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Pollen Bees (Hymenoptera: Apoidea) and Their Nesting Sites in Selected Vegetable Fields in the Kandy District, Sri Lanka

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ABSTRACT

Pollen bees are considered as important pollinators. Their abundance is strongly influenced by availability of nesting sites. Knowledge on nesting sites of pollen bees is limited under local conditions; therefore, present study was conducted with objectives of investigating availability of nesting resources for pollen bees in vegetable ecosystems and assessing acceptability of introduced reed nests for their in-situ conservation. Nesting sources such as bare ground percentage, availability of dead wood, pithy stems, snail shells, pre-existing burrows and cavities were surveyed in four vegetable agro-ecosystems, in Dodangolla, Gampola, Gannoruwa and Meewathura areas in Kandy District. Three types of nests: bamboo, gliricidia and drinking straws were installed in each location. Diversity and abundance of pollinators in each location were measured. Nesting sources were not significantly different among locations except cavities of land. It was significantly high (P<0.05) in Gannoruwa. Out of 60 compound nests, 12 (20%) were accepted. Gliricidia nests were accepted by Anthidiellum *sp. (dia. 4.06 ± 0.07 mm) and* Braunsapis cupulifera *(dia. 2.8 ± 0.1 mm) while bamboo nest were adopted by* Heriades binghami *(2.81 ± 0.28 mm). A total of 41 bees were collected and they belonged to three families and 10 genera. Family Apidae was most dominant and genus Apis was significantly (p<0.05) high compared to other genera, followed by genus* Heriades*. Bee abundance was not significantly different (p>0.05) among locations. Highest bee diversity was recorded from Gannoruwa (H'=0.364) and the lowest (H'= 0.260) at Gampola.*

KEYWORDS: *Agro-ecosystem; artificial nest; pollen bees; pollinators; Sri Lanka*

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Introduction

Honey bees and pollen bees (non-*Apis* spp.) are considered as important pollinators (Phipps, 1990). Pollen bees could be either social or solitary; the solitary bees live on their own nests, not in colonies with a queen and workers like honey bees. Some solitary bees may nest in large groups, but they do not actively help each other. Most solitary bees are also native, though there are a few exceptions. Native bees are usually, but not necessarily solitary. Some native bees and carpenter bees are also social. The term "wild bees" or "pollen bees" therefore, can be used as a general catch all for basically any bee that is not under genus *Apis*.

Human impact, especially through intensive agriculture and urbanization, can contribute to the instability of vital habitat and floral resources for bees. Many researchers have shown the correlation between declining native bee populations and habitat degradation through pesticide use (O'Toole 1994; Buchmann & Nabhan, 1996; Kremen *et al.,* 2002; Kevan, 2004). There is an increasing body of evidence suggesting that nest-sites and nesting resources may also play an important role for bee community structure (Petanidou & Ellis 1997). Bees exhibit a diverse array of nesting strategies with respect to the part of the habitat they nest in, the type of substrate they use, and the materials required for nest construction. Indeed, bees can be partitioned into several exclusive guilds on the basis of their nesting habits, known as miners, masons, carpenters, and social nesters.

Various approaches have been introduced worldwide for the pollinator conservation and to increase the availability of pollinators (Southwick & Southwick, 1992; Osborne *et al.,* 1991; Williams *et al.*, 1991). In Europe, preservation and management of habitats throught suitable bees' forage or nesting sites have been repeatedly proposed as a method to maintain or increase pollinator numbers (Banaszak, 1996). Enhancing native pollinator populations by habitat management is a potentially cost-effective option that deserves attention (Williams *et al,*. 1991). Providing artificial nesting sites can help these species build up much healthier populations (Steffan-Dewenter & Schiele, 2008).

Statement of the problem

There is a paucity of data on the nesting resources available in the agro-ecosystems and the acceptance of introduced nesting sites by the wild bees.

Objective

The objective of this study was to investigate different nesting habits of the pollen bees found in selected cropping ecosystems.

Literature Review

About 35% of global crop production depends on animal-mediated pollination (Kevan & Viana 2003; Klein et al., 2007). Pollinators supply a valuable input to agricultural production that can increase both the size and quality of harvests (Allen-Wardell et al., 1998). As agricultural intensification continues, the wild pollinators are threatened by human land-use practices, exotic species, and other factors (Biesmeijer et al., 2006). Loss of native habitats within agricultural landscapes may be of particular importance, because crop pollination by wild species is provided locally, constrained by the foraging ranges of pollinators.

Crop pollinators include a range of insects (e.g. beetles, flies, butterflies), as well as birds and bats, the majority of crops are most effectively pollinated by bees (Klein et al., 2007). Sri Lankan fauna of bees is consisting 132 species in 25 genera belonging to 4 families (Wijesekara, 2001). Honeybees and other managed species are often used to ensure adequate pollination; many crops are also effectively pollinated by wild bees (Free, 1993; Freitas & Paxton, 1998). Maintaining these pollination services requires the conservation and management of sufficient resources for wild pollinators within agricultural landscapes.

Honeybee remain as the most economically valuable pollinators of crop monocultures worldwide (McGregor 1976; Watanabe, 1994) and yields of some fruits, seeds and nut crops decrease by more than 90% without these pollinators (Southwick & Southwick, 1992). However, pollen bees, exactly like the much better known honeybee, are playing an important role as pollinators for lots of important horticultural crops. They contribute significantly to crop pollination and, on farms with sufficient natural habitat located nearby, may even provide all of the required pollination for some crops. Pollination is vital process in plant reproduction and in quality seeds and fruit production of plant species including agricultural crops. Not only do pollinators provide us with a significant amount of the food we eat and contribute to the economy, they also perform key roles in natural ecosystem, by helping to keep plant communities healthy and able to reproduce naturally. Pollinated plants produce fruit and seeds which are a major part of the diet of approximately 25 percent of bird species, as well as many mammals. The value of non-managed native pollinators in crop production and in other ecosystem services has also recently received attention (Kearns et al., 1998; Tscharntke et al., 2005; Winfree et al., 2007).

In the mid-1990s, scientists and agriculturists around the world became concerned by a decline in pollinator diversity. Globally, over 100 species of birds and mammals in sixty genera of vertebrate pollinators are already listed as endangered and untold numbers of invertebrates are at risk as well. In Costa Rica, pollen bee diversity in degraded forest land dropped from 70 to 37 species in just 14 years. There are several factors contributing for this population declining, these include habitat alteration (Westrich, 1996), introduction of alien pollinators (Buchmann, 1996; Thorp, 1996; Roubik, 2000), and pesticide poisoning (Sipes, 1995), increasing monoculture farming, and climate change.

Various approaches have been introduced worldwide for the pollinator conservation and increase the availability of pollinator (Southwick & Southwick, 1992; Williams et al., 1991; Osborne et al., 1991). In Europe, preservation and management of habitats thought suitable for bees' forage or nesting sites have been repeatedly proposed as a method to maintain or increase pollinator numbers (Westrich, 1996). Enhancing native pollinator populations by habitat management is a potentially cost-effective option that deserves attention, and may become essential if honey bees become less readily available (Osborne et al., 1991). Construction of 'bee walls', maintenance of crop-free fields, cultivation of hedgerows, reduce use of pesticide are the recent concerns in pollinator conservation programs.

Food and shelter are the two basic requirements of bees. The shelter refers to places where bees can nest. In order to support the native bee community, it is essential to provide nesting sites in addition to floral resources. Unfortunately, intensively managed farm landscapes often lack the untilled ground, tree snags and small cavities that native bees require for nest construction. The life span of these pollinators varies between species and may last from a few months to a couple of years. Bees have specific shelter and foraging needs at different stages of their lives, both during the larval and pupal stages when they are not pollinating, and during the adult stage when they are. It is important to understand the habits and life span of individual species to provide adequate habitats, nesting sites and foraging options.

Agro-forestry practices can provide essential nesting habitat for bees, our most important crop pollinators. As materials for nest building are used hollow plant stems, small gaps in loam and walls, death wood and lots of other materials. The decline of available natural nesting sites can be compensated with simple constructions, which can be built very fast. Nearly 70 % of pollen bee species nest underground, digging slender tunnels off which they excavate cells for their eggs. Most other pollen bees choose to nest in cavities, chewing into the pithy center of stems, or clearing out existing holes, in which they create a linear series of partitioned cells. Some pollen bees need specific nest-building materials such as mud, resin, or flower petals (Linsley, 1958), which they use to form the partitions.

The breeding habitats of bees in agricultural landscape are primarily hedgerows, forest edges, dry-stone walls, and field edges. Generally, soil-nesting species' nests are placed in south-faced, warm, and sun-exposed sites, with loosely packed, dry, sandy soil and patchy or no vegetation (Cane 2010; Müller et al., 1997; Westrich, 1996). Other species are more conservative in their choice of nest substrate that prefers areas with bare, loose sand, often near streams or in sand dunes. Breeding sites available to cavity-nesting species are primarily insect borings in dead wood. Most non-parasitic bees (between 60 and 70%) dig burrows in the ground. Many solitary pollen bees nest in a small series of tunnels and cells they construct underground. These burrow narrow tunnels down to small chambers. In order to build these nests, bees need direct access to the soil surface, often on sloped or well-drained sites. Ground-nesting bees can attract simply by making sure to leave some spots of exposed, undisturbed soil. Some bees nest underground, but use abandoned rodent burrows instead of digging their own.

Various introduced nest have been developed and used as a 'trap nest' for the collecting solitary bees for the research purpose around the world (Krombein & Norden, 2001). Several workers have studied solitary bees and their nesting habits in Sri Lanka (Krombein & Norden, 2001; Karunaratne & Edirisinghe, 2008). However local literature on rearing of solitary bees using alternative nesting habits is scarce. Therefore, providing wooden or bamboo nests having different diameters would facilitate nesting of these bees (Karunaratne & Edirisinghe, 2008). Use of introduced nesting sites in agricultural ecosystems is a quiet popular in many countries, however it has not been attempted in Sri Lanka so far. Therefore, the result of this study has a national significance in developing a bee conservation programme within agro-ecosystems in Sri Lanka.

Methodology

Pollen bees and their nesting habits were studied in four locations: Dodangolla, Gampola, Gannoruwa and Meewathura in mid-country regions of Sri Lanka during July to November, 2014. The collected bees were studied under laboratory conditions. Bees were collected using a standard insect net for 15 minutes following observation. Captured pollinators were killed in ethyl acetate fumes in killing jars. Samples were collected from each site during 9 to 11 am. Specimens were dry preserved and kept in a standard insect box.

Available nesting resources within the vegetable ecosystem and surroundings were identified and the following parameters were measured.

Table 1: Availability of nesting resources

Nesting resource	Measurement
Dead wood	Availability of dead wood suitable for nesting
Pithy stems	Availability of 'pithy' stems suitable for nesting
Snail shells	Availability of snail shells suitable for nesting
Pre-existing burrows	Availability of existing insect burrows suitable for nesting
Pre-existing cavities	Availability of cavities suitable for nesting
Bare ground	Proportion of bare ground available

Number of dead woods, pithy stems, and pre-existing burrows and cavities present in 1m2 of land area was calculated on the average of five randomly selected places in each location. Three types of nests were designed using bamboo stem pieces, gliricidia stem pieces and plastic drinking straws. Plastic straws (20), bamboo pieces (10) and gliricidia pieces (5) were bundled separately and one from each nest was placed as five places in each tested location. Diameters of each hollow stem of the nest was measured using a vernier caliper (least count = 0.02 mm). The introduced nests were examined weekly to confirm the acceptance of the nest by bees. Presences of eggs, larval or adult stages were used as indications of the acceptance. The Table 2 provides the crops cultivated in locations where the study was conducted.

Table 2: Corps cultivated in the locations studied

Location	Vegetable crops
Dodangolla	Bean, Brinjal, Capsicum, Chili, Tomato,
Gampola	Bean, Cassava, Chili
Gannoruwa	Bean, Brinjal, Chili, Luffa
Meewathura	Brinjal, Cassava, Chili

Pollen bees collected during the survey were recorded with the location found. Pollinator diversity was assessed by calculating Shannon diversity index (H) (Table 7) (Magurran, 1998, Shannon and Weaver, 1949). The bee diversity indices among locations were compared by conducting a T-test (Table 6). A Chi square test was conducted to compare the abundance of pollinators between different locations (Table 8).

Results and discussion

The nesting resources were not significantly different among the tested locations except the cavities of the land (Table 3). The cavities available in the land nesting sites were varied as Gannoruwa> Dodangolla > Gampola > Meewathura.

Table 3: Nesting resources (average of five locations) found in each location and their significance level

Parameter	Dodangolla	Gampola	Gannoruwa	Meewathura	Significance level (p)
Dead wood /1m^2	2.2	1.2	1.8	0.8	0.557
Pithy stems/1m^2	3.8	2.4	3.4	1.8	0.339
Snail Shells/ 1m^2	1.0	1.6	1.8	1.6	0.745

Burrows in stem/1m^2	1.8	1.8	0.6	1.0	0.447
Cavities in land/1m^2	2.8	2.4	4.8	1.4	0.012
Bare ground %	36.0	67.2	48.8	34.4	0.287

Highest amount of dead wood and pithy stems were found from Dodangolla, which can provides the nesting sites of many solitary bees. Although the bear ground percentage was not significantly different (P> 0.05) the highest value was recorded from Gampola, whereas the lowest was recorded from Meewathura. The amount of bear ground is a crucial factor on the nesting sites of soil nesting bees.

Table 4: Acceptance of the introduced reed nests by pollen bees

Type of nest	Dodangolla	Gampola	Gannoruwa	Meewathura
Bamboo nest	**Occupied**	Not Occupied	**Occupied**	Not Occupied
Gliricidia nest	**Occupied**	Not Occupied	Not Occupied	Not Occupied
Plastic straw nest	Not Occupied	Not Occupied	Not Occupied	Not Occupied

The nests made up of drinking straws were not occupied at all. This could be either the hole in the straws is not sufficient them to live or the inner surfaces are too smooth to initiate a nest development.

Table 5: Pollen species occupied in the introduced nests and the internal diameters of the each nest

Pollen bee species	Dodangolla	Gannoruwa
Anthidiellum sp	Gliricidia (3.98, 4.12, 4.08)	-
Braunsapis cupulifera	Gliricidia (2.84, 2.68, 2.88)	-
Heriades binghami	Bamboo (3.28, 2.98)	Bamboo (2.66, 2.69, 2.82, 2.48)

*The internal diameter of the respective nest is given in the parenthesis in mm

Three pollen bees accepted gliricidia and bamboo nests. Gliricidia hollow stems having average internal diameter 4.06±0.07 mm were accepted by *Anthidiellum* sp., relatively a large bee species, whereas, *Braunsapis cupulifera*, a small bee species accepted the gliricidia stem having the internal diameter of 2.8±0.1 mm (Table 5). *Heriades binghami* accepted bamboo stem nest with the internal diameter of 2.81± 0.28 mm in Dodangolla and Gannoruwa.

Among the 60 nests that were introduced in all locations, only 12 nests (20%) were accepted by pollen bees. There were several reasons for this low level of acceptance. Some of the introduced nests were initially invaded by termites, snails and beetles making less chance for bees accepting such nests. Although this non-target groups were later removed and nest were reestablished, they were not accepted by bees.

The bees collected during the study belonged to three families and 10 genera of bees. Of the recorded families, family Apidae was more abundant than others.

Table 6: The bee species collected during the study period

Family	Genus	No.
Apidae	*Amegilla*	3
	Apis	10
	Braunsapis	3
	Ceratina	2
	Trigona	4
	Xylocopa	3
Halictidae	*Patellapis*	1
Megachilidae	*Anthidiellum*	5
	Pseudoanthidium	4
	Heriade	6
3	10	41

The genus *Apis* had the highest ($p<0.05$) abundance followed by the genus *Heriades*. Highest bee diversity was recorded from Gannoruwa (H'=0.364) area and the lowest diversity was recorded (H'= 0.260) from Gampola. The decreasing trend of the bee diversity was Gannoruwa > Dodangolla > Meewatura > Gampola. The evenness was also high in Gannoruwa area (Table 7).

Table 7: The Shannon index and evenness of bee species collected from each location during the study period

Locations	Shannon Index (H')	Evenness (E)
Dodangolla	0.359	0.223
Gampola	0.260	0.161
Gannoruwa	0.364	0.226
Meewathura	0.352	0.219

The bee abundance was not significantly different ($p > 0.05$) among the different locations. However, relatively high population of bees was recorded in Gannoruwa and lowest was recorded in Meewatura (Table 8).

Table 8: Number of bees collected during the study period

Locations/Day	1	2	3	4	5	Average
Dodangolla	14	21	28	31	23	23.4±6.6
Gampola	16	10	23	27	30	21.2±8.6
Gannoruwa	15	8	20	87	52	36.4±32.9
Meewatura	0	15	21	26	25	17.4±10.6

($P= 0.401$; $R^2 = 0.64$ %)

The decreasing trend of the abundance was Gannoruwa>Doadangolla>Gampola>Meewathura. In Dodangolla, six bee genera were recorded and *Heriades* bees were dominated (25%). It was followed by genus *Apis* (15%), *Ceratina* (6%), and *Xylocopa* (5%). Among the six genera recorded from Gampola, genus *Apis* was the dominant group. It was followed by *Heriades* > *Xylocopa* > *Amegila* bees. The similar trend was followed in Gannoruwa and Meewatura also. However in Meewatura, there was a higher percentage of *Amegila* (11%) and *Heriades* (16%) were recorded than other location.

Conclusions and Recommendations

Except the available cavities in the land, all other nesting resources were not significantly different among the tested locations. Highest amount of dead wood and pithy stems were found from Dodangolla, which can provides the nesting sites of many solitary bees.

Since gliricidia and bamboo stick nests were repeatedly accepted by above bee species, those nest can established in vegetable cropping systems more frequently in order to maintain high population levels of pollen bees.

Among the bee genera recorded during the study, genus *Apis* was dominant bee genus than other genera, followed by genus *Heriades*, which was the most abundant pollen bee genus. Highest bee diversity was recorded from Gannoruwa and the lowest diversity was recorded from Gampola. Highest bee population was recorded in Gannoruwa and the lowest was recorded in Meewatura. The species composition and their abundance were varied in different locations.

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Appendix 1 List of Solitary pollen bee species recorded during the study

Family Apidae

1. *Amegilla* Friese
    - i. *Amegilla puttalama* (Strand, 1913)
    - ii. *Amegilla* sp.1
2. *Braunsapis* Michener
    - i. *Braunsapis cupulifera*
3. *Ceratina* Latreille
    - i. *Ceratina binghami* (Cockerell, 1910)
4. *Xylocopa* Latreille
    - i. *Xylocopa fenestrate* (Westwood, 1842)

Family Megachilidae

1. *Anthidiellum* Cockerell
    - i. *Anthidiellum* sp.1
    - ii. *Anthidiellum* sp.2
2. *Psudoanthidium* Friese
    - i. *Psudoanthedium* sp.1
3. *Heriades* Spinola
    - i. *Heriades binghami* (Cameron, 1897)

Family Halictidae

1. *Patellapis*
    - i. *Patellapis* sp.1