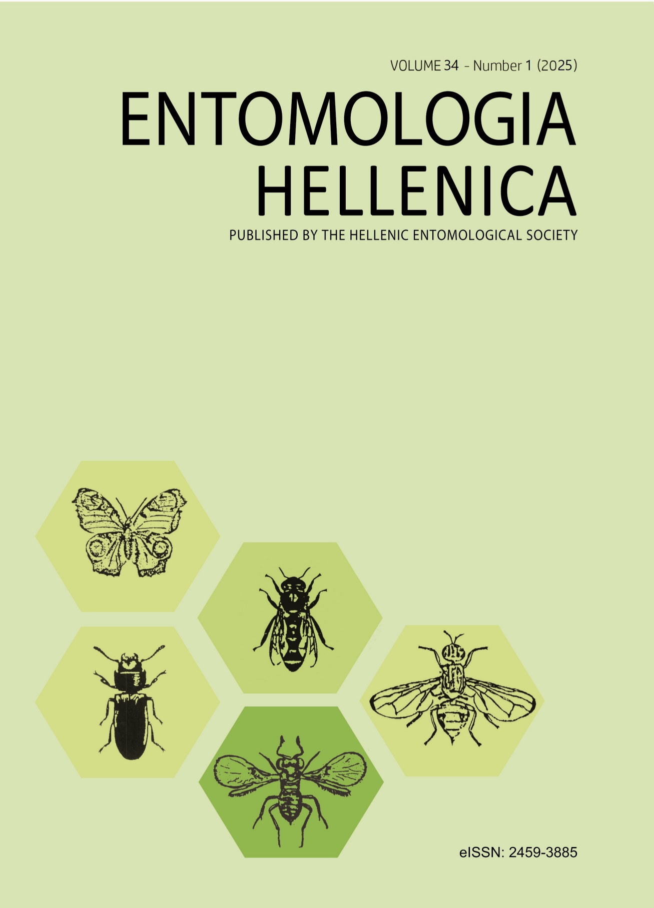
ENTOMOLOGIA HELLENICA

Vol 34, No 1 (2025)

Entomologia hellenica 34(1)



Utilization of Waste Materials for Rearing the Small Carpenter bee, Ceratina (Pithitis) smaragdula F. (Hymenoptera, Apidae)

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doi: [10.12681/eh.38450](https://doi.org/10.12681/eh.38450)

ENTOMOLOGIA HELLENICA **34** (2025): 38-48

Received 16 July 2024 Accepted 15 March 2025 Available online 27 April 2025

Utilization of Waste Materials for Rearing the Small Carpenter bee, *Ceratina* (*Pithitis*) *smaragdula* F. (Hymenoptera, Apidae)

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ABSTRACT

Ceratina (*Pithitis*) *smaragdula* is a recognized pollinator of alfalfa and various other crops. Artificial nesting of the species will aid its conservation and enhance its pollination services to the agroecosystems. Hollow waste stems of *Saccharum* spp., which are typically discarded as waste, were tested as nesting material for *C. smaragdula* and found to be highly beneficial for enhancing and maintaining these insect-pollinators in the agroecosystems.

KEY WORDS: *Saccharum* spp., pollinators, biowaste, nesting.

Introduction

Medicago sativa (Fabaceae), commonly known as alfalfa, is a perennial herb grown worldwide, primarily for use as a forage crop. An alfalfa plant produces racemes of small perfect flowers typically ranging in color from pale to dark purple. The flowers require bee visitation for pollination. When a bee opens the keel petals, the hidden stamen and pistil spring forward, forcibly striking the bee. Foraging honeybees learn quickly to avoid this mechanism by approaching the flower sideways, inserting their proboscides through the petals near the base of the flower to reach the nectar, acting as nectar thieves. *Ceratina* (*Pithitis*) *smaragdula* (Fabricius, 1787) maintains high agricultural importance and has been well documented by Kapil and Kumar (1969) as an important pollinator of alfalfa, cucurbits, sunflower and several other crops.

Ceratina spp. are usually medium-sized to rather small (2.2 to 12.5 mm), robust, cylindrical bodies. *C. smaragdula* is a small carpenter bee that makes nesting tunnels in cut pithy stems such as common reeds (*Tripidium bengalense* (Retz.) H. Scholz). It has also been observed to nest in the dead pithy wood of *Albezzia lebbek* Benth., *Caesalpinia pulcherrima* (L.) Sw., *Sesbania aegyptiaca* Poir., *Chenopodium album* L., *Poinciana regia* Bojer, *Sopphora tomentosa* L., *Vitis vinifera* L., *Sorghum vulgare* Pers., *Pennisetum typhoides* Rich. and in the hollow straws of *Avena sativa* L., *Triticum vulgare* L. and *Hordeum vulgare* L. Some of these have been used to make thatch for huts. Amongst the above, *C. pulcherrima*, *V. vinifera* and *S. aegyptiaca* have been reported as the mostly preferred for nesting.

C. smaragdula is present from Kashmir and Pakistan to Indonesia and Japan (Shiokawa and Sakagami 1969; Hirashima,1969). According to Shiokawa and Sakagami (1969), it is the most common and widely distributed species of the genus in the Oriental Region, being recorded at various localities from Karachi, Pakistan and Muzaffarabad, Kashmir to Hangchow in China, and Ambon in Indonesia. It is possible that the range extends further to the west, into Iran.

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Materials and Methods

Ceratina smaragdula handling

For the handling of *Ceratina smaragdula* the study was carried out from 2012 to 2015 at the Research Farm of Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu. Hollow *Saccharum* spp. waste stems were taken from their wild and cultivated habitats and subsequently segmented at their nodes, ensuring that one end remained closed while the other was open. These fragments formed the hollow nesting tunnels, which were transferred to wooden baskets/hives and then placed in shelters near different crops grown in the region all year round, at 2-6 ft above ground, facing east (Figs. 1, 2). The area is rich in cultivated plants, particularly alfalfa, Egyptian clover, sunflower and several other species. The response of *C. smaragdula* to these tunnels was documented. Specifically, we determined the number of accepted *Saccharum* spp. tunnels and their acceptability ratio, by recording the total number and the number of tunnels occupied during different years of the study. On this basis, the usefulness of these bio-wastes was determined.

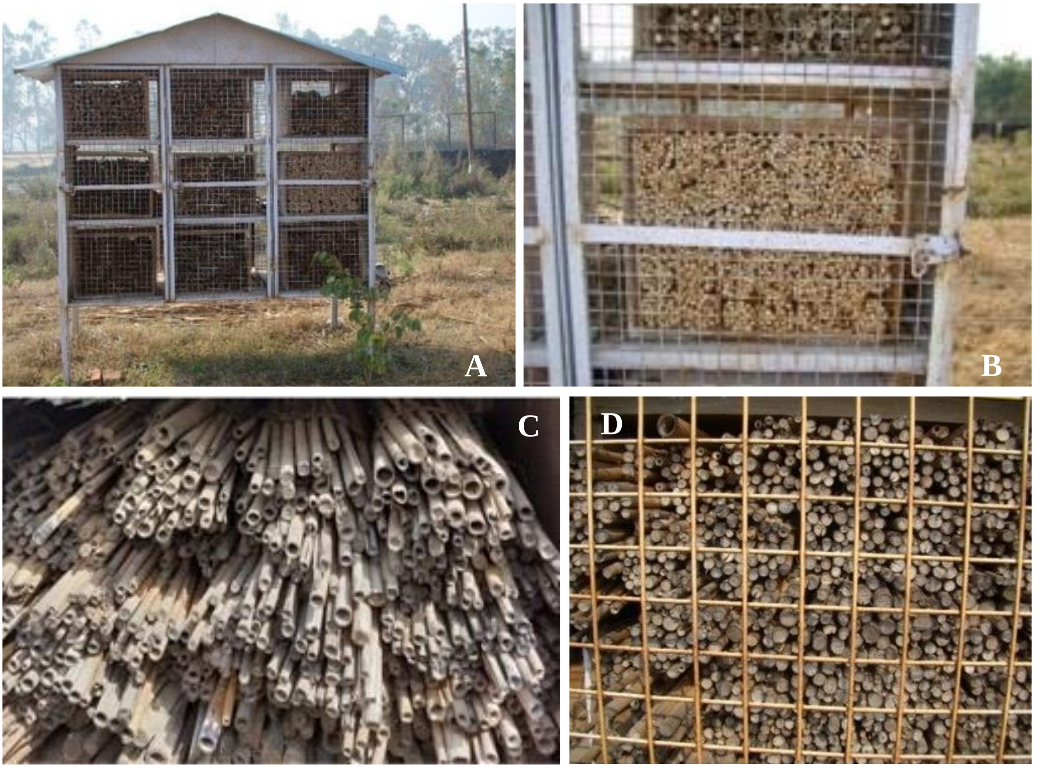

FIG. 1: A) Hut prepared for the domiciliation of non-*Apis* bees B-D) close ups of pithy stem stacking for the domiciliation of *Ceratina* (*Pithitis*) *smaragdula.*

Results and Discussion

The polylectic Indian alfalfa pollinator *C. smaragdula* is important for alfalfa pollination (Daly et al. 1971). Although *Apis florea* F. and *Nomioides* spp. were abundant on alfalfa flowers, the latter were most effectively pollinated by *C. smaragdula* and *Megachile flavipes* (Kapil et al 1970, Sandhu et al 1976). Batra (1975) reported that laboratory trials showed that *C. smaragdula* is an efficient pollinator of caged alfalfa and other plants grown in green houses. On the other hand, Goyal and Atwal suggested that the presence of nesting materials like reeds is crucial for *C. smaragdula* and *M. flavipes* near alfalfa fields. In Punjab, nests are excavated by females in pithy reeds and stems, such as thatch. The serial cell partitions are constructed from agglutinated sawdust. Nest entrances are guarded by the females and mating occurs therein (Batra 1967). These polylectic bees produce 6-7 generations in their 8-month active period and overwinter as adults. *C. smaragdula* females cannot be easily distinguished, but the males have black markings on the abdominal terga, in management trials, horizontal reeds attached to supports were placed in alfalfa field (Atwal 1970). Several researchers suggest that *C. smaragdula* is an effective pollinator of alfalfa (Atwal 1970; Sandhu et al 1976), while foraged legumes have specialized pollination mechanisms and requirements, which result in cross-pollination, and are explained for each crop as follows:

Medicago sativa (Lucerne)

The flower structure of lucerne is so unique that it must be tripped and cross-pollinated to set high yields of vigorous seeds. In addition to this, lucerne flowers have also another pollination barrier, their stigmatic surface, which is covered by a thin transparent membrane, preventing pollen germination. During tripping, the membrane also gets ruptured resulting in easy pollen germination. Important pollinators of lucerne comprise *A. dorsata*, *A. mellifera*, *A. cerana indica*, *C. smaragdula*, *C. binghami*, *M. rotundata*, *M. f1avipes*, *M. nana*, *M. lanata*, *Andrena levilabris*, *Xylocopa fenestrata*, *Chalcidoma rubripes* and *Nomia* spp. Bee activity was recorded from 06:00 h to 18:00 h with activity peaks from 08:00 to 11:00 and 16:00 h to 17:00 h, at the Research Farm of Sher-e - Kashmir University of Agricultural Sciences & Technology of Jammu (32.683762°N, 74.824394°E). Supplementary pollination with A. mellifera doubled the seed yield and improved seed quality.

Trifolium alexandrium (Berseem/ Egyptian clover)

A piston-type pollination mechanism was recorded for this flower. Important pollinators include *A. dorsata*, *M. f1avipes*, *C. smaragdula*, *A. mellifera*, *Lassioglossum cattulum*, *Halictus* sp., *Xylocopa* sp., *Nomioides variegata* and *Bombus* sp. Surplus honey can be produced from berseem at the Northwestern plains. An average of 15-20 kg honey is obtained per colony from this crop.

Trifolium spp. (Clovers)

The most important clover species are white (*Trifolium repens*), red (*T. pratense*), Crimson (*T. incarnatum*) and alsike clover (*T. hybridum*). The piston-type of pollination mechanism was also present here, as in the case of berseem, however differing in the length of the corolla tube. Various species of bumblebees with varying tongue or proboscis length are important pollinators, including *Bombus agrorum*, *B. hortorum* and *B. ruderatus* for red clover and *B. lucotum*, *B. terrestris*, *Melitta leporine* and *Anthidium punctatum* for white clover.

Interestingly, *C. smaragdula* that is a pollinator of alfalfa in Punjab, India, has been recorded on several other plant species (Table 1), and Kapil et al. (1969) reported that it is very active on clover and other flowers on bright sunny days. It is widely distributed in Punjab, Haryana and Himachal Pradesh and has been recorded at altitudes up to approximately 2000 meters. At Ludhiana, this species has been recorded mostly on lucerne, berseem and other clovers in spring and summer, and on sanhemp (*Crotalaria juncea*), arhar (*Cajanus indica*), urd (*Phaseolus mungo*) and cotton (*Gossypium* spp.) later in the season. Kapil et al. (1975) obtained 12.2 individuals of *C. smaragdula* per 100 sweeps.

TABLE 1. Important host plants of *Ceratina* (*Pithitis*) *smaragdula*

Plant species	**Common name**	**Family**	**Reference**
Medicago sativa	Alfalfa	Fabaceae	Kapil et al 1974, Abrol 1985
Trifolium alexandrium	Egyptian clover, berseem clover		Kapil and Jain 1980
Crotalaria juncea	Sunn hemp		Kapil & Jain 1980
Pisum sativum	Pea		Kapil & Jain 1980
Ipomoea batatas	Sweet potato	Convolvulaceae	Kapil & Jain 1980
Solanum melongena	Egg plant	Solanaceae	Kapil & Jain 1980
Allium cepa	Onion	Liliaceae	Batra 1967
Brassica campestris	Field mustard	Cruciferae	Batra 1967
Brassica napus	Rape		Batra 1967
Brassica juncea	Raya		Batra 1967
Eruca sativa	Taramira		Batra 1967
B. oleracea	Cabbage, cauliflower		Batra 1967
Raphanus sativus	Raddish		Batra 1967
Cucurbita spp.	Pumpkin and squashes		Batra 1967
Luffa aegyptica	Smooth loofah		Batra 1967
Cucumis melo	Muskmelon		Batra 1967
Gossypium spp.	Cotton	Malvaceae	Sidhu & Singh 1961
Abelmoschus esculentus	Okra		Abrol 1995
Coriandrum sativum	Coriander	Umbelliferae	Abrol 1985
Foeniculum vulgare	Fennel		Abrol 1991
Dacus carota	Carrot		Abrol 1997, Abrol 2004, Abrol 2006
Traechyspermum ammi	Jowain		Abrol 1985
Psidium guajava	Guava	Myrtaceae	Abrol 1985
Helianthus annuus	Sunflower	Compositae	Rahoo & Munshi 1971, Abrol 1985, Abrol 1996
Luffa cylindrica	Ghiyatori	Cucurbitaceae	Batra 1967,

			Atwal 1970
L. aegyptica	Sponge gourd		Batra 1967
L. acutangular	Ridge gourd		Batra 1967
Momordica charantia	Karela bitter gourd		Batra 1967, Atwal 1970, Dorjay et al 2017
Citrullus vulgaris	Watermelon		Kapil & Jain 1980
Cucurbita maxima	Pumpkin		Kapil & Jain 1980
Cucurbita pepo	Summer squash		Kapil & Jain 1980
Cucumis melo	Musk melon		Kapil & Jain 1980
Benincasa hispida	Petha or wax gourd		Kapil & Jain 1980
Allium cepa	Onion	Amaryllidaceae	Abrol 2010
Mangifera indica	Mango	Anacardiaceae	Batra 1967
Punica granatum	Pomegranate		Abrol 1985

C. smaragdula collected both nectar and pollen but during a different visitation pattern. In the case of nectar, the bee lands on its wings and moves directly to the base of the vexillum. Contrary to *Megachile* sp., when it sucks nectar, its head points outwards to the tip of the wings and keel, then its lower body part presses against the vexillum, not the wings or keel. In the case of pollen grains, it opens the wings and forcibly enters the keel to collect. The pollen is maintained in the pollen baskets or corbicula on its hind legs likewise to the honeybee (Abrol et al 2015).

Alfalfa is largely self-fertile, but for mechanical reasons, flowers require bee visitation for pollination (Bohart 1957, Free 1993, Richards 1996). Alfalfa flowers resemble small pea flowers, with a sexual column of fused stamens and pistil held under tension within the keel. When a visiting bee inadvertently “trips” the flower, the sexual column snaps upwards, sometimes striking the bee. The sexual column is inevitably driven against the banner petal, which furls around it. Once tripped, the flower can no longer be pollinated. Certain wild bee species are known to be more effective than honeybees, as pollinators of crops such as alfalfa and other forage legumes (Bohart 1957, 1960; Hobbs 1958; Lecomte and Tirgari 1965; Linsley 1958) and squash (Cane et.al 2013).

Plants provide a crucial ecological service in both natural environments and agricultural systems. Most angiosperms rely on animals for their pollination. The co-evolution of bees and flowers has resulted in special morphological adaptations for both insects and plants and the need of some plants for pollination by bees is necessary. Honeybees consistently deliver effective pollination for many of our cultivated flowering crops, often achieving excellent results. Certain crops with specific pollination requirements, like lucerne and possibly red clover, benefit from specialist bee species introduced to meet their needs. Alfalfa, for instance, relies on visiting bees to trigger its reproductive processes, ensuring successful pollination, pod development, and seed formation. However, tripping is done by a specialized group of bees such as carpenter bees *Ceratina* (*Pithitis*) *smaragdula*, which enter the flowers and press their keel with their own weight by releasing male and female organs to distribute pollen and affect cross-pollination (Abrol, 1993). In areas where the populations of these bees have been adequate, crop yields have increased. Peak yields and peak quality for some crops may be obtained through the exploitation of specialist pollinators. Solitary bees and bumblebees are the most efficient alfalfa pollinators. The efficiency of honeybees, however, decreases significantly after repeatedly opening alfalfa flowers. Honeybees “learn” to collect nectar without tripping flowers, due to the specific structure of the alfalfa flower. For that reason, despite their abundance in alfalfa fields, seed yield per hectare may be very poor when solitary bees and bumble bees are not present.

Wild bees have a greater significance in the ecosystems than their domesticated counter parts. In such cases, the generalist pollinators, like honeybees, often fail to pollinate these plant flowers or are poor pollinators for such plants. Entomologists worldwide are more focused on plant protection and overlook the safety of bees, especially the wild species. Likewise, excessive ploughing/irrigation and removal of nesting places of wild bees have threatened their survival. Soil scientists and agronomists should also work towards the conservation of bee habitats. This will help the conservation of wild bees, which are not only beautiful but also an integral part of our ecosystem.

Wild bees and their management

Continuously changing climatic conditions and over-exploitation of forests and barren lands for agriculture are the major hurdles in natural propagation of wild bees. Between 1976 and 1978, in northern India alone, a significant 73% decline in their native population has been recorded (Jain, 1993). Recognizing their significance in preserving flora through pollination, it is crucial to protect and conserve these bees due to their utility and ecological importance.

Despite their substantial presence, non-*Apis* bee pollinators have received minimal attention. The probable reason seems to be their unpredictable seasonal availability, lack of knowledge about their biology and host plant relationship. It was only in the mid-sixties that scientific interest was generated to study and understand their life processes in India (Atwal, 1970). The decline of honeybee effectiveness in pollinating alfalfa, which relies on tripping (Kapil et al., 1977; Kapil and Jain, 1979, 1980), is exacerbated by factors such as reduced bee colonies during the monsoon period from June to September and harsh winter conditions in the Himalayan ranges from November to February, along with prevalent bee diseases. These challenges underscore the urgent need to explore alternative, non-*Apis* bee pollinators that can effectively enhance crop yields in India. In addition to alfalfa, clovers and fruits like apple, pear, peach, almond and several other crops such as sunflower, hybrid tomato, cotton, onion, carrot and cucurbits (Kapil and Dhaliwal,1968) can be future potential crops requiring the services of the non-*Apis* pollinators.

Non-*Apis* bees and future prospects

Honeybees have often been given credit for pollination services that are in fact carried out by other bee species. It is now known that hundreds of crops dependent on insect pollination receive inadequate pollination from honeybees alone. The primary contributors to this pollination are non-*Apis* bees, commonly referred to as wild bees (Parker et al., 1987). Estimates for the economic value of non-*Apis* pollination are scarce. The pollination services of non-*Apis* pollinators were valued at USD 3.44 billion, but honeybees contributed approximately USD 11.68 billion by 2009 in USA (Calderone, 2012, Bosch et al 2021, Khalifa et al 2021).

The impact of flower abundance and pollinator movement on seed or fruit yield has economic importance and may have implications for crop pollinator management. The number of open flowers and nectar availability declined more rapidly closer to bee shelters than at a distance. The rapid decline in floral resources was partly interrupted because of steady pollination over time (Strickler and Freitas, 1999).

Future endeavors should consider several interconnected aspects, such as conducting studies on bee foraging patterns alongside crop rotation, exploring population dynamics by observing different bee species on various crops, evaluating pollinator efficiency, examining the effects of insecticides on diverse pollinator species, researching immature stages and their developmental cycles under controlled conditions. These efforts aim to synchronize brood production with crop flowering, develop techniques for brood transfer, investigate interactions between parasites, predators, and pests affecting both adult bees and broods, assess the influence of ecological factors on bee populations, study crop yields, and design nesting devices tailored to different bee species to maximize their presence on crops. These initiatives are crucial for initiating artificial domestication and management programs aimed at enhancing seed yields through the exploitation of valuable bee species in the country.

FIG. 2: Natural *Ceratina* (*Pithitis*) *smaragdula* nesting in pithy stems.

Conclusions

Relying on honeybees alone for crop pollination may lead to a decrease in seed production. It is mandatory to search for other bee pollinators and it is possible that conservation of wild bees might solve this problem. Using and conserving alfalfa pollinators will increase alfalfa seed production. Utilization of artificial hives is recommended to farmers as they are easy to handle, provide storability and are reusable. Furthermore, employing beehives can aid in preserving bees in their natural habitats and safeguarding them from extinction.

C. smaragdula seems to be an ideal candidate for managed pollination services, with the ease of finding and trapping the bees making it likely to encourage its utilization by local farmers.

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Χρήση παραπροϊόντων για τη δημιουργία ενδιαιτημάτων για την μικρή μέλισσα ξυλοκόπο, *Ceratina* (*Pithitis*) *smaragdula* F. (Hymenoptera, Apidae)

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ΠΕΡΙΛΗΨΗ

Το *Ceratina* (*Pithitis*) *smaragdula* είναι ένας αναγνωρισμένος επικονιαστής της μηδικής και διαφόρων άλλων καλλιεργούμενων φυτών. Η δημιουργία τεχνητών ενδιαιτημάτων για το είδος θα βοηθήσει στη διατήρησή του και θα ενισχύσει τις υπηρεσίες επικονίασης που προσφέρει στα αγροοικοσυστήματα. Στην παρούσα εργασία δοκιμάστηκαν τα κοίλα στελέχη του *Saccharum* spp., τα οποία συνήθως απορρίπτονται ως παραπροϊόντα, ως υλικό για δημιουργία ενδιαιτήματος του *C. smaragdula* και διαπιστώθηκε ότι είναι εξαιρετικά ωφέλιμα για την ενίσχυση και τη διατήρηση αυτών των επικονιαστών στα αγροοικοσυστήματα.

