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Diversity, abundance and pollination efficiency of native bees on teasel gourd (*Momordica subangulata* Blume ssp. *renigera*) in Western Ghats region of Karnataka

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ABSTRACT: The study was conducted during 2022–2024 at the research farm of ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Central Horticultural Experiment Station, Chettalli, Kodagu, India, to investigate the diversity of bee visitors, their foraging behaviour, and their pollination efficiency in teasel gourd. Six groups of native bees belonging to the families Apidae and Halictidae were observed visiting the male flowers of teasel gourd. Among them, *Apis cerana indica* was the predominant visitor, accounting for nearly 89% of the total bee visits, followed by *Halictus* spp. (8%) and *Tetragonula* spp. (3%). Natural visitation to female flowers was very limited; however, occasional visits by *A. cerana indica* and *Tetragonula* spp. were recorded following hand pollination. The highest foraging activity of *A. cerana* was recorded between 07:00 and 08:00 h, which coincided with peak floral receptivity. Different pollination methods had a significant effect on fruit yield and quality during both years of the study. Hand pollination and pollen augmentation significantly enhanced fruit set, fruit weight, fruit length, and fruit diameter compared with open pollination. Conversely, exclusion of bee visitors led to negligible fruit development, underscoring the critical role of insect pollinators in supplementing hand pollination for improved yield and fruit quality. This finding suggests that conserving and maintaining native bee populations, particularly *A. cerana*, together with appropriate pollination management practices, could substantially improve teasel gourd production.

Key words: Teasel gourd, diversity, abundance, pollination efficiency, native bee visitors

INTRODUCTION

Pollination is a fundamental ecological process that ensures sexual reproduction, fruit set, and seed production in flowering plants. Approximately 95% of flowering plant species are cross-pollinated, with nearly 85% relying on animals for pollen transfer, of which insect pollination (entomophily) accounts for about 90% of animal-mediated pollination (Tewari and Singh, 1983; Richards, 1986; Buchmann and Nabhan, 1996). In agriculture, animal-mediated pollination is indispensable, with 87 of the world's 124 leading food crops benefiting from or depending on visitors (Klein *et al*., 2007). Among insect visitors, species of the orders Hymenoptera, Lepidoptera, and Diptera play a dominant role in crop pollination (Jadhav *et al*., 2011). In cucurbits, pollination is primarily arbitrated by insects, with honey bees (*Apis mellifera* Linn), squash bees (*Peponapis* and *Xenoglossa* spp.) and bumble bees (*Bombus* spp.) recognised as the most effective pollinators (Klein *et al*., 2007; Artz *et al*., 2011). Pollination services are estimated to contribute more than US$ 800 billion annually to global agriculture through enhanced crop productivity and nutritional security (Devkota *et al.,* 2024). Cucurbit crops are particularly dependent on insect pollination because their large, sticky pollen grains cannot be effectively dispersed by wind. Also, most of the cucurbits are monoecious, few exceptions like pointed gourd, spine gourd, teasel gourd and Ivy gourds are dioecious in nature. Efficient transfer of pollen between male and female flowers is therefore essential not only for successful fruit and seed set but also for improving fruit quality and yield (Free, 1970; McGregor, 1976).

Teasel gourd (*Momordica subangulata* Blume ssp. *renigera*) is an underutilized, high-value indigenous cucurbit cultivated in South and Southeast Asia, particularly by tribal and smallholder farmers. It is a perennial, dioecious, cross-pollinated climber with tuberous roots belonging to the family Cucurbitaceae and is cultivated across diverse agro-climatic regions ranging from plains to mid-hills in Assam, Tripura, West Bengal, Odisha, and the Andaman Islands. This climbing creeper is also grown in Pakistan, Bangladesh, and Sri Lanka

(Ashoka *et al*., 2024; Verma *et al*., 2025; Koundinya *et al*., 2025). The crop is valued for its high nutritional and medicinal properties, including antioxidant, antimicrobial, antidiabetic, hepatoprotective, and anticancer activities (Bhagat *et al*., 2017). However, its productivity is often constrained by poor natural pollination of female flowers and susceptibility to biotic stresses (Sudhakar Pandey *et al*., 2020). Since the flowers remain receptive for only a single day, this period is very important for pollination of this crop for successful fertilization and fruit set. Despite the economic and nutritional importance of teasel gourd, information on the diversity, abundance, and pollination efficiency of native insect visitors remains limited. Therefore, the present study was undertaken to (i) document the diversity and abundance of native insect species visiting teasel gourd flowers and (ii) evaluate the pollination efficiency of the native insect species on Teasel gourd flowers.

MATERIAL AND METHODS

Field experiments were conducted during 2022–23 and 2023-24 at the ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Central Horticultural Experiment Station (CHES), Chettalli, Kodagu, Karnataka, India (12°26'N, 75°47'E; 1050 m msl) to study native bee species diversity and foraging behaviour in teasel gourd, *M. subangulata ssp. renigera*. Observations were made during the cropping seasons from June to August in both years. The experimental field was located near the CHES apiary containing Indian honey bees, *Apis cerana indica* F., along with naturally occurring bee population. Hand-pollinated teasel gourd plants were maintained at a spacing of 1.8 × 2 m with a male to female plant ratio of 1:5.

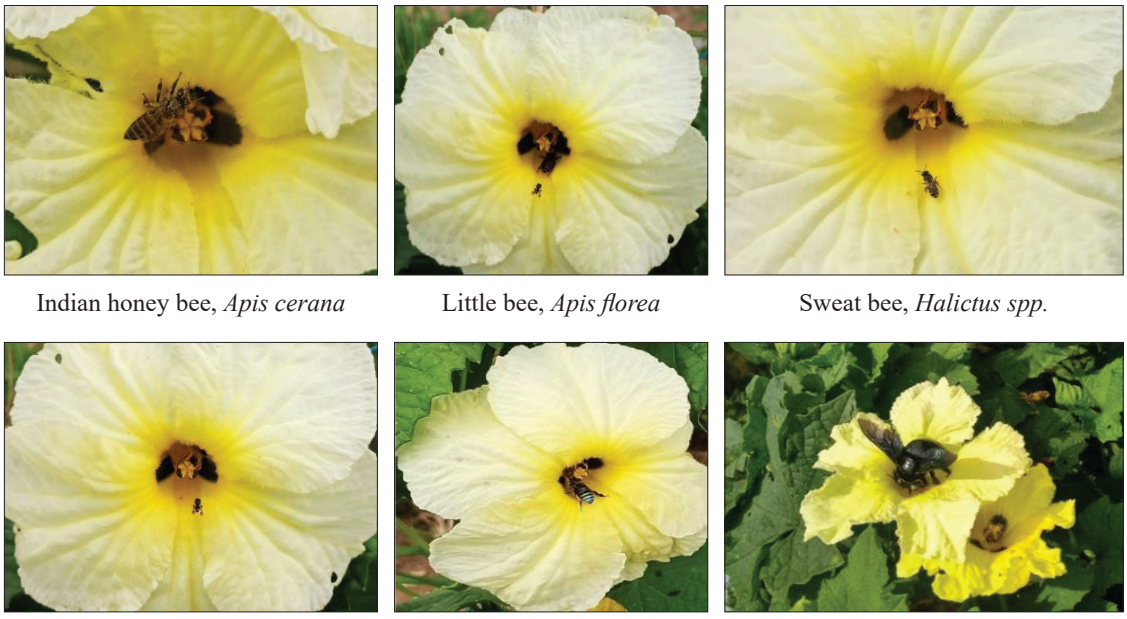
Flower visitors were observed from 06:00 to 18:00 h during the peak flowering period. Data on the number and type of insect visitors were recorded hourly from 15 each randomly selected male and female flowers for seven consecutive days. The diurnal foraging activity of different insect visitors on male flowers of teasel gourd were recorded at different hours of the day. Their visitation frequency was recorded as the mean number of insects visited per flower in 10 min. Diurnal foraging activity on female flowers was not recorded because no insect visitors were observed on female flowers during the study period. To assess the influence of pollination on yield parameters, four treatments were imposed: open pollination (Female flowers left open without bagging), pollinators/bee visitors exclusion (Female flowers were bagged with nylon net), hand pollination (Female flowers after hand pollination were again bagged with butter paper), and pollen augmentation (Female flowers after hand pollination were left open for insect visitation). Final fruit set was recorded 10 days after treatment, and fruits were harvested to record fruit weight, length, and diameter. Fifteen flowers per treatment were selected randomly and labelled. The data were subjected to Analysis of Variance (ANOVA), and treatment means were compared using Critical Difference at 5% significance level under 95% confidence interval.

RESULTS AND DISCUSSION

Bee visitor diversity, abundance and foraging activity on teasel gourd

A total of six bee species belonging to two families, Apidae and Halictidae (Order: Hymenoptera), were recorded visiting the flowers of teasel gourd during June–July 2022 (Fig. 1). Members of the family Apidae dominated among the native bee population and included *A. cerana indica* Fabricius (Indian honey bee), *Apis florea* (little bee), *Tetragonula* spp. (stingless bees), *Amegilla* spp. (blue-banded bees) and *Xylocopa* spp. (carpenter bees), representing the tribes Apini, Meliponini, Anthophorini and Xylocopini, respectively. The only representative from the family Halictidae was *Halictus* spp. (tribe Halictini). Female flowers received negligible or no insect visitation under natural conditions. However, after hand pollination, *A. cerana* and *Tetragonula* spp. were occasionally observed visiting female flowers (Fig. 2), indicating that the rewardless nature of pistillate flowers discourages bees visitation.

The predominance of bee visitors observed in the present study agrees with earlier reports that Hymenopteran bees are the principal pollinators of cucurbit crops (Dorjay and Abrol, 2022). Honey bees and halictid bees have been recognized as major visitors of cucurbits in tropical regions (Grewal and Sidhu, 1978; Chaudhary *et al*., 2024). Similar visitor assemblages comprising *A. cerana*, *A. florea*, *Tetragonula* spp. and *Halictus* spp. have been reported in bitter gourd (Deyto and Cervancia, 2009; Yogapriya et al., 2019). Although Balina *et al*. (2012) documented nine bee species belonging to three families on bitter gourd flowers, the present study recorded fewer species, possibly reflecting differences in crop species, dioecious, plant nature and type of reward provided by the plants to the insect visitors. Nevertheless, the dominance of native bee



Indian honey bee, *Apis cerana* | Little bee, *Apis florea* | Sweat bee, *Halictus spp.*

Stingless bees, *Tetragonula spp.* | Blue banded bee, *Amegilla spp.* | Carpenter bee, *Xylocopa spp.*

Fig. 1. Insect visitors on male flowers of teasel gourd

Indian honey bee, *Apis cerana* | Stingless bee, *Tetragonula spp.*

Fig. 2. Insect visitors on female flowers of teasel gourd

species highlights the ecological importance of teasel gourd as a resource for native bee fauna in the Western Ghats.

Among all bee species, *A. cerana* was the predominant visitor, accounting for approximately 89% of the total bee population on male flowers, followed by *Halictus* spp. (8%) and *Tetragonula* spp. (3%) (Fig. 3). The overwhelming dominance of *A. cerana* indicates its primary role as the effective pollen vector under the study conditions. Similar dominance of honey bees has been reported in muskmelon (Belavadi, 2019) and several cucurbit crops where *Apis* species constitute the major proportion of floral visitors (Dorjay and Abrol, 2022; Ikram *et al*., 2025). Although *Halictus* spp. were less abundant, previous studies have demonstrated their importance as efficient pollinators of bitter gourd (Grewal and Sidhu, 1978; Balina *et al*., 2012), suggesting that even less abundant native bees may contribute significantly to pollen transfer.

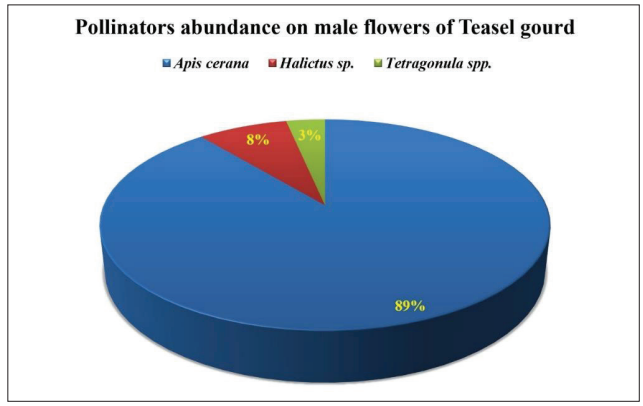


Fig. 3. Relative abundance of major *Apis* and non-*Apis* bee visitors on male flowers of teasel gourd

Distinct temporal differences were observed in the foraging activity of different bee species. *Apis cerana* commenced foraging during 06:00–07:00 h with approximately 4.5 visits per flower/10 min and reached peak activity during 07:00–08:00 h (about 7.1 visits per flower/10 min), after which visitation gradually declined with slight fluctuations during mid-morning (10:00–11:00 h, 5.4 visits/flower/10 min) and afternoon hours, reaching the lowest level during 17:00–18:00 h (1 visit/flower/10 min) (Fig. 4). This indicates that *A. cerana* prefers cooler morning hours for active foraging. In contrast, *Halictus* spp. exhibited comparatively low activity during the early morning but attained maximum visitation around 12:00–14:00 h (one visit per flower/10 min), whereas *Tetragonula* spp. showed consistently low activity with slight increases during 10:00–11:00 h and 14:00–15:00 h (0.3–0.7 visits per flower/10 min), while activity remained almost absent during the remaining hours. Overall, *A. cerana* remained as the principal visitor of teasel gourd male flowers throughout the flowering period, whereas *Halictus* spp. and *Tetragonula* spp. showed minimum foraging activity (Fig. 4).

The early morning peak in bees activity corresponds well with the flowering biology of cucurbits, where anthesis, maximum pollen viability, nectar secretion and stigma receptivity occur during the morning hours. Similar peak foraging activity between 06:00 and 10:00 h has been reported in several cucurbit crops (Hanh, 2008; Taha and Bayoumi, 2009; Dan *et al.,* 2019; Knapp and Osborne, 2019). Dalio (2021) further reported that insects visitation coincides with maximum floral rewards shortly after anthesis, while visitation declines later in the day as nectar availability decreases and flowers begin to senesce. Therefore, synchronization between floral phenology and insect activity appears to maximize pollination efficiency in cucurbits.

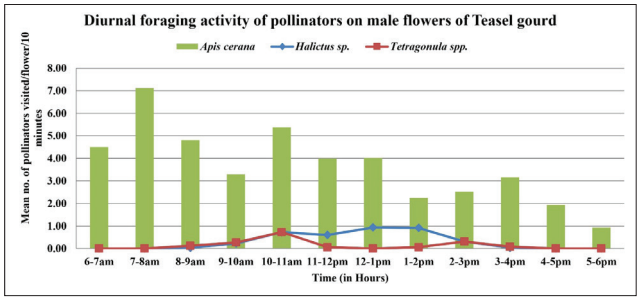


Fig. 4. Diurnal foraging activity of bee visitors on male flowers of teasel gourd

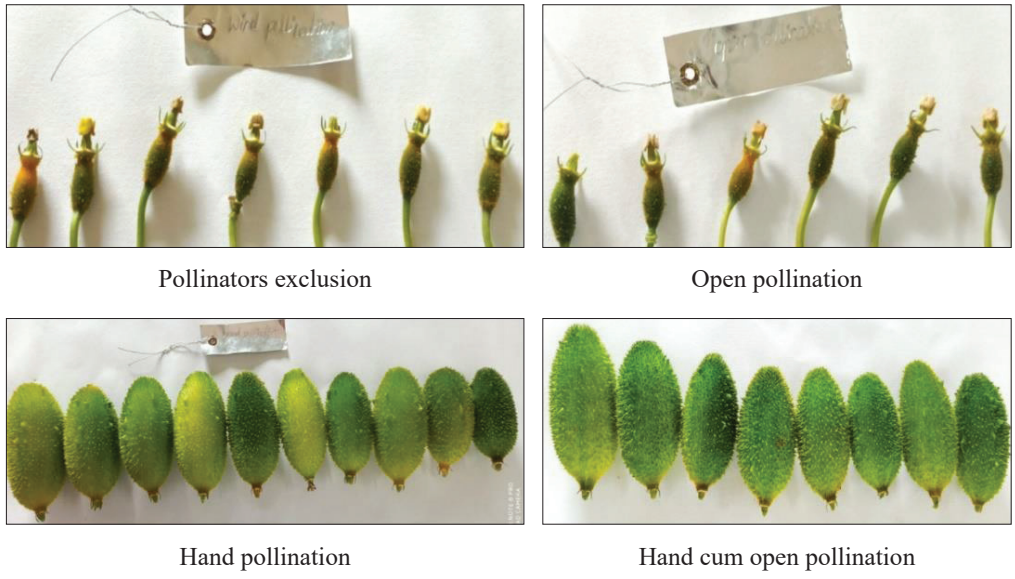
Pollination efficiency

Pollination efficiency experiment was conducted to record the effect of different pollination treatments on the yield parameters of teasel gourd during the years 2022–23 and 2023–24. Significant differences among pollination treatments were observed for all fruit yield parameters during both years of experimentation. During 2022–23, pollen augmentation and hand pollination produced significantly greater fruit weight ($F_{3, 39}$ = 83.727, P = <0.001; Mean=62.66 and 52.94 g), fruit length ($F_{3, 39}$ = 93.446, P = <0.001; Mean=8.69 and 7.56 cm) and fruit diameter ($F_{3, 39}$ = 109.112, P = <0.001; Mean=3.99 and 3.50 cm), respectively, compared with open pollination and pollinators exclusion treatments (Fig. 5; Table 1). Both pollen augmentation and hand pollination treatments performed comparably, with no significant differences observed between them for most fruit quality parameters. However, pollen augmentation showed a slight improvement in fruit quality attributes, which may be attributed to the activity of naturally occurring bee pollinators, particularly *A. cerana* and *Tetragonula* spp. These bees likely utilized the pollen manually deposited on the stigmas and facilitated additional pollen transfer among previously pollinated female flowers, thereby enhancing pollen deposition, improving fertilization efficiency, and minimizing the limitations associated with hand pollination. Consequently, pollen augmentation achieved the highest fruit set (100%), compared with 86.67% under hand pollination.

In contrast, exclusion of bee visitors resulted in complete failure of fruit set at 10 days after treatment, with the female ovaries undergoing degeneration due to the absence of effective pollination. This was reflected in the extremely poor ovary development, with mean fruit weight, length, and diameter of only 0.88 g, 2.04 cm, and 0.81 cm, respectively. Open pollination recorded only 6.67% fruit set, indicating that under natural field conditions, pollinator visitation to female flowers was insufficient to achieve satisfactory pollination and fruit development (Table 1).

A similar trend was observed during 2023–24. The fruit set recorded under open pollination, hand pollination, and pollen augmentation was 13.33%, 86.67%, and 100.00%, respectively. Hand pollination was recorded the highest fruit weight ($F_{3, 42}$ = 54.881, P = <0.001; Mean = 61.36 g) and fruit length ($F_{3, 42}$ = 53.850, P = <0.001; Mean = 7.16 cm), whereas pollen augmentation produced the maximum fruit diameter

(F3, 42 = 55.429, P = <0.001; Mean = 4.01 cm). Both treatments were statistically superior and remained at par with each other for most parameters. Bee visitor exclusion again resulted in negligible fruit development, confirming the necessity of hand pollination supported by the insects visits to the pollinated flowers for effective pollination and successful fruit set in teasel gourd (Table 2). Across both years, the results clearly demonstrated the importance of hand pollination accompanied by the insect-mediated supplementary pollination substantially enhances fruit size and quality attributes in teasel gourd. The poor performance under bee visitor exclusion treatments further emphasizes, there is some role of insect visitors in pollination, fruit development, and productivity of the crop to some extent in natural condition for the future perpetuation of crop in wild.



Pollinators exclusion | Open pollination

Hand pollination | Hand cum open pollination

Fig. 5. Effect of different pollination treatments on fruits of teasel gourd

Table 1: Means of yield parameters for the different pollination treatment in teasel gourd *Momordica subangulata* ssp. *renigera* in Research farm of CHES Chettalli, Kodagu (2022-23)

Treatments/Yield parameter	Fruit set (%)	Fruit weight (g) ± S.E	Fruit length (cm) ± S.E	Fruit diameter (cm) ± S.E
Open pollination	6.67	2.18±0.96^{b} (1.251)	2.49±0.28^{b} (1.554)	0.99±0.13^{b} (0.973)
Pollinators exclusion	0.00	0.88±0.04^{b} (0.936)	2.04±0.04^{b} (1.428)	0.81±0.02^{b} (0.898)
Hand Pollination	86.67	52.94±7.28^{a} (6.817)	7.56±0.61^{a} (2.708)	3.50±0.29^{a} (1.840)
Pollen augmentation	100.00	62.66±3.34^{a} (7.881)	8.69±0.23^{a} (2.944)	3.99±0.05^{a} (1.999)
F value		83.727	93.446	109.112
df		3, 39	3, 39	3, 39
p		<0.001	<0.001	<0.001
CV		35.260	13.960	14.358
CD (0.05)		1.138	0.230	0.157

Means followed by the same letter in superscript within column are not significantly different based on Treatment Means comparison at 95% significant level. N=15; Figures in parentheses are √(x) transformed values.

Table 2: Means of yield parameters for the different pollination treatment in teasel gourd *Momordica subangulata* ssp. *renigera* in Research farm of CHES Chettalli, Kodagu (2023-24)

Treatments/Yield parameter	Fruit set (%)	Fruit weight (g) ± S.E	Fruit length (cm) ± S.E	Fruit diameter (cm) ± S.E
Open pollination	13.33	11.56±5.93[b] (2.273)	1.83±0.72[b] (1.298)	1.11±0.44[b] (1.126)
Pollinators exclusion	0.00	0.27±0.06[b] (0.871)b	1.18±0.19[b] (1.260)	0.43±0.07[b] (0.953)
Hand Pollination	86.67	61.36±7.38[a] (7.499)a	7.16±0.52[a] (2.738)	3.72±0.27[a] (2.034)
Pollen augmentation	100.00	57.86±4.29[a] (7.563)	7.05±0.26[a] (2.741)	4.01±0.09[a] (2.121)
F value		54.881	53.850	55.429
df		3, 42	3, 42	3, 42
p		<0.001	<0.001	<0.001
CV		40.059	22.155	20.182
CD(0.05)		1.344	0.328	0.232

Means followed by the same letter in superscript within column are not significantly different based on Treatment Means comparison at 95% significant level. N=15; Figures in parentheses are √(x+0.5) transformed values.

The superior performance of hand pollination and pollen augmentation clearly demonstrates that fruit production in teasel gourd is strongly pollen-limited under natural conditions. Being a dioecious species, successful fertilization depends entirely on the transfer of pollen from male to female flowers. The negligible visitation observed on female flowers further limits natural fruit set because pistillate flowers do not provide nectar or pollen rewards to attract insect visitors. Similar observations have been reported in bitter gourd, where rewardless pistillate flowers receive fewer and shorter insect visits than staminate flowers (Oronje *et al*., 2012). Consequently, fruit set under open pollination remains poor, and manual pollination has long been recommended to improve productivity (Mishra and Sahoo, 1983; Joseph, 2005; Behera *et al*., 2010).

The results are also consistent with recent findings of Koundinya *et al*. (2025), who reported that natural fruit set in teasel gourd generally ranges from negligible levels to only 15–20% because of inadequate visitor activity. Similar responses have been documented in cucumber, where honey bee pollination produced fruit yield and quality comparable with hand pollination and significantly superior to open pollination (Thakur and Rana, 2008). Earlier studies have also reported that, pollination efficiency is influenced by factors such as floral phenology, nectar and pollen rewards, insect foraging behaviour and environmental conditions, including temperature, humidity and wind (Nepi and Pacini, 1993; Winfree *et al*., 2008).

The present study further demonstrates that pollen augmentation, which combines manual pollen transfer with continued insect visitation, can produce fruit quality equivalent to hand pollination while allowing naturally occurring insect visitors to contribute to pollen deposition. This finding suggests that conserving and maintaining native bee populations, particularly *A. cerana*, together with appropriate pollination management practices, could substantially improve commercial production of teasel gourd.

Overall, the present investigation identifies *A. cerana* as the principal visitor of teasel gourd, exhibiting the highest abundance and foraging activity during the early morning hours when floral receptivity is greatest. The comparable performance of pollen augmentation and hand pollination highlights the importance of conserving native bee populations and integrating managed pollination strategies to enhance fruit yield and quality

in teasel gourd cultivation. Future research should focus on evaluating different bee attractants for increasing pollinator visitation to female flowers and assessing their effectiveness in enhancing pollination efficiency, fruit set, and overall productivity under field conditions.

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AUTHORS CONTRIBUTION

ATR, MGS: Manuscript writing, Carrying research experiment; GN: Assisted in taking observation, Carrying research experiment; MBM: Data compilation and analysis; RS, PVR: Proof reading.

CONFLICT OF INTEREST

Authors don't have conflict of interest to express

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