



Evaluation of artificial nesting materials for domiciliation of *Megachile* spp. and their impact on pigeonpea yield

Manoj Kumar Jat^{1#}, Sunita Yadav¹ and Lomash Kumar¹

Summary

A field investigation was conducted to evaluate the nesting preferences of Megachilid bees and their contribution to pigeonpea yield under artificial domiciliation. Two nesting substrates—Sarkanda sticks (*Saccharum spontaneum*) and bamboo drilled blocks were monitored at 15-day intervals. Sarkanda sticks exhibited higher acceptance (4.53%), whereas bamboo blocks remained unused throughout the study. Nesting activity peaked in October 2024 with 21 nests (3.96%), followed by November with 16 nests (3.01%). Four Megachilid species were recorded: *Megachile lanata*, *M. sculpturalis*, *M. bicolor*, and *M. disjuncta*. Among these, *M. lanata* was dominant, with activity ranging between 2.19–3.12 individuals per minute per square meter. Diversity indices revealed moderate species diversity (Shannon–Wiener index H' : 1.31–1.34; Simpson's diversity D : 0.70–0.73) coupled with high evenness (0.94–0.97), indicating balanced species distribution across nesting sites. The impact of domiciliation on crop productivity was evident. Pigeonpea plots with artificial nests recorded significantly higher yields (13.89–14.68 q/ha) compared to control plots without nests (9.47 q/ha). This enhancement underscores the role of Megachilid bees as efficient pollinators, directly contributing to improved seed set and yield. Overall, the study highlights Sarkanda sticks as a suitable substrate for domiciliation of Megachilid bees and demonstrates the potential of managed nesting to augment pollination services in pigeonpea. Adoption of such practices could serve as a sustainable strategy to enhance legume productivity while conserving native pollinator diversity.

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Introduction

Insect pollinators play a crucial role in enhancing agricultural productivity and maintaining ecosystem stability, with bees being the most efficient group. Among them, Megachilid bees (*Megachile* spp.), commonly known as leafcutter bees, are important solitary pollinators known for their efficiency in cross-pollination and yield enhancement in various crops. Unlike social bees, their population dynamics largely depend on the availability of suitable nesting substrates, which directly influence their abundance and pollination efficiency in agro-ecosystems (Klein et al. 2007; Singh et al. 2022; Nidhi et al. 2025). Pigeonpea (*Cajanus cajan* L.) is an important pulse crop cultivated extensively in semi-arid regions of India. Although it is primarily self-pollinated, insect pollination has been reported to significantly improve pod set, seed quality and yield (Free 1993). Megachilid bees have been recognized as effective pollinators of leguminous crops, and their activity can be enhanced through the provision of artificial nesting structures (Singer & Cane 2011). Artificial domiciliation has emerged as a promising strategy for the conservation and augmentation of solitary bees in agricultural landscapes. The success of this approach depends largely on the type of nesting material provided, as

different *Megachile* species exhibit specific preferences for nesting substrates such as hollow stems and drilled wooden blocks. Previous studies have demonstrated that appropriate nesting materials significantly improve nesting success, population buildup and pollination services of Megachilid bees (MacIvor & Packer 2015; Haldhar et al. 2021). In this context, the present study was undertaken to evaluate artificial nesting materials for domiciliation of *Megachile* spp. and to assess their impact on pigeonpea yield. The findings are expected to contribute towards developing sustainable and cost-effective pollinator management strategies for improving crop productivity and conserving beneficial insect biodiversity.

Materials and Methods

The present investigation was carried out from July 2024 to June 2025 at three experimental locations, namely the Pulse Research Area, Research Farm of the Department of Entomology and the Dryland Research Farm at Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India, with the objective of evaluating artificial nesting materials for domiciliation of *Megachile* spp. and their subsequent impact on pigeonpea yield. The study area comprised pigeonpea fields along with nearby uncultivated land, which was systematically surveyed to identify the natural nesting habitats of Megachilid bees.

Artificial nesting structures were prepared using locally available materials, viz., sarkanda

¹Department of Entomology, College of Agriculture, Chaudhary Charan Singh Haryana Agricultural University, Hisar - 125 004, Haryana, India

#Corresponding author: Jat MK E-mail: nitharwal84@gmail.com

(*Saccharum spontaneum*) sticks and bamboo wooden drilled blocks. Sarkanda sticks of 25 cm length and varying diameters (7–10 mm) were selected and categorized into different treatments based on diameter, namely 8 mm, 9 mm and 10 mm. These sticks were bundled together to form compact nesting units and securely tied to facilitate easy installation in the field. The bundles were installed at suitable heights within pigeonpea fields across all study locations under open environmental conditions to encourage natural nesting by Megachilid bees. In addition to sarkanda sticks, bamboo wooden drilled blocks of 15 cm length with uniform hole diameter of 15 mm were also prepared and installed as an alternative nesting substrate for comparative evaluation.

The placement of nesting structures was done in such a way that they remained exposed to natural environmental conditions while being protected from direct disturbance. All nesting materials were installed prior to the onset of peak flowering of pigeonpea to allow sufficient time for bee nesting. The experimental sites were regularly monitored throughout the study period. Observations on nesting activity were recorded at 15-day intervals from July 2024 to June 2025. The number of occupied nests in each treatment was carefully counted to assess the per cent of domiciliation by Megachilid bees. Monthly observations were also compiled to determine seasonal trends and peak nesting periods (Plate 1,2).

In addition to nesting observations, the abundance of *Megachile* spp. visiting pigeonpea flowers was recorded during the flowering stage. Observations were made by counting the number of bees per minute/m² to assess their relative activity and contribution to pollination. Species identification was carried out using standard taxonomic keys to document the diversity of Megachilid bees across different locations. To determine the impact of artificial nesting on crop productivity, pigeonpea yield was recorded from plots provided with nesting structures and compared with control plots without nesting materials. The yield data were collected from all three locations and expressed in quintals per hectare (q ha⁻¹).



Plate 1 a,b. Experiment view

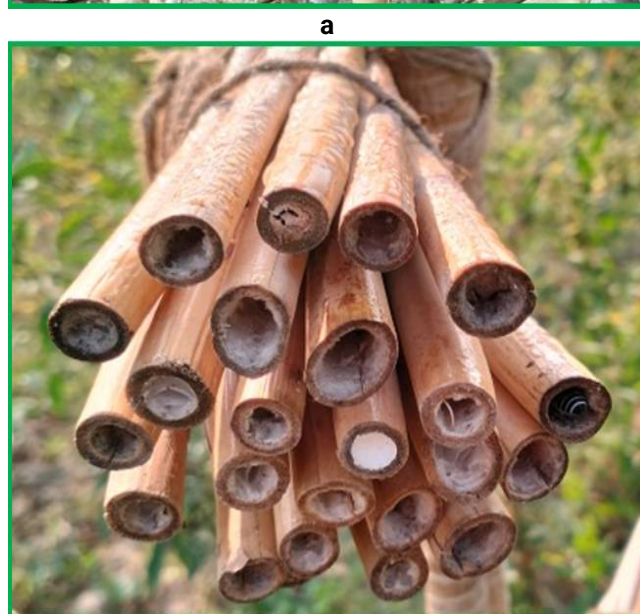


Plate 2 a,b. Nest occupancy of *Megachile* spp.
Results and Discussion

Nest occupancy by *Megachile* spp. in Sarkanda sticks

The present investigation clearly demonstrated that the nesting preference of *Megachile* spp. varied significantly with the type of artificial nesting material and location. Among the tested substrates, sarkanda (*Saccharum spontaneum*) sticks were accepted at all locations, with utilization ranging from 2.66 to 4.53 per cent (Table 1 & Figure 1). The highest acceptance was recorded at the Pulses Research Farm (4.53%), followed by the Entomology Research Farm (3.11%) and the Dryland Research Farm (2.66%). In contrast, bamboo wooden drilled blocks showed no acceptance, indicating that Megachilid bees strongly prefer natural hollow stems over artificial wooden substrates. This finding is supported by Pitts-Singer and Cane (2011), who reported that cavity-nesting bees exhibit strong

selectivity towards nesting substrates based on diameter, texture and internal microclimate. Similarly, MacIvor and Packer (2015) observed that nesting success of solitary bees is significantly higher in plant-based materials compared to artificial structures lacking natural characteristics. Further support is provided by Bosch and Kemp (2001), who highlighted that *Megachile* spp. prefer substrates that mimic natural nesting conditions, particularly hollow stems with suitable internal diameters. Likewise, Cane et al. (2007) reported that artificial nesting structures made from natural reeds and stems showed higher occupancy compared to wooden blocks due to better insulation and moisture regulation.

Table 1. Nest occupancy by *Megachile* spp. in Sarkanda sticks (Artificial nesting structure) during 2024

Plot No.	Locations	Length of sticks (cm)	Diameter of entrance hole (mm)	Number of sticks kept	Number of bundles	Total Number of sticks accepted	Acceptance percentage
1	Entomology research farm	25	7-9	450*	30	14	3.11
2	Pulses research farm	25	8-9	375	25	17	4.53
3	Dryland research farm	25	7-10	300	25	8	2.66

*15 sticks tie in each bundle



Figure 1. Acceptance percentage of by *Megachile* spp. in Sarkanda sticks

Nest occupancy of *Megachile* spp. in Sarkanda sticks during different month

Nest occupancy revealed that nesting activity was absent from January to August, except for minimal activity in March (0.46%) and increased sharply from September onwards (Table 2). The highest nesting was observed during October (3.96%), followed by November (3.01%) and December (2.26%). That trend closely corresponds with the flowering period of

pigeonpea, suggesting that nesting activity is directly linked with the availability of floral resources. These results are in agreement with Free (1993), who reported that bee activity and nesting behaviour are synchronized with flowering phenology and environmental conditions. The reduced activity during summer months may be attributed to high temperature stress and lack of forage. Similar seasonal patterns have been reported by Michener (2007), who

documented that most solitary bees exhibit peak nesting during periods of optimal floral availability. Additionally, Kremen et al. (2002) observed that

pollinator activity is highly dependent on seasonal resource distribution and climatic conditions, particularly temperature and humidity.

Table 2. Nest occupancy of *Megachile* spp. in Sarkanda sticks during different months

S. No	Month	Total no. of sticks	No. of sticks accepted for nest construction	% acceptance
1	January	650	0	0.00
2	February	650	0	0.00
3	March	650	3	0.46
4	April	650	0	0.00
5	May	650	0	0.00
6	June	650	0	0.00
7	July	650	0	0.00
8	August	530	0	0.00
9	September	530	14	2.64
10	October	530	21	3.96
11	November	530	16	3.01
12	December	530	12	2.26

Abundance of *Megachile* spp. on pigeonpea bloom

The abundance of *Megachile* spp. on pigeonpea flowers showed significant variation among species and locations. *Megachile lanata* was the most dominant species, with mean abundance ranging from 2.19 to 3.12 individuals per minute/m², followed by *M. bicolor* (1.90–2.43), *M. sculpturalis* (1.30–1.80) and *M. disjuncta* (0.90–1.38) (Table 3). At Pulses Research Farm recorded the highest overall mean abundance (2.18 individuals per minute/m²), which also corresponded with higher nesting acceptance. These

findings are in line with Klein et al. (2007), who emphasized that pollinator abundance is a key determinant of crop pollination success and yield. Similarly, Ricketts (2008) reported that increased pollinator visitation rates directly enhance fruit and seed set in agricultural crops. Further, Winfree (2009) highlighted that native solitary bees, including *Megachile* spp., play a crucial role in crop pollination and often outperform managed pollinators under suitable habitat conditions.

Table 3. Mean abundance of *Megachile* spp. on pigeonpea bloom at different locations during 2024

<i>Megachile</i> species	Mean number of <i>Megachile</i> spp./m ² /min		
	Entomology research farm	Pulses research farm	Dryland research farm
<i>Megachile lanata</i>	2.30 ^a	3.12 ^a	2.19 ^a
<i>Megachile bicolor</i>	2.02 ^a	2.43 ^b	1.90 ^a
<i>Megachile sculpturalis</i>	1.42 ^b	1.80 ^c	1.30 ^b
<i>Megachile disjuncta</i>	1.12 ^b	1.38 ^c	0.90 ^c
CD(p<0.001)	0.46	0.41	0.17
SE(m)	0.15	0.13	0.07
Overall Mean	1.72	2.18	1.57

Diversity index of *Megachile* spp. in pigeonpea

The diversity indices indicated a stable pollinator community across all locations, with species richness (S = 4) remaining constant (Table 4). The Shannon-Wiener index ranged from 1.31 to 1.34, while Simpson's index ranged from 0.70 to 0.73, indicating moderate diversity. However, high species evenness (0.94–0.97) suggested a uniform distribution of species. According to Garibaldi et al. (2013), even moderate diversity with high evenness can ensure efficient and stable

pollination services in agro-ecosystems, as functional complementarity among species enhances pollination efficiency. In addition, Tylianakis (2010) reported that biodiversity and species interactions contribute significantly to ecosystem stability and resilience. Similarly, Albrecht et al. (2012) emphasized that diverse pollinator communities improve pollination reliability and crop productivity under varying environmental conditions.

Table 4. Diversity index of *Megachile* spp. in pigeonpea cropping system at different locations

Parameters	Locations		
	Entomology research farm	Pulses research farm	Dryland research farm
Species Richness (S)	4	4	4
Shannon-Wiener index (H)	1.33	1.34	1.31
Simpson's Index (1 – D)	0.72	0.73	0.70
Species Evenness (E)	0.96	0.97	0.94

Impact of megachilid artificial nesting structures on pigeonpea crop yield

The impact of artificial nesting structures on pigeonpea yield was highly significant (Table 5). The yield in plots provided with nesting materials ranged from 13.89 to 14.68 q ha⁻¹, compared to only 9.47 q ha⁻¹ in control plots, representing an increase of approximately 46–55 per cent. The highest yield was recorded at the Pulses Research Farm (14.68 q ha⁻¹), which also exhibited the highest nesting acceptance. This strong positive relationship between nesting availability, pollinator activity and yield clearly demonstrates the effectiveness of artificial domiciliation in enhancing

crop productivity. Similar yield improvements due to pollinator augmentation have been reported by Garibaldi et al. (2013) and Potts et al. (2010), who observed that fields with higher pollinator activity consistently produce greater yields. Furthermore, similar findings were reported by Klein et al. (2007) and Ricketts et al. (2008), who demonstrated that enhanced pollinator presence significantly increases agricultural output. In addition, Blaauw and Isaacs (2014) showed that the provision of nesting habitats and floral resources leads to improved pollinator abundance and crop yield.

Table 5. Impact of megachilids artificial nesting structures on pigeonpea crop yield

S. No.	Pigeonpea field	Yield (q/ha)
1	Entomology Research Farm*	14.12
2	Pulses Research Farm*	14.68
3	Dryland Research Farm*	13.89
Control	(Bagging 10 plants)	9.47
CD(p<0.001)		0.51
SE(m)		0.16

* Megachilid artificial nesting structures

Conclusion

Sarkanda stick-based nesting structures hold significant potential for conservation and augmentation of *Megachile* populations. With further standardization and large-scale adoption, this approach can contribute to sustainable pollination management and improved crop productivity

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Declarations of interests

All authors of this manuscript declare that they have no conflict of interest.

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