Natural parasitization and biological control: case of the coconut caterpillar

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Successful biological control of insect pests often depends on reliable baseline information on natural mortality imposed by natural enemies. Generating such data requires painstaking long-term studies over considerable geographical area. We attempted to produce such data on the extent of natural pupal parasitization of Opisina arenosella (Walker) a defoliating pest of coconut palms. Pupal parasitization in 31 discrete generations across different locations in South Karnataka, India, where coconut is widely cultivated and where Opisina frequently causes serious losses, was quantified between 1999 and 2005. Each parasitoid species makes a characteristic exit hole on the host pupa, which was used to quantify the extent of parasitization. Results show that parasitoids emerged from ~44% and moths from ~41% of the pupae. Consistently, Meteoridea hutsoni (Nixon) was the dominant parasitoid of the region followed by Brachymera spp. Together, they contributed to ~90% of the pupal parasitization. There was a negative correlation between extent of parasitization by Meteoridea and that of Brachymera, and between parasitization by Meteoridea and emergence of Opisina moths. Extent of parasitization by Brachymera does not appear to have significant influence on moth emergence in the study area. Although parasitization by the two parasitoids varied with respect to seasons, the overall parasitization percentage, interestingly, remained unaffected and hovered around 50% all through the year. Finally, we comment on some of the implications of the study on the current recommendations in biological control of Opisina, and emphasize the need for long-term data on natural parasitization before arriving at ‘recommendations’ in biological control of insect pests.

Data on natural mortality in a species, generated over considerable space and time, have wide applications that include pest management. In this communication we present such data for an important pest of coconut palm, Opisina arenosella (Walker) (Lepidoptera: Oecophoridae), and suggest its implications for biological control. Opisina, commonly called coconut black-headed caterpillar, is the most important defoliator pest of coconut palms in India1,2 and Sri Lanka3. Among the few species of palms that serve as its host, coconut is the only one that is cultivated. Populations breed throughout the year in five discrete generations, each generation lasting 65–75 days4. Biological control has been the much sought-after management practice against this pest; in as much that the State Department of Horticulture, Government of Karnataka has laboratories dedicated to mass multiplication and release of larval parasitoids of Opisina (Goniozus nepanthidis Muesbeck (Bethylidae: Hymenoptera) and Bracon brevicornis Wesmeal (Braconidae: Hymenoptera)) in all the taluks where the pest is known to frequent. Perhaps one of the earliest organized attempts for biological control of an insect pest in India was the campaign against Opisina. In 1923, the erstwhile Madras Government undertook methodical mass multiplication and field releases of several parasitoids when Opisina reached alarming proportions in the Malabar and South Canara region5. Among the 45 species of parasitoids reported so far, four cause mortality at the egg stage (egg parasitoids), ten at the larval stage (larval parasitoids) and 31 at the pupal stage (pupal parasitoids) of the pest6,7 (we have considered the host stage that is finally killed by the parasitoid to classify it as egg, larval or pupal parasitoid). Pupal parasitoids of Opisina have been found to be the most diverse and the most abundant8–9. In the present study, natural parasitization of pupae of Opisina was re-
corded for 31 field generations in the dry agro-climatic zones of southern Karnataka, India, during 1999–2005 (locations are listed in Table 1). In this communication we aim not only at presenting data on the extent of natural pupal parasitization, but also at providing a broad image of the interactions among the dominant pupal parasitoids and of pupal parasitization in different seasons of the year. We discuss the implication of the study on some of the current recommendations for biological control of *Opisina*.

According to the classification of agro-climatic zones in Karnataka\(^9\), the populations of *Opisina* studied belonged to southern and eastern dry zones where annual rainfall does not generally exceed 800 mm. Here, coconut is cultivated in vast areas and infestation by *Opisina* is regularly noticed. Although artificial releases of larval parasitoids are commonly made in the locations where samples have been drawn, pupal parasitoids have never been released. Density of *Opisina* pupae in each of these locations was ≥1 per leaflet, which is higher than the economic threshold level (0.5 larvae per leaflet)\(^1\). As populations of *Opisina* have discrete generations\(^3,4\), parasitization was recorded generation-wise. Pupal cases were sampled after completion of a generation, i.e. when individuals of the next generation were in their early- and mid-larval stages. Among the samples, pupae with no emergence (intact pupal case, but dead pupa) were separated from the others. Pupal cases from which moths emerged were completely hollow, light brown in colour and the edysial cleavage line was ruptured; there was no hole on the pupal case. Pupal cases from which parasitoids emerged were blackish, tough and relatively heavier with a distinct hole. It is important to note that each parasitoid species leaves behind a characteristic exit hole on the pupal case\(^8,12\), based on which the extent of parasitization by each parasitoid within a host generation can be quantified with considerable accuracy\(^8\). The descriptions of the exit holes available in Pillai and Nair\(^8\) were reconfirmed in the present study by comparing them with the actual emergences obtained from field-collected samples. The

<table>
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<tr>
<th>Location</th>
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<th>Sample size</th>
<th>Non-emerged pupae</th>
<th>Moth emerged pupae</th>
<th>Parasitized pupae</th>
<th>Number of emergence holes of different parasitoids on pupal cases</th>
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\(^a\) Different alphabets within each location indicate different populations.
emergence hole of one of the parasitoids obtained during the study, *Meteoridea intuviso* (Nixon) (Bracconidae: Hymenoptera), does not appear in the earlier descriptions. The location of the exit hole of this parasitoid is unique, in that it is the only one that exits from the anterior tip of the host pupa. Following this procedure, data were generated from 31 different generations spread across six populations at various times (see Table 1 for details).

The pooled sample size was 7557 pupal cases, of which emergences were recorded from 6466 (Table 1). Overall, 44.22% of the pupae was parasitized by various pupal parasitoids. Moths emerged from 41.34% of pupae, while the remaining 14.44% did not have any emergence from them. An important information for those advocating biological control is that there is an almost 60% natural mortality at the pupal stage. It is essential to realize that this is an underestimation, as it excludes those that were predated upon.

Among parasitoids, *Meteoridea* was the most dominant accounting for 70.71% of the parasitized pupae, followed by *Brachymeria* spp. (Chalcididae: Hymenoptera; 20.29% of the parasitized pupae), while all others summed up to 9.01%. (Three species of the genus *Brachymeria*—*lasus*, *nepantidis* and *attieveae* were recorded during the study. These different species have been studied together as their behaviour and development patterns are similar.) It is important to note that *Meteoridea* prevailed over other parasitoids in 29 of the 31 generations sampled (Table 1). An earlier study conducted in south interior Karnataka recorded 3.96–19.24% parasitization by *Meteoridea* at various times of a year, while parasitization by *Meteoridea* appeared to fluctuate highly in Kerala (0.36–35.64%). Parasitization by *Brachymeria* spp. has been shown to oscillate between 3 and 48% in south interior Karnataka.

In the present study, non-emerged pupae have been discarded from further analysis because of the uncertainty over the cause of death. Per cent parasitization by *Meteoridea* (36.55 ± 10.45) differed significantly from that of *Brachymeria* (10.49 ± 5.43) (Student’s *t* test; values were arcsine transformed; *t* = 12.13; *P* < 0.00; Figure 1). Correlating per cent moth emergence with per cent parasitization by *Meteoridea* and *Brachymeria* revealed an interesting pattern in their relationships. It suggested that *Meteoridea* had a negative relation with the number of moths that emerged (Figure 2a) and with *Brachymeria* (Figure 2b), while *Brachymeria* had no relationship with the number of moths that emerged (Figure 2c). The consistent dominance of *Meteoridea* and its ability to influence the density of moths make it a potential candidate for future biological control programmes. In this context, it is also essential to note that the coefficient of variance (in per cent parasitization of *Opisina*) was lower for *Meteoridea* (28.59%) than *Brachymeria* (51.76%), which connotes relatively stable interactions between *Meteoridea* and *Opisina*. Lower variance and higher abundance for *Meteoridea* implies that *Brachymeria* might not be able to compete with it, while greater variance and relatively lower abundance for *Brachymeria* suggests that its densities are perhaps influenced by those of *Meteoridea*. Negative relation between the two parasitoids may be due to the response in *Brachymeria* densities to those of *Meteoridea*; *Brachymeria* might not influence *Meteoridea*. The extent of parasitization by *Brachymeria* is probably too low in the study area to influence moth densities. However, as suggested by the negative relation that *Brachymeria* has with *Meteoridea*, it is possible that it might be able to build substantial populations in the absence of *Meteoridea*. Interestingly, it has been discovered that populations of *Meteoridea* and *Brachymeria* are positively correlated with pupal densities of *Opisina*. It can be easily visualized that at high densities positive correlation with host pupae can explain negative correlation with host moths. Population density of *Brachymeria* recorded during the study is perhaps not enough to affect a relationship with the moths. In the absence of *Meteoridea*, Pillai and Nair mention that *Brachymeria* spp. can account for ~94% of pupal parasitization.

Data from 31 generations were grouped into those from summer (February to May; *n* = 9), rainy (June to September; *n* = 10) and winter (October to January; *n* = 12) months. Per cent parasitization by *Meteoridea* was relatively lower during summer than during the rainy and winter months (Figure 3; one-way ANOVA; values were arcsine transformed; *F* = 5.18; *P* = 0.01). This is consistent with some of the observations made earlier. However, parasitization by *Brachymeria* was higher during the summer than winter months (one-way ANOVA; values were arcsine transformed; *F* = 5.90; *P* < 0.01). In spite of these minor variations in the two major parasitoids, the proportion of parasitized *Opisina* pupae during all the

![Figure 1](image_url)
three seasons remained the same (one-way ANOVA; values were arcsine transformed; F = 1.19; P = 0.32). Therefore, practitioners of biological control can conveniently assume that ~50% of Opisina pupae are killed by parasitoids all around the year in the study area. Another study in Kerala also showed that parasitoids could bring about ~50% natural pupal mortality and that Brachymerea spp. dominated parasitization (Meteoridea was not reported to occur in these samples).

As a parasitoid of Opisina, Meteoridea was first reported from India in 1979 and was first recorded from Karnataka in 1996. During 1996–97, Meteoridea was noticed to dominate Brachymerea and other parasitoids in coastal and interior Karnataka. By 1999, Meteoridea had become the foremost pupal parasitoid of Opisina (as reflected in the present study). Prior to its incidence, reports on pupal parasitoids showed the dominance of Brachymerea. Both Meteoridea and Brachymerea are solitary endoparasitoids (one parasitoid in one host individual) and potential competitors. Although both emerge from host pupae, Meteoridea is temporarily ahead of Brachymerea, as it parasitizes Opisina in its late-larval stage; Brachymerea is a complete pupal parasitoid. Therefore, given that Opisina has discrete generations, it is possible for Meteoridea to dominate Brachymerea through sheer temporal advantage. However, if parasitization by Brachymerea could affect successful emergence of Meteoridea, the latter might not be able to gain from early parasitization. This issue needs to be resolved.

It should be noted that in spite of ~50% mortality inflicted by pupal parasitoids alone (other biotic factors like diseases, parasitoids on other host stages and predators should cause an even greater natural mortality), the populations were sufficient to impose economic losses to growers in all the orchards where samples were drawn. Therefore, if biological control needs to be effective, it is obvious that the quantum of release of natural enemies should be high and some of the present recommendations (for example, releasing one adult Brachymerea per infested palm) must be reviewed. For instance, it is common to find at least 1000 Opisina pupae per palm during moderate to severe infestation (the economic threshold level for Opisina is 0.5 individual per leaflet; there are ~200 leaflets per frond and at least ten fronds are damaged during

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**Figure 2.** Comparison between number of emergences of adults of (a) Meteoridea and Opisina, (b) Meteoridea and Brachymerea, and (c) Brachymerea and Opisina from pupae of Opisina. Emergence was determined based on the characteristics of the exit holes on pupal cases. Data presented have been pooled from 31 generations (n = 6466 emerged pupal cases; values are expressed in percentages).

**Figure 3.** Pupal parasitization of Opisina by different parasitoids during summer (black bar), rainy season (grey bar) and winter (white bar) months of the year. Whiskers indicate one standard deviation.
an outbreak). The present study indicates that at least 50% of them would be parasitized and about 70% of those parasitized would be by Meteoridea, which puts the total number of Meteoridea per palm at ~350. Similarly, the total number of active Brachymera in a palm can be estimated to be ~100. Adding one or two more might not serve any purpose.

Although Meteoridea has taken on Opisina only during the past decade in the study area, it has been able to rule over other parasitoids. Its overwhelming dominance implies that the interactions that other parasitoids had with Opisina prior to the incidence of Meteoridea should have undergone a drastic change. In orchards where Meteoridea occurs at high densities (say, exceeding 100 individuals per palm), biological control cannot be effective when releases are made in small numbers, and factors like cost of production can become prohibitive for effecting large releases. Additionally, it might also be unreasonable to take up mass releases of Brachymera in Meteoridea-dominating orchards. However, this can only be a matter of debate at this juncture; there is need for hard data to be generated.

Larval parasitoids — G. nephantis and B. brevicornis are being mass multiplied and released by parasitoid breeding laboratories located at each of the locations. These are gregarious ectoparasitoids attacking late larval stages of their host, and can potentially compete with Meteoridea. However, as parasitization by both larval parasitoids rarely crossed 10% during the entire study period⁵¹⁹, Meteoridea appears to have had few problems in building large populations. Nevertheless, there is a need to comprehend interactions between Meteoridea and the larval parasitoids, especially at higher densities of the latter.

Overall, we suggest that there has to be an impetus on generating long-term data on natural parasitization over a considerable spatial scale, which should serve as a basis for recommendations in biological control. Further, data should be periodically strengthened, because host-parasitoid and parasitoid-parasitoid interactions can be dynamic. However, generating and interpreting the data is a complex process with factors like degree of polyphagy in the insect, heterogeneity in the landscape, development stage of the metamorphic insect and varieties among the agencies of death playing major roles.


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