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Assessing the Impact of Trap Nests on *Megachile* Bee Population in Mung Bean

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study explores the impact of nest installation on *Megachile* bee populations, which are potential pollinators of mung bean crops in Uttarakhand, India. Field investigations over two seasons reveal that six *Megachile* species visit mung bean blooms regularly for their provisioning. Assessments performed pre- and post-nest installation show slight changes in *Megachile* abundance and species-specific responses to environmental factors. Post-nest installation *M. lanata* showed the highest abundance (5.13±0.77 bees/m^2/5min) followed by *M. umbripennis* (4.76±1.05 bees/m^2/5min), although nest occupancy rates were low. Correlation analyses of weather parameters show preferences for specific climatic conditions with temperature having a considerable influence. These findings highlight the intricate relationship between *Megachile* bees and environmental factors, underlining the need for specific pollinator management approaches. Further research into *Megachile* nesting behaviours is essential to enhancing crop pollination and ensuring sustainable agricultural practices.

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1. INTRODUCTION

India stands as the leading producer and consumer of pulses on a global scale. This includes 25% of production, and 27% of consumption globally including more than two-thirds of pulse production accounted by the six states viz., Madhya Pradesh, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, and Uttar Pradesh. Apart from the key states in pulse production, Uttarakhand has shown an ongoing rise in pulse yield from 2015-16, with an expected production of 1069 kg/ha by 2021-22 [1]. Among pulses, mung bean (*Vigna radiata* L. Wilczek) is nutritionally valuable with high protein content and adaptability to diverse climates [2,3]. It is cultivated in broad rows, but reduced row spacing is more effective in weed control [2]. This plant is a member of the Leguminosae family, specifically the Papilionoideae subfamily, they bear tiny yellow or greenish-yellow flowers that cluster into groups of 10-15. Mung beans have a rare trait: they are cleistogamous, which implies that pollination can occur whilst the flowers are closed [4]. However, pollinators facilitate cross-pollination, which benefits legume crops including mung beans, insect pollination has a substantial influence on mung bean production in smallholder systems of farming [5]. Family Megachilidae is a significant crop pollinator Hall and Avila, [6], among these, those in the genus *Megachile*, are excellent pollinators.

Megachile bees (leafcutter or mason bees) are a large, solitary species in the family Megachilidae, having unique nesting practices, and displaying a wide range in size, colour, and habits. Leafcutter bees build their nests by excising leaf pieces. In contrast, mason bees use resin or clay Chaudhary and Jain, [7] to create partitions within tunnels or cavities, resulting in distinct cells for their provisioning and egg-laying leading to progeny development [8]. These complex nesting behaviours show *Megachile* bees' persistence and resourcefulness, supporting pollination dynamics across various plant species. These bees interact with a variety of plant species, especially those in the Leguminosae (Fabaceae) and Compositae (Asteraceae) in Uttarakhand [9], Malvaceae in Uttar Pradesh [10], Lamiaceae, Umbelliferae, and Leguminoceae in Jammu and Kashmir [11], Leguminosae in Tamil Nadu and Odisha Rakesh et al*.* [12], Padhy et al*.* [13] and Cucurbitacea, in Haryana [14].

For bees and wasps, which commonly create their nests in pre-existing cavities trap nests are built to provide artificial nesting sites. Trap-nesting wasps are important predators of crop pests while cavity-nesting bees are important pollinators of native plants and crops [15]. Trap nests are artificial cavities used by bees and wasps to attract females seeking suitable nesting sites [16]. Artificial trap nests are essential in providing a habitat for solitary leafcutter bees. These nests promote bee activity and nesting abundance [17]. Six *Megachile* bee species (subgenus: *Callomegachile, Pseudomegachile,* and *Eutricharaea*) have been found to nest in tunnels (5-10 mm diameter) in various nests, including drilled tunnels in posts, wooden logs, and hollowed tunnels in bamboo sticks and reed stems [18]. These artificial nests are used to study cavity nesters' groups and environmental impact on them, with the size of the nest crucial for success, progeny characteristics, and survival. Trap nesting is also a conservation tool in areas where farming practices destructively affect bee populations. Keeping the above-mentioned points in mind, the present study was planned to examine the influence of nest installation on *Megachile* bee abundance, revealing their significant role as potential mung bean pollinators in Uttarakhand, India, and highlighting the need for targeted pollinator management strategies based on environmental factors.

2. MATERIALS AND METHODS

The study was conducted to understand the effect of nest installation on the *Megachile* population in the mung bean crop at Norman E. Borlaug Crop Research Centre at the G.B.P.U.A.T., Pantnagar (29.0222° N, 79.4908° E) from Sept. 2021 to Oct. 2022. *Megachile* bees were tallied on flowers from mung beans. Counts were made per square meter area for five minutes amid different day hours using a stopwatch. Overall visits were recorded three times a day. Data were averaged to get a daily count of bees. To study the impact of artificial nesting on *Megachile* abundance, the data on *Megachile* was recorded for two seasons viz., pre- and post-nest installation. Meteorological data from the Department of Agrometeorology, G.B.P.U.A.T., Pantnagar were also used to evaluate the correlation between weather parameters and *Megachile* abundance.

3. RESULTS AND DISCUSSION

3.1 Impact of Trap Nests on *Megachile* Bee abundance

Six *Megachile* species [*M.* (*Creightonella*) *albirons*, *M.* (*Xanthosarus*) *anthracina*, *M.* (*Amegachile*) *bicolor*, *M.* (*Pseudomegachile*) *lanata*, *M.* (*Callomegachile*) *relata,* and *M.* (*Callomegachile*) *umbripennis*] were identified to be regular visitors to the experimental fields in both seasons, suggesting that these bees could be possible pollinators for mung beans. Table 1 and 2 indicate the population abundance (bees/m²/5min) of *Megachile* bees visiting mung bean flowers pre- and post-nest installation. The results presented in Table 1 indicate that the abundance of all *Megachile* pollinators varied significantly during the pre-nest installation phase across the various weeks of the mung bean flowering period. *M. umbripennis* was abundant on most observation days, followed by *M. bicolor* and *M. relata*. In the 39th standard meteorological week, *M. umbripennis* had a higher abundance than *M. relata* and other species. *M. albirons* and *M. anthracina* had the lowest activity levels during the observation period. However, Table 2 data from the post-nest installation phase indicates the number of *Megachile* pollinators changed significantly across different standard meteorological weeks throughout the mung bean flowering period. *M. lanata* was the most abundant during the majority of the observation days, followed by *M. umbripennis* and *M. bicolor*. In the 40th standard meteorological week, *M. lanata* had the highest abundance than *M. umbripennis* and other species. Again, *M. albirons* and *M. anthracina* exhibited the lowest activity rates throughout the observation period. Only *M. lanata* nested in the trap nests provided in the fields, and even then, the nest occupancy rate remained low.

These findings point to a broader role for these species in legume pollination. Similar to this study different *Megachile* bees have been reported from all over the country. The importance of *Megachile* bees has been thoroughly studied in states like *M. anthracina* in Jammu and Kashmir [19], *M. bicolor* in the pigeon pea in Odisha and Arunachal Pradesh [13,20]. *M. cephalotes* in mung bean and pigeon pea in Uttarakhand and Odisha, respectively Kunjwal et al., 2016; Singh et al., [21], *M. lanata* in Arunachal Pradesh and Odisha [20,21] *M. relata* in Odisha and Uttarakhand Singh et al., [21], Kunjwal et al 2016), and *M. umbripennis* in Uttarakhand (Kunjwal et al 2016). This broad spectrum of *Megachile* Bees pollinating legume crops warrants additional exploration into other crops as well.

3.2 Correlation with Weather Parameter

Megachile bees' relative abundance was affected by a variety of meteorological conditions, positive as well as negative. Correlation and regression studies were carried out in 2021 and 2022 to assess the connection between the dependent and independent variables [maximum temperature (T_{MAX}), minimum temperature (T_{MIN}), morning relative humidity (MRH), evening relative humidity (ERH), rainfall (RF), number of rainy days (NRD), sunshine hours (SSH), wind velocity (WV), and evaporation (EVP)]. The impact of different dependent variables on different independent factors on mung bean flowers is described below (Table 3 and Fig.1).

3.3 *Megachile anthracina*

The findings indicated that the pre-nest installation, T_{MAX}, T_{MIN}, MRH, and SSH showed non-significant and positive correlation (r=0.048, 0.030, 0.185, and 0.072), however, ERH, RF, RD, WV, EVP showed non-significant and negative correlation (r= -0.292, -0.596, -530, -0.419 and -0.434) with *M. anthracina* population. The regression equation being y=-67.85+1.48(T_{MAX})+0.12(RHM)+0.19(RHE)-0.15 (RF). Whereas, post-nest installation, *M. anthracina* showed a non-significant and negative correlation with MRH and RF (r= -0.404 and -0.585) but a non-significant and positive correlation with T_{MAX}, T_{MIN}, ERH, NRD, SSH, and WV (r=0.531, 0.783, 0.378, 0.030, 0.187 and 0.368). The regression equation being y=8.48-0.21(RHM)+0.19(RHE)-0.01(RF)+0.15(NRD).

3.4 *Megachile bicolor*

The findings indicated that the pre-nest installation, T_{MIN}, ERH, WV, and EVP showed a non-significant and positive correlation (r = 0.680, 0.308, 0.348, and 0.213) however, T_{MAX}, MRH, RD, and SSH showed non-significant and negative correlation (r= -0.459, -0.073, 0.037, and -0.469) with *M. bicolor* population. The regression equation being y=127.47-2.79(T_{MAX})-0.53(RHM)+0.26(RHE)-0.16(RF). Whereas, post-nest installation, *M. bicolor* showed a significant and negative correlation with EVP (r= -0.919). The regression equation being y=24.66-0.41(RHM)+0.22(RHE)-0.37(NRD).

Table 1. The abundance of *Megachile* pollinators on mung bean fields in the blooming period at Pantnagar (2021)

***Megachile* Species**	**Number of *Megachile* bees on Different Dates (bees/m^2/5 min)**					**Grand Mean**
	37th SMW	**38th SMV**	**39th SMV**	**40th SMV**	**41th SMV**	
Megachile anthracina	1.06	1.46	2.52	2.43	1.48	**1.90± 0.65**
Megachile bicolor	2.49	4.77	4.10	1.75	1.49	**3.17± 1.45**
Megachile cephalotes	0.66	0.80	0.28	0.54	0.16	**0.56± 0.27**
Megachile lanata	1.31	1.94	3.59	2.07	0.99	**2.11± 1.00**
Megachile relata	2.48	3.56	4.20	2.25	0.48	**2.84± 1.42**
Megachile umbripennis	3.21	3.81	5.58	3.61	1.63	**3.89± 1.41**
Mean	**2.80±1.00**	**2.72±1.55**	**3.38±1.81**	**2.11±1.00**	**1.04±0.61**	**2.22±1.42**
S.Em±	**0.41**	**0.63**	**0.74**	**0.41**	**0.25**	**0.26**
CD at 5%	**2.401**	**2.711**	**3.392**	**2.685**	**1.805**	**1.011**

Table 2. The abundance of *Megachile* pollinators on mung bean fields in the blooming period at Pantnagar (2022)

***Megachile* species**	**Number of *Megachile* bees on Different Dates (bees/m^2/5 min)**					**Grand Mean**
	37th SMW	**38th SMV**	**39th SMV**	**40th SMV**	**41th SMV**	
Megachile anthracina	3.33	1.94	1.52	1.01	0.42	**1.64± 1.10**
Megachile bicolor	2.97	4.55	2.97	2.16	1.63	**2.86± 1.10**
Megachile cephalotes	0.24	0.97	1.35	0.83	0.94	**0.86± 0.40**
Megachile lanata	5.31	5.98	5.09	5.38	3.88	**5.13± 0.77**
Megachile relata	2.40	4.28	2.50	2.12	1.79	**2.62± 0.97**
Megachile umbripennis	5.92	5.56	3.96	4.89	3.45	**4.76± 1.05**
Mean	**3.36±2.06**	**3.87±2.00**	**2.89±1.44**	**2.73±1.95**	**2.01±1.38**	**2.98±1.77**
SEm±	**0.84**	**0.82**	**0.59**	**0.80**	**0.56**	**0.32**
CD at 5%	**3.176**	**2.495**	**2.805**	**3.125**	**1.742**	**0.893**

Table 3. Correlation between *Megachile* pollinators and weather parameters on mung bean flowers (2021-2022)

Megachile	T_{MAX}		T_{MIN}		MRH		ERH		RF		NRD		SSH		WV		EVP	
Species	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
M. albifrons	-0.574	-0.188	0.771	-0.381	0.361	-0.127	0.843	-0.075	0.661	0.565	0.799	-0.201	-0.936*	-0.305	0.496	-0.293	0.156	-0.259
M. anthracina	0.048	0.531	0.030	0.783	0.185	-0.404	-0.292	0.378	-0.596	-0.585	-0.530	0.030	0.072	0.187	-0.419	0.368	-0.434	-0.276
M. bicolor	-0.459	0.382	0.680	0.809	-0.073	-0.173	0.308	0.742	0.000	0.069	-0.037	-0.378	-0.469	-0.413	0.348	-0.421	0.213	-0.919*
M. lanata	0.064	0.803	0.455	0.950*	-0.196	-0.456	0.022	0.285	-0.327	-0.409	-0.384	-0.752	-0.040	0.120	0.083	-0.413	0.055	-0.880*
M. relata	-0.193	0.244	0.849	0.709	-0.159	0.028	0.489	0.770	0.120	0.245	0.083	-0.414	-0.467	-0.546	0.473	-0.626	0.306	-0.936*
M. umbripennis	0.014	0.649	0.708	0.935*	-0.220	-0.213	0.327	0.352	-0.038	-0.569	-0.091	-0.382	-0.256	0.177	0.343	-0.141	0.237	-0.521

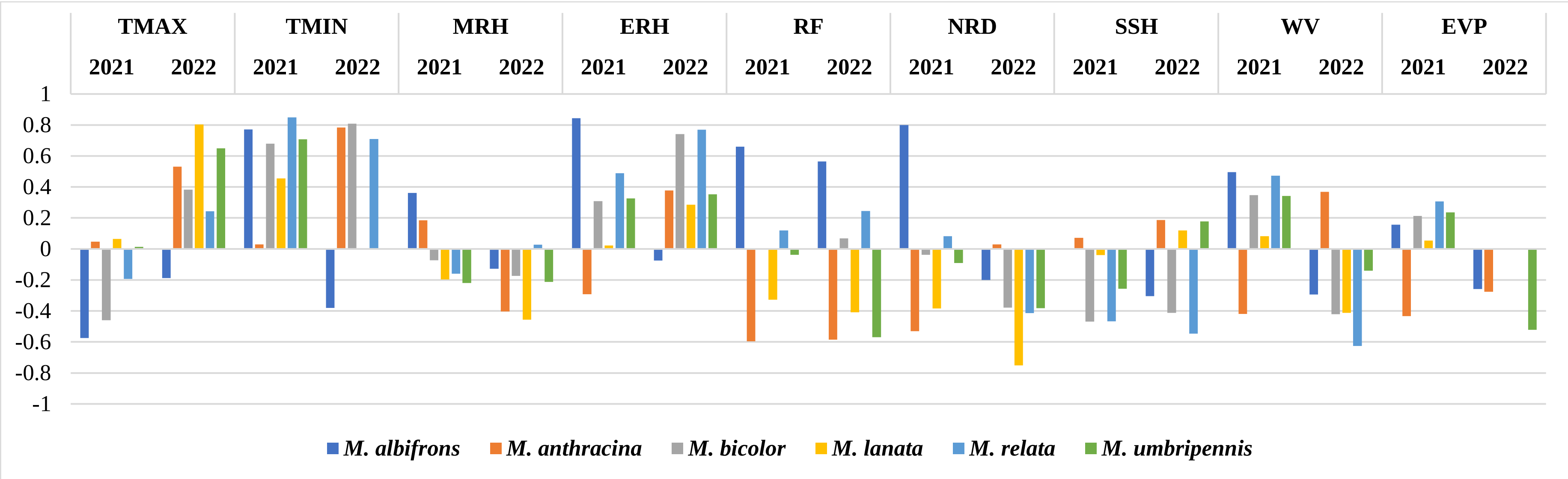

Fig. 1. Correlation between *Megachile* pollinators and weather parameters on mung bean flowers (2021-2022)

3.5 *Megachile cephalotes*

The findings indicated that the pre-nest installation and sunshine hours showed a significant and negative correlation (r=-0.936) with *M. cephalotes* population. The regression equation being y= 7.63 -0.27 (T_{MAX}) +0.02 (RHE) +0.01 (RF). Whereas, post-nest installation, *M. cephalotes* showed non-significant and negative correlation with T_{MAX}, T_{MIN}, MRH, ERH, NRD, SSH, WV, and EVP however non-significant and positive correlation with RF (r= -0.188, -0.381, -0.127, -0.075, -0.201, -0.305, -0.293, -0.259 and 0.565). The regression equation being y=27.30-0.28(RHM)-0.03(RHE)+0.01(RF)-0.11(NRD).

3.6 *Megachile lanata*

The findings indicated that the pre-nest installation, T_{MAX}, T_{MIN}, ERH, WV, and EVP showed a non-significant and positive correlation (r= 0.064, 0.455, 0.022, 0.083, and 0.055), however, MRH, RF, RD, and SSH showed non-significant and negative correlation (r= -0.196, -0.327, -0.384, -0.040) with *M. lanata* population. The regression equation being y=-41.17+1.04(T_{MAX})-0.11(RHM)+0.35(RHE)- 0.25 (RF). Whereas, post-nest installation, *M. lanata* showed a significant and positive correlation with T_{MIN} and a significant and negative correlation with EVP (r= 0.950 and -0.880). The regression equation being y=11.66-0.14(RHM)+0.11(RHE)-0.36(NRD).

3.7 *Megachile relata*

The findings indicated that the pre-nest installation, T_{MIN}, ERH, RF, NRD, WV, and EVP showed a non-significant and positive correlation (r= 0.849, 0.489, 0.120, 0.083, 0.473, and 0.306), however, T_{MAX}, MRH, and SSH showed non-significant and negative correlation (r= -0.193, -0.159, and -0.467) with *M. relata* population. The regression equation being y=12.78-0.27(T_{MAX})-0.30RHM) +0.46(RHE)-0.27(RF). Whereas, post-nest installation, *M. relata* showed a significant and negative correlation with EVP (r= -936). The regression equation being y=7.32-0.18(RHM)+0.18(RHE)-0.39(NRD).

3.8 *Megachile umbripennis*

The findings indicated that the pre-nest installation, T_{MAX}, T_{MIN}, ERH, WV, and EVP showed a non-significant and positive correlation (r= 0.014, 0.708, 0.327, 0.343, and 0.237), however, MRH, RF, NRD, and SSH showed non-significant and negative correlation (r= -0.220, -0.038, -0.091, -0.256) with *M. umbripennis* population. The regression equation being y= -46.41+1.15(T_{MAX})-0.19(RHM)+0.52(RHE) 0.33 (RF). Whereas, post-nest installation, *M. umbripennis* showed a significant and negative correlation with T_{MIN} (r= 0.935). The regression equation being y=-29.29-0.28(RHM)+0.17(RHE)-0.01(RF)-0.17(NRD).

The present study shows similarity with the higher preference of *Megachile* bees towards warmer temperature and higher activity during flowering seasons [22]. Temperature and intensity of light impact foraging, with low temperatures and high light intensity leading to foraging and lowering light intensity ceasing daily foraging activities [23]. Megachilid bees thrive in temperatures ranging from 26.9°C to 38.9°C, with peak activity between March-May and October-November, and activity dropping amid high humidity and winter/rainy seasons [24]. Similar environmental interactions have been identified for *M. lanata* [25]. However, the prevalence and nesting of these pollinators in mung bean fields remain unresolved necessitating additional research.

4. CONCLUSION

This study highlights the vital role of *Megachile* bees as mung bean pollinators in Uttarakhand, India. Nest installation influences *Megachile* abundance and species responses to environmental conditions, as shown by correlation analysis between bee population and meteorological parameters.

Despite low pollinator population and nest occupancy rates in mung bean, *Megachile* bees were reported to frequently visit mung bean flowers. Trap nests substantially enhance pollinator populations, such as *M. lanata.* This shows the potential of trap nests for increasing bee numbers in mung bean crop as well as in other crops for managed pollination. Understanding the nesting behaviour and habitat management of *Megachile* bees is essential for improving pollination services while promoting sustainable agriculture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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