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STUDIES ON THE CHALCIDID PUPAL PARASITOIDS OF THE COCONUT CATERPILLAR *OPISINA ARENOSELLA* WALKER IN KERALA, INDIA

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The coconut caterpillar *Opisina arenosella* Walker has a *Brachymeria* – dominated parasitoid community in Kerala, among which *Brachymeria nosatoi* Habu is the most important species, followed by *B. nephantidis* Gahan. The females of *B. nosatoi*, *B. nephantidis*, *B. atteviae* Joseph *et al.*, *B. lasus* (Walker) and *Antrocephalus hakonensis* (Ashm.) are monandrous, but their males are polygynous. *B. nosatoi* possesses the essential attributes of an effective biocontrol agent. It adheres to rigid selection of males and elaborate courtship, provides higher percentage parasitism, breeds well in summer months and prolonged drought conditions and disperses uniformly in pest-infested coconut gardens. However, at present it dominates over the south Kerala tracts only.

The males of *Brachymeria*, during courtship, press the wings and abdomen of the female with their antennae from the rear, while *A. hakonensis* mounts on the female to have an antennal to antennal contact. *B. nosatoi* presses the wings (and abdomen), slightly rubs on the wings upwards, rocks the female and inseminates without jerking. *B. nephantidis* presses the wings only and inseminates with jerking. *B. lasus* places the antennae over the wings, applies more downward pressure at frequent intervals, rocks the female, slightly rubs downwards and mates without jerking. *B. atteviae* rubs the wings down and up, rocks and mates with jerking.

Mating in *Brachymeria* spp. lasts 4–12 seconds. *A. hakonensis* does not select males. Courtship is also simple and it mates with jerking, for 25 to 35 seconds. The life cycles of four species of *Brachymeria* are almost identical and completed in 12 to 20 days. Their adults survive to parasitise 2 to 3 generations of the pest. *A. hakonensis* has a longer life cycle of 16 to 23 days.

(*Key words*: *Brachymeria* spp., *Antrocephalus*, courtship behaviour, life cycle, biological suppression, *Opisina arenosella*)

INTRODUCTION

The parasitoid community of *Opisina arenosella* Walker (Lepidoptera: Oecophoridae) on coconut is unique in that it is dominated by *Brachymeria* spp. Seven species of them *B. nosatoi* Habu., *B. nephantidis* Gahan, *B. atteviae* JOSEPH, NARENDRAN & JOY (*B. hime atteviae* JOSEPH *et al.*), *B. lasus* (Walker), *B. euploeae* (Westw.) *B. excarinata* Gahan (JOSEPH *et al.*, 1973) and *B. megaspila* Cameron (PILLAI & NAIR, 1986b) parasitise the pupae of *O. arenosella* in Kerala. Among them, *B. nosatoi* is the most important one followed by *B. nephantidis* (JOY & JOSEPH, 1977a: PILLAI & NAIR, 1981). Three species of *Antrocephalus* are listed by NARENDRAN (1985) as pupal parasitoids of *O. arenosella*. They are *A. hakonensis* (Ashm.), *A. carinicep*s (Cam.) and *A. phaeospilus* Waterston. Among them, *A. hakonensis* is more common,

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even though all of them play only an insignificant role in the natural suppression of *O. arenosella*. Excepting *B. nosatoi* and *B. nephantidis*, other species of *Brachymeria* are rather unimportant, when their role in the biological suppression of the pest is taken into account. However, *B. excarinate* is a dominant parasitoid of the coleopteran, *Calopepla leayana* Latr. on the forest tree *Gmelina arborea* in Kerala (MOHANDAS, 1986).

A good deal of work on *Brachymeria* spp. had already been done by JOY & JOSEPH (1972, 1973, 1977a, 1977b), JOSEPH et al. (1973); JOY *et al.* (1978); NARENDRAN & JOSEPH (1975, 1976a); PILLAI & NAIR (1981, 1982a, 1982b) and SATPATHY & RAO (1972). According to PILLAI & NAIR (1982b) 52.3% of pupae of *O. arenosella* are suppressed by the pupal parasitoids, of which *Brachymeria* spp. claimed 49%, the share of *B. nosatoi* was 30.1%, *B. nephantidis* 15.7%, *B. lasus* 1.3%, *B. atteviae* 1.3%, *Trichospilus pupivorus* Ferr. 2.6%, *Xanthopimpla punctata* F. 0.7% and *Eurytoma albotibialis* Ashmead (hyperparasitoid) killed 0.7% population of *Brachymeria* spp. In this paper, the courtship and mating behaviours and life history of *B. atteviae* and courtship and mating behaviours of *B. nephantidis* are presented for the first time. Additional information collected on *B. nosatoi*, *B. nephantidis*, *B. lasus* and *A. hakonensis* and the salient features of *Brachymeria* spp. are also furnished.

MATERIALS AND METHODS

Courtship and mating behaviours of parasitoids were studied under a stereoscopic binocular microscope in the laboratory. The parasitoids were reared in the laboratory using the method described by PILLAI & NAIR (1982a). Pupae of *O. arenosella* remaining within the cocoons inside the silken galleries were exposed for oviposition to *B. nosatoi* and the pupae with or without cocoons (excised) to the other species of parasitoids.

About 50 adults of *B. nosatoi* comprising both sexes are released in a clean, dry cylindrical glass jar, 17.5 cm long and 6.75 cm wide, inside which 12 cm long and 6.25 cm wide cardboard piece is inserted to facilitate the parasitoids to move and rest. The mouth of the jar is closed with a piece of muslin cloth tightened with rubber bands. The bottle is kept horizontally. The parasitoids are transferred to fresh clean bottle in every 4 to 5 days. For studies on longevity of adult parasitoids, undiluted honey was provided as minute droplets on wax-coated paper continuously.

RESULTS

Salient features of Brachymeria spp.:

Under similar conditions of temperature and relative humidity, the life cycle of *B. nosatoi*, *B. nephantidis*, *B. atteviae* and *B. lasus* are almost identical. During courtship, the female parasitoid keeps her wings folded on the abdomn. Standing behind in a straight line with the female the male keeps the entire length of his anteriorly projected antennae over the middle of the female's wings covering the base to tip of the abdomen and applies pressure. The front part of the head of the male is also pressed against the tip of the wings of the female.

There is selection of males is varying degrees. The courting male should be able to apply a certain amount of pressure on the wing and abdomen of female with the antennae, which are either held closely (*B. nosatoi*, *B. nephantidis* and *B. atteviae*) or held apart is in *B. lasus*, the limit of which appears to vary in each species and the male which applies the required amount of pressure is allowed to mate. Courtship is elaborate and selection of males is rigid in *B. nosatoi*.

Insemination is quick in *Brachymeria*. t takes only 4–12 seconds and they mate vith jerking or without jerking.

Females are monandrous and the males polygynous. Host feeding is present in all species to a lesser extent. Adults are very sturdy and they survive to parasitise 2 or 3 generations of the pest. All of them are amenable to laboratory multiplication. All are affected by the hyperparasitoid *Eurytoma albotibialis* Ashm. (PILLAI & NAIR, 1985). With the exception of *B. nasatoi* all others make holes in the cocoon of the host pupa for oviposition. Disorganisation of host tissues prior to oviposition is absent with the exception of *B. nosatoi*. Superparasitism in the laboratory and multiparasitism in the field are quite common among them. Sex-ratio is favourable to female progeny. With the exception of *B. nosatoi*, others have hyperparasitic tendency as well.

Brachymeria nosatoi Habu

JOY & JOSEPH (1972) reported *B. nosatoi* for the first time from Kerala, India. It is distributed in Japan, Sri Lanka (COCK & PERERA, 1987) Lacs, the Philippines, India and New Guinea and its hosts include the cotton pink boll worm, *Pectinophora gossypiella* (Sound.), *Dioryctria splendidella* H., *Evetria cristata* W., (NARENDRAN & JOSEPH, 1975) *Conogethes* (*Dichocrocis*) *punctiferalis* (Guen.) and *Hapalia machaeralis* (Wlk.). Although oligophagous, its main host is *O. arenosella* and it breeds with perfect synchrony with this host. MOHAMED *et al.* (1982) briefly discussed its life history and mating behaviour.

B. nosatoi dominates most other pupal parasitoids of *O. arenosella*, except *Xanthopimpla punctata* F. and *X. nana nana* Schulz. in South Kerala. When simultaneous multiparasitism occurs with other *Brachymeria* spp. and *A. hakonesis*, *B. nosatoi* emerges successfully. It has high searching and dispersal capacity. It parasitises *O. arenosella* throughout the year and provides over 30% natural parasitism. It parasitises pupae with big cocoons (without making holes) and it also oviposits in pupae through the leaf (JOY & JOSEPH, 1977b).

Responding to the rapid increase of population of *O. arenosella* it also numerically increases its population, especially during summer months. It can withstand prolonged drought, high summer temperatures and low humid conditions. There was an unprecedented drought during August, 1982 to June, 1983 in Kerala. Eventhough all other pupal parasitoids were affected by drought, *B. nosatoi* was not at all affected and nearly 90% of *Brachymeria* emerged from the field-collected pupae during April to August, 1983 were *B. nosatoi*. There is no hyperparasitic tendency in *B. nosatoi*.

In days of continuous rain, especially morning hours, mating is difficult, thereby the male population increases in the field for a short period. Mating and oviposition are also rare in sultry weather conditions (JOY & JOSEPH, 1977b).

Courtship and mating:

Females usually mate in 1 to 3 days of emergence, with the earlier emerged males. Sunlight stimulates sexual activity in both the sexes. Courtship is generally long and eloborate and selection of male is very rigid. Many males usually court a female before mating occurs. The following steps lead to successful mating.

1. On recognition of the virigin female, the sexually stimulated male sways the front part of the body and establishes antennal to wing and abdominal contact with her from the rear. The female usually does not stop, kicks the male

and moves away, so the male exhibits the following courtship behaviour to make the female receptive;

a. Makes clockwise and anticlockwise swaying movements around the female in quarter, semi or full circles.

b. The male may come face to face with the female and pats on the head with the antennae, fans his wings and moves his abdomen up and down.

c. It may tap or press at the thorax of the female, standing at a 99° angle.

d. The male mounts the female from the front proceeds to the rear to dismount, takes up the usual courtship position behind the female and presses the wings.

2. When one male courts a female, it will stand behind the female in a straight line and place the closely held and anteriorly projected antennae on the middle of the abdomen over the wings and apply pressure. But, when two males court at a time, deviating from the abovementioned position, both males stand on either side of the female in 45° angles and press the wings.

3. When many males try to court a female they assemble one behind the other, the first male presses the wings of the female and others press the wings of the male just in front of it. This indicates the presence of a strong sex pheromone in tne virgin female of *B. nosatoi*, which guides the male in courtship and mating. When the female parasitoid moves, all the courting males also follow her in a line just like the bogies of a moving train. Courtship often exceeds half an hour.

4. While pressing the wings, it also rocks the female. Under the stereoscopic microscope, slight upward rubbing of the antennae over the wings, on the same place, could also be observed. Male lowers and raises his abdomen occasionally.

5. The male in courtship also kicks other intruding males.

6. He soon becomes excited, stands tall on the tarsus of the meso - and metathoracic legs and applies as much pressure as he can apply.

7. If the female is satisfied that the male is sutiable, she widens her legs, raises the abdomen and exposes the genital pocket. The male stops wing pressing, moves forward to hold her with all his legs and mates without jerking for 8 to 10 seconds. The mated female may allow other males to court subsequently, but never mates for a second time.

Oviposition:

When host pupae are offered along with the cocoons, after standing over them, the female parasitoids insert their ovipositor directly into the thoracic region of the host pupae, lacerate the internal tissues, with 40 to 50 ovipositor thrusts at a stretch, and lay eggs in them. When several females are present in the rearing jar, upto 23 eggs are found laid in a host pupa. As superparasitism is common in the laboratory, host pupae should be exposed only for four to six hours. The points of insertions become black in two days after oviposition, by which the parasitised and unparasitised pupae can be separated. Five to six days after oviposition, the abdominal segments enlarge and become darker.

Herculia nigrivitta (Walker) infesting dry leaves of coconut was recorded as a new host of *B. nosatoi*, but this appeared to be an insignificant host.

The life histories of *B. nosatoi*, *B. nephantidis* and *B. atteviae* are presented in Table 1.

Brachymeria nephantidis Gahan

This is the second important pupal parasitoid of *O. arenosella*. Unlike *B. nosatoi*, it is widely distributed in Kerala and other parts of India. In North Kerala region, *B. nephantidis* provides higher percentage parasitism than that of *B. nosatoi* (JOY & JOSEPH, 1977a). In some localities of south Kerala it may also provide higher parasitism than that by *B. nosatoi* for a short period. However, average parasitism by this does not exceed 15.7% (PILLAI & NAIR, 1982b).

B. nephantidis mates easily in laboratory cages. Compared to *B. nosatoi* it is more capable of maintaining its population in areas that are colonised by the ichneumonids, *X. punctata* and *X. nana nana*. In high humid areas near the sea shore, it often produces higher proportion of female progeny (1 male 9 females). Although oligophagous, it prefers *O. arenosella* and continues to breed in it throughout the year. It can develop in host pupae which are in the advanced stages of development as well. In areas where parasitism by *B. nosatoi* is low (eg. Badagara, Kerala) or it is absent (eg. Salem, Tamil Nadu) *B. nephantidis* has failed to take advantage of the situation to build-up its population and to suppress outbreaks of *O. arenosella* (JOY & JOSEPH, 1977a, 1977b; PILLAI & NAIR, 1989). *B. nephantidis* often acts as a facultative hyperparasitoid of *Eriborus trochanteratus* (Morley) (PILLAI & NAIR, 1986a), *Apanteles taragamae* Wilkinson and *Stomatomyia bezziana* Baranoff.

It cannot withstand continuous drought conditions. Depletion of its population occurred in Kerala during the drought period of 1982–1983. Only very few adults of *B. nephantidis* emerged from the field-collected pupae of *O. arenosella* during April to August, 1983.

Courtship and mating :

Females mate on the day they emerge or on the subsequent days, with the earlier emerged males. The courtship behaviours of *B. nephantidis* are similar to *B. nosatoi*, except steps 3, 4 and 7. The male does not rock the female or rub on the wings, but only presses the wings with the closely held antennae. It stands tall on its hind legs on becoming excited and presses the wings with maximum

TABLE 1. Life history or *Brachymeria* spp.

	B. nosatoi	*B. nephantidis*	*B. atteviae*
Pre-oviposition period (days)	4 to 5	3 to 5	4 to 5
Egg period (hours)	23 to 24	24	23.5 to 28.0
Larval period (days)	5 to 9	5 to 10	5 to 8
Pupal period (days)	6 to 10	6 to 10	6 to 9
Egg to adult periods (days)	12 to 20	12 to 20	12 to 18
Majority adult emergence (days)	14 to 18	14 to 18	14 to 16
Sex – ratio (male : female)	1 : 2.5	1 : 1.35	1 : 2
Longevity of adults (days)	30 to 115	30 to 93	30 to 155

strength. The female raises the abdomen and exposes the genital pocket. Keeping the metathoracic legs on the substratum and holding the female with the other legs, the male mates with 4 to 8 jerks. Mating lasts for 4–7 seconds.

Rearing of *B. nephantidis* in the laboratory is very easy as it accepts pupae with or without cocoon. In excised *O. arenosella* pupae, oviposition is effortless and quick, normally taking 3 to 4 minutes against 35 to 40 minutes to make a hole and oviposit in pupae which remain within cocoons. However, SATPATHY & RAO (1972) did not observe *B. nephantidis* ovipositing in naked pupae.

H. nigrivitta and *Phalacra vidhisaria* Walker (Lepidoptera: Drepanidae), a foliage feeding pest of coconut, were also recorded as hosts of *B. nephantidis*.

Brachymeria lasus (Walker)

Various aspects of this highly polyphagous species were studied in detail by NARENDRAN & JOSEPH (1976a). Besides *O. arenosella*, its hosts include many serious crop pests such as the cotton boll worms *Pectinophora gossypiella* (Sound), *Earias* spp., the teak skeletoniser, *Hapalia machaeralis* (Wlk.) and the rice skipper *Pelopidas mathias* (F.) (NARENDRAN & JOSEPH, 1976c.). As the quantity of nourishment available in the pupae of *O. arenosella* is quite inadequate for the development of *B. lasus*, more number of male progeny than females are produced when it parasitises *O. arenosella* pupae (NARENDRAN & JOSEPH, 1976b). The average parasitism by it does not exceed 0.22% to 1.33% (PILLAI & NAIR, 1981). During July-September, the pupae of *Anadevidia peponis* (F.) were observed to be heavily parasitised by *B. lasus* under field conditions and mostly female parasitoids emerged from them.

Courtship and mating:

The females mated on the day of emergence or on the subsequent days. The males of *B. lasus* are more vigorous than those of *B. nosatoi*, *B. nephantidis* and *B. atteviae*. The males in courtship lower and raise their abdomen, sway their heads and fan their wings. In some cases only the forewings are fanned. If the female kicks, the male may go to the front and tap on the head of the female with his anteannae. Circling round the female swaying is uncommon although the male makes vigorous quarter or semicircling movements. The male in courtship follows the female from the rear through the same path on which the female was moving. The female keeps her antennae almost vertically and cleans her wings and body during courtship. Standing behind the female, the male keeps his antennae apart without touching one another and keeps them over the wing and applies more downward pressure at frequent intervals with the base of the scape and pedical and rocks the female occasionally. Under the stereomicroscope slight downward and then upward rubbing on the wing with antennae could be observed. The male mates without jerks for 6 to 8 seconds.

B. lasus completed its life cycle in 12–18 days and the adult longevity upto 100 days was recorded.

Brachymeria atteviae Joseph, Narendran & Joy

Intensity of parasitism by *B atteviae* was higher at Salem, Tamil Nadu, where it parasitised 7.12% pupae (25/351) of *O. arenosella* in 1981 (PILLAI & NAIR, 1989). This oligophagous species is distributed in north and south India and it parasitises *Atteva fabriciella* Swed., *H. machaeralis* etc. (NARENDRAN, 1985).

Courtship and mating:

1. The male sways the front part of the body in sexual excitement, lowers and raises its abdomen, approaches the female from the rear and attempts to stop her with the antennae.

2. The unreceptive female folds and keeps her antenae behind her head and kicks.

3. Then the male makes swaying movements around the female in quarter, semi or in full circles like *B. nosatoi,* He may also stand face to face with the female and may rub on the head or tap at the thorax of the female with the antennae and then move to the rear to resume wing pressing.

4. With the closely held and anteriorly projected antennae, kept on the middle of the abdomen of the female, over the wings, the male applies pressure, rocks the female occasionally and rubs the wings downwards and upwards. After some time, the male becomes more excited and standing tall on the hind legs, it applies maximum downward pressure rocking the females and rubbing on the wings.

5. The female, raising the abdomen, exposes the genital pocket and holding the famle, mates with 8 to 29 jerks for 6 to 12 seconds. During each jerking, the male fans his wings.

6. The female terminates mating. The virgin female mates even 8 days after emergence.

Oviposition:

Like *B. nephantidis* and *B. lasus,* it also makes a hold in the cocoon, when pupae of *O. arenosella* along with the cocoons are offered for oviposition. Unmated females produced male progeny. Laboratory rearing is easy as it accepts naked host pupae also.

Hosts recorded include *Gangara thyrsis* Moore, *H. nigrivitta* and *P. vidhisaria.*

Antrocephalus hakonensis (Ashm).

A hakonensis, on an average, parasitises less than 1% pupae of *O. arenosella* in the field, and as such, is only an unimportant parasitoid of the pest. However, it was observed as a dominant species of parasitoid of *H. nigrivitta* infesting dry coconut leaves used in thatch or fencing. Moreover, it appears to prefer host in dried leaves rather than in green leves. In *H. nigrivitta,* the extent of parasitism by *A. hakonensis* went up to 31.25% (25/80 pupae) at Kayangulam, Kerala. This parasitoid was studied in detail by ABDURAHIMAN *et al.* (1983).

Salilent features of A. hakonensis :

This parasitoid is amenable to laboratory multiplication. Courtship is simple and there is no selection of males. The females mate immediately on emergence. Females are monandrous, but incomplete sperm transfer leads to a second mating, which was not, so far, observed in *Brachymeria spp.* The male courts the female with antennal to antennal contact on mounting. The males are aggressive and polygynous.

A. hakonensis also acts as a hyperparasitoid by ovipositing on *Apanteles taragamae* Wilkinson in the field. Puny males emerge from such cocoons. Life cycle is longer than that of *Brachymeria* spp. and longevity of adults is almost comparable to that of *Brachymeria* spp.

Courtship and mating :

There are three interesting aspects about the courtship and mating behaviours of *A. kakonensis.*

1) The virgin females always mate afer a brief resistance.

2) The first male that mounts the virgin female always succeds in mating. If the male is thrown out of her body, he immediately remounts and resumes antennation.

3) After termination of mating, the exhausted male crashes on the substratum and remains motionless for a while, after which he moves away.

On mounting the virgin female, the older male proceeds towards her head and makes contact with her antennae. Her antennae are brought to a near horizontal plane with her body and antennates in two ways.

The most common type of antennation is as described by MATHEWS (1975) in the case of the cynipid, *Diastrophus* nebulosus which produces knot gall on wild black berry, *Rubus* sp. "The male alternately strokes the inner side of each of the female's antennae with the outerside of his own corresponding antennae". The point of actual contact could not be determined. The antennation is at an average rate of 1.5 strokes per second and it lasts for 34 seconds (range 14 to 76 seconds). When the female elevates the abdomen and exposes the genital pocket the male hurriedly backs up and mates with jerking after assuming a vertical position behind the female. During mating, the male does not hold the female with his legs, but balances with the movement of his wings. It mates for 31 seconds (range 25 to 34 seconds) with 48 jerks (range 39–63). Mating is terminated by the female by virtually removing the male with her hind legs and the exhausted male crashes on the substratum for a while.

The second type of antennation is the sweeping of the antennae of the female as observed by ABDURAHIMAN *et al.* (1983).

Life cycle:

The life cycle is normally completed in 16 to 23 days, but rarely it extends up to 29 days. Adults lived for 30 to 105 days. Sex ratio of parasitoids emerged from field-collected *O. arenosella* pupae was 1:3 (Male : Female).

DISCUSSION

Among the several indigenous pupal parasitoids of *O. arenosella, B. nosatoi* is the most useful parasitoid and *B. nephantids* the second best. *B. nosatoi* has many outstanding qualities of an ideal biocontrol agent. Unlike the other species of *Brachymeria,* it does not act as a facultative hyperparasiticid. High summer temperatures and prolonged drought have no adverse effect on the rate of its multiplication. These qualities are seldom found in other species of parasitoids. *B. nosatoi* exerts strong regulatory pressure and its effect on the pest population is not highly variable. Although it was thought to be not amenable to laboratory multiplication. It can be reared in sufficient numbers in the laboratory using the method described by PILLAI & NAIR (1982*a*). Unfortunately, this species is scarce is North Kerala tracts. It will be interesting to study the factors responsible for the low percentage of its parasitism in North Kerala. *O. arenosella* is such a pest which can cause frequent outbreaks and extensive damage to coconut plantations and in south Kerala, this is averted to a great extent, by the activity of *B. nosatoi*, which is capable of suppressing nearly one third of the pupal populations.

B. nephantidis is widely distributed in India, but it suppresses only nearly one sixth of the pupal population of *O. arenosella* in south Kerala. Outbreaks of *O. arenosella* occur in areas where *B. nephantidis* is present without *B. nosatoi* (JOY & JOSEPH, 1977b).

B. lasus, B. atteviae and *A. hakonensis* are not significant species of parasitoids of *O. arenosella* in Kerala. However, parasitism by *B. atteviae* was observed to be significant at Salem, Tamil Nadu.

Courtship behaviour among *Brachymeria* includes wing fanning, lowering and raising of abdomen, swaying the front part of the body wing pressing and applying intermittent downward pressure, rocking the female and rubbing on the wings downwards and upwards or *vice versa*. Insemination is with jerking or without jerking. In *B. nosatoi*, courtship is very elaborate, selection of males also is rigid, and hence it is genetically wise. On the other hand, courtship in *A. hakonensis* is simple and it mates with the first male that happened to mount her, indicting that it is genetically unwise. Although monandrous like *Brachymeria*, inadequate insemination induces *A. hakonensis* immediately to mate for a second time.

Under identical conditions of temperatures and relative humidity, the life cycle of all the four species of *Brachymeria* is almost identical.

In areas where *Xanthopimpla nana nana* Schulz and *X. punctata* are dominant, *B. nosatoi* is unable to build up its population (PILLAI & NAIR, 1989). However *Xanthopimpla* spp. colonise only in selected territories towards the latter half of the year and they also do not uniformly disperse in all the *Opisina*- infested coconut gardens. Biological suppression of *O. arenosella* can be achieved to a very great extent by getting *B. nosatoi* established in areas where it does not occur at present. Augmentation of the population of *B. nosatoi* in north Kerala tracts will reduce the incidence of *O. arenosella* in that region.

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