown that attract bees to aster flowers (Veeranjaneyulu*et al*., 2024) may be because it contains geraniol and citral which is major nasonov pheromone compound, (Shearer and Boch, 1966; Conrad, 2010). While these essential oils have been reported to attract bees, their effectiveness was generally lower compared to sugar and jaggery solutions in our study. This may be because the concentration of essential oils in our trials was not high enough to attract bees over long distances, or because these oils did not provide the same nutritional benefits as food-based attractants.

Our study found that the effectiveness of attractants decreased after just one day, likely due to the volatilization of these compounds under sunlight (Malerbo-Souza *et al*., 2004). However, we observed that the second spraying of attractant led to more bee visits, probably because of the greater number of open flowers available for pollination at the 70% flowering stage of aster (Kulkarni *et al*., 2017).

Table 2: Effect of bee attractants on visitation rate of *A. florea* in *C. chinensis* (2021-22 and 2022-23)

Treatment details	Concentration (%)	Number of bees /m^2 / 5 minutes										
		First Spray					Second Spray					Mean
		1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	
T_1 – Citral	0.1	11.64 (3.46)	18.60 (4.36)[b]	17.68 (4.21)[b]	16.86 (4.14)[b]	15.22 (3.94)[b]	14.05 (3.81)	24.64 (5.01)[b]	22.66 (4.76)[b]	19.82 (4.50)[b]	18.01 (4.30)[b]	19.19 (4.42)[b]
T_2 – Geraniol	0.1	11.52 (3.44)	21.10 (4.63)[b]	20.71 (4.59)[b]	18.25 (4.33)[b]	16.43 (4.07)[b]	14.02 (3.80)	27.73 (5.30)[b]	25.45 (5.09)[b]	21.93 (4.73)[b]	19.83 (4.51)[b]	21.43 (4.68)[b]
T_3 – Lemongrass Oil	0.1	11.52 (3.44)	17.69 (4.26)[b]	16.63 (4.12)[b]	15.86 (4.04)[b]	14.95 (3.90)[b]	13.90 (3.79)	21.49 (4.68)[b]	19.86 (4.51)[b]	18.53 (4.35)[b]	17.15 (4.20)[b]	17.77 (4.27)[b]
T_4 – Sugar solution	10	11.37 (3.42)	46.53 (6.85)[a]	36.45 (6.07)[a]	26.97 (5.24)[a]	21.48 (4.67)[a]	15.69 (4.02)	51.63 (7.22)[a]	39.46 (6.32)[a]	31.69 (5.67)[a]	26.47 (5.18)[a]	35.08 (5.96)[a]
T_5 – Jaggery solution	15	11.03 (3.35)	39.69 (6.25)[a]	32.79 (5.71)[a]	23.48 (4.87)[a]	18.12 (4.31)[a]	14.38 (3.86)	45.17 (6.67)[a]	35.62 (5.89)[a]	28.56 (5.33)[a]	23.36 (4.85)[a]	30.85 (5.58)[a]
T_6 –Control (water spray)	-	11.27 (3.40)	11.54 (3.47)[c]	12.11 (3.54)[c]	12.41 (3.58)[c]	11.77 (3.48)[c]	13.69 (3.76)	14.34 (3.81)[c]	14.63 (3.87)[c]	16.14 (4.03)[c]	14.43 (3.86)[c]	13.42 (3.72)[c]
T_7 - Control ~~(without water spray)~~	-	11.08 (3.38)	11.26 (3.42)[c]	11.99 (3.52)[c]	12.26 (3.55)[c]	11.69 (3.45)[c]	13.64 (3.75)	14.00 (3.80)[c]	14.42 (3.86)[c]	16.02 (4.06)[c]	14.33 (3.85)[c]	13.24 (3.70)[c]
S.E(m)±			0.32	0.29	0.15	0.14		0.35	0.34	0.19	0.16	0.14
CD at 5%			0.99	0.88	0.45	0.44		1.08	1.03	0.57	0.48	0.42
CV (%)			11.67	10.91	6.91	6.27		11.66	11.84	6.86	6.09	6.10

*Figures in parenthesis are $\sqrt{x} + 0.5$ transformed values

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

Table 3: Effect of bee attractants on visitation rate of *A. ceranaindica* in *C. chinensis* (2021-22 and 2022-23)

Treatment details	Concentration (%)	Number of bees /m^{2} / 5 minutes										
		First Spray					Second Spray					Mean
		1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	
T_1 - Citral	0.1	4.16 (2.14)	9.30 (3.11)^{b}	8.53 (2.99)^{b}	7.57 (2.82)^{b}	6.64 (2.66)^{b}	9.80 (3.19)	15.43 (3.98)^{b}	14.73 (3.89)^{b}	13.20 (3.69)^{b}	12.44 (3.58)^{b}	10.98 (3.38)^{b}
T_2 - Geraniol	0.1	4.57 (2.24)	10.60 (3.33)^{b}	9.87 (3.22)^{b}	8.78 (3.04)^{b}	7.66 (2.84)^{b}	10.00 (3.24)	16.57 (4.13)^{b}	15.65 (4.02)^{b}	14.32 (3.83)^{b}	12.93 (3.66)^{b}	12.05 (3.54)^{b}
T_3 - Lemongrass oil	0.1	4.30 (2.18)	7.83 (2.88)^{b}	7.20 (2.77)^{b}	6.57 (2.66)^{b}	6.23 (2.59)^{b}	9.20 (3.11)	14.70 (3.90)^{b}	14.27 (3.84)^{b}	12.36 (3.58)^{b}	12.19 (3.56)^{b}	10.17 (3.26)^{b}
T_4 - Sugar solution	10	4.44 (2.22)	16.72 (4.12)^{a}	15.71 (3.95)^{a}	12.17 (3.52)^{a}	10.18 (3.25)^{a}	9.63 (3.18)	25.61 (5.05)^{a}	22.54 (4.77)^{a}	19.36 (4.42)^{a}	17.20 (4.18)^{a}	17.44 (4.20)^{a}
T_5 - Jaggery solution	15	4.20 (2.16)	15.03 (3.90)^{a}	13.31 (3.69)^{a}	9.51 (3.16)^{a}	8.69 (3.02)^{a}	9.80 (3.21)	22.80 (4.76)^{a}	19.51 (4.44)^{a}	17.04 (4.18)^{a}	14.77 (3.91)^{a}	15.08 (3.93)^{a}
T_6 - Control (water spray)	-	4.07 (2.13)	4.89 (2.31)^{c}	5.13 (2.36)^{c}	5.35 (2.41)^{c}	5.61 (2.46)^{c}	8.10 (2.93)	10.05 (3.23)^{c}	10.57 (3.31)^{c}	10.63 (3.30)^{c}	9.56 (3.15)^{c}	7.72 (2.85)^{c}
T_7 - Control (without water spray)	-	4.47 (2.22)	4.70 (2.27)^{c}	4.83 (2.29)^{c}	5.27 (2.39)^{c}	5.57 (2.45)^{c}	8.07 (2.92)	9.70 (3.19)^{c}	10.30 (3.28)^{c}	10.35 (3.28)^{c}	9.11 (3.08)^{c}	7.48 (2.82)^{c}
S.E(m)±			0.16	0.19	0.12	0.09		0.22	0.16	0.12	0.12	0.13
CD at 5%		NS	0.50	0.60	0.38	0.27	NS	0.66	0.49	0.36	0.37	0.39
CV (%)			9.00	11.06	7.45	6.51		9.25	6.93	6.33	6.81	6.40

*Figures in parenthesis are $\sqrt{x + 0.5}$ transformed values

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

3.2Effectofbeeattractantonseed yield parameters ofasterflowers

Effects of bee attractant on different seed yield parameters have been presented in table 4. highest number of seeds/flower (171.63), weight of seeds /flower (0.40g), seed yield (291.33 kg/ha), test weight of seeds (2.79g) was recorded in sugar solution (10%) which was statistically on par with jaggery solution (15%) (159.63, 0.39g, 281.74kg/ha and 2.57g, respectively) indicating both the attractants were equally effective in recording higher seed yield parameters (Table 4). Whereas, lowest seed yield parameters was recorded in control (water spray) (81.29, 0.20g, 222.46 kg/ha and 2.16g, respectively) which was statistically on par with control (without water spray)(77.94, 0.19g, 222.08 kg/ha and 2.13g, respectively).

Our results clearly show that higher bee activity leads to better seed yields, a finding consistent with several previous studies. When bees visit more frequently, it helps to increase seed set in various Asteraceae crops (Altayeb and Nagi, 2015; Özyiğit *et al*., 2015). However, seed yield is a complex process that's strongly influenced by the use of plant growth regulators and insect attractants (Maynard *et al*., 1992).

Among the treatments we tested, both sugar and jaggery solutions had a notable positive effect on all studied key yield parameters. This highlights how important honey bee visits are for improving seed quality. The results are in close agreement with Chandrashekhar and Sattigi (2010) More *et al*. (2020) and Kumar *et al.* (2021), Dwarka *et al*. (2024) who reported the sugar and jaggery solution significant increases the seed yield parameters such as seed/flower, seed yield, 1000-seed weight in radishes, onion, berseem, sunflower and niger crop respectively.

Table 4: Effect of bee attractants on seed yield parameters of *C. chinensis* (2021-22 and 2022-23)

Treatment details	Concentration (%)	No. of seeds/flower	Seeds/flower (gm)	Seed yield (kg/ha)	Seed test weight (1000 seeds)
T_1 - Citral	0.1	132.75 (11.54)^{b}	0.30^{b}	250.43^{b}	2.40^{b}
T_2 - Geraniol	0.1	135.60 (11.66)^{b}	0.32^{b}	257.00^{b}	2.47^{b}
T_3 - Lemongrass oil	0.1	128.19 (11.34)^{b}	0.28^{b}	246.45^{b}	2.36^{b}
T_4 - Sugar solution	10	171.63 (13.12)^{a}	0.40^{a}	291.33^{a}	2.79^{a}
T_5 - Jaggery solution	15	159.63 (12.65)^{a}	0.39^{a}	281.74^{a}	2.57^{a}
T_6 - Control (water spray)	-	81.29 (8.86)^{c}	0.20^{c}	222.46^{c}	2.16^{c}
T_7 - Control (without water spray)	-	77.94 (8.84)^{c}	0.19^{c}	222.08^{c}	2.13^{c}
S.E(m)±		0.43	0.02	8.85	0.09
CD at 5%		1.32	0.05	27.28	0.27
CV (%)		6.66	9.61	6.06	6.28

*Figures in parenthesis are $\sqrt{x + 0.5}$ transformed values

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

4. CONCLUSION

The findings highlight that both sugar solution (10%) and jaggery solution (15%) are effective in increasing bee activity, which in turn helps boost seed production in cross-pollinated crops like Aster. Using locally available attractants has great potential to improve seed yields in Aster. Since commercial bee attractants are not widely available, these local alternatives offer a practical solution for enhancing Aster seed production, especially in the central India.

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