Acta Scientific Biotechnology (ASBT)

Volume 1 Issue 5 May 2020

Research Article

Life Cycle and Feeding Potential of *Illeis indica*, a Mycovorous Ladybird Beetle on Powdery Mildew of Mulberry

Swatilekha Garai and Kunal Sarkar*

Department of Sericulture, CSR&TI, Mysore, India

***Corresponding Author:** Kunal Sarkar, Department of Sericulture, CSR&TI, Mysore, India.

Received: February 29, 2020

Published: April 23, 2020

Abstract

Mulberry is a perennial, heterogenous, dioecious, cross pollinated fast growing tree plant. The total area under mulberry cultivation is over 3,13,000 hectares covering 19 states are Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu, Jammu and Kashmir. Powdery mildew is one of major disease of mulberry, is caused by *Phyllactinia corylea* (*Pers*) Karsts, the fungus belongs to the class Ascomycetes, order Erysiphales, and family Erisiphaceae. The fungus causes 8 - 10% loss in the annual yield of mulberry leaves, besides reducing the leaf quality Generally when disease progress, we use chemicals or fungicide for controlling the disease. The indiscriminate use of chemical fertilizer and pesticides has an adverse impact on the environment and disturbed ecological balance. Majority of the chemicals pesticides are harmful to man and animals, some of which are not easily degradable and tend to enter food chains, thereby spreading the toxic effects. The fungivorous insects *Illeis indica* is a biocontrol agent of *Phyllactinia corylea*. Keeping the view of the importance of *I. indica* as potent biocontrol agent against powdery mildew, the present study has been undertaken with the following objectives-to completely observe the morphology and biology of mycophagous insect *I. indica*, feeds on powdery mildew and to analyse the consumption rate of *I. indica* on fungal spores.

Keywords: Powdery Mildew; Biological Control Agent; Morphology and Biology of *I. indica*

Introduction

Mulberry plants are extensively cultivated for silkworm rearing in tropical, sub-tropical and temperate zones, most of it belongs to the north of equator, and ranging from 50N latitude to 10S latitude (Yokoyoma, 1962).

Mulberry is a perennial, heterogenous, dioecious, cross pollinated fast growing tree plant. The total area under mulberry cultivation is over 3,13,000 hectares covering 19 states are Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu, Jammu and Kashmir. About98% of the country's total mulberry silk production comes from these states. Karnataka is the highest raw silk producer, with a production of 8121 MT of raw silk per annum and about 1,20,119 hectares of land is employed for mulberry cultivation in Karnataka.

Mulberry is affected by a number of diseases and pests. Among the disease, Powdery mildew is one of major disease of mulberry, which occurs in low temperature and high humidity. It is caused by *Phyllactinia corylea (Pers*) Karsts, the fungus belongs to the class Ascomycetes, order Erysiphales, and family Erisiphaceae. The powdery mildew are a group of fungi, which cannot be grown outside their respective hosts as they are obligate parasites. The symptom at the initial stage of infection appears as a powdery mycelial growth of the undersurface of the mature leaves in small patches. As the disease advances the lower surface of the leaves is covered with the patches which makes the leaves yellowish brown, coarser and leathery, reducing the protein (Anonymous, 1969), total sugar starch and total carbohydrate contents [1] poor performance of silkworm rearing, like prolongation of the larval period, poor cocoon crop and deterioration of cocoon characters were reported when feeding the worms with mildew affected leaves [1].

In India, powdery mildew was first reported from Ootacamund, Tamil nadu by Salmon in 1905. Besides, *P. corylea, P. guttala*, was also reported from Jabalpur causing powdery mildew on mulberry. The fungus causes 8 - 10% loss in the annual yield of mulberry leaves, besides reducing the leaf quality. There are two hyphomycetous hypoparasitic fungi of *Phyllactinia corylea* were reported by Rao and Sallia (1981).

CSR&TI, Mysore has developed the package for control of Powdery mildew, which become a serious menace in mulberry gardens of South India. The package includes the following control measures: A) Physical: Removal and burning of affected leaves, B) Cultural: adoption of wider spacing C) Chemical: 0.2% Karathene (Dinocap 30% EC/Bavistin).

Generally, when disease progress, we use chemicals or fungicide for controlling the disease. The indiscriminate use of chemical fertilizer and pesticides has an adverse impact on the environment and disturbed ecological balance. Majority of the chemicals pesticides are harmful to man and animals, some of which are not easily degradable and tend to enter food chains, thereby spreading the toxic effects.

Earliar, Kapur [2] reported that "the species of the genus *Illeis* like other genera of the tribe Phylloborini, feed on mildew is the yellow beetle which devours the mycelia and conidia of powdery mildew.

Keeping the view of the importance of *I. indica* as potent biocontrol agent against powdery mildew, the present study has been undertaken with the following objectives:

- A: To completely observe the morphology and biology of mycophagous insect *I. indica*, feeds on powdery mildew.
- B: To analyse the consumption rate of *I. indica* on fungal spores.

Materials and Methods

The detail methodology adopted during laboratory and glass house studies given below: Mulberry twigs containing mildew infected leaves and adults and grubs of the yellow beetle *I. indica,* were collected both from the mulberry fields and glass house (mulberry potted plants kept within polytunnel for powdery mildew inoculation and beetles released) CSR&TI, Mysore, Karnataka and maintained the laboratory conditions at 25 - 27 degree temperature and 70 - 80% RH.

The rearing set up was made in the laboratory in order to study the complete biology of insects. The following parameters were studied for the biology of *I. indica:*

1. Incubation Period
2. Grub (1, 2, 3, 4) duration
3. Prepupal Period
4. Pupal Period
5. Mating Period
6. Preoviposition Period
7. Oviposition Period
8. Adult Longevity: Male and Female
9. Fecundity
10. Number of egg catches
11. Egg Viability (10%)
12. Sex Ratio.

The feeding potential of predatory nature of beetle was observed besides its fungivorous character, both in laboratory and field condition. Morphology of *I. indica* was also studied using standard taxonomy keys.

Keeping the petiole of each of the infected leaves in the middle, the stem was cut on either side with a sharp knife at 1" distance from the node. Both the cut ends are plugged with wet cotton swabs. The extent of the infection was determined according to the scale of 1 to 7, as per Krishna., *et al.* [3] as follows:

- Rating 0, free
- Rating 1, traces of mildew specks
- Rating 2, 1 - 10% leaf area covered,
- Rating 3, 11 - 20% leaf area covered,
- Rating 4, 21 - 30% leaf area covered,
- Rating 5, 31 - 50% leaf area covered,
- Rating 6, 51 - 75% leaf area covered,
- Rating 7, 76 - 100% leaf area covered.

Three replications were taken for each rating of infection with one leaf in each replication, which was provided with an adult and a grub separately and kept in a covered Petridish (153 x 17 mm/149 x 20 mm). A constant was undertaken to maintain succulence of the leaves by providing to the cotton swabs from time to time. Observation was made on the feeding efficiency of *I. indica* at every 12 hours interval till the mycelia of the respective ratings of infection were cleared off. The predators were taken out while the leaves were left in the Petridishes under the same conditions for three days to observe redevelopment of mildew of the leaves if any. The rate of consumption of mildew patches by an adult beetle and a grub was calculated by the following formula:

$$\text{Consumption rate } (Cm^2/hr) = \frac{\text{Average leaf area x Rating value x Mycelia consumed (\%)} \times 100}{\text{Time in hours}}$$

SEM studies

The hatching and emergence of neonates were observed under light microscope and the samples were also fixed for SEM study. Besides mouthparts of ladybird beetle *I. indica* were also observed under SEM study.

The neonates released in separate petri dishes (7.5 x 7.5) were fed on the fungus present in patches on infected leaves. The later stage grubs were allowed to feed on fully infected mulberry leaves till they grew into adults. Growth and development of the insect as well as their feeding behaviors were observed under light microscope at regular intervals. Old mulberry leaves with exhausted fungal mass were periodically replaced with infected fresh leaves. Leaves with partially and fully consumed fungus were also processed for SEM study. Further, new samples of each stage viz., Egg to Adult of *I. indica* was kept separately for microscopic (Leitz wild M8) at different magnifications.

Samples for SEM were fixed in 2.5% Glutaraldehyde prepared in 0.2M cacodylate buffer at pH 7.2 for 4 hours at 4 degree C. The samples were washed in cacodylate buffer and then washed again

with double distilled water, dehydrated in ethanol series. The dehydrated samples were critically dried in a critical point dryer (EMS-850) using liquid CO_2 as transition fluid, the dried samples were then mounted onto copper stubs and coated by gold (20 mm thickness) in a sputter coater (EMS-550). The coated stubs were observed under scanning electron microscope (JEOL 100 CX- ASID 4D) at 20 Kv.

Results and Discussion

Morphology of I. indica

Male

Body short, 4.85 mm long and 3.26 mm wide, slightly elongated, whitish yellow in colour, pronotum1.05 mm long and 2.32 mm wide, without spots, antenna 1.37 mm. Long elytra 3.79 mm long and 2.42 mm wide, middle and apex of lateral lobes of tag men covered by setae.

Head

Head is black in colour. It measures 1.35 mm in long and 1.36 mm long and 1.26 mm wide, somewhat quadrate with slightly projected anterior side, frins pale, frontoclypeal structure indistinct, clypeus extended in front of compound eyes, mouthparts is yellowish brown, compound eyes is black, laterally projected, intraocular distance of 0.42 mm. dorsum smooth, lateral borders covered by setae, ventrum smooth, black.

Antenna

11 segmented, 1.37mm long, clavate and somewhat serrated, scape large, more longer than wide with six fine sate on inner side, pedicel as broad as long, somewhat quadrate with 2 fine setae on inner side, 1st, 2nd, 3rd segments are longer than the other segments each with one fine setae on inner side, 4th, 5th and 6th segments more of less similar, 5th segment with one long satae and 5 fine satae on inner anterolateral side, 7th, 8th and 9th segments larger than preceding segments and forms distinct club, 9th segment larger than the other, narrow at base and apically broader with 6 long setae, yellowish with brown tinge on scape and terminal segment.

Labrum

Oval, yellowish sub-rounded, lateral side covered by the setae with elevations in middle.

Mandible

0.42 mm long and 0.34 mm wide at base, somewhat triangular at broad base, apical tooth bifid, brownish, sharply pointed with depression 0.12 mm. Basal tooth small, very slightly curved and abruptly pointed, membranous prostheca 0.31 mm.

Maxilla

Cardo as broad as long, 0.23 mm, stipe longer than width, 0.33 mm long and 0.23 mm wide, galea large, hood like, 0.25 mm. long with thick dense setae, lacinia 0.12 mm long, small, simple, leaf like with fine satae on inner side, maxillary palpus 4 segmented, 0.82 mm long, basal segment small, 0.06 mm long and wide, 2nd segment.

Labium

Post mentum fused with gula, mentum broad, 0.18 mm long and 0.16 mm wide, prementum triangular, 0.23 mm long and 0.46 mm wide, apically broad and not covered by hairs labial palpus 3 segmented, 0.31 mm long, 1st segment very small, 2nd as long as broad 3rd segment bluntly pointed.

Thorax

1.79 mm long and 2.57 mm wide, prothorax broader the long, pronotum 1.05 mm long and 2.32 mm wide, quadrate, pale yellow, smooth, without spots and with rounded lateral borders, hypomerone slightly foveate, prosternum with parallel carinae, not reaching to anterior border of sternum, anterior margin of mesosternum slightly convex, metasternum slightly triangular, matendosternite Y shapped with paired arms, scutellum triangular.

Elytra

3.79 mm long and 2.42 mm wide, pale yellowish without spots, finely punctate in middle and densely punctate on outer margin, when elytra on body, it shows black stipes, elytrepipleuron pale, without punctuates, transversely broad and reaching to apex.

Hind leg

Coxa 0.88 mm long and 0.31 mm wide, shortly elongated and broad, trochanter somewhat triangular, 0.37 mm and 0.27 mm wide, cap like structure on femur with prominent denticulate process on inner side, femur elongated, 0.69 mm long and 0.35 mm wide, broad in middle, tibia more elongated, 1.54 mm long and 0.23 mm wide, cylindrical with tibial spines on all sides and without tibial spurs, tarsi3 segmented, 0.84 mm long, 1st segment elongated, 0.42 mm long with satae on inner side, 2nd segment triangular, 0.46 mm long with satae on anterior border, terminal segment 0.44 mm long, flattened, narrow at base and gradually broad towards apex and terminate into bifid claw, claw 0.16 mm long, pointed with sub quadrate basal tooth.

Abdomen

2.32 mm long and 3.16 mm wide, dorsum yellowish, ventrum pubescent, 8 terga visible, broader at base and narrower towards apex, six sternite visible, lateral border covered by satae, coxal line on 1st abdominal sternite straight, femoral line incomplete and reaching to the posterior border of sternum. Male genitalia 9th tergite 0.16 mm long and 1.47 mm wide, sipho U shapped, 10th tergite strongly transverse 0.14.mm long and 0.16 mm wide, covered by setae, apophasis 0.78 mm long elongated, base not bifid.

Sipho

Siphonal capsule 0.42 mm long and 0.37 mm wide, well developed, outer lobe quadrate, 0.16 mm long and 0.25 mm wide, inner lobe slightly curved, 0.08 mm long and 0.12 mm wide, siphonal tube immediately curved, 3.05 mm long and 0.08 mm wide uniform in width up to middle and then gradually smaller towards apex, apex curved and terminate into pointed structure with characteristic structure on curvature.

Tegmen

Tegmen stout 0.99 mm long, similar in width through length with slightly broad and flat apex, lateral lobes 0.63 mm long, narrow in middle and slightly broad rounded at apex with satae on middle and apex, median lobe 0.73 mm long, narrow towards apex and terminate hook like.

Female

Body oval, 6.21mm long and 5.27mm wide, dorsum weakly convex, pronotum 1.37 mm long and 2.74 mm wide, coarsely punctuated without spots, spermatheca 0.35 mm long and 0.10 mm wide, broadly U shapped.

Head

1.47 mm long and 1.68 mm wide, surrounded, dorsum pubescent, posterior border coated by hairs, frons black finely pubescent, fronto clypeal structure indistinct, clypeus slightly broad and extended in-front of compound eyes, surface of compound eyes glabrous, interocular distance 0.63mm, gular structures slightly distinct, tentorium with parallel arms.

Antenna

11 segmented, 1.94 mm long serrated and thin, scape large, longer than width with 7 long setae, pedicel as long as wide, sub quadrate, 1st segment longer than wide with 2 setae, 2nd and 3rd segments more or less equal, 7th and 8th segments distinctly longer than wide, 9th segment elongated, oval and truncate to apical side and covered by long setae.

Labrum

Flat, 0.32 mm long and 0.63 mm wide, oval plate like, lateral sides rounded with elevations in the middle and densely covered by the setae.

Mandible

Somewhat triangular, 0.31 mm long and 0.27 mm wide, apical tooth bifid, reddish, sharply pointed with 0.21 mm depression, basal tooth absent, membranous prostheca 0.29 mm.

Maxilla

Cardo as wide as stipe, 0.21 mm long and 0.23 mm wide, stipe more longer than width, 0.31 mm long, galea large, 0.21 mm long, spatulate and covered by thick long satae, lacinia simple, 0.10 mm long, leaf like with long setae, maxillary palpus 4 segmented, 0.99 mm long and basal segment small, 2nd segment larger than 3rd 0.35 mm long, 3rd segment small. 0.14 mm long quadrate, as wide as long, terminal segment large, 0.33 mm long and 0.84 mm wide, transverse, outer and inner border expended, capitulate with rough hairy surface.

Labium

Post mentum fused with gula, mentum squarish, 0.12 mm long and 0.18 mm wide, prementum somewhat triangular, 0.23 mm long and 0.48 mm wide, apically broad and covered by numerous fine hairs, labial palpus 3 segmented, 0.37 mm long, basal segment small. 2nd and 3rd segments more or less equal, 3rd segment slightly broad at base with narrowly and bluntly pointed apex.

Thorax

1.68 mm long and 3.16 mm wide, pronotum yellowish, 1.37 mm long and 2.74 mm wide with 2 black spots on posterior margin, spots small and subquadrate, lateral corners bluntly rounded, surface very finely punctuated and less shagreened, prosternal carinae straight, except posterior end, anterior margin mesosternum accurately marginate, metendosternite Y shaped with pair of fulcra, scutellum triangular.

Elytra

Pale yellowish 3.37mm long and 2.23mm wide, anterior corners rounded, outer border inclined towards apex and pointed, reticulate and without spots, elytralepipleuron horizontal without fovae and not reaching elytral apex.

Hind leg

Coxa-stout, 0.16 mm long and 0.42 mm wide, elongated cylindrical, trochanter 0.42 mm long and 0.35 mm wide, triangular, cap like with denticulate process on inner side femur 1.79 mm long and 0.65 mm wide large, braid in middle with coating of septate. Tibia 1.89 mm long and 0.29 mm wide, cylindrical coating of tibial spines on inner side, tarsi 3 segmented, 2nd segment 0.53 mm long with setae on anterior side, terminal segment 0.78 mm long gradually broad towards the apex and terminate into bifid claw. Claws pointed, 0.21 mm long, immediately curved with somewhat quadrate basal tooth.

Abdomen

2.59 mm long and 2.80 mm wide, yellowish six sternite visible lateral borders covered by thick hairs, coxal line nearly straight, femoral line on first abdominal sternite incomplete, reaching to posterior margin of sternite and area around femoral line smooth. Female genitalia, 9th segment tergite, a pair of 9 pleurite and a pair of hemi sternites together from ovipositer, hemisterniteoval, elongate with stylus.

Spermatheca

Broadly V shapped, 0.35 mm long and 0.10 mm wide, slightly broad at base and narrow poor apex, surface shows markings with depression on lateral side.

The observations of morphological characters of *I. indica* are closely related other species like *I. sathe* and *I. cincta* described by Sathe and Bhosle, 2001 and Krishnakumar and Maheshwari [4].

Biology of I. indica

The powdery mildew of mulberry is manifested as patches on the abaxial surface of leaves. When the disease advances, the entire abaxial surface of leaves gets covered with the fungal mass. The fungal mass consists of mycelia and enormous number of conidia borne singly on conidiophores. The mycelium is predominantly ectoparasitic except for short hyphal branches or stomatopodia which enter the leaf through stomata.

The fungivorous insect *I. indica* during its all life stages feed voraciously on *P. corylea* and its life cycle is reported on the infected mulberry leaves. Eggs are laid mostly on abaxial leaf surface, but occasionally egg cluster with less number of eggs are found also on adaxial surface. Eggs are found in cluster with 25 - 60 eggs in each cluster. The eggs are elliptical in shape and are vertically attached to the leaf surfaces by its proximal end. Each egg has 16 - 18 aeropyles circularly arranged at its distal end around a micropylar plate. The inner layer of eggshells seems to have an air layer between the vertical columns, which may help to protect the developing embryo from shocks and other damages.

Hinton, 1981 emphasized that the eggs of coccinellidae, at least those that are laid in exposed places, have an inner layer of air in the chorion between columns. In those species, the aeropyles are in a circle around the micropyle at the anterior pole of the eggs which is very much similar to those found in *I. indica*. The eggs of *I. indica* hatched out within 4-5 days in two different coccinellids viz. *Cryptolaemus montrouzieri* Mulsant and *Scymnus coccivora* Ayyar. Padmaja., *et al.* [5] reported that the incubation period of *S. coccivora* was about 50 percent longer than at 23 degree C in December than at 34.5 degree C. After the incubation period the grub inside pushes its head region along with mouthparts outwards which create a pressure on the micropylar plate and finally it wriggles out by breaking it off. The hatching is noticed in the morning hours and the newly hatched grubs feed on empty egg shells for sometime. First inster crawler measures 1.12 ± 0.003 mm in length and 0.35 ± 0.003 mm in width. After two days the first inster grubs stop feeding and settle for first moult.

After about 3 hours, the 2nd inster grub comes out its moulting stage leaving aside an exuvia and start crawling and feeding on the fungal mass. This stage of grub measures 1.69 ± 0.001 mm in length and 0.45 ± 0.001 mm in width. The 2nd stage grubs feed on conidia with conidials tock, which may be because they have a little advanced mouthparts than the earlier stage. They can't consume the mycelial mat. After 3 - 4 days of 2nd inster, the grub stops feeding and settle for 2nd moult. They freshly moulted 3rd stage grubs are almost similar to the 2nd inster except their larger size. The grubs grow upto 2.27 ± 0.021 mm in length and 0.78 ± 0.008 mm in width within 4 - 6 days of the 3rd inster. The mulberry leaves fed by the 3rd stage grubs were kept for 48 hours.to observed any growth of hyphae and it was found that mycelia do not regenerate on the leaf cleared by *I. indica*. Final inster grub measures 4.76 ± 0.014 mm in length and 1.49 ± 0.007 mm in width, and the duration of this stage is 3 - 4 days. The 4th and final inster grubs consume most of the hyphae leaving only short remnants of hyphae adjoining stomatopodia. The grubs were probably unable to pull out the stomatopodia since they have penetrated the leaf tissue and developed haustoria into mesophyll cells. However, many widely opened stomata are found in the leaf areas cleared off the mycelium by final inster grubs. Those stomata remain open probably because the final inster grubs pulled off the stomatopodia and is completed in four insters.

Before pupation the grub stops feeding and get attached to the abaxial leaf surface by its host abdominal segments, hanging head region free. The body of the grubs retract together with appendages, marking the prepupal stage. Prepupa measures 4.23 ± 0.037 mm in length and 1.75 ± 0.025 mm in width. After 1 - 2 days prepupa transforms into pupa leaving an exuvia. The freshly formed pupae are elliptical in shape and greenish in colour, which later turn yellow. The pupal period is 6 - 7 days and they measures 3.33 ± 0.053 mm in length and 2.67 ± 0.035 mm in width. Pupal periods of two coccinellids, *C. montrouzieri* and *S. coccivora* were 7 - 9 days and 5.25 - 5.60 days respectively. All the larval stages of *I. indica* have dark spots on their thoracic and abdominal segments. In the early 3 stages of grubs each thoracic segment has a pair of large spots on either sides of mid-dorsal line, and the abdominal segments have four spots each. But in the later stage of grub, in prepupa and pupa, each spot on thoracic segments is found incompletely divided into two. Of the four spots on the abdominal segments two are dorsal on either sides of mid-dorsal line and two are lateral. The dorsal spots are larger than the lateral spots. The spots on the thoracic segments and the lateral spots of the abdominal segments disappear in the pupal stage leaving only the dorsal spots on the abdominal segments. Similar spots on thoracic and abdominal segments are absent in *C. montrouzieri* and *S. coccivora*.

The observation on the sensory receptors on the labrum, maxilla and thoracic leg carried out under sensory electron microscope during the present study. Several apical sensilla known to be olfactory were observed on the distal end of the maxillary palp. A single pair of labial palp, considered to be mechanoreceptors, was also observed. A" U" shapped unguins 'pointed at tip' is located on the terminal end of the thoracic leg, which probably helps the insect to hold the infected leaves while feeding on the conidia of *P. corylea.* A large number of sensory hairs were also observed on the distal end of the thoracic leg.

The light yellow coloured adults emerge out by bursting the pupal case ventrally. The pupal exuviate mains attached to the ab axial leaf surface and freshly emerged adults short feeding on the fungal mass after some time. Compared to the other stages, the adults are larger and tapering towards the head region. All the above features were agreement with the observations on *I. indica* made by Kapur [2]. The sex ratio of *I. indica* in the present study was found 1:2.5 which was different with the sex ratio of *Scymnus* interrupts and *C. montrouzieri*, i.e. 1:1. The feeding behaviour of male and female adults of *I. indica* is similar to that of 4th stage grubs except that the adults and fast eaters. The efficiency of adults and grubs are the natural enemy for biological control of white powdery mildew disease in mulberry was studied by Bhattacharjee., *et al* [6]. They studied the rate of consumption of mycelia by adults and grubs and found that the adults were more voracious eaters than the grubs. They observed that the mildew cleared leaves and normal leaves were equally accepted by the silkworm, *B. mori* and the performance of silkworms reared on mulberry leaves recovered from mildew by the predator was at per with that of silkworm reared on healthy leaves.

On the average the premating and post-mating periods are 3.21 ± 0.056 and 11.89 ± 0.275 days respectively. The mating period is 13.33 ± 0.82 minutes while the preoviposition and oviposition periods are 3.95 ± 0.057 and 7.03 ± 0.114 days respectively. The longevity is 9.17 ± 0.75 days for males and 15.17 ± days for females, which is almost double to that of males the mated females lay eggs mostly on the infected mulberry leaves where the infection is restricted in patches. When the crawlers come out from the eggs they initially reached the periphery of a fungal patch and start eating conidia. The grubs of last insters and adults eat conidia and mycelia by a clipping movement of mandibles and proceed forward, turning their head left and right. Once cleared off the mildew by grubs and adults, no trace of mycelia was visible and the cleared leaves looked like disease free leaves. It was also observed that the fungus doesn't regenerate on a leaf cleared by *I. indica*. Further, field observations indicated that there was a drastic reduction in the infection of *P. corylea* with increased activity of the fungivorous insect *I. indica* on mulberry during September to March, the peak period of powdery mildew.

The present findings on the life stages of *I. indica*, on the recovered mulberry leaves and on the control of powdery mildew by the natural enemy, could be helpful for proper utilisation of *I. indica*, for biological control of the powdery mildew disease of mulberry.

Sl. no.	Life cycle parameters	Period (days) (mean ± sd)	Range
1	Incubation Period	4.33 ± 0.52	4 - 5
2.	**Grub Duration** 1. 2. 3. 4. Total	 2.33 ± 0.52 3.33 ± 0.52 4.83 ± 0.75 3.33 ± 0.52 13.82 ± 2.31	 2 - 3 3 - 4 4 - 6 3 - 4 12 - 17
3.	Prepupal Period	1.5 ± 0.55	1 - 2
4.	Pupal period	6.5 ± 0.55	6 - 7
5.	Mating Period	13.33 ± 0.82	12 - 14 mins
6.	Preoviposition Period	3.83 ± 0.75	3 - 5
7.	Oviposition Period	7.00 ± 0.89	6 - 8
8.	**Adult Longevity** Male Female	 9.17 ± 0.75 15.17 ± 0.75	 8 - 10 14 - 16
9.	Fecundity	95.0 ± 18.71	70 - 120
10.	Number of Egg Clutches	4.33 ± 0.82	3 - 5
11.	Egg Viability (%)	89.83 ± 5.00	82 - 93
12.	Sex Ratio	1:2.5 ± 0.45	1:2 - 1:3

Table 1: Biology of *I. indica.*

Predatory potential

It was observed from the field study that both adults and grubs of *I. indica* showed the predatory potential by feeding on mulberry aphid, Aphiscoccivora and Jassid, *Empoasca flavescens* besides its fungivorous nature on powdery mildew

Consumption of mycelia

In the mulberry fields an association of powdery mildew infected leaves, beetles and grubs of *I. indica* was observed on the ventral side of mature and over mature leaves i.e. from the top 8th leaf to the bottom leaves of a plant.

The present consumption of mycelial area by an adult beetle and a grub is presented in table 2 and 3 respectively. The data revealed that an adult could completely consume the mycelial growth in 1 - 3 ratings of infection in 24 hours 4 - 5 ratings in 36 - 48 hours and 60 - 72 hours in table 2, while a grub could clear off the mycelia of the ratings 1 - 2 in 60 hours, rating 3 in 72 hours, rating 4 - 5 in 84 hours and rating 6 in 96 hours and rating 7 in 108 hours (Table 3).

RMI						
	12hrs.	**24hrs.**	**36hrs.**	**48hrs.**	**60hrs.**	**72hrs.**
1.	71.14	100.00	-	-	-	-
2.	68.51	100.00	-	-	-	--
3.	64.36	100.00	-	-	-	-
4.	60.12	91.10	100.00	-	-	-
5.	46.42	59.40	85.91	100.00	-	-
6.	29.12	62.24	79.54	89.06	100.00	-
7.	19.43	31.54	60.02	74.92	94.36	100.00
CD at 5%	5.14	5.63	15.36	20.42	12.31	11.26

Table 2: Consumption of Mycelial area (%) by an adult of I. indica.

*RMI: Rating of mildew infection

The rate of consumption of mycelial area by an adult beetle and a grub was measured in Cm^2/hour. And is presented in table 2 and 3 respectively. Voracity was found to be always more in adults than the grubs and directly proportional to the intensity of infection in both cases.

The low rate of consumption in the lower ratings might be due to the fact there were small patches of mycelial growth scattered on the leaves. After finishing one mycelial patch both adults and grubs required some time for searching another patch, while in higher ratings there was continuity of mycelial growth along the patches that made it easier for the predators to clear off the mycelial patches on a leaf uninterruptedly. Therefore, the predator could eat away more area of powdery mildew per unit time period in the higher ratings of infection.

It was observed that their feeding mechanism was always a forwarding process. They initially reached the periphery of any of the mycelial patches and started eating mycelia by clipping movement of mandibles and proceed forward, turning their head left and right. Having been cleared off the mildew patches by the insect, no trace of mycelium was found left over on those areas and the ventral surface of leaves as clear as the disease free leaves.

Both adults and grubs were found to prefer young and fresh mycelia to older ones. It was observed that no regeneration of mycelia

RMI									
	12hrs.	**24hrs.**	**36hrs.**	**48hrs.**	**60hrs.**	**72hrs.**	**84hrs.**	**96hrs.**	**108hrs.**
1.	44.27	56.71	9.32	92.41	100.00				
2.	36.14	47.02	63.19	86.14	100.00				
3.	30.11	43.22	56.07	73.00	89.00	100.00			
4.	24.31	40.41	53.10	69.14	81.01	95.19	100.00		
5.	20.44	31.02	44.91	61.36	79.36	93.01	100.00		
6.	17.30	23.55	30.01	40.63	71.11	87.19	93.29	100.00	
7.	15.17	20.22	24.36	36.46	48.71	59.36	74.31	89.00	100.00
CD at 5%	3.94	4.86	5.01	18.34	14.16	11.36	18.41	3.64	11.36

Table 3: Consumption of mycelial area (%) by an adult of I. indica.

*RMI: Rating of Mildew Infection.

was observed till the 3rd day after clearing of mycelia from the disease leaves by *I. indica*. The fungivorous nature of *I. indica* feeding on mycelia and conidia of powdery mildew by Kapur [2] was confirmed by the present observation [8,9].

Conclusion

Keeping the view of the importance of *I. indica* as potent biocontrol agent against powdery mildew, the present study has been undertaken with the following objectives-to completely observe the morphology and biology of mycophagous insect *I. indica*, feeds on powdery mildew and to analyse the consumption rate of *I. indica* on fungal spores.

Acknowledgement

I am very much thankful for getting opportunity to acknowledged those respective persons who i helped me directly that Dr. S. Rajdurai, SRO, Pest management laboratory, CSR&TI, Mysore for his guidance, invaluable help, and wise counseling conferred by him, right from selection of the topic and successful completion of that. I am also thankful to my co- guide Dr. Vineet Kumar, SRO OF Electron Microscopic Unit, CSR&TI, Mysore… who always provided constructive input useful interpretations, fruitful advices, full cooperation as well as valuable suggestions, throughout my study period.

Bibliography

1. Noamani KR., *et al*. "Studies on the effect of feeding multivoltine silkworm (*B. mori*) larvae with mildew affected mulberry leaves". *Indian Journal of Sericulture* 9.1 (1970): 49-52.

2. Kapur Aap. "The Coccinellidae (Coleoptera) of the Andamans". *Proceedings of the National Academy of Sciences, India* 32.32 (1966): 180.

3. Krishna A., *et al*. "Thickness of cuticle and epidermis in relation to show powdery mildewing in pea". *Indian Phytopathology* 40.2 (1987): 218-221.

4. Krishna Kumar R and Maheswari P. "Management of powdery mildew in mulberry using coccinellid beetles, I. cincta (Fabricious) and I. bistigmosa (Mulsant)". *Journal of the Entomological Research* 28.3 (2004): 241-246.

5. Padmaja Ch., *et al*. "Biology and predation potential of *Scymnus coccivora* Aiyar (Coccinellidae: Coleoptera) on mealy bugs". *Journal of Entomological Research* 19.1 (1995): 79-81.

6. Bhattacharjee SS., *et al*. "Control of white powdery mildew, *Phyllactinia corylea* (Pers.) Karst, with the ladybird beetle, *I. indica* Timb. (Coccinellidae: Coleoptera)". *Sericologia* 34 (1994): 485-491.

7. Itoi S., *et al*. "Studies on the powdery mildew on mulberry tree, caused by *P. corylea* (pers) Karst. (I) On the outbreak and subsequent development of the disease". *The Journal of Sericulture Science of Japan* 29 (1960): 72-78.

8. Kumar V Babu., *et al*. "Penetration and infection Process of *P. corylea* on mulberry leaf causing powdery mildew-1. Sexual stage". *Journal of Phytopathology (Berlin)* 146.10 (1988): 469-472.

9. Vineet Kumar., *et al*. "Light and SEM studies on the life stages of Illeis INDICA (TIMB.) and its predatism on *Phyllactinia corylea* (Pers.) Karst. Infecting mulberry". *Archives of Phytopathology and Plant Protection* 33 (2000): 149-159.

1. Molyneux DH., *et al.* "Rapid-Impact Interventions": How a Policy of Integrated Control for Africa's Neglected Tropical Diseases Could Benefit the Poor". *PLOS Medicine* 2.11 (2005): e336.

2. Hotez PJ and Kamath A. "Neglated tropical diseases in sub-saharan Africa: review of their prevalence, distribution and disease burden". *PLoS Neglected Tropical Diseases* 3 (2009): 412.

3. Gurarie D., *et al*. "Modelling control of Schistosoma haematobium infection prediction of long term impact of mass drug administration in Africa". *Parasite Vectors* 8.11 (2015): 529.

4. WHO. "Report of the WHO informal consultation on schistosomiasis control". Geneva, Switzerland (2012): 110.

5. Ntonifor HN and Ajayi JA. "Water contact and Schistosoma haematobium infection. A case study of some communities in Toro local government council area (TLGCA) of Bauchi state". *Nigeria Journal of Natural and Applied Sciences* 1.1 (2012): 54-59.

6. Richardson EJ., *et al.* "Schistosome infection of transgenic mice defines distinct and contrasting pathogenic roles for IL-4 and IL-13: IL-13 is a profibrotic agent". *Journal of Immunology* 164 (2016): 2585-2591.

7. Parkin DM. "The global burden of urinary bladder cancer". *Scand Journal of Urogenital Schistosomiasis* 218 (2008): 12-20.

8. Adenowo A., *et al*. "Impact of human schistosomiasis in sub-Saharan Africa". *Brazilian Journal of Infectious Diseases* 19.2 (2015): 196-205.

9. Bello YM., *et al*. "Urinary schistosomiasis in some villages around the Goronyo Dam, Sokoto State, Nigeria". *Nigerian Journal of Parasitology* 24 (2003): 109 -114.

10. Rine CR Habibu T and Jasini AM. "Epidemiology of urinary schistosomiasis among secondary school students in Lafia, Nasarawa State Nigeria". *Journal of biology, Agriculture and Healthcare* 3.2 (2013): 2224 -3208.

11. Ezhim M., *et al*. "The prevalence of urinary schistosomiasis among primary school children in a northern Nigeria population". *International Journal of Advance Research* 3.11 (2015): 511-519.

12. Badmos KB., *et al*. "Schistosomiasis presenting as acute appendicitis". *East Africa Medical Journal* 83.10 (2006): 528-532.

13. Okwori AEJ., *et al.* "Prevalence of schistosomiasis among primary school children in Gadabuke District, Toto LGA, North Central Nigeria". *British Microbiology Research Journal* 4.3 (2014): 255-261.

14. Adekoya RA. "Prevalence and factors associated with urinary schistosomiasis among school aged children, in Lafia Local Government Nasarawa State, Nigeria". Unpublished B. Sc. Research Thesis Submitted to Federal University of Lafia (2016): 7-42.

15. www.sengpielaudio.com/calculator-geommean.htm (2019).

16. Omenesa HO., *et al.* "Prevalence of urinary schistosomiasis among pupils attending primary schools in Bomo Village, Zaria Nigeria". *International Journal of Research in Engineering and Science* 3.5 (2015): 14-19.

17. Negussu N., *et al.* "Prevalence and distribution of schistosomiasis in Afder and Gode zone of Somali region, Ethiopia". *Journal of Global Infectious Diseases,* 5 (2013): 149-152.

18. Bishop HG and Akoh RI. "Risk factors, symptoms and effects of urinary schistosomiasis on anthropometric indices of school children in Zaria, Kaduna State, Nigeria". *Open Access Journal of Science* 2.1 (2018): 61-65.

19. Chigozie JU., *et al*. "Urinary Schistosomiasis Among School Age Children in Ebonyi State, Nigeria". *The International Journal of Laboratory Medicine* 2 (2007): 1.

20. Samuel U., *et al.* "Epidemiology of urinary schistosomiasis in Ilorin, Nigeria". *Cruz* 104.3 (2009): 112-124.

21. Anosike JCI., *et al*. "Prevalence of parasitic diseases among nomadic Fulanis of South-Eastern Nigeria". *Annals of Agriculture and Environmental Medicine* 11.2 (2004): 221-225.

22. Hotez PJ., *et al*. "Nigeria: ''Ground Zero'' for the high prevalence neglected tropical diseases". *PLOS Neglected Tropical Diseases* 6.7 (2012): e1600.