Technical Bulletin No. 30

Pollinators of cashew, their foraging behaviour and conservation measures

भा.कृ.अनु.प. – काजू अनुसंधान निदेशालय
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Citation:

K. Vanitha and T.N. Raviprasad. 2019. Pollinators of cashew, their foraging behaviour and conservation measures. ICAR - DCR Technical Bulletin No. 30, ICAR-Directorate of Cashew Research, Puttur, Karnataka. 33 p.

Published by

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DECEMBER 2019

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Printed at:

Codeword Process and Printers
C - 18, Yeyyadi, Mangaluru– 575 008
Tel. No.: 0824-2214618, 9900100818
E-mail : codeword.process@gmail.com

FOREWORD

Cashew is an important tree nut crop, grown in several regions of the country. Presently, it is grown in 10.62 lakh hectares of area with the production of 8.17 lakh MT. According to FAOSTAT 2017, India contributes around 19 per cent of the global cashewnut production. Though the country has large area under cashew, the production as well as productivity are lesser compared to Vietnam and Nigeria. Production of cashew is hampered by several biotic as well as abiotic factors. Inadequate pollination is a primary factor for poor nut set and yield. As cashew is a cross pollinated crop, it requires insects especially bees for pollination.

Knowledge on pollinators of cashew in a particular region is very much important to devise suitable conservation measures for them. This bulletin comprises detailed information on pollinators of cashew, their foraging behaviour, bee pasturage, natural enemies and their conservation measures. I hope this publication will serve as reference material on pollinators of cashew and be immensely useful to cashew farmers and other stakeholders.

Puttur
December, 2019

(M.G. NAYAK)
Director (Acting)

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CONTENTS

INTRODUCTION

Pollination is a vital process of nature. It refers to the transfer of pollen grains from the anther of one flower to the stigma of the same or another flower. It is the first process of sexual fertilization in flowering plant communities. In self-pollination, there is less dependence on the external factors to cause pollination. Whereas, cross-pollination is always dependant on another agent (biotic or abiotic) for the transfer of pollen. Thus, flowers requiring cross-pollination are of different types: Anemophilous (wind), Hydrophilous (water), Zoophilous (animals), Entomophilous (insects), Ornithophilous (birds) etc.

Cashew (*Anacardium occidentale* L.) is a cross pollinated tree crop. It is reported to tolerate an annual precipitation of 400 - 4200 mm, average minimum temperature of 10-22°C, average maximum temperature of 32 to 40.1°C and pH of 4.3 - 8.7. Cashew growing area lies along loamy red and lateritic soil, mixed red and black soil, coastal and deltaic alluvium soil. Unseasonal rains and heavy dew during flowering and fruiting stages are the major factors which adversely affect the yield and quality of cashew nuts, besides insect pests and diseases. Cashew bears both staminate (male) and hermaphrodite (bisexual/ perfect) flowers on the same inflorescence. The duration of vegetative and reproductive phases varies with varieties depending on the genetic and ecological factors. Cashew bears inflorescence usually at the apical tips of current season lateral shoots. Thus, during flowering season majority of flowers are seen on the periphery of the cashew trees (Fig. 1). The inflorescences are either conical or pyramidal or irregular in shape.

Fig. 1. Cashew tree in full blossom

Cashew flowers are produced in a gradual manner and hence in an inflorescence, flowers are seen for three to five months period along with fruits. In general, inflorescences last around 100 days in a flowering season that varies from 5-7 months, with each tree producing hundreds of inflorescences during its flowering period. Among the different ecological factors, temperature strongly influences initiation and duration of flowering. Both self and cross-pollination set fruits in cashew, while it has been reported that most of the fruits originating from self-pollination shed within 9 to 15 days after pollination, thus fruits harvested are primarily set from cross-pollination. Flowering season of cashew widely vary with regions.

Fig. 2. Cashew flowers and hermaphrodite flower

FLORAL BIOLOGY AND POLLINATION IN CASHEW

In general, three distinct phases of flowering has been reported in cashew *viz.,* (i) first male phase with 19 to 100 % male flowers (ii) mixed phase with 0 to 60 % male flowers and (iii) second male phase with 0 to 6.7 % male flowers. Due to coincident flowering of male and hermaphrodite flowers on the same inflorescence, self pollination may also happen to a lesser extent. The flowers are pentamerous, small, white or light green at the time of opening, later turn to pink. The androecium consists of a fully developed long stamen and 7 to 9 staminodes with pink anthers. The staminodes posses short filaments and are hidden in the lower half of the flower. In hermaphrodite flower, the long stamen itself has short filament and its anther is far below the level of stigma. The pistil is dorsiventral; ovary is monocarpellate, superior and reniform.

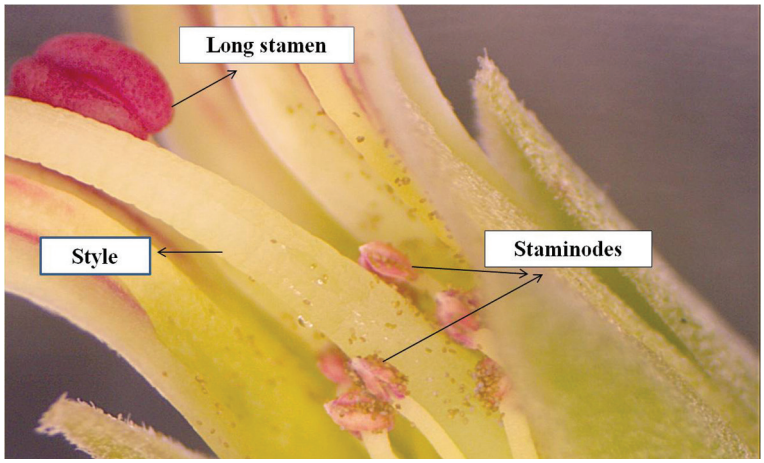

Fig. 3. Cashew flower showing style, long stamens and staminodes

Anthesis occurs between 9.00 and 14.00 hours depending on the sun shine and over 80 per cent of the perfect flowers remain open between 10.00 and 12.00 hours. Peak period of anther dehiscence occurs between 9.30 and 11.30 hours. The viability of pollen grains of staminate and perfect flowers is high and plays an important role in pollination, while staminodes do not produce viable pollen grains. Stigma becomes receptive one day prior to anthesis and retains its receptivity for two days. As the pollen grains of cashew are sticky in nature, possibility of wind pollination is ruled out. Though cashew flowers profusely, only less than 10% are hermaphrodite flowers in majority of genotypes. Several workers have reported that, in nature, pollination in cashew is inadequate and the potential yields are not realized. Thus pollinators are very essential in obtaining good yield. It is observed that only 4-6 % of hermaphrodite flowers set fruits and the remaining shed away may be due to physiological reasons or other biotic factors. Cashew requires cross pollination for proper fruit set because of the position of stigma and long stamen in the hermaphrodite flowers. The nature of flower requires insects to carry pollen grains for pollination and hence, cashew is necessarily pollinator dependent. Varied extent of pollination has been recorded in different regions,

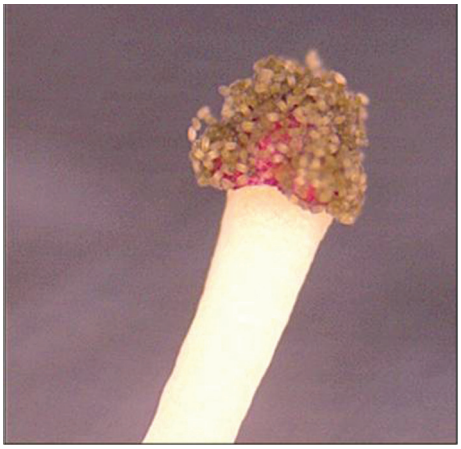

Fig. 4. Pollen grains on anthers of long stamen

but more than 25 % of pollination is considered optimum. Studies conducted at Brazil reported that, high nut set in cashew demands a high rate of pollinator visitation during the peak time of stigma receptivity, despite of having single ovule per flower.

IMPORTANCE OF POLLINATORS

Pollinators provide an ecosystem service that enables the plants to produce fruits and seeds. Ninety percent of the world food supplies are from 100 crop species, in which, 71 are bee pollinated. It is estimated that about 9.5 % of the total agricultural output of the world is by insect pollination. Among the crops pollinated by insects, only 15 % are pollinated by domestic bees and 80 % by wild bees and other pollinators. In general, wild bees are very efficient, having diverse foraging behavior, collect both nectar and pollen and they can supplement honey bees. The floral rewards for the pollinators are pollen and nectar. Over 1,00,000 invertebrate species comprising bees, moths, butterflies, beetles and flies and at least 1,000 vertebrates including birds, mammals and reptiles serve as pollinators worldwide. Among these agents, 90% of animal pollination is only through insects. The common insect pollinators are Hymenopterans, Dipterans, Lepidopterans, Coleopterans and Thysanopterans. Among the insects, bees are considered as important pollinators of several crop species. The information on pollinators diversity in an ecosystem is the basic requirement to understand the status of pollination biology. Accordingly, suitable conservation measures are to be devised in order to protect them for sustainable yield.

FLOWER VISITORS OF CASHEW

Cashew is entomophilous and requires insects for pollination. Its yield is often pollinator dependent. Earlier studies on cashew pollinators reported many insect species like ants, thrips, butterflies, flies, wasps and bees visit cashew flowers and are pollinating agents of cashew. However, their importance has not been critically determined. Less quantity of nectar produced by the cashew flowers favours mainly small and metabolically undemanding pollinator species. Insect visitors documented on cashew flowers at Puttur include 40 species belonging to 13 families of three insect orders. The Hymenopterans were the major floral visitors comprising of bees (belonging to Apidae and Halictidae), ants and wasps followed by Dipterans (Table 1). The list excludes pests of cashew flowers, natural enemies (except ants and wasps that visit cashew flowers for nectar from extra floral nectarines (EFN) and floral nectar, respectively). Few studies conducted in other countries suggest that native bees are the efficient pollinators of cashew.

Observations showed that many of the dipterans are just visitors of cashew flowers; they collect nectar by bending sideways without touching stigma. Besides they rarely visit freshly opened flowers. The lepidopterans pierce a small part of proboscis at the flower base to search for nectar, without touching the stigma. The tiny beetles forage the flowers in plenty but they forage on the anthers and move towards flower base. Similarly, wasps like sphecids and vespids move among cashew flowers frequently which might be for nectar as well as, prey insects. Hence, visits of butterflies, beetles and flies can be 'nectar robbing' without touching stigma.

Fig. 5. A syrphid fly visiting cashew flowers

Table 1. List of flower visitors of cashew at Puttur, Karnataka

Sl. No.	Common name	Scientific name	Family	Order
1	Reed bees	*Braunsapis picitarsus* (Cameron) *	Apidae	Hymenoptera
2	Small carpenter bee	*Ceratina hieroglyphica* Smith *	Apidae	Hymenoptera
3	Small carpenter bee	*Ceratina binghami* *	Apidae	Hymenoptera
4	Small carpenter bee	*Ceratina* sp.	Apidae	Hymenoptera
5	Reed bees	*Braunsapis* sp. *	Apidae	Hymenoptera
6	Sweat bee	*Pseudapis oxybeloides* Smith*	Halictidae	Hymenoptera
7	Sweat bee	*Pseudapis* sp.	Halictidae	Hymenoptera
8	Sweat bee	*Lasioglossum* sp. 1*	Halictidae	Hymenoptera
9	Sweat bee	*Lasioglossum* sp. 2	Halictidae	Hymenoptera
10	Sweat bee	*Seledonia* sp.*	Halictidae	Hymenoptera
11	Asian hive bee	*Apis cerana indica* F.*	Apidae	Hymenoptera
12	Indian little bee	*Apis florea* L. *	Apidae	Hymenoptera
13	Stingless bee	*Tetragonula* sp.*	Apidae	Hymenoptera
14	Potter wasp	*Eumenes* sp.	Vespidae	Hymenoptera
15	Wasp	*Antepipona* sp.	Vespidae	Hymenoptera

16	Blow fly	*Stomorhina* sp.	Calliphoridae	Diptera
17	Flies	Undetermined sp.	Calliphoridae	Diptera
18	Flies	Undetermined sp.	Sciaridae	Diptera
19	Flies	Undetermined sp.	Tabanidae	Diptera
20	Hover fly	*Paragus* sp.	Syrphidae	Diptera
21	Hover fly	*Ischiodon scutellaris* F.	Syrphidae	Diptera
22	Hover fly	Undetermined sp.	Syrphidae	Diptera
23	Flies	Undetermined sp.	Cecidomyidae	Diptera
24	Flies	Undetermined sp. 1.	Bombyliidae	Diptera
25	Flies	Undetermined sp. 2.	Bombyliidae	Diptera
26	Flies	Undetermined sp.	Muscidae	Diptera
27	Carpenter bee	*Xylocopa* sp.	Apidae	Hymenoptera
28	Wasp	*Chalybion bengalense* (Dahlbom)	Sphecidae	Hymenoptera
29	Butterflies	Undetermined sp.	Lycaenidae, Nymphalidae	Lepidoptera
30	Carpenter ant	*Camponotus compressus* F.	Formicidae	Hymenoptera
31	Black golden ant	*Camponotus sericius* F.	Formicidae	Hymenoptera
32	Ant	*Prenolepis naoroji* Forel	Formicidae	Hymenoptera
33	Yellow Crazy ant	*Anaplolepis gracillipes* Smith	Formicidae	Hymenoptera
34	Weaver ant	*Oecophylla smaragdina* (F.)	Formicidae	Hymenoptera
35	Cocktail ant	*Crematogaster* sp.	Formicidae	Hymenoptera
36	Ant	*Monomorium* sp.	Formicidae	Hymenoptera
37	Short legged hunchback ant	*Myrmecaria brunnea* Saunders	Formicidae	Hymenoptera
38	White footed ghost ant	*Technomyrmex albipes* Smith	Formicidae	Hymenoptera
39	Odour ant	*Tapinoma melanocephalum* F.	Formicidae	Hymenoptera
40	Arboreal bicoloured ant	*Tetraponera rufonigra* Jerdon	Formicidae	Hymenoptera

*Important and abundant species

Are ants pollinators of cashew?

It is generally believed that ants could be pollinators of cashew as they are abundant on cashew flowers and perform erratic movement over the flowers. But few studies indicated that it is not the case. Though several ant species move over the cashew inflorescences throughout the day in abundance, the major need is for extra floral nectarines at the base of flowers and buds as well as the honey dew secreted by certain sucking pests attacking cashew inflorescences like aphids, mealy bugs etc. Ants crawl randomly on the flowers mainly at flower base and they chew the anthers and are assumed to feed on pollen fluids during nectar crisis period. It is reported that most pollen grains fed by ants have lost their entire liquid contents and became less viable. Studies on pollen viability on cashew indicated that, pollen viability might be lost due to ants, which forage on cashew flowers continuously. Further, presence of ants makes the cashew flowers less attractive to bees, because it is uneconomical to the bees to visit such flowers. Thus association of ants with cashew flowers may not be beneficial in pollination, however, further investigations are required to ascertain this.

Crematogaster sp.

Camponotus sericius

Fig. 6. Foraging of ants on cashew inflorescence

Pollination syndrome in cashew

Pollination syndromes are suites of flower traits that have evolved in response to natural selection imposed by different pollen carriers. According to studies conducted in Brazil, the following could be the pollination syndrome in cashew. The large floral display of hermaphrodite flowers attracts bees and directs to pollinate which individually have a short receptive period. A much greater number of male than hermaphrodite flowers may ensure both that panicles are attractive to pollinators and that pollen grains have access to stigmas for pollination at the optimal time of day; anthers of male flowers dehisce just before and during anthesis of hermaphrodite flowers, coinciding with the time of highest insect visitation to the flowers and maximum stigma receptivity.

POLLINATORS OF CASHEW

Among the flower visitors of cashew, honey bees and few native bees are considered as important pollinators. Ability of cashew to produce large amounts of pollen could be probably to attract pollen gatherers rather than nectar foragers. It is to be noted that the species composition of bees vary with ecosystem and other management measures adopted.

- In west Bengal, *A. c. indica, A. florea, A. dorsata, Trigona* sp., *Bombus* sp., *Chrysomya megacephala, Musca* sp., different species of ants, butterflies and Coleopterans were recorded as flower visitors of cashew.
- In coastal Tamil Nadu, the bee species reported as pollinators of cashew include *C. binghami, C. smaragdula, Braunsapis* sp., *P. oxybeloides* and *A. mellifera.*
- While in Brazil, *A. mellifera* L. and *Centris tarsata* Smith are the efficient pollinators of cashew.
- In Ghana, two stingless bees, *Dactylurina staudingeri* and *Liotrigona parvula* and seven solitary bees *Braunsapis* sp., *Ceratina* sp., *Compsomelissa* sp., *Halictus* sp., *Lasioglossum* sp., *Lipotriches* sp. and *Thyreaus* sp. are known to be pollinators with strong affinity to cashew flowers but not *A. mellifera*.
- Earlier, in coastal Karnataka, bees namely *P. oxybeloides*, *Lasioglossum* sp., *Halictus* sp., *Braunsapis* sp., *Ceratina smaragdula* and *Ceratina* sp., *A. c. indica* and *A. florea* were reported as pollinators of cashew.
- Subsequent observations revealed that *A. c. indica, A. florea, A. mellifera, A. dorsata, Tetragonula* sp., *B. picitarsus, Braunsapis sp., P. oxybeloides, Pseudapis* sp.1, *Lasioglossum* sp., *Seledonia* sp., *C. hieroglyphica*, *C. binghami* and *Ceratina* sp.1 visits cashew flowers at Puttur, Karnataka. In Honnavar Taluk of Karnataka, *A. c. indica, A. dorsata* and *A. florea* are the major polliantors of cashew.

Honey bees visit the cashew flowers mainly for nectar than pollen and a report from Brazil indicated that there would be 50:50 chance of the honey bee worker effecting pollination in the hermaphrodite cashew flowers they visit. Scanty and unrewarding forage offered by cashew could be the reason for fewer visits by honey bees compared to native wild bees. Native bees could collect both pollen and nectar more effectively and pollinate cashew flowers. They can survive on other floral resources which are comprised of weeds, perennial trees and other plants present in the surroundings during non-flowering period of cashew. It was reported that in the west coast regions of India, the native bees maintain two separate constancies on cashew and other floral sources simultaneously during the cropping season of cashew, which is not the case in East coast of India.

GENERAL DESCRIPTION OF IMPORTANT POLLINATORS OF CASHEW

Eight species of bees belonging to Apidae and five species belonging to Halictidae are the important pollinators of cashew at Puttur, Karnataka. The family Apidae contains the highly social bees as well as some solitary and communal species. It is the largest family containing around 5,700 species of bees including honeybees, carpenter bees, orchid bees, cuckoo bees and other smaller stingless native bees. Halictids are very diverse group of bees, dull to metallic black or green, blue or purple. Halictids display the more diverse social behavior. Most species are polylectic and nest underground, while, nests that are built in rotting wood usually resemble ground nests.

I. Honey bees (*Apis* spp.)

Honey bees are eusocial insects, have overlapping generations, cooperative brood care and reproductive castes.

1. *Apis cerana indica* F. (Apidae: Hymenoptera) (Indian hive bee/ Asian bee)

A. c. indica are the domesticated species and are native of India/Asia, found almost throughout India. Adult bee is black in colour with four yellow abdominal stripes. Though, various regional strains exist, hill and plain strains are the two recognized ones. Worker bees of the plains are comparatively smaller and yellower, but at high altitudes, larger and darker bees are found. If there is abundant food resources and large colony size, swarming takes place. These bees are larger than *A. florea*, but smaller than *A. mellifera*.

Fig. 7. *A. c. indica* colony on a cashew tree branch and the bee foraging on the flower

It is a common bee species visiting cashew flowers. Its activity can be noticed from early morning (8.00 am onwards depending on sun shine) till 6.00 pm. Its main foraging reward is nectar. It forages more on fresh flowers, but also visit one and two days old cashew flowers for nectar. When the bees sit on the flower petals, the anthers of long stamen in male flowers comes into contact with abdomen of the bees most of the times (Fig.7), thereby pollen grains get adhered on its body parts which further get transferred to stigma of the hermaphrodite flowers upon subsequent visits by the bees, thus ensuring pollination.

2. *Apis florea* (Apidae: Hymenoptera) (Little bee / Dwarf honey bee)

A. florea build a single-comb nest, vertical, usually fairly low down in bushes, or in the open, suspended from a branch. Their nests are small, often not larger than 15 - 20 cm wide. They also construct comb in branches of bushes, hedges, buildings, caves, empty cases etc. This bee species is not rearable as it frequently changes its nesting place. Bees exhibit frequent foraging and long migration range. They tend to build combs at lower elevations, away from direct sunlight and on the peripheral side of plant branches. This species visits cashew flowers from early morning to afternoon hours, but mainly for nectar.

Fig. 8. Colony of *A. florea* on cashew twig and a worker bee

3. *Tetragonula* sp. (Apidae: Hymenoptera) (Stingless bees/ Dammer bees)

Tetragonula species are stingless and harmless to human. They are the smallest of the honey-yielding bees. The entire body is black to blackish-brown. These bees build irregular combs of wax and resinous substances in crevices and hollow tree trunks. Bees collect nectar and pollen from a number of different flowers. They do not sting, but bite their

Fig. 9. *Tetragonula* sp.

enemies or intruders. It can be domesticated, however the average honey yield per hive per year is very less and the extraction of honey is difficult.

This bee species visits cashew early in the morning and forages till evening. They collect lot of pollen grains during early flowering period and also forage on leaves, inflorescences, developing nuts and fruits mostly for extra floral nectarines (Fig.10). During fruiting season, the bees also collect juice from the cracks of matured and ripe cashew apples.

Fig. 10. *Tetragonula* sp. collecting fruit juice from cashew apple and nectar from extra floral nectarines of cashew leaf

4. *Apis dorsata* Fab. (Apidae: Hymenoptera) (Rock bee/ Giant honey bee)

A. dorsata has a widespread distribution throughout southern Asia, and is not found in North America. These honey bees build a single, large, exposed comb under tree branches, high hedges, under cliffs, rather than in cavities. These bees are highly

Fig. 11. Colony of *A. dorsata* on cashew tree trunk and the worker bee

ferocious and are. These bees are the largest among the bees described. Compared to *A. mellifera* workers, *A. dorsata* seems to live significantly longer, especially during migration. Some of the major crops thought to be heavily dependent upon *A. dorsata* pollination include: cotton, mango, coconut, coffee, pepper, star fruit, and macadamia. Its visits are rare on cashew flowers, hence could not be considered as important pollinators.

5. *Apis mellifera* (Apidae: Hymenoptera) (European bee / Italian bee/ Western bee)

A. mellifera is indigenous to Africa, Europe and the Middle East and largely introduced in to other parts of the world. They are bigger than *A. cerana* but smaller than *A. dorsata. A. mellifera* are red/ brown with black bands and orange yellow rings on abdomen *i.e.,* three abdominal stripes but comparatively less pronounced than *A. cerana*. There are different races of *A. mellifera*, vary in sizes of individual bees and colonies. Like *A. cerana*, they also build parallel combs. They are less prone to swarming and absconding. This particular species is reported as major bee species visiting cashew in east coast region of India especially Tamil Nadu and also in Brazil and parts of Africa, but not found in Puttur, Karnataka.

Fig. 12. *A. mellifera*

II. Wild bees/ Native bees (non - Apis species)

1. *Braunsapis* sp. (Apidae: Hymenoptera)

Braunsapis is a genus of bees in the tribe Allodapini. It is the largest genus of the tribe and is known for its array of social behaviours. A total of 14 species of *Braunsapis* have been recorded from India. *Braunsapis* bees are quite lean and black, and are less than 1 cm in length. There are some species having red abdomen or light colour. Females have a sting, but they are not aggressive and sting only if handled. These species are solitary and nest in stems and twigs,

Fig. 13. *Braunsapis* sp.

preferably pithy stems. There is continuous brood production throughout the year, but relatively more broods are present from September to March. These tiny bees forage on cashew flowers with its characteristic short vibrant movements. Many a times, bees land on the anther lobes directly and collect pollen grains and then move towards the flower base for collecting nectar.

2. *Braunsapis picitarsus* (Cameron) (Apidae: Hymenoptera)

B. picitarsus is the most common bee visiting cashew in Puttur region. Male bees are simple, black and usually have yellow or white spot on the clypeus. This is the most abundant bee species visiting cashew flowers at Puttur. The peak foraging activity occurs between 10:00 am and 1:00 pm. Nests of *B. picitarsus* are commonly found in dry tiny sticks as well as pruned cut ends of cashew and *Mussanda* sp.

Fig. 14. *B. picitarsus*

3. *Ceratina hieroglyphica* Smith (Apidae: Hymenoptera): Small carpenter bee

C. hieroglyphica is also a predominant bee species visiting cashew flowers in the Indian subcontinent. It is a stem nesting bee, exhibiting subsocial nature. No distinct longitudinal impression is seen in the clypeus of *C. hieroglyphica*. It is commonly seen on cashew flowers at Puttur region. This bee makes nests in hollow or pithy stems. Nests of these bees can also be located in cashew and Mussanda. The bee collects lot of pollen grains so as to feed its larva.

Fig. 15. *C. hieroglyphica*

4. *Ceratina binghami* Cockerell (Apidae: Hymenoptera)

This species is slightly more bluish than the other closely related species. The female bees resemble that of *C. smaragdula* so much, but not the males. Bees are bright metallic green in colour, partly slightly golden green; with

Fig. 16. *C. binghami*

more bluish sixth abdominal tergite. Yellow spot is present in the clypeus region. The bees nest in hollow reeds and thatch, excavate tunnels in dried pithy branches of trees. Its nests are also located inside the pruned cut ends of dried cashew stems.

5. *Pseudapis* sp. 1 (Halictidae: Hymenoptera)

Fig. 17. *Pseudapis* sp. 1

There are 73 known species of *Pseudapis* from different parts of the world, particularly Africa, Europe, Australia and Asia. Pseudapis bees do not produce honey but are likely to be important pollinators of crops and wild plants. Females have a sting, but they are not aggressive and will sting only if handled. These ground-nesting bees live independently. *Pseudapis* bees have large tegula and pale bands on the abdomen. They prefer to nest in soils. In general, these bees prefer flowers of Asteraceae family, but visit other flowers as well. This bee species is less common on cashew flowers.

6. Pseudapis oxybeloides Smith (Halictidae: Hymenoptera)

Fig. 18. *P. oxybeloides*

P. oxybeloides is a soil nesting bee and known to be one of the major insect pollinators in the world. It is quasi-social, mostly prefers sandy, alkaline soil with little vegetation. The bees have large tegula and pale bands on the abdomen. This bee species is polylectic and gathers pollen and nectar from a variety of flowers. It collects plenty of pollen grains within a short period and is a very good forager. Nests of this bee species are located in the ground of open surface, sides of rain water passages in the cashew plantations and also in the lateritic surface on the ground.

7. *Lasioglossum* sp. (Halictidae: Hymenoptera) (Sweat bee)

Fig. 19. *Lasioglossum* sp.

Genus, *Lasioglossum* is the largest of all bee genera, containing over 1700 species in numerous subgenera world wide. Lasioglossum bees are small, black known to have bands of light hairs at the base of their abdominal segments, but not always.

Most Lasioglossum species nest in the ground, but some nest in rotten logs. They live independently or in small groups. They are not aggressive but can sting for defence. This species is common on cashew flowers, but can also be seen over the leaf surface at times. Though it prefers nectar in fresh flowers, also visits extra floral nectarines.

8. *Seledonia* sp. (=*Halictus* sp.) (*Halictidae:* Hymenoptera) (Furrow bees)

The genus *Halictus* has 200 spp. in 18 subgenera worldwide. Bees are shiny in nature and small. The hair bands are apical and not basal. This species is common on cashew flowers. It also collects lot of pollen grains.

Fig. 20. *Seledonia* sp.

DIVERSITY INDICES OF CASHEW POLLINATORS

Based on the data set on the efficient pollinators of cashew observed between 2014 and 2017, the diversity indices of pollinators in the cashew plantations at Puttur were worked out. As 13 bee species are considered as pollinators of cashew (described above), the species richness (S) is 13. Simpson diversity index of 0.11 and Shannon diversity index of 2.3 shows rich diversity of bees in cashew plantations of the study location. Similarly, Berger Parker index of 0.21 reveals that bee population is not dominated by a single species, but diverse groups of bee species (Table 2).

Table 2. Diversity indices of bee pollinators of cashew

Diversity indices	
Richness	13.00
Simpson index	0.11
Shannon Index	2.30
Berger parker index	0.21

RELATIVE ABUNDANCE OF POLLINATORS IN CASHEW

The number of different bee species visiting ten randomly selected cashew inflorescences was recorded for 10 min at hourly intervals from 8.00 am to 5.00 pm for 20 days. These observations were taken up during full bloom period. Among the 13 bee species observed, eight species belong to Apidae contribute to 75.6 % of the bee abundance,

while five species belonging to Halictidae contribute to 24.4 % of abundance. Within Apidae, highest species abundance is recorded for *B. picitarsus* (20%) followed by *A. c. indica* (16.7 %) (Table 3). Similarly among the Halictids, *P. oxybeloides* is the most abundant species (17.6 %). Based on the abundance, *A. c. indica, A. florea, B. picitarsus, C. hieroglyphica, Tetragonula* sp., *Lasioglossum* sp., *P. oxybeloides* and *Seledonia* sp. are regarded as major pollinators of cashew at Puttur.

Table 3. Relative abundance of pollinators of cashew at Puttur

Sl. No.	Family	Species	Species abundance (%)	Total abundance (%)
1	Apidae	*A. c. indica*	16.7	75.6
2		*A. florea*	10.3	
3		*B. picitarsus*	20.0	
4		*Braunsapis* sp.	8.1	
5		*C. hieroglyphica*	11.4	
6		*C. binghami*	1.5	
7		*Ceratina* sp.	0.4	
8		*Tetragonula* sp.	5.0	
9	Halictidae	*Lasioglossum* sp. 1	2.2	24.4
10		*Lasioglossum* sp. 2	0.6	
11		*P. oxybeloides*	17.6	
12		*Pseudapis* sp.	3.1	
13		*Seledonia* sp.	3.1	

FORAGING BEHAVIOUR OF MAJOR POLLINATORS OF CASHEW

Foraging period

Bees after foraging an inflorescence move to nearby inflorescences of the same tree or nearby cashew trees then fly away, which is an ideal behaviour for effective cross pollination. In general, flower visitors are abundant during morning hours especially late morning to early afternoon hours, which might be due to the higher nectar volume and sugar concentration present during that time compared to late afternoon hours. A study in West Bengal reported that amount of nectar was maximum in cashew flowers between 11.00 am and 3.00 pm (0.85 -1.16µl), but very less quantity was available during early morning and late afternoon hours (0.04-0.07µl). Similarly, sugar concentration was maximum during 11.00 am - 3.00 pm (4.5 to 5.1%), and very less during early morning and evening hours (0.4 to 0.7%).

Observations taken up at ICAR-DCR, Puttur indicated that number of bees visiting cashew flowers was maximum during 11.00 am - 12.00 N followed by 12.00 N - 1.00 pm (Table 4). Between 8.00 - 9.00 am, only three bee species foraged on cashew inflorescences, in which the stingless bees, *Tetragonula* sp. were the abundant (80%) followed by *A. c. indica* and *A. florea*. During 10.00 am - 1.00 pm, the most abundant species was *B. picitarsus* followed by *P. oxybeloides*, *A. c. indica*, *Ceratina* sp. and *A. florea*. After 3.00 pm, *B. picitarsus*, *C. hieroglyphica*, *Lasioglossum* sp. were seen, but less in numbers, while, *Seledonia* sp. and *P. oxybeloides* were not seen. After 4.00 pm, few bees of *A. c. indica*, *A. florea* and *Tetragonula* sp. were noticed. Drastic reduction in the foraging activities of the bee species was observed during heavy wind and rain.

Table 4. Temporal variation in foraging activity of major insect pollinators of cashew

Time	Relative abundance of major pollinator species (%)								Total bees observed (Nos)
	A.c. indica	*A. florea*	*B. picitarsus*	*P. oxybeloides*	*C. hieroglyphica*	*Seledonia* sp.	*Lasioglossum* sp.	*Tetragonula* sp.	
8 - 9 am	16.00 (4.0)	4.00 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	80.00 (20)	25
9 -10 am	13.73 (7)	7.84 (4)	5.88 (3)	5.88 (3)	3.92 (2)	15.69 (8)	15.69 (8)	31.37 (16)	51
10 - 11 am	14.86 (22)	6.76 (10)	22.30 (33)	18.24 (27)	8.11 (12)	8.78 (13)	10.14 (15)	10.81 (16)	148
11-12 N	12.64 (33)	6.13 (16)	31.42 (82)	19.54 (51)	13.03 (34)	6.51 (17)	4.21 (11)	6.51 (17)	261
12 – 1 pm	15.09 (35)	8.19 (19)	29.31 (68)	19.83 (46)	13.79 (32)	6.03 (14)	5.60 (13)	2.16 (5)	233
1 - 2 pm	14.67 (22)	14.00 (21)	26.00 (39)	25.33 (38)	11.33 (17)	2.00 (3)	4.67 (7)	2.00 (3)	150
2 - 3 pm	34.69 (17)	22.45 (11)	12.24 (6)	6.12 (3)	12.24 (6)	0.00 (0)	2.04 (1)	10.20 (5)	49
3 - 4 pm	47.83 (11)	30.43 (7)	4.35 (1)	0.00 (0)	8.70 (2)	0.00 (0)	4.35 (1)	4.35 (1)	23
4 - 5 pm	61.54 (8)	23.08 (3)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	7.69 (1)	12
Insects observed (Nos)	**159**	**92**	**233**	**168**	**105**	**55**	**56**	**84**	**952**

*Figures in parenthesis are number of bees recorded.

Foraging rate and foraging speed

Foraging rate of pollinators is recorded as the number of flowers visited by pollinating species at peak foraging hour per trip in vicinity. High visitation frequency of bees may increase the chances of pollen delivery on the hermaphrodite flower thus increases the chance of fruit setting. Number of flowers visited per trip by *A. c. indica* was more (6-20) followed by *A. florea* (3-11) and *B. picitarsus* (4-7). Most of the other bee species visited @ 2-5 flowers per trip (Table 5).

Foraging speed in terms of time spent on each cashew flower varied between the bee species. The time spent on a flower was minimum for collection of either pollen or nectar than collection of both. Time spent by *A. c. indica* for nectar and *P. oxybeloides* for pollen was short (i.e., 1-4 sec), while it was 3-21, 8-16 and 5-11 sec for *A. florea, B. picitarsus* and *Tetragonula* sp., respectively. *C. hieroglyphica, Lasioglossum* sp. and *Seledonia* sp. spent 2-6 sec on individual flower. The difference in the time spent on the flower by a particular bee species may be dependent on the foraging reward available.

Table 5. Foraging rate and foraging speed of important pollinators of cashew

Pollinator species	Foraging rate (Nos /trip)		Foraging speed (sec)	
	Mean	Range	Mean	Range
A. c. indica	11.2	6-20	3.0	1-4
A. florea	6.4	3-11	10.9	3-21
B. picitarsus	5.3	4-7	11.5	8-16
C. hieroglyphica	3.8	3-5	4.3	2-6
Tetragonula sp.	2.5	2-3	8.5	5-11
Lasioglossum sp. 1	2.7	2-3	3.6	2-5
P. oxybeloides	3.9	3-5	3.1	1-4
Seledonia sp.	3.7	3-5	3.3	2-5

It is observed that peak foraging period of most of the bee species is between 11.00 am and 1.00 pm (Table 6). According to earlier reports, peak anthesis of male flowers occurs between 9.00 and 11.00 am and hermaphrodite flowers during 10.00 am and 12.00 N. More than 85 % of male and hermaphrodite flowers open during forenoon hours. Peak anther dehiscence is recorded during 10.00 am and 1.00 pm. It is important to note that peak foraging period of most pollinator species coincides with peak anthesis, which is very much advantageous for effective pollination in cashew. Hence, utmost care should be taken to avoid spraying of insecticides during the peak foraging period.

Table 6. Peak foraging hours and pollen load of important bee pollinators of cashew

Pollinator species	Peak foraging hours	Pollen load/ insect (nos)	
		Mean	Range
A. c. indica	10.00 am - 3.00 pm	166.0	89 - 196
A. florea	10.00 am - 2.00 pm	49.6	41 - 66
B. picitarsus	11.00 am - 1.00 pm	804.9	524 - 924
C. hieroglyphica	11.00 am - 2.00 pm	117.1	74-134
Tetragonula sp.	08.00 am - 2.00 pm	135.1	84-156
Lasioglossum sp. 1	11.00 am - 1.00 pm	123.3	79-136
P. oxybeloides	11.00 am - 1.00 pm	813.9	502-998
Seledonia sp.	11.00 am - 1.00 pm	809.6	456- 902

Pollen load per bee is found to vary with bee species depending on the pollen collecting structures on the bee species, requirement of floral rewards, foraging behaviour and period of collection. After 2-3 visits of bees, high pollen load per bee was recorded on *B. picitarsus, P. oxybeloides* and *Seledonia* sp.

A. c. indica *B. picitarsus* *P. oxybeloides*

Fig. 21. Pollen grains of cashew on body parts of bee species.

Foraging reward

It was reported that glucose, fructose and 19 free amino acids are present in the pollen grains of cashew, with higher levels in hermaphrodite flowers compared to male flowers. Thus, the pollen of male flower is specialized for pollination and fruit set, whereas, that of hermaphrodite flower is for insect attraction. Certain bees visit cashew flowers mainly for pollen, while, few bees visit for nectar and EFN (Table 7). For *Tetragonula* sp., foraging reward is nectar from EFN following pollen and nectar. Lasioglossum bees also collect nectar from EFN besides pollen and nectar. Whereas, pollen is the major foraging reward for *B. picitarsus, C. hieroglyphica, P. oxybeloides, Lasioglossum* sp.

and *Seledonia* sp. followed by nectar. For *A. c. indica* and *A. florea*, nectar is the major foraging reward. Since pollen is the foraging reward for most of the bee species, fresh male flowers are mostly preferred. Interestingly, bees of *B. picitarsus* alight directly on the anthers of long stamen to collect pollen grains from dehisced anther lobes. Similarly, *P. oxybeloides* is able to collect pollen grains directly from anthers of long stamens at flight itself.

Almost all bee species prefer fresh flowers with white petals for foraging, however, *A. c. indica, A. florea, C. hieroglyphica* and *Seledonia* sp. also visit a day or two days old flower for nectar especially during early morning and afternoon hours but not often (Table 7). Most bees collect pollen grains followed by nectar in the same male flower or vice-versa. Nevertheless, same hermaphrodite flower gets visited by multiple bee species consequently during peak anthesis thus effecting pollination.

Table 7. Foraging reward of important bee pollinators in cashew

Bee species	Foraging reward	Preferred flower	
		♂/♀	Fresh or old
A. c. indica	Nectar > pollen	Both	Fresh > a day old
A. florea	Nectar> pollen	Both	Fresh > a day old
B. picitarsus	Pollen>nectar	♂>♀	Fresh
C. hieroglyphica	Pollen>nectar	♂	Fresh > a day old
Tetragonula sp.	Pollen > nectar from EFN > nectar	♂>♀	Fresh
Lasioglossum sp. 1	Pollen > Nectar > nectar from EFN	♂>♀	Fresh > a day old
P. oxybeloides	Pollen>Nectar	♂>♀	Fresh
Seledonia sp.	Pollen>Nectar	♂>♀	Fresh > a day old

POLLINATION EFFICIENCY IN CASHEW

Observations on the cashew trees at DCR, Puttur revealed that around 42 % of the fresh hermaphrodite flowers are devoid of any pollen grains even at the end of the day. This indicates that there is definite pollination deficit in cashew. The mean number of pollen grains per stigma was 0.2 during 10-10.30 am and, and 2.65 during the evening, which may be due to multiple visits by the bee species on the same flower during the day. A maximum of 21 pollen grains has been recorded per stigma (Table 8).

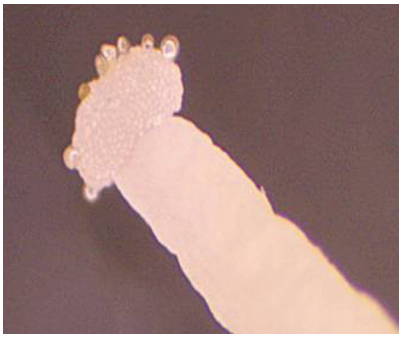

Fig. 22. Pollen grains deposited by bees on stigma

Table 8. Pollen deposition in a cashew flower at different time period of a day

Period of flower observation	Mean % of flowers without pollen grains	Mean No. of pollen grains /stigma	Max. No. of pollen grains / flower
10.00 -10.30 am	88	0.20	2
12.00 - 12.30 pm	48	2.73	16
2.00 - 2.30 pm	44	2.87	21
4.00 - 4.30 pm	42	2.65	13

As hermaphrodite cashew flower has single ovule, it needs one viable pollen grain for fertilization. However, a study in Brazil reports that more pollen loads are required for high rate of successful pollination. Viability of pollen grains (non-viable pollen grains or pollen from staminodes) accounts for the discrepancy between the large amount of pollen deposited on stigma and the resultant low rate of fertilization of ovules.

An experiment was conducted at ICAR-DCR, Puttur to understand the influence of timings of bee visits on nut set of cashew. The inflorescences with buds ready to open were tagged and the fine mesh nylon net cages were used to restrict bee visits. Care was taken to ensure no bees enter through the nylon net cages in the required treatments. Exposure of inflorescences for bee visits between T1 - 9.30 - 11.30 am, T2 - 11.30 am - 1.30 pm, T3 - 2.00 pm - 4.30 pm, T4 - 4.30 pm - 9.00 am were allowed, T5 - open pollination (not caged), T6- Caged throughout (devoid of flower visitors) and T7- hand pollination+ open pollination with five replications (Table 9). Flower counts were taken in each inflorescence and the initial as well as final nut set percentage was calculated.

Results indicated that controlled exposure of bees on flowers during different time periods has difference in nut set percentage. Nut set was more when the flowers were exposed to bees during 11.30 am - 1.30 pm followed by 9.30 am - 11.30 am. This indicates that bee visits during 11.30 am and 1.30 pm is very efficient in effecting pollination of cashew followed by visits during 9.30 am - 11.30 am. There was no nut set in flowers exposed for insect visits after 4.00 pm till 9.00 am, which indicates that nocturnal and crepuscular insects have no role in pollination of cashew. No nut set was recorded in fully caged inflorescences ensuring that insect visits are necessary for pollination. While maximum nut set was recorded under combined hand and open pollination confirming more pollination results in higher nut set.

Table 9. Nut set in cashew upon restricted bee visits

Rep	T1		T2		T3		T4		T5		T6		T7	
	♂:♀	INS %	♂:♀	INS%	♂:♀	INS%	♂:♀	INS%	♂:♀	INS%	♂:♀	INS%	♂:♀	INS%
1	1:0.19	10.64	1:0.27	10.26	1:0.42	4.08	1:0.23	1.82	1:0.30	47.06	1:0.29	0.02	1:0.30	41.18
2	1:0.29	15.49	1:0.23	9.30	1:0.10	5.88	1:0.23	0.00	1:0.37	30.95	1:0.28	0.01	1:0.27	46.15
3	1:0.38	12.73	1:0.18	22.86	1:0.23	5.66	1:0.35	0.00	1:0.30	39.34	1:0.67	0.00	1:0.29	40.68
4	1:0.13	14.71	1:0.28	12.96	1:0.34	4.44	1:0.31	2.63	1:0.30	40.74	1:0.25	0.00	1:0.32	50.00
5	1:0.28	7.69	1:0.19	4.23	1:0.20	2.04	1:0.14	0.00	1:0.35	29.69	1:0.31	0.00	1:0.20	51.02
Mean	1:0.25	12.25	1:0.23	11.92	1:0.26	4.42	1:0.25	1.11	1:0.32	37.56	1:0.37	0.01	1:0.28	45.81
FNS (%)	3.25		3.31		1.62		0		7.96		0		8.56	

INS- Initial nut set, FNS- Final nut set

A similar study conducted at West Bengal also indicated that fruit set percentage in inflorescences allowed for bee visits between 9.00 am and 1.00 pm was high compared to bees exposed between 1.00 pm - 5.00 pm, 5.00 pm - 07.00 pm. Further, higher fruit set of plants caged with bees as compared to those of open pollinated trees was also reported. Further, studies in Brazil had reported that pollen viability and stigma receptive drops to near zero in the evening of the day the flower opens. Hence, it is proved that pollination by the bees during the morning hours increases fruit set in cashew.

ADVANTAGES OF BEE KEEPING IN CASHEW

The honey bees, *A. dorsata, A. c. indica* and *A. florea* in western ghat forests are found to be well distributed. Therefore this area has tremendous scope for taking up an integrated beekeeping development programme for sustainable management.

a. Cashew fruit set and yield

Studies conducted in Brazil and Ghana indicated that enhanced bee visits (both honey bees and native bees) in the cashew plantations resulted in good yields. Detailed observations on bee visits in Brazil showed that visits by *Centris tarsata* on cashew flowers may enhance reproductive success over flower visits by *A. mellifera*, but both the bee species are found suitable for the pollination of commercially grown cashew. While, in Ghana, high nut yields of cashew were related to great diversity and abundance of native bee pollinators favoured by the cashew agro-ecosystem adopted. An increase in cashewnut yield by 116.7 per cent in Ghana and 212.5 per cent in Benin has been reported by the pollination activities of the honeybee colonies.

In Honnavar taluk of North Karnataka, though there was no significance difference observed between total number of fruits set per inflorescence in cashew orchards with and without *A. cerana* colonies, a magnitude of 19.44 to 70.37 per cent increase in number of fruits retained per inflorescence was recorded over control. This indicates that bee keeping is advantageous in increasing cashew yield. But, care should be taken to ensure the availability of other pollen and nectar sources nearby throughout the bee rearing period especially during non-flowering period of cashew.

b. Honey and other products

Besides pollination service, a variety of bee products can be obtained from the hives of honey bees which have economic value. The products are honey, royal jelly, pollen, propolis, bee wax, bee venom etc.

NESTING SITES OF POLLINATORS

Nesting sites of few common pollinators of cashew are located in the cashew plantations itself (Table 10). It is well known that *Apis* spp. make bee hives, and such bee hives were seen on cashew trunks and branches as well. Nests of *B. picitarsus* and *C. hieroglyphica* were noticed inside burrows of tiny dried sticks of cashew with neat circular entrance holes. *Tetragonula* bees nested inside holes in lamp posts, tubes and bamboo culms. Interestingly, nests of *P. oxybeloides* were noticed in barren soil exposed to sunlight as well as in the hard lateritic stones (Fig. 23c). These nests were deep inside beyond 40 cm in the hard lateritic stones. It has been reported that *Lasioglossum* sp. also nest in soil.

Table10. Nesting sites of important cashew pollinators

Bee species	Nest/nesting site
A. c. indica	Cashew trees /branches- hive
A. florea	Cashew trees /branches -hive
B. picitarsus	Dried twigs of cashew trees, mussanda
Braunsapis sp.	Dried twigs of cashew trees, mussanda
C. hieroglyphica	Dried twigs of cashew trees
Tetragonula sp.	Holes (lamp posts, tubes, bamboo culms)
P. oxybeloides	Soil, lateritic stones

Fig. 23. Nesting sites of common cashew pollinators. a. *C. hieroglyphica*, b. *B. picitarsus*, c. *P. oxybeloides*

Nesting behaviour and life cycle of *C. hieroglyphica*

Nesting sites of *C. hieroglyphica* are located in dried tiny sticks of cashew trees itself. Presence of neat circular entrance hole at the end of dried thin sticks of the cashew trees indicates the presence of bee nests. In general, the sticks having smooth cut ends especially pruned ones are occupied by the bees. Bees either make fresh nests by excavating the soft pith region of the sticks or sometimes occupy old /abandoned nests. Besides, they also rarely occupy the holes made by other insects like ants and beetles. Nests of *C. hieroglyphica* comprise of circular excavations (3.5 - 4.5mm dia.) made in the pithy region of dried sticks up to a maximum of 16 cm deep, and individual cells are separated by partitions of powdered wood. Cells with older stages are at the deeper end of nests, while that of young ones towards the entrance. Among the different bee stages, adults are more (52.7%), followed by pupal stages (20.9%). Each egg is laid on bee bread (mixture of pollen and nectar) of 5.5 - 6.0mm x 3mm size placed in separate cells. The incubation period lasts for 3 days. Grub and pupal period last for 6-8 days and 7.85 ± 0.32 days, respectively.

Fig. 24. *C. hieroglyphica* bee at nest entrance

Fig. 25. Life stages of Ceratina hieroglyphica inside a cashew stick (split opened)

Nesting behaviour and life cycle of *B. picitarsus*

Nesting sites of *B. picitarsus* are also located in dried tiny sticks of cashew trees itself. The nests of these bees are also found on mussanda plants found nearby cashew plantations. Nest entrance of *B. picitarsus* is smaller (1.5 - 3 mm) than that of *C. hieroglyphica* (4 - 4.5mm). Sometimes, the size of entrance hole is made small (2 mm) compared to its inner nest space (3.0 - 4.0 mm) by circular sealing with a mixture of wood powder. The nests have no partitions and all the stages from egg to adult are found together within a short space at the posterior end of the nest. A maximum of 23 bees of different developmental stages were recorded in single nest, in which 8 were adults. Unlike *C. hieroglyphica,* grubs of *B. picitarsus* were fed by the adult bees *i.e.,* progressive provisioning. Regular nest collection and observation in laboratory revealed that egg period lasted for 4-6 days, grub and pupal period lasted for more than 30 and 9-10 days, respectively. Since lab rearing of grubs was difficult as they need to be fed by pollen progressively, total grub period could not be recorded, though medium sized field collected grubs survived up to 20 days.

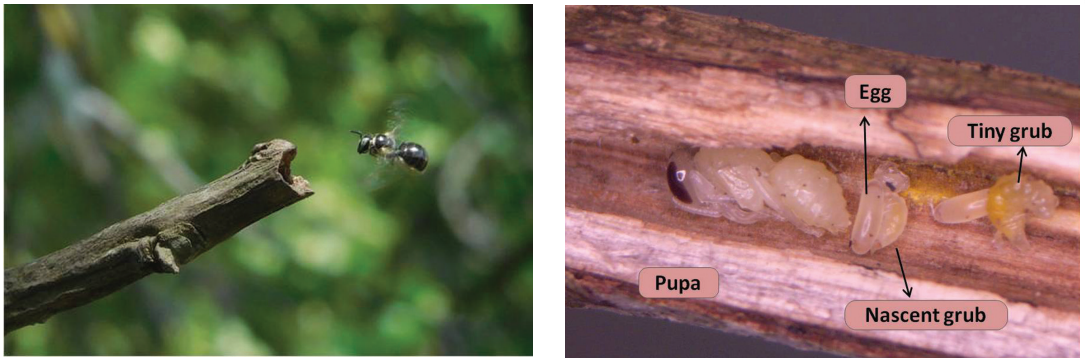

Fig. 26. Nesting behaviour of *B. picitarsus*

BEE PASTURAGE / BEE FLORA

Plants that yield pollen and nectar are collectively called 'bee pasturage' and 'bee flora'. India has wide varieties of floral geography and the bee pasturage also varies. The knowledge on bee pasturage existing in and around the cashew plantations and their flowering phenology is very important to understand the bee foraging range and choice of bee flora. The flowering plants of an area having good value as bee pasture are necessary to maintain bee colonies. In cashew plantations of ICAR-DCR, Puttur and Shantigodu, during flowering period of cashew most of the bee species forage on cashew. But during non flowering period, bees forage on surrounding wild and cultivated tree species, crops and several weed plants in and around cashew plantations. This bee pasturage is very important for the survival and conservation of bee species especially during non flowering period of cashew.

The weed species in the cashew plantations serving as bee pasturage include *Spermacoce hispida, Alternanthera* spp., *Mimosa pudica, Tridox procumbens, Lantana camara, Thevetia* sp., *Ixora* spp., *Leucas aspera, Vedalia trilobata, Melastoma malabathricum, Blumea* sp., *Passiflora foetida* etc. Flowers of perennials like *Terminalia* spp., *Caesalpinia* sp., *Antigonon leptopus, Semecarpus pranau, Peltophorum pterocarpum, Delonix regia* and *Cassia* spp. also attract plenty of bee species. Flowers of *M. pudica* attract plenty of *A. florea, Tetragonula* sp and *Ceratina* spp. While, flowers of *L. aspera* and *V. trilobata* are visited by three honey bee species *viz., A. c. indica, A. dorsata* and *A. florea* besides wild bees like *Ceratina spp. Braunsapis* sp., *Xylocopa* sp. Among the bee flora, flowers of coral creeper, *A. leptopus* (Polygonaceae) which profusely bloom throughout the year attract lot of *Braunsapis* sp., *Certaina* spp., *Apis florea, Xylocopa* sp. and few other wild bees, hence recorded as a most suitable flora for

bee species. This plant can be well utilized for conservation of bee species by planting within or near the cashew plantations.

A.cerana on V. trilobata

Tetragonula sp. on M. pudica

Bees foraging on A. leptopus

C. hieroglyphica on T. procumbens

C. hieroglyphica on L. aspera

C. hieroglyphica on V. trilobata

Fig. 27. Bee flora and the foraging bees

Earlier, visits of halictid bees on *Spermacoce ocymoides* B., *S. stricta, M. pudica, Caesalpinia mimosoides, Lindernia antipoda, Acacia pennata, Rungia repens, L. aspera, Muntingia calabura* and *Blumea* sp. in cashew plantations of coastal Karnataka were reported. Whereas in Tamil Nadu, *Ocimum americanum, O. adscendens, Cleome viscosa, Oldenlandia umbellate, L. aspera* and *Celosia* sp. were found as good floral resources in cashew plantations. The knowledge on bee flora and flowering phenology helps to encourage their conservation which will lead to conservation of several bee species.

PESTICIDAL TOXICITY

Pesticides are highly toxic to pollinators. In general, pesticides are not to be used when value of bees as pollinators is more important than insect control. Insecticidal sprays could cause adverse effects on both honey bees and wild bees when they come in

direct contact with the foraging bees. In most crop species, insecticide applications are generally not recommended during blooming stage especially highly toxic group of insecticides and their toxic formulations having more residual action. Besides, wide herbicidal applications when weeds are in bloom destroy the abundant weed bee flora that serves as food resources for several bee species.

Symptoms of insecticidal poisoning recorded in honey bees are as follows:

- Dead bees near the entrance of hive or colonies, the top of frames or bottom board
- Paralyzed bees crawling on nearby objects
- Aggressiveness, fighting among bees
- Sudden decline in food storage and brood rearing
- Dead and deserted brood in the hive, depleted population
- Contaminated bee products.

Hence, the following precautions need to be followed to avoid pesticide toxicity to bees.

- Avoiding the exposure of bees to insecticides is the major step to be taken care to save bees.
- Before spraying, listed precautions with regard to bee safety mentioned in the particular pesticide label must be carefully followed.
- Close co-operation with farmers is required to avoid irrational use of pesticides during flowering season especially at peak foraging period.
- Spray schedules need to be adjusted in relation to weather conditions. Pesticides need to be sprayed only when essential, during early morning and late evening hours. Spray should be avoided during strong winds.
- The timing of insecticide application may be reconsidered if unusually low temperatures are expected that night because residues can remain toxic to bees which enter the field the following day.
- Care need to be taken that spray solution does not contact hives.
- Foraging of bees during spraying should be restricted by confining the bees inside the hives along with required food source.

MEASURES FOR BEES CONSERVATION

Despite the importance of pollinators, both honey bees and wild bee species are under threat as a result of indiscriminate use of pesticides, pests and diseases, habitat fragmentation, intensive agriculture, climate change etc. If there is decline in pollinators,

reduction in yield of crops will result. Further, loss of a pollinator species may lead to extinction of the plant species depending on it. Thus, pollinators are to be conserved to realize yield potentials of several pollinator dependent crop species including cashew. India, being a signatory for the CBD (Convention on Biological Diversity) is obliged to take up studies on the importance of pollinators which constitutes an important component of development.

The following are the common ways to conserve pollinator populations

- In general, good beekeeping practices are to be followed to avoid different kind of problems to the bees
- Monitoring decline of pollinators and taking up suitable conservation measures.
- Knowledge on pollination research and bee biology helps to understand the requirements of bees.
- Apiary sites should be selected with much care. Strong winds, damp, unhygienic conditions and of food should be avoided.
- Colonies must be protected against poisoning by reduced usage of pesticides.
- Conservation of natural habitats of bees, pollinator friendly sites, gardens etc. is essential. It is important to locate the nesting sites of the common pollinator species and make efforts to conserve them. Non-Apis bees which are solitary require entirely different kinds of nesting sites like dried stems, twigs, ground surface without vegetation etc. Out of ignorance, these nesting sites are often disturbed and the bees are destroyed which needs to be avoided.

Fig. 28. Nesting sites for *Braunsapis* spp. and *Ceratina* spp. (right) nesting sites of *P. oxybeloides (left)*

- Maintenance of suitable bee flora and wild forage. Bee conservation and management by bee flora is inexpensive and adopted activities can also improve the aesthetic value of the landscape. Simple step involves, leaving one or two metre strips in the borders of the farmland to host all year round food resources for the bees, as well as safer sites for nesting, mating, resting and refuge from natural enemies. Farmers should also minimize pesticide drift from the field to adjacent areas.
- Maintenance of undisturbed fragment / strip of forest land near cashew plantations also helps in conservation of bees. A study in Brazil showed that, cashew nut yield was highest when plantations bordered a small forest fragment and were close to the large forest fragment. Deforestation in the areas surrounding cashew plantations prevented effective pollinators from visiting cashew flowers led to reduction in yield. It was concluded that the increasing number of wild pollinator visits will increase yield of cashew, for which proximity to large forest fragments is important.
- Using artificial nesting sites/ trap nests for native bees by adopting following approach. Artificial nesting sites can be prepared by drilling holes of 2-5 mm dia. into wooden pieces. Ideally any soft wood can be used. In these pieces, as many holes as possible may be drilled using the corresponding drill bits and an electric drill. The trap nests can be placed before flowering of the crop so that solitary bees start nesting.
- Timely management of predators, parasitoids and diseases needs to be adopted. The vast Asian land-mass carries millions of feral nests (undomesticated) of native species, constituting great reservoirs of pathogenic microorganisms and parasites. Though, it is nearly impossible to keep honey bee colonies free of diseases and parasites for long periods of time, care must be taken to take up suitable control measures timely and maintain healthy vigorous colonies.
- Raising awareness of neighbours, farmers and others about the benefits of the bees.

Trap nests for *Braunsapis* spp.

Fig. 29. Artificial bee nest

Artificial bee nests consist of small wooden blocks have been developed at ICAR-DCR, Puttur for an important cashew pollinator *viz., Braunsapis* spp. Neat circular holes of 2.0 - 5 mm diameter and 7-9 cm length were made in the wooden blocks and the blocks were arranged in a stand as in Fig. 29. Besides, thin sticks of bamboo, *Lantana camara, Cenchrus* sp., and cashew of 15 -20 cm length were made as small bundles and kept in between. It was observed that, bigger holes in wooden blocks were occupied by Megachilids, *Ceratina* sp. besides a lot of wasps and Tetragonula sp. Whereas, medium sized holes (2.5 to 3 mm dia.) were successfully occupied by *Braunsapis* sp. (>60%) during the course of time. The tiny sticks with holes especially of bamboo and *Cenchrus* sp. were also well occupied by *Braunsapis* sp. Thus, establishing such artificial bee nests could help in conserving these bees which in turn help in pollination of cashew and other plants.

Fig. 30. Nests occupied by *Braunsapis* sp.

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