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Studies on certain aspects of parasitism of the silkworm, *Bombyx mori* L., by the tachinid fly, *Exorista bombycis* (Louis)

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Abstract
The investigations on parasitism of silkworm by *E. bombycis* were undertaken using PM x CSR_2 hybrid of the silkworm, *Bombyx mori* L. The study were taken in the aspects of host larval instar dependent parasitism by uzi fly under choice and no-choice conditions, parasitized host for oviposition and parasitoid density on growth and development of uzi fly. The results revealed that the female uzi fly laid considerably more number of eggs under non-choice condition when compared to choice condition on the silkworm larva. In exploited and unexploited host larvae female uzi fly preferred less for oviposition on the exploited host larvae as evidenced by the reduced number of eggs laid on such host larvae. The number of eggs laid on unexploited host larvae registered increased as compared to the exploited ones. The uzi female laid 1 to 5 eggs on considerably more number of host larvae (69) compared to laying 6 to 10 eggs on host larvae (16). Based on the above investigation it was noticed that there is a negative correlation between the number of eggs laid per host larva and the maggots emerging from the parasitized host larvae.

Keywords: *Bombyx mori*, *Exorista bombycis*, PM x CSR2 hybrid, uzi fly, maggots

1. Introduction

The tachinid fly, *Exorista bombycis* (Louis) (Diptera tachinidae), popularly known in India as uzi fly, is a serious endo-parasitoid of the silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae). The parasitoid begins its endoparasitic life by depositing eggs on the body of the silkworm larva. The eggs hatch in 2-3 days. The young maggot immediately pierces the host's integument using the pro-thoracic hook attached to its mouth and enters the host's body to lead the parasitic life. The maggot feeds voraciously on the body tissues for a period of 5-7 days and emerges out from host body as post-parasitic maggot. The post-parasitic maggot pupates in about a day's time. The pupal duration lasts 10-12 days. As such, the parasitoid completes its life cycle in 17-22 days (Narayanaswamy and Devaiah, 1998) [9]. The parasitism of the silkworm larva by *E. bombycis* results in 10-20% reduction in the cocoon yield in the southern sericultural belt comprising Karnataka, Andhra Pradesh and Tamil Nadu (Samson, 2000) [12].

It has been reported that uzi incidence in the early instars (I-III) of the silkworm rearing remains far less than that in the later instars (IV-V) (Narayanaswamy and Devaiah, 1998) [9]. This clearly indicates that parasitoid prefers grown up silkworms to the younger ones. When the younger larvae (I-III instars) are parasitized, irrespective of the parasitoid load, they die long before attaining spinning stage. By contrast, the parasitism of the host larvae in their grown up stage (IV-V instars) results in spinning of cocoons, more so, when the parasitism occurs in V instar though cocoons spun by the infested larvae would be flimsy and are not fit for commercial reeling. Further, it has also been observed that the number of eggs laid on each silkworm larva, irrespective of larval instar, is limited 2-3 eggs (Kumar, 1987; Narayanaswamy and Devaiah, 1998) [9]. However, under compelling circumstances, such as non-availability of adequate number of host larvae, uzi fly lays more number of eggs (some time in excess of 50) on each of the host larvae. Nevertheless, it seems that there exists a specific behavioral mechanism, perhaps in the form of parental care, to restrict the number of eggs to be laid on each of the host larvae. As such, this would ensure availability of adequate amount of host resources to the foraging parasitoid maggot for feeding in the host body.

2. Objectives

- To understand the influence of host larval growth stages on the rate of parasitism when provided together and independently for oviposition by uzi fly.
- To know whether uzi female prefers unparasitized host over parasitized one for oviposition.

3. Materials and Methods

The investigations on some aspects of parasitism of silkworm by *E. bombycis* were undertaken using CSR2 as well as PM x CSR2 breeds / hybrids of the silkworm, *B. mori*. The studies were conducted in the Department of Studies in Sericulture Science, University of Mysore. The treatments comprised 3 replications.

3.1 Host larval instar dependent parasitism by uzi fly under choice and no-choice conditions

The experiment contained two distinct aspects namely (1) to provide choice of host larval instars for oviposition (egg laying) by providing III, IV and V instars of silkworm together and (2) to provide the host larva of a specific instar for oviposition.

In the first aspect, III, IV and V instar larvae of PM× CSR2 were confined together to a nylon net oviposition cage (1'x1'x1') for egg laying by *E. bombycis*. Altogether, 20 larvae of each instar were used. For oviposition, 2 gravid females of uzi fly were released in to the cage. After 2 h, the host larvae were removed from the cage and examined for the presence or absence of uzi eggs and the data were recorded.

Plate 1: Uzi oviposition cage

Plate 2: Silkworm larvae being confined to uzi oviposition cage

In the second aspect related to no-choice condition, III, IV and V instar larvae of PM×CSR2 (20 each) were placed separately in oviposition cages. Then, to each of the cages, two gravid females of uzi fly were released for egg laying for a period of 1½ h. After the stipulated period of ovipotion by uzi fly, the silkworm larvae were taken out of the cages and the eggs laid on them were counted and the data were documented instar-wise.

3.2 Descriminatory ability of uzi fly between exploited and non-exploited host larvae for egg laying

The investigation was conducted to know whether the female of *E. bombycis* can identify/descriminate the host larva on which another female has oviposited previously. For this purpose, 50 larvae of silkworm (PM×CSR2 - V instar) were placed in a nylon net oviposition cage and 5 gravid females of uzi fly were allowed for egg laying for duration of 2 ½ h. After the allocated duration of oviposition, the number of eggs laid on each of host (exploited) larvae was counted and recorded. Thereafter, the larvae were marked with a blue marker pen on their thoracic region and were kept back into the oviposition cage. Further, another set of 50 fresh (non-exploited) host larvae (PM×CSR2 - V instar) were placed into the cage which had contained 50 V instar silkworm larvae on which uzi fly had laid eggs previously. Then, 5 fresh gravid females of uzi fly were released into the cage for the egg laying for a duration of 2 ½ h. Further, all the host larvae in the oviposition cage were examined for eggs laid on each larva and the data were recorded.

Data collected under different experiments were not subjected to statistical analysis. However, the results are presented only as the average values in Tables 1-5.

Plate 3: Uzi exploited silkworm larvae being marked on thoracic segment

Plate 4: Uzi females ovipositing on silkworm larvae

4. Results and Discussion

4.1 Host larval instar dependent parasitism by uzi fly under choice and non-choice conditions

4.1.1 Host larval instar dependent parasitism by uzi fly under-non choice condition

When III, IV, and V instar larvae of the silkworm, *B.mori*, were offered together for oviposition by the uzi fly, *E. bombycis*, it was found that the parasitoid female showed distinct preference for egg laying on IV and V instar larvae with the latter instar being preferred to the former as evidenced by the average number of eggs laid on each of the silkworm larvae, which was 1.04, 3.25, and 9.15, respectively. When the results were compared between the host larval instars, it was found that the average number of eggs laid on IV and V instar larvae were in excess of 2 and 6 folds, respectively over the III instar (Table 1)

4.1.2 Host larval instar dependent parasitism by under-choice condition

The egg laying pattern (the number of eggs laid) by the female of *E. bombycis* followed exactly that observed under non-choice condition, with average number of eggs laid increased with the host larval instars. The average number of eggs laid on each of the III, IV, and V instar silkworm larvae being 0.15, 1.05 and 8.00, respectively. Further, the percent increase in egg laying by uzi female on IV and V instar compared to third instar was in excess of 7 and 53 folds, respectively.

When the data for average number of eggs laid per host larva of respective instar under non-choice and choice conditions were compared, it was observed that there was several fold increase in the number of eggs laid on the larvae under non-choice condition over choice condition. However, such on increase in egg laying under non-choice condition was much greater in III instar compared to IV and V instars, with the increase in V instar being the least.

The mechanism of avoiding or minimizing oviposition on the exploited host by a parasitoid female through host marking has been demonstrated in *Trichogramma evancescens* by Salt (1937), *Ceraphractus cinctus* (Jackson, 1966), *Habrocytus cerealellae* (Fulton (1933) and *Eurytoma tibialis* (Varley, 1941). The findings of all these workers have been quoted by Patnaik (2001) [11]. The observations documented under the present investigation fall in line with those by the above investigators as also by Kumar (1987) [7] and Narayanaswamy and Devaiah (1988) [9] in *E. bombycis.* By adopting such a mechanism, the parasitoid female would be able to avoid superparasitism/multiple parasitism both of them would prove to be detrimental to the survival of its progeny.

Host size is one of the most important cues that have been employed by female parasitoid for its breeding. Whether or not the host is a natural or a factitious one, the parasitoid female, especially the gregarious one, first estimates the host size (host resources) and accordingly adjusts the egg load (clutch size) in relation to that estimate with larger hosts receiving more eggs (Hagvar and Holfsang, 1969; Omwega and Overhalt, 1997; Seko and Nakasuja, 2004) [10, 13]. The ability to estimate host size and adjust the egg load in response to resources appears to be widespread in bethylids (Legner *et al*., 1969; Gordh *et al*., 1983; Gordh and Medved, 1986) [5, 4, 8]. The mechanism of estimating host size before allocating the progeny is undoubtedly a strategy to avoid competition among the developing individuals.

From the above findings, it can be inferred as follow:

- Irresepective of whether the condition was choice or non-choice, the number of eggs laid by uzi female increased with age of the silkworm larva.
- The uzi female laid considerably more number of eggs under non-choice condition compared to choice condition on the silkworm larva of the corresponding ages.

4.1.3 Discrimination of parasitized host for oviposition by uzi fly

The average number of eggs laid on silkworm larva by uzi female stood that at 2.57 based on 40 out of 50 larvae that were provided for oviposition. When these 40 ‘exploited’ host larvae were provided for egg laying along with 40 fresh (‘unexploited’) larvae for oviposition, the average number of additional eggs laid on the exploited larvae remained much inferior (1.05) compared to that on the unexploited host larvae (3.56) (Table 2).

Further, it appeared that, in the presence exploited host larvae, the parasitoid female laid considerably more number of eggs as it deposited on an average 2.57 eggs per unexploited larva as against 3.56 eggs per unexploited host larva in the presence of exploited host larvae. Further, this works out to be a decrease of 59.14% in the number of eggs laid on the exploited larva compared to the unexploited larva (Table 3).

Furthermore, when the comparison between the average numbers of eggs laid by uzi female was made, it was observed that there was an increase in the number of eggs on the unexploited larva over the exploited ones, which work out to be 2.51. When this increase egg laying on the unexploited larvae over the exploited one was converted in to percentage, it becomes noteworthy that the increase was of the order of 239.04% (Table 4).

Gordh *et al*. (1999), quoting Salt (1961), reported that the parasitoid female discriminates the host that have been parasitized and those that haven’t been parasitized, although the ability may be imperfect or temporary. Under some circumstances, the females refrain from laying additional eggs, while under some other conditions (scarce healthy hosts) the strategy fails and they are forced to oviposit into parasitized hosts. Thus, for lack or failure of discrimination, or by break down of restraint, superparasitism ensues and competition results. The observations made using *E. bombycis* in the present investigation agree with the reports of Gordh *et al*. (1999).

Based on the perusal of the above inference can be drawn:

- The uzi female was found to discriminate the exploited host larvae from the unexploited ones.
- The uzi female showed considerably less preference for oviposition on the exploited host larvae as evidenced by the reduced number of eggs laid on such host larvae.
- There was an appreciable decrease in the number of eggs laid by uzi female when the exploited host larvae (those with uzi eggs) were provided for oviposition.
- There was a marked increase in the number of eggs laid on the unexploited host larvae compared to the exploited ones**.**

4.1.4 Impact of parasitoid density on growth and development of uzi fly

When as many as 85 V instar silkworm larvae were offered for oviposition by *E. bombycis*, it was observed that the parasitoid female laid 1-5 eggs on 69 host larvae and 6-10 eggs on only 16 larvae. This works out to be 4.31% higher number of host larvae with 1-5 eggs compared to their counterparts with 6-10 eggs. Further, the number of maggots emerging from host body decreased with increase in the number of uzi eggs laid. In other words, the percent emergence of uzi maggots decreased from 47.37% in the host larvae with one egg to a meager 10.00% in the treatment with 10 eggs per larva. Further, the decrease in the uzi maggot emergence was rapid at treatment involving three eggs per larva from where the reduction was more or less gradual (Table 5).

From the results presented in Table 5, it becomes quite evident the parasitoid female shows considerable restraint for depositing more number of eggs on each host larva as long as it has adequate number of host larvae for this purpose. The decrease in the number of maggot emergence per host larva with increase in the number of eggs laid can be explained based on the fact that the larvae with more number of eggs, obviously with more number of maggots developing in host body, wouldn't be possessing adequate amount of resources as to cater to the needs of the foraging parasitoid maggots. The maggots thus developing in such hosts wouldn't be attaining the required growth and development which would culminate in their reduced emergence, perhaps due to their decreased survival. Considerable reduction in the adult emergence consequent to enhanced parasitoid load in host system also has been reported by Aruna (2007), Veena (2008) and Gangadhar (2009) having worked on three distinct parasitoids *viz*., *Nesolynx thymus*, *Trichopria* sp. and *Tetrastichus howardi*, respectively. Similarly, Biswas and Singh (1995) too have reported the increase in total progeny and decrease in mean number of progeny per mother with increase in parasitoid density in *Lysiphlebus delhiensis.*

From above findings the following inference can be drawn:

- The uzi female laid 1-5 eggs on considerably more number of host larvae (69 in number) compared to laying 6-10 eggs on host larvae (16 in number).
- There was a negative correlation between the number of eggs laid per host larva and the maggots emerging from the parasitized host larvae.

Table 1: Host larval instar-dependent parasitism by uzi fly under choice and non-choice conditions

Sl. No.	No. of silkworm larvae	Total no. of eggs laid on III instar larvae	Average	Total no. of eggs laid on IV instar larvae	Average	Total no. of eggs laid on V instar larvae	Average
Non-Choice Condition							
1	20	28	1.40	65	3.25	183	9.15
Choice Condition							
2	20	03	0.15	21	1.05	160	8.00
Percent increase in egg laying in non-choice over choice condition		----	833.33	----	209.52	----	12.56

Table 2: Discrimination between parasitized and unparasitized host larvae for oviposition by uzi fly

Sl. No.	Parameters	Results
1.	No. of silkworm larvae provided for oviposition by uzi fly	50
2.	Total no. of silkworm larvae with uzi eggs	40
3.	Average no. of uzi eggs /larva	2.57
4.	No. of exploited silkworm larvae provided for oviposition by uzi fly	40
5.	Average no. of additional uzi eggs /larva	1.05 (3.62)
6.	No. of unexploited larvae provided for oviposition by uzi fly	40
7.	Average no. of uzi eggs /larva	3.56

Figure in parenthesis indicates the total number of eggs found on exploited host larva.

The terms "exploited silkworm larvae "collectively refer to those larvae that were previously utilized by uzi female for egg laying.

The terms "unexploited silkworm larvae" collectively refer to those larvae that were not utilized by uzi female for egg laying previously.

Table 3: Detection efficiency of uzi female for oviposition with respect to exploited host larva

Sl. No.	Parameters	Results
1.	Average no. of eggs/exploited larva	3.62
2.	Average no. of eggs/unexploited larva (first oviposition)	2.57
3.	Average no. of excess eggs/larva (second oviposition)	1.05
4.	% decrease in the no. of eggs in the exploited larva (second oviposition over the first one)	59.14

Data are based on observations on 50 silkworm larvae (V instar)

Table 4: Detection efficiency of uzi female for oviposition with respect to unexploited host larva

Sl. No.	Parameters	Results
1.	Average no. of uzi eggs/unexploited larva	3.56
2.	Average no. of uzi eggs/ exploited larva	1.05
3.	Average increase in no. of eggs/unexploited larva over exploited larva	2.51
4.	% Increase in the no. of eggs in the unexploited larva	239.04

Data are based on observations on 50 silkworm larvae (V instar)

Table 5: Relationship between the number of eggs laid per host larva (*Bombyx mori*) and the number of maggots emerging from the parasitized host.

Sl. No.	No. of eggs/ silkworm larva	No. of silkworm larvae	Total no. of eggs laid	Total no. of maggots emerged	% maggot emergence
1	1	19	19	09	47.37
2	2	09	18	07	38.88
3	3	14	42	14	23.81
4	4	17	68	15	22.06
5	5	10	50	09	18.00
6	6	04	24	04	16.67
7	7	06	42	06	14.29
8	8	04	32	04	12.50
9	9	01	09	01	11.11
10	10	01	10	01	10.00

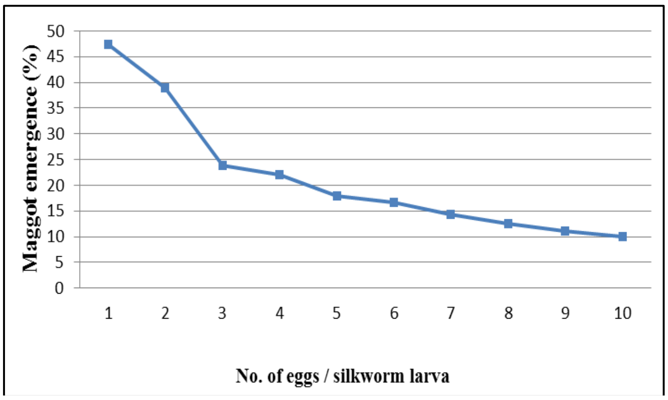

Fig 1: Relatioship between the number of uzi eggs laid per host larva (*Bombyx mori*) and the number ofuzi maggots emerging form the parasitized host

5. Conclusion

- Irrespective of whether the condition was choice or non-choice the number of eggs laid by uzi female increased with age of the silkworm larva.
- The uzi female laid considerably more number of eggs under non-choice condition compared to choice condition on the silkworm larva of the corresponding ages.
- The uzi female was found to discriminate the exploited host larvae from the unexploited ones.
- The uzi female show considerably less preference for oviposition on the exploited host larvae as evidenced by the reduced number of eggs laid on such host larvae.
- There was an appreciable decreased in the number of eggs laid by uzi female when the exploited host larvae (those with uzi eggs) were provided for oviposition
- There was a marked increase in the number of eggs laid on the unexploited host larvae compared to the exploited ones.
- There was a negative correlation between the number of eggs laid per host larva and the maggots emerging from the parasitized host larvae.
- There was a marked increased rate emergence of uzi adult from the bigger pupa.
- The uzi female fly emerging from bigger pupae lived considerably then there counterparts emerging from the smaller pupae.

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