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Impact of indigenous bee attractants on non-*Apis* pollinators foraging and productivity of niger, *Guizotia abyssinica* (L.f.) Cass

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Abstract
A study was conducted at experimental farm of PC Unit Sesame and Niger, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, during *Kharif* 2021. To evaluate the efficacy of different floral attractants for enhancing the activity of non-*Apis* pollinators (*Xylocopa violacea, Amata cyssea, Eristalinus megacephalus, Parnada guttatus, Danaus genutia, Zizina otis, Musca domestica*) and improving seed productivity of niger. The experiment comprised nine treatments, including flower extract of *Madhuca longifolia* 10%, juice of *Saccharum officinarum* 10%, jaggery solution 10%, honey solution 10%, fruit extract of *Phoenix dactylifera* 10%, sugar solution 10%, rose water 10%, water spray and an untreated control. The attractants were applied as foliar sprays at 10% and 50% flowering stages and the population of non-*Apis* pollinators was recorded one day before spraying and at 1, 3, 5 and 7 days after spraying. Marked differences were observed among treatments in attracting non-*Apis* pollinators. At 10% flowering, *Madhuca longifolia* flower extract 10% recorded the highest mean pollinator population of 13.33 individuals m^{-2} 5 min^{-1}, whereas at 50% flowering it recorded the maximum mean population of 14.58 individuals m^{-2} 5 min^{-1}. Rose water 10% ranked second, recording mean populations of 12.42 and 13.83 individuals m^{-2} 5 min^{-1}, respectively. The maximum individual population of 19.67 individuals m^{-2} 5 min^{-1} was recorded with *M. longifolia* flower extract at 3 days after spraying at 50% flowering. Seed yield also varied considerably among treatments. The highest seed yield of 6.90 q ha^{-1} was obtained with rose water 10%, followed by *M. longifolia* flower extract 10% (6.30 q ha^{-1}) and *Phoenix dactylifera* fruit extract 10% (6.00 q ha^{-1}), while the untreated control recorded the lowest yield (3.15 q ha^{-1}). The study demonstrated that floral attractants, particularly rose water and *M. longifolia* flower extract, can enhance pollinator activity and contribute to improved seed productivity in niger.

Keywords: *M. longifolia* flower extract, non-*Apis* pollinators, *Madhuca longifolia*, sugar solution and flowering periods

Introduction
Niger [*Guizotia abyssinica* (L. f.) Cass.] is an important oilseed crop of the family Asteraceae (Compositae) and is native to Tropical Africa. In India, it is often regarded as a vital component of tribal agriculture and rural livelihoods because of its ability to perform reasonably well on marginal and sub-marginal soils with limited external inputs, particularly under rainfed conditions (Ranganatha *et al.*, 2009) [17]. According to the available statistics, niger was cultivated on approximately 112.8 thousand hectares in India, producing about 40.3 thousand tonnes with an average productivity of 357.2 kg ha^{-1}. Madhya Pradesh accounted for nearly 16.0 thousand hectares, with a production of 4.9 thousand tonnes and productivity of 308.8 kg ha^{-1} (Anonymous, 2021–22). Niger contributes approximately 3% of India's edible oil requirement and is valued primarily for its high-quality edible oil (Getinet and Sharma, 1996). The seeds generally contain about 32–40% oil and 18–24% protein. Niger oil is pale yellow, mildly nutty in flavour and characterized by a pleasant odour, while both the seed and oil are considered free from toxic constituents (Dwarka *et al.*, 2024 [a, b, c, d, e]). Niger is predominantly self-incompatible and depends extensively on insect-mediated cross-pollination for successful fertilization and seed formation (Dwarka *et al.*, 2022) [4]. Consequently, pollinating insects play a critical role in determining seed set, yield and, potentially, the uniformity of crop maturity. Effective insect pollination can substantially improve reproductive success in cross-pollinated oilseed crops, while managed pollination through the provision of bee colonies during peak flowering may serve as an important production input (Dwarka *et al.*, 2022) [4]. Earlier investigations have demonstrated considerable reductions in niger yield, ranging from 11 to 78%, when honey bees and other natural pollinators were excluded, highlighting the importance of pollinator activity in this crop. Moreover, beekeeping associated with niger cultivation can provide an additional source of farm income through honey production (Anonymous, 2005) [1]. Among insect pollinators, honey bees are considered particularly efficient because of their floral fidelity, foraging behaviour and ability to visit a large number of flowers during the flowering period. However, the effectiveness of managed pollination depends greatly on the ability of bees to locate and preferentially forage on the target crop in the presence of competing floral resources. Therefore, strategies that enhance the attractiveness of niger flowers to pollinators may improve visitation frequency and consequently enhance pollination efficiency. A range of commercial and locally available bee attractants, including Bee Line, Bee Here, Bee

Scent, Bee Scent Plus, Fruit Boost, Bee-Q, sugar solution, sugarcane juice, jaggery solution and molasses, has been evaluated or used to stimulate bee foraging in niger-growing areas of Jabalpur, Madhya Pradesh (Dwarka *et al.*, 2022 [4]; 2023[a,b,c]). Nevertheless, systematic information concerning the efficacy of different naturally derived attractants in enhancing the visitation of specific pollinator species remains limited under Indian agro-ecological conditions. In particular, comparative information on attractants capable of increasing the activity of non-*Apis* and their subsequent influence on niger seed production is inadequate.

In view of the indispensable role of insect pollinators in niger production and the increasing emphasis on pollinator conservation and ecological crop management, the present investigation was undertaken to evaluate the efficacy of different bee attractants in enhancing the foraging activity of non-*Apis* pollinators (*Xylocopa violacea, Amata cyssea, Eristalinus megacephalus, Parnada guttatus, Danaus genutia, Zizina otis, Musca domestica*) and to determine their influence on seed yield of niger. The study was also intended to identify promising, locally accessible attractants that could be integrated into pollinator-management practices for improving the productivity of niger under field conditions.

Material and methods

The field experiment investigating the influence of different bee attractants on the foraging activity of non-*Apis* pollinators in niger was conducted during the *Kharif* season of 2021 at the experimental farm of the PC Unit (ICAR) on Sesame and Niger, College of Agriculture, JNKVV, Jabalpur, Madhya Pradesh, India. Jabalpur is located along the Narmada River in central Madhya Pradesh and lies approximately between 22°49′ and 24°08′ N latitude and 78°21′ E longitude, at an elevation of about 411.78 m above mean sea level.

The experiment was laid out in a Randomized Block Design (RBD) with three replications to assess the relative effectiveness of different bee attractants in enhancing non-*Apis* pollinators visitation to niger flowers. The study was conducted under field conditions with the objective of identifying suitable attractants capable of increasing pollinator activity during the crop flowering period and thereby contributing to improved reproductive performance and seed yield of niger.

Table 1: List of attractants

Sl. No.	Treatments/attractants
1.	T_1- Flower extract of *Madhuca longifolia* 10%
2.	T_2 –Juice of *Sachharum officinarum* 10%
3.	T_3 -Jaggery solution 10%
4.	T_4 -Honey solution 10%
5.	T_5 -Fruit extract of *Foenix dactylifera* 10%
6.	T_6-Sugar solution 10%
7.	T_7 -Rose water (Marketed) 10%
8.	T_8 -Water spray.
9.	T_9-Control

Table 2: Effect of different attractants on the attraction of non-*Apis* pollinators and their impact of seed yield in niger crop.

Treatment	Population of non-*Apis* pollinators/m²/5 minutes												Yield (q/ha)
	1st spray at 10% flowering						2nd spray at 50% flowering						
	1DBS	Days after spray				Mean	1DBS	Days after spray				Mean	
		1DAS	3DAS	5DAS	7DAS			1DAS	3DAS	5DAS	7DAS		
T_1-Flower extract of *M. longifolia* 10%	7.67 (2.85)	10.00 (3.20)	12.33 (3.55)	15.00 (3.93)	16.00 (4.06)	13.33 (3.71)	6.00 (2.51)	15.00 (3.89)	19.67 (4.49)	14.67 (3.87)	9.00 (3.06)	14.58 (3.88)	6.30 (2.61)
T_2-Juice of *S. officinarum* 10%	6.00 (2.54)	6.67 (2.62)	11.33 (3.43)	1.67 (1.39)	12.00 (3.51)	7.92 (2.89)	5.33 (2.40)	10.33 (3.25)	11.00 (3.32)	11.33 (3.43)	10.67 (3.33)	10.83 (3.36)	5.82 (2.51)
T_3-Jaggery solution 10%	4.33 (2.18)	7.00 (2.72)	9.67 (3.07)	8.67 (3.00)	9.33 (3.10)	8.67 (3.03)	4.00 (2.11)	5.67 (2.48)	10.00 (3.15)	12.00 (3.51)	10.67 (3.32)	9.58 (3.17)	4.40 (2.21)
T_4-Honey solution 10%	5.33 (2.40)	11.67 (3.48)	9.33 (3.13)	6.67 (2.62)	8.67 (2.98)	9.08 (3.10)	8.00 (2.89)	6.00 (2.54)	11.33 (3.42)	16.33 (4.09)	15.00 (3.94)	12.17 (3.56)	5.45 (2.44)
T_5- Fruit extract of *F. dactylifera* 10%	4.00 (2.11)	11.67 (3.47)	12.67 (3.59)	8.00 (2.86)	12.33 (3.58)	11.17 (3.40)	5.67 (2.47)	4.67 (2.21)	14.33 (3.85)	10.67 (3.33)	12.00 (3.53)	10.42 (3.30)	6.00 (2.55)
T_6-Sugar solution 10%	7.33 (2.79)	7.00 (2.73)	4.00 (2.03)	3.33 (1.73)	11.00 (3.38)	6.33 (2.60)	8.33 (2.97)	4.67 (2.26)	3.00 (1.72)	4.00 (2.08)	9.67 (3.15)	5.33 (2.41)	6.70 (2.68)
T_7-Rose water 10%	6.00 (2.54)	8.67 (3.02)	14.33 (3.84)	13.67 (3.75)	13.00 (3.64)	12.42 (3.59)	7.67 (2.81)	9.33 (3.12)	14.33 (3.84)	17.33 (4.20)	14.33 (3.82)	13.83 (3.78)	6.90 (2.72)
T_8-Water spray	3.67 (2.02)	5.67 (2.46)	9.00 (3.07)	8.33 (2.93)	9.00 (3.06)	8.00 (2.91)	5.00 (2.34)	8.33 (2.96)	5.67 (2.47)	9.67 (3.14)	5.00 (2.33)	7.17 (2.77)	4.80 (2.30)
T_9-Control	3.00 (1.71)	5.67 (2.47)	8.67 (3.02)	7.00 (2.71)	6.33 (2.60)	6.92 (2.72)	4.33 (1.99)	7.67 (2.86)	4.67 (2.24)	7.00 (2.71)	4.33 (2.16)	5.92 (2.52)	3.15 (1.92)
SEm±	0.23	0.24	0.32	0.32	0.27	0.13	0.25	0.25	0.35	0.28	0.27	0.12	0.03
CD at 5%	0.69	0.71	0.95	0.97	0.80	0.39	0.76	0.74	1.04	0.85	0.80	0.36	0.09

*Figures in parenthesis are square root of $\sqrt{x+0.5}$

The selected bee attractants were applied as foliar sprays on two occasions, corresponding to the 10% and 50% flowering stages of the niger crop. Standard recommended agronomic practices were adopted throughout the experiment to maintain uniform and healthy crop growth. To quantify pollinator activity, a 1 m² observation area was randomly selected within each experimental plot, and the number of non-*Apis* pollinators visiting the flowers was counted. Pollinator observations were recorded at one day before spraying (1 DBS) and subsequently at 1, 3, 5 and 7 days after spraying (DAS) following both applications. The observations were used to assess the temporal response of non-*Apis* pollinators to the different attractant treatments. At crop maturity, seed yield from each treatment plot was harvested, measured separately and expressed as q ha^{-1}. Representative insect specimens collected during the

investigation were preserved and submitted for taxonomic confirmation. The identity of the pollinator was verified with the assistance of taxonomic experts at the Regional Centre, Zoological Survey of India (ZSI), Jabalpur, Madhya Pradesh, and the specimens were confirmed as non-*Apis* pollinators.

Results and discussion

The results indicate clear treatment-wise variation in the population of non-*Apis* pollinators and seed yield of niger. The observations recorded at 10% and 50% flowering stages showed that the response of non-*Apis* pollinators generally increased following application of the different floral attractants, although the magnitude and persistence of attraction varied among treatments. The data presented in Table-2 revealed significant differences among the treatments with respect to the population of non-*Apis* pollinators and seed yield of niger. The population of non-*Apis* pollinators varied considerably with the type of attractant, stage of application and period after spraying.

At the 10% flowering stage, the population of non-*Apis* pollinators recorded one day before spraying (1 DBS) ranged from 3.00 to 7.67 individuals m^{-2} 5 min^{-1}. The highest pre-spray population was recorded in T1 (flower extract of *Madhuca longifolia* 10%), with 7.67 individuals m^{-2} 5 min^{-1}, followed by T6 (sugar solution 10%) with 7.33 individuals m^{-2} 5 min^{-1}. The lowest population was observed in T9 (control), with 3.00 individuals m^{-2} 5 min^{-1}.

Following application, the population of non-*Apis* pollinators showed a marked increase in most attractant treatments. Present findings are supported by the findings of Painkra *et al.,* (2015) [15] 15 species of insect pollinators were found visiting on niger flowers. In T1, the population increased progressively from 10.00 individuals m^{-2} 5 min^{-1} at 1 DAS to 16.00 individuals m^{-2} 5 min^{-1} at 7 DAS, resulting in the highest mean population of 13.33 individuals m^{-2} 5 min^{-1}. The corresponding transformed mean value was 3.71. The increase over the pre-spray population indicates a pronounced and sustained attractiveness of *M. longifolia* flower extract to non-*Apis* pollinators. The second-best response at the 10% flowering stage was recorded with T7 (rose water 10%), where the population increased from 6.00 individuals m^{-2} 5 min^{-1} before spraying to 8.67, 14.33, 13.67 and 13.00 individuals m^{-2} 5 min^{-1} at 1, 3, 5 and 7 DAS, respectively. Its mean population was 12.42 individuals m^{-2} 5 min^{-1}. T5 (fruit extract of *Foenix dactylifera* 10%) also produced a relatively higher population, with a mean of 11.17 individuals m^{-2} 5 min^{-1}. The attractant treatments T4 (honey solution 10%), T2 (juice of *Saccharum officinarum* 10%), T3 (jaggery solution 10%) and T6 (sugar solution 10%) resulted in intermediate levels of pollinator attraction, with mean populations of 9.08, 7.92, 8.67 and 6.33 individuals m^{-2} 5 min^{-1}, respectively. The water spray treatment recorded a mean population of 8.00 individuals m^{-2} 5 min^{-1}, whereas the untreated control had the lowest mean population of 6.92 individuals m^{-2} 5 min^{-1}. At the 50% flowering stage, the pre-spray population ranged from 4.00 to 8.33 individuals m^{-2} 5 min^{-1}. The highest pre-spray population was recorded in T6 (8.33 individuals m^{-2} 5 min^{-1}), followed by T4 (8.00) and T7 (7.67), while the lowest population was observed in T3 (4.00). After the second spray, a substantial increase in pollinator population was observed particularly in T1, T7 and T4. The highest mean population was recorded with T1 (*M. longifolia* flower extract 10%), with 14.58 individuals m^{-2} 5 min^{-1}, followed by T7 (rose water 10%) with 13.83 individuals m^{-2} 5 min^{-1} and T4 (honey solution 10%) with 12.17 individuals m^{-2} 5 min^{-1}. In T1, the pollinator population increased from 6.00 individuals m^{-2} 5 min^{-1} at 1 DBS to 15.00, 19.67, 14.67 and 9.00 individuals m^{-2} 5 min^{-1} at 1, 3, 5 and 7 DAS, respectively. The maximum population under this treatment was therefore observed at 3 DAS (19.67 individuals m^{-2} 5 min^{-1}). Under T7, the population increased from 7.67 individuals m^{-2} 5 min^{-1} at 1 DBS to 17.33 individuals m^{-2} 5 min^{-1} at 5 DAS, followed by 14.33 individuals m^{-2} 5 min^{-1} at 7 DAS. Similarly, T4 recorded a population of 16.33 and 15.00 individuals m^{-2} 5 min^{-1} at 3 and 5 DAS, respectively. These observations indicate that the effect of floral attractants was more pronounced during the period following spraying and remained evident for several days. The mean population recorded with T5 (fruit extract of *F. dactylifera* 10%) was 10.42 individuals m^{-2} 5 min^{-1}, followed by T2 (juice of *S. officinarum* 10%) with 10.83, T3 (jaggery solution 10%) with 9.58 and T6 (sugar solution 10%) with 5.33 individuals m^{-2} 5 min^{-1}. Water spray and untreated control recorded comparatively lower mean populations of 7.17 and 5.92 individuals m^{-2} 5 min^{-1}, respectively. Present findings supported that the finding of Nath, 2008 [14]; Kumar *et al.,* 2024; Chaudhary, 1998; Kumari and Rana, 2018; Sreedhara *et al.,* 2012; Pandit *et al.,* 2026; Kumar, 2023 [3, 11, 12, 13, 16, 18].

Overall, the pooled trend clearly demonstrated that flower extract of *M. longifolia* 10% was the most effective treatment for enhancing the abundance of non-*Apis* pollinators, followed by rose water 10% and honey solution 10%. The comparatively higher pollinator population under these treatments suggests that their volatile or soluble attractant components and/or associated floral cues enhanced pollinator visitation during the flowering period.

Effect on seed yield

The treatments also differed appreciably in their influence on seed yield. The highest seed yield of 6.90 q ha^{-1} was recorded with T7 (rose water 10%), closely followed by T1 (flower extract of *M. longifolia* 10%) with 6.30 q ha^{-1} and T5 (fruit extract of *F. dactylifera* 10%) with 6.00 q ha^{-1}. These treatments were associated with comparatively higher populations of non-*Apis* pollinators, indicating a positive relationship between enhanced pollinator visitation and reproductive performance of niger. T6 (sugar solution 10%) recorded a seed yield of 6.70 q ha^{-1}, while T2 (juice of *S. officinarum* 10%), T4 (honey solution 10%) and T3 (jaggery solution 10%) produced 5.82, 5.45 and 4.40 q ha^{-1}, respectively. Water spray recorded 4.80 q ha^{-1}, whereas the lowest seed yield of 3.15 q ha^{-1} was obtained in the untreated control. Thus, the highest seed yield under rose water 10%, followed by *M. longifolia* flower extract 10% and *F. dactylifera* fruit extract 10%, was consistent with their superior or relatively higher pollinator-attracting ability. The substantially lower yield in the untreated control suggests that enhancement of pollinator activity through attractant application can contribute to improved pollination and subsequent seed production in niger.

The statistical analysis further confirmed significant treatment effects. The standard error of mean (SEm±) for pollinator population varied across observations, while the corresponding critical difference (CD) at 5% ranged from

0.36 to 1.04, depending upon the observation period. Therefore, the differences observed among the major treatments were sufficiently large to demonstrate meaningful treatment effects. Present findings closely related to Dwarka *et al.,* 2022 [4]; Dwarka *et al.,* 2023 [a, b, c.]

Conclusion

The rose water 10% and flower extract of *M. longifolia* 10% were the most promising treatments for enhancing non-*Apis* pollinator activity and improving seed yield of niger, with the response being particularly pronounced after the second spray at 50% flowering. The findings indicate that floral attractants can be effectively exploited as an ecological approach for enhancing pollinator-mediated pollination and productivity in niger.

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