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ON THE INCIDENCE, BIOTIC POTENCY AND CONTROL OF THE UZI FLY, *EXORISTA SORBILLANS* WIEDEMANN, A PARASITOID OF SILKWORM, *BOMBYX MORI* L.

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CHAPTER ONE

REVIEW OF LITERATURE

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The silkworm rearers in Bangladesh are menacingly facing the infestation of the Uzi fly that causes severe damage to the silkworm cocoon crops. According to Rahman and Rahman (1976, 1978), the Uzi fly is a serious larval and pupal endoparasite of silkworm in Bangladesh, which takes a heavy toll during silkworm rearing. The author reviewed related literature available up to date which are briefly presented.

HISTORICAL BACKGROUND AND TAXONOMY

Tachinid flies are known to parasitise the silkworm, *B. mori* and are called the Uzi flies. Records on the infestation of the Uzi fly on silkworm in silkgrowing countries exhibited that at least four species of this parasitoid attack the silkworm (Tanaka, 1964 and Jolly, 1967). These flies are identified as: the Japanese Uzi fly, *Crossocosmia sericariae* (Rondani); the Hime Uzi fly, *Blepharipa zebina* Walker and the Indian Uzi fly, *Exorista bombycis* (Louis). The common name "Uji" is known to appear in the history of this insect from the name of a place of Japan where the tachinid parasite of silkworm was first reported(Maxwell-Lefroy, 1917). Subsequently, it was also called "the Bengal fly pest" or "the Bengal silkworm fly" and the scientific name given to this fly was *Oestrus bengalensis*. Workers in the latter part of this century, however, named this fly as "Uzi fly" similar to the previous name

with slight alteration in the spelling (Das Gupta, 1962; Krishnaswami *et al.*, 1973; Ullal and Narasimhanna, 1981 and Jolly, 1987).

During its long history of attachment with silkworm the nomenclature of the Indian Uzi fly was a matter of controversial issue. This genus was variously named that misled the workers in identifying it in different localities of the sub-continent. Accordingly, it was called *Tricolyga*, *Tricholyga* and *Trycolyga*, only changing in spelling. However, initially it was identified as *Oestrus bombycis* (Cotes, 1889b; Stebbing, 1983; De, 1914; Ishikawa, 1934; Tanaka, 1964). The generic name *Trycolyga* persisted and it was called as *Trycolyga bombycis* (Louis) which, in fact, was the synonym of *Trycolyga sorbillans* (Wiedemann) (Crosskey, 1976). In this stage Crosskey (1976) was of the opinion that the types of *O. bombycis* Louis were wiped out. Moreover, he finally designated the generic name as *Exorista* instead of *Trycolyga*, since *Trycolyga* is the synonym of *Exorista*. Therefore, the name appeared as *Exorista sorbillans*. Siddappaji (1985) followed this nomenclature, which was also confirmed by Dr. K. M. Harris (IIE, London). Ghorpade (1986) after critically examining the Uzi flies from the collection in Karnataka state of India came to a conclusion that the Indian Uzi fly is distinctly different from *sorbillans* and thus it should go by the name *Exorista bombycis* (Louis). Very recently, an Uzi researcher in India in a National Seminar on Uzi fly and its control, 16-17 January, 1992 came to the conclusion that Indian Uzi fly is *Exorista bombycis* (Louis), which is also confirmed by a

Diptera taxonomist, Ian M. White of the IIE, London. In Bangladesh the Uzi fly, which infests the silkworm, *B. mori* was identified as *Exorista sorbillans* (Wiedemann). It may, therefore, a different species from that of the Indian species. This species was first reported in Bangladesh by Rahman and Rahman(1976) and the identification was confirmed by the IIE, London.

ABUNDANCE, HOST RANGE AND ECONOMIC IMPORTANCE

The earliest record of this pest of silkworm was reported by Louis (1880) from the then Bengal and Assam. After a long gap of time, Maxell-Lefroy (1917) reported that the Uzi fly was abundant only in Bengal, Assam and Burma and till then no case of infestation was recorded in other parts of India. Jameson (1922) was also of the opinion that this fly was exclusively abundant in Bengal and Assam. Others, however, believed that the Uzi fly was abundant in other states of India where sericulture in practised (Beeson and Chatterjee, 1935; Crosskey, 1976; Arnaud, 1978). Recent reports on Uzi infestation proved that Uzi fly was introduced in the major silkproducing state of India, Karnataka during 1980 (Datta, 1992). In subsequent years, this fly established its population in almost all the districts of Karnataka and spread to nearby states, like Andhra Pradesh and Tamil Nadu.

A good number of hosts of the Uzi fly have been reported from the order Lepidoptera. For *E. sorbillans*, Thompson (1944) reported

44 species of Lepidoptera that belong to 36 genera. Gujarati and Gangrade (1973) found that *E. sorbillans* was an important parasite on *Mocis undata* Fabricius in India. Thangavelu and Subba Rao (1982) noted severe attacks of the Uzi fly on the muga silkworm, *Antheraea assama* West. in the southern regions of Sibsagar district of Assam. Other non-mullerry silkworms like the tasar silkworm, *Antheraea mylitta* D., the eri silikworm, *Samia cynthia ricini* (Boisd.) and the oak tasar silkworm, *Antheraea proylei* Jolly are also known as the hosts of *E. sorbillans* (Kumar *et al.*, 1987).

In laboratory trial with larvae of *Spodoptera litura, Amata pasallis, Eupterote mollifera, Dicrisia obliqua, Heliothis armigera* and *Adisura atkinsoni* did not prove any impressive results in support of the alternate hosts of *E. sorbillans* (Bannerjee, 1993). Instead Kumar and Jolly (1986) showed that *E. sorbillans* preferred *B. mori* larvae than other nine Lepidopteran larvae put to the test of ovipositional preferance. Recently, Narayanaswami *et al.* (1993) reported that among 11 species of Lepidopteran larvae, the Uzi fly preferred *B. mori* larvae (54.52%) for oviposition followed by *S. c. ricini* (13.22%), *A. mylitta* (10%) *S. litura* (8.91%), *H. armigera* (7.41%), *Achoea janata* ((5.16%) and *A. atkinsoni* (0.86%). The fly, however, did not lay eggs on the larvae of *D. obliqua, Euproctis fraterna, E. mollifera* and *Atteva fabriciella.* Among the oviposition hosts, flies did not emerge from *A. atkinsoni.*

Economic losses in silkworm rearing incurred due to the attack of the Uzi fly have been reported by a number of workers. An

estimate showed that in undivided Bengal crop losses ranged between £20,0000 to £300,000 annually due this manacing fly (Cotes, 1889b; Louis, 1880). Cotes (1889b) also reported that in a single season the loss of cocoon crop went up to Rs.500,000. He also furnished a report from the observations made on silkworm rearing in West Bengal that some batches of silkworm in farmer's rearing house were destroyed to a minimum limit of 90%.

It is really impossible to assess the loss of a crop due to the infestation of the Uzi fly, since not only the fly is the cause of crop loss but some diseases, viz. grasserie and flacharie are present during the peak infestation season of the Uzi fly. Whatever it may be, the researchers working on the pest are of the opinion that the Uzi fly is a serious parasitoid of the mulberry silkworm (Mukherjee, 1912; Jameson, 1922; Das Gupta, 1962; Krishnaswami *et al.*, 1964; Bharali, 1968; Datta and Mukherjee, 1978a; Ullal and Narasimhanna, 1981; Jolly, 1987; Mathur *et al.*, 1990; Mohan *et al.*, 1991; Datta, 1992; Bannerjee, 1993). Sriharan *et al.*(1971b) reported a 40-75% parasitization by the Uzi fly in Berhampore area of West Bengal. A similar report has also been given by Siddappaji and Channa Basavanna (1981a) from the Karnataka sericulture tract. In another report, crop losses are estimated at 35-50% in major the sericulture areas of Karnataka and also in the neighbouring states of Tamil Nadu and Andhra Pradesh. The attack was so serious and beyond management that the sericulturists found no alternative than switching to some other crops (Anon., 1981). Kumar *et al.* (1987) in a report revealed that the Uzi flies cause great damages in South

East Asia, the Korean Peninsula and China. According to them, it causes considerable seasonal damages in West Bengal where cocoon crop infestation exceeds 40%. They also reported that the first appearances of the Uzi fly in the premier silk producing state, Karnataka have been known during 1980. Initially the damage recorded in heavily infested areas of Karnataka was even beyond 40%. Several farmers lost their crops completely and continuously. It had created panic to the silkgrowing farmers and the yield of silkcocoons out of rearing from mulberry silkworms was reduced to as low as 5 to 10 kg in many villages of Karnataka (Anon., 1982). It is surprising to note that the Uzi fly infestation was 81.3% on the spinning worms and 68.2% on mountages in experimental rearings (Kumar *et al.*, 1983a,b).

The Uzi fly, on the other hand, is beneficial, since it attacks various crop pests. Thus it plays a dual role, i.e. beneficial as well as harmful. It is now established that the host diversity of *E. sorbillans* is greater than *E. bombycis* (Siddappaji and Basavanna, 1990). Fortunately, the Uzi fly identified as a pest of silkworm in Bangladesh is *E. sorbillans*, which in the gap period of silkworm rearing, will definitely attack other Lepidopteian crop pests.

BIOLOGY OF THE UZI FLY

Among the pioneering workers, Cotes (1889b) had given some aspects of the life history of the Indian Uzi fly (*E. bombycis*).

Later Jameson (1922) gave a detailed description of the maggots and how they emerged from silkworm larvae and cocoons. Among the recent workers on the biology of this fly are Sriharan *et al.*(1971a,1980); Datta and Mukherjee(1978a); Siddappaji and Channa Basavanna(1981b); Kumar *et al.*(1983a); Siddappaji(1985); Kasturi Bai *et al.* (1986); Veeranna and Nirmala (1989).

Incubation and hatching

Review of literature reveal that there exists a lot of controversy on the duration of the incubation period of the Uzi fly. Jameson (1922) reported that the incubation period varied from 15-20 hours. According to Ishikawa(1934), this period ranged from 2-3 days, which is in conformity with the results of Sriharan *et al.*(1971b). The incubation period of the fly reported by Das Gupta (1962) corroborated with the information furnished by the earliest worker De (1914) who noted a range of 3-4 days. Other reports include 2.45 days (Datta and Mukherjee, 1978a) and 22 h- 2.5 days (Siddappaji, 1985). An inverse relationship of the incubation period was noted with temperature by Patil and Govindan (1984b). Recent studies of Bhat (1986) revealed that the incubation of the Uzi fly lasts from 1.48-2.53 days while Kumar and Jolly (1986) noted it as 30-60 hours. The longest incubation period (5-12 days) was reported by Thangavelu and Sahu (1986) depending upon the climatic condition in Assam. The variation in different studies could be explained due to variations in the temperature and also the rearing conditions.

The tolerable limit of temperature for hatching is 40°C beyond which no hatching was recorded(Patil and Govindan, 1984b). The percentage egghatch also vary, viz. 19.5-68.9% (Sriharan *et al.*, 1971b), 60-71% (Siddappaji, 1985), 86.50% (Kumar and Jolly, 1986) and 86.88% (Narayanaswamy, 1991).

Maggots

After hatching from egg, the first instar maggot work their way inside the host body. At this stage they are sedentary in nature and lie very close to the entry point surrounded by host tissue, the point of entry remains open which facilitate respiration. A black spot or scar appears on the body of the silkworm at the point of entry after penetration by the maggot. In fact at this point of entry a triangular black siphon is formed (Ullal and Narasimhanna, 1981 and Jolly, 1987). The maggot feeds on the tissue of the silkworm, especially the fat bodies. After completion of feeding the fullygrown maggot wriggles out of the body of the silkworm killing the host ultimately. If the infestation takes place in the later part of the fifth instar the silkworm larva can spin cocoon. Since the silkworm pupae die in the process, they become unfit for egg production and commercial reeling. The maggots come out from the silkworm cocoons, wriggle around and finally settle in the soil or cracks or crevices (Cotes, 1889a; Jameson, 1922; Ullal and Narasimhanna, 1981 and Jolly, 1987). A detailed physiological description has been given by Datta and Mukherjee (1978a). The first instar larva is a typical maggot which uniformly cylindrical. It measures on an average 0.51 mm long

and 0.28 mm wide. Further description of the cephalopharyngeal skeleton is provided by Siddappaji (1985). It consists of three parts, viz. the anterior mouth hook, the median hypostomal selerite and the posterior selerite. The cephalopharyngeal skeleton measures 0.15 mm long and 0.06 mm in height. However, it is shed off during the time of moulting.

The second instar larva is fusiform, subcylindrical and white. Segmentation on larval body is more clear than the first instar larva. The body of the larva is divided into 12 segments. The mean length of the larvae is 3.735 mm with a range of 2.142-4.284 and the breadth is 1.26 mm with a range of 0.561- 1.280. The body is broadest at the 5th abdominal segment. Non-articulate type of cephalopharyngeal skeleton is reported by Siddappaji (1985) which is highly developed and consists of anterior, intermediate and posterior regions. The cuticle is thin and transparent and the abdomen bears a number of minute brownish spines. The spines are more prominent on the ventral side. Abdominal rows of spines located at the anterior margins are projected posteriorly and those on the posterior margins are projected anteriorly. The maggot is amphipneustic. The spiracles present at the anterior end of the prothoracic segment are brownish in colour. The caudal spiracles are not visible from the dorsal side(Datta and Mukherjee, 1978a).

The maggots of the third instar are subcylindrical and fusiform. The posterior end is broadened. It is also amphipneustic. It measures 15.40 mm long (range 14.11-16.93) and 4.72 mm wide

(range 4.31-5.15) at the fullgrown stage, i.e. before pupation. In this larval instar 12 segments can be recognized easily, among which one cephalic, three thoracic and eight are abdominal. All the segments bear bands of minute spines. The cephalic segment has two pairs of sensory papillae. The dorsal pair represents the antennae and the ventral pair the maxillary palps. A long cephalopharyngeal skeleton is present, which has two articulations and is divided into three regions. The anterior region is curved and pointed, devoid of serration and is known as the mouthhook. The middle region is a H-shaped hypostomal sclerite that articulates with mouthhooks anteriorly. The salivary duct opens at the base of the hypostomal sclerite which is the largest part of the cephalopharyngeal skeleton. The floor of the pharyngeal sclerite is trough-like and smooth. The anterior spiracles are welldeveloped. They are located on the posterior margin of the prothoracic segment laterally. Each spiracle has 3-5 perforated yellow openings, called digits, at the tip. The spiracles open and close by a pinch-cock mechanism. The number of digits in the spiracle may vary in different individuals. The two posterior caudal spiracles are large and are located on the eighth abdominal segment. They are heavily sclerotized. The spiracular slits are elliptical with coil-like projections protruding into the lumen. The spiracular distance factor is 0.69 mm (range 0.50-0.71) (Siddappaji and Basavanna, 1990).

The duration of the maggot was about 4-7 days inside the host body depending on the seasonal temperatures (Cherian and Israel,

1939; Patil and Govindan, 1984a; Anon., 1971; Narayanaswamy, 1991; Sriharan *et al.*, 1971b; Datta and Mukherjee, 1978a; Siddappaji, 1985; Bhat, 1986). The duration of larval period reported by Thangavelu and Sahu (1986) was, however, much longer who noted it to be up to 12 days in the North-Eastern region of India. The mature maggots come out from the host larva and crawled for sometime and in about 6-8 hours time they were transformed into pupae (Jameson, 1922; Sriharan *et al.*, 1971b; Ayuzawa *et al.*, 1972; Datta and Mukherjee, 1978a). This period, however, depends upon the prevailing temperature. According to Siddappaji (1985) pupation time may vary from 3.84-24 hours.

Pupa

The pupa is covered within a transparent thin membrane known as the puparium. In the beginning, the puparium is whitish and afterwards it turns creamy, crimson, dull red, dark red and brownish black two days prior to eclosion. The puparium is barrelshaped with narrow rounded anterior and broadly rounded posterior end (Devaiah *et al.*, 1993). Depending on the number of maggot in a host larva the size of the puparium varied (Kumar *et al.*, 1986a). The size of the puparium also varies depending on the age of the host larvae (Patil, 1983) and the variation of host species (Narayanaswamy, 1991).

Variation in the duration of pupal period was noted which ranged from 7-18.50 days depending on the rearing season. The shortest period recovered was during March-May while the longest

being during December (Cotes, 1889a; Jameson, 1922; Das Gupta, 1962; Anon., 1971; Sriharan *et al.*, 1971a; Isarangkul *et al.*, 1972; Patil and Govindan, 1984b; Siddappaji, 1985; Bhat, 1986; Kumar and Jolly, 1986; Narayanaswamy, 1991). The longest pupal period was recorded by Beeson (1941) who noted it as 26 days during last week of September and about 55 days during the cold months of November to January. In North-East India, Thangavelu and Sahu(1986) recorded a maximum pupal duration of 24 days.

Adult

The imago breaks through the anterior end of the puparium and makes its way for emergence. The fly emerges in the morning by expending ptilinum between compound eyes (Cotes, 1889a and Narayanaswamy, 1991). Immediately after emergence the adult flies remain in congregation till their body is hardened. They become active and move toward the light source. Nector of flowers and honey dew were found to be foods of the adult Uzi flies (Cotes, 1889b and Siddappaji, 1985). For maintenance of stock cultures in the laboratory a 10-15% glucose solution as adult food helps in culturing the insect (Sriharan *et al.*, 1980 and Jahan *et al.*, 1994). The adult recovery from the puparium varied between 18.46 (Thangavelu and Sahu, 1986) to 92.25% (Narayanaswamy, 1991). The highest adult emergence, i.e. 100% was reported by Patil and Govindan (1984b) at a constant temperature of 25°C.

The adult is grayish-yellow with longitudinal stripes on the dorsal surface of the thorax and crosswise stripes on abdomen

(Ayuzawa *et al.*, 1972). According to Datta and Mukherjee (1978a), the fly is blackish-gray in colour, which is also true for *E. sorbillans* of Bangladesh. The measurements of Uzi fly recorded from solitarily parasitized specimens were 11.45 mm (range 11.12-11.62), 3.37 mm (range 3.32-3.48) and 8.79 mm (range 8.3-9.29) in length, width and wing length, respectively in males; and 10.50 mm (range 9.30-11.29), 3.36 mm (range 3.15-3.49) and 8.09 mm (range 7.64-8.47) in length, width and wing length respectively in females (Siddappaji, 1985). He also recorded the sexual dimorphism in the adult flies. The important difference between the male and female are: The lateral margins of the abdomen are covered with bristles, which are thicker on the male than on the female. The absence of proclinate orbital setae, enlarged first abdominal segment and the large pulvilli of the male along with the golden yellow stout setae which arise laterally and directed meshed around the genital aperture of the male, distinguish the male from the females. The males are stouter and longer than the females. The differences between male and female genitalia have also been discussed in detail by Siddappaji (1985) which have important taxonomic significance. Patil and Govindan (1984a) have also given detailed description of the adult Uzi fly. The cytological studies revealed that *T. bombycis* possesses five pairs of autosomes and one pair of dot-like sex chromosome (Puttaraju and Chowdaiah, 1984).

The sex-ratio in the adult Uzi flies was almost 1:1 (Anon., 1971; Datta and Mukherjee, 1978a). However, seasonal effects on sex-ratio of the adults is pronounced. Patil and Govindan (1986)

reported a sex-ratio (M:F) of 1:0.466 - 1:1.246; Thangavelu and Sahu (1986) from 1:0.83 - 1:7.00 and Narayanaswamy (1991) from 1:1.19.

Longevity of the male and female flies varies significantly. Female fly had much longer longevity than the males. Males lived for 5-15 days (Sriharan *et al.*, 1971b; Patil and Govindan, 1986; Narayanaswamy, 1991). On the other hand, female flies lived for 3-12 days (Thangavelu and Sahu, 1986), 10-15 days (Siddappaji, 1985), 10.29-14.25 days (Narayanaswamy,1991), 15.39-19 days (Kumar and Jolly, 1986), 20-25 days (Cherian and Israel, 1939), 21 days (Sriharan *et al.*, 1971b), 21.80 days (Patil and Govindan, 1984b), 5 weeks or more (King, 1940).

The adult flies become sexually mature after 1.5-2.0 days of emergence. Literature on the frequency of mating varies. Both polygamy and polyandry were observed. Within a period of 24 hours the female fly mates 2-3 times (Datta and Mukherjee, 1978a; Jolly, 1981; Narayanaswamy, 1991). Duration of mating may also vary and the records showed 10-147 minutes (Siddappaji, 1985), 2-4 hours (Anon., 1975) and 10 hours to two days (Veeranna and Nirmala, 1989) mating period of the flies. Normally mating takes place on some substratum, however, mating at flight was also recorded (Jameson, 1922 and Siddappaji, 1985). Normally, the flies mate during day time, preferably between 10 am to 1.00 pm, however, they are also seen to mate during night or in dark. The Japanese Uzi fly is known to mate several times in the forenoon (Anon., 1975).

After successful mating females enter into the rearing house and settle on the rearing tray moving on silkworm larvae of suitable size. According to Kasturibai *et al.*(1986), fourth and fifth instar larvae produce a Kairomone which is strongly attractive to the female Uzi fly, therefore, they approach to the larvae of these mature instars instead of the young larvae. It deposits eggs on the intersegmental region. Surveys in commercial rearing of silkworm indicated that a single egg is laid on host, sometimes they lay two or three or very rarely more than three eggs on a single worm. Egglaying started after one day of emergence (Sriharan *et al.*, 1971a). They start depositing eggs indiscriminately on the worms (Cotes, 1889a). During its life time the fly laid 70 to 968 eggs (De, 1914; Anon., 1971; Sriharan *et al.*, 1971b; Ayuzawa *et al.*, 1972; Sinchaisri *et al.*, 1972; Anon., 1975; Jolly, 1981; Patil and Govindan, 1984a; Siddappaji, 1985; Bhat, 1986; Devaiah and Patil, 1986; Kumar and Jolly, 1986 and Narayanaswamy, 1991). The highest number of eggs laid by the female fly was recorded under Berhampuri condition of West Bengal, India by Datta and Mukherjee (1978a) who noted up to 1180 eggs. The pre-spinning worms were found to be infested rarely and no egg laying was recorded on spinning worms on mountage (Siddappaji, 1985). A contrasting report is available from Kumar *et al.* (1983b) and Jolly and Kumar (1985) who indicated that the eggs were laid on ripe worms and worms on mountages. The peak period of oviposition was within 4-7 day after emergence.

NATURAL ENEMIES OF THE UZI FLY

In recent years a substitutional effort towards achieving biological control of the Uzi fly has begun resulting in recording and conducting biological studies on its natural enemies. Ants are known for long time as predators of the Uzi fly. *Monomorium* sp., *Tapinoma melanocephalum* (Fabricius) and *Camponotus pallidus* (Smith) were noted to pick up maggots from soil of the rearing house and also from cocoon market (Siddappaji and Basavanna, 1990). The preying mantid, *Gongylus gongaloides* L. was also known to prey upon adult Uzi fly in the backyard of the rearing house. Some spider species were also observed to prey upon adult flies (Siddappaji, 1985). House sparrow, *Passer domesticus* (L.), crow, *Corvus splendens* Vicillot, tree pie, *Dendrocitta vagabunda* (Latham), myna, *Acridotheres trestis* (L.) and drongo, *Dicrurus adsimiles* (Bechstiin) like to feed on the Uzi maggots and puparia outside the rearing house as well as in the cocoon market (Siddappaji, 1985).

Early reports showed that only a few hyperparasitoids attacked the Uzi fly. Cotes (1891-1893) reported that *Phora eleghorni* Bigot attacked the Uzi maggots the same way as the Uzi attacked the silkworm larvae. Dowden (1935) noted that *Brachymeria intermedia* Neess could attack the Uzi fly puparia and causes death of its host fly. *Mermonielle vitripennis* and *Pleurotropis* sp. were also known to parasitize the Uzi fly, which would have promise as agents of biological control (Thompson, 1944).

In recent years, efforts by various workers towards achieving biological control of the Uzi fly concentrated their attention in the search of natural enemies. The endeavour resulted in record of 11 hyperparasitoids. These are: *Brachymeria lugubris* (Walker) (Samson and Remadevi, 1985), *Dirhinus himalayanus* (Chalcididae) (Samson and Remadevi, 1985), *Nesolynx thymus* (Girault) (Kumar *et al.*, 1986b), *Trichopria* sp. (Veeranna *et al.*, 1987a), *Exoristobia philippinensis* Ashmead (Kumar and Remadevi, 1987; Ram Kishore *et al.*, 1990), *Spilomicrus Karnatekensis* Sharma (Kumar *et al.*, 1988), *Spalangia cameroni* Perkins (Kumar *et al.*, 1989a), *Pachycrepoideus vindemmiae* Rondani (Kumar *et al.*, 1889a), *Dirhinus* sp. (Kumar *et al.*, 1991), *Dirhinus anthracia* (Veeranna and Jyothi, 1988) and *Trichopria khandelansis* (Kaiser, 1991).

Veeranna *et al.* (1987a) reported the life cycle of *Trichopria* sp. Kumar *et al.* (1994) studied the biological aspects of *Brachymeria* sp. on *E. bombycis*. According to them, *Brachymeria* is a solitary larval-pupal hyperparasitoid. The developmental period from egg to adult required 26.35±1.08 days. Mean progeny production by a mated female was 156±10.35 with a sex-ratio (♂:♀) of 1:1. A single female can be able to parasitise 73.80±5.71 host puparia. Male lived for 30.20±0.83 days while the female survived for 35.0±0.79 days. Kumar *et al.* (1989b) gave a brief account on the biology and morphology of the immature stages of *N. thymus*. They reported that *N. thymus* has three larval instars and is an ecto-pupal parasite of *E. sorbillans*. The larvae are hymenopteriform with 13 body segments. Pre-pupal stage is recognized by the

appearance of the faintly developed eyes. The pupa is of exarate type. Rahman (1989) recorded the rate of parasitism of *N. thymus* in pre-pupal and pupal stages of the Uzi fly, and found the rate of parasitism to be 1:17.14 and 1:7.01 respectively in pre-pupal and pupal stages. The survival of *N. thymus* to the next generation was 38.79%.

The searching ability and parasitism(%) of the hyperparasitoids of the Uzi fly had been studied by Kumar *et al.* (1993) (Table 1).

Table 1. The searching ability and parasitism by hyperparasitoids of *E. sorbillans*

Hyperparasitoid	Searching ability (distance in ft.)	Parasitism range(%)
N. thymus	200	32.97 - 94.31
E. philippinensis	90	0.00 - 8.69
Trichopria sp.	90	0.00 - 2.65
Dirhinus sp.	200	0.00 - 66.30

According to studies conducted by Kumar *et al.* (1990a) a maximum of about 52,000 adults of *N. thymus* can be obtained by maintaining a density of 2000:500 host (1 day-old) to hyper-parasitoid (1 day-old) in 30x30x30 cm area of glass cage. Jyothi *et al.* (1993) made a comparison of some biological features like longevity, fecundity, parasitism(%), sex-ratio and life table of six hyperparasitoids of *E. bombycis* (Table 2).

Table 2. Some biological parameters of the hyperparasitoids of the Uzi fly, *E. sorbillans*

Hyperarasitoid	Longevity	Fecundity	Parasitism (%)	Sex-ratio ♂:♀
Trichopria sp.	9.95	283.33	4.236	1:2.97
E. philippinensis	19.06	334.80	4.56	1:4.59
D. anthracia	43.73	137.46	29.51	1:2.01
N. thymus	16.80	309.90	4.07	1:4.43
P. veerannai	30.60	40.20	11.0	1:3.00
Spalangia endius	15.13	12.79	-	1:3.00

Kumar *et al.* (1993) compared 12 hymenopteran as hyperparasitoid of *E. sorbillans*. Their study indicated that *N. thymus* and *Dirhinus* were efficient biocontrol agents of *E. sorbillans*. They released these hymenopterans in the field after mass multiplication in the insectary. Field studies revealed that *N. thymus* was more efficient than *Dirhinus* sp. The highest recovery (72.08%) of *N. thymus* was observed during rainy season followed by winter (59.97%) and summer (53.57%) months. On the other hand, the recovery of *Dirhinus* sp. ranged from 1.33 (rainy) to 4.61%(summer). Recently the biology of *Tetrastichus howardi* (Kishore *et al.*, 1993) and *D. anthracia* (Jyothi and Veeranna, 1993) have been studied.

The prospect of biological control of the Uzi fly is bright which demand vigorous search for the natural enemies available in our country. In Bangladesh *N. thymus* has been reported by Rahman (1989) but it has not been exploited commercially. Therefore, the establishment of insectary for mass multiplications of the hyperparasitoids of proven efficiency for large-scale evaluation in the field is highly desirable.

OTHER METHODS OF THE UZI FLY MANAGEMENT

Researchers have suggested various methods including preventive measures such as fly-proof wire mesh, mosquito nets, antroom and skip rearing (Mukherjee, 1912; Maxwell-Lefroy, 1917; Jameson, 1922; Bharali, 1968) and fish meal traps (Mohan *et al.*, 1991) for the Uzi fly management. Cultural methods such as destruction of maggots emerging from infested silkworms and cocoons; chemical methods using kerosenized water in pots exposed near windows of rearing houses to kill adults (Mukherjee, 1912), and feeding the worms with 1-3% solution of bleaching powder (Sengupta *et al.*, 1980); genetic control like using sterility techniques employing chemosterilants such as apholate (Sriharan *et al.*, 1971b); Thiotepa (Singh and Mukherjee, 1973); Tepa and Thiotepa (Datta and Mukherjee, 1978b) and regulatory quarantine methods preventing the movement of cocoon from West Bengal to Mysore (Maxwell-Lafroy, 1917) have been employed.

During the last decade some advancements have been made in the Uzi fly control (Siddappaji and Channa Basavanna, 1981a, 1983).

Though the utilization of toxic chemicals in controlling the Uzi fly pest has limited possibility because the exposed stages of the pest outside the host worm are few, and the risk of the applied chemicals becoming toxic to the silkworm itself is rather hard to overcome. However, some workers have attempted to tackle the pest by employing toxic chemicals. Diflubenzuron, which is

wellknown as a chitin inhibitor and stomach poison to insects, has been used successfully as a chemosterilant against the fly maggots in the cocoon markets (Kumar *et al.*, 1983a; Jolly and Kumar, 1985). Biswas *et al.* (1982) have reported complete sterilization of the inseminated as well uninseminated Uzi flies with diflubenzuron, tepa, thiotepa and apholate have been studied for their sterilizing effects on the Uzi fly (Das Gupta, 1962; Sriharan *et al.*, 1971b). Diflubenzuron and benzoic acid are reported to possess ovicidal action also against the Uzi fly when applied to silkworms having Uzi eggs or even before egg laying (Kumar *et al.*, 1983a; Jolly and Kumar, 1985). Since diflubenzuron is welldocumented as a chitin inhibitor and thus lethal particularly to Lepidoptera, it is to be confirmed whether this chemical is safe to the silkworm on which it is applied.

Recently a combination product has been developed by the Central Sericultural Research and Training Institute, Mysore, India and has been marketed under the name " Auxocyte " for use by the silkworm rearers against the Uzi fly (Anon., 1987). However, Auxocyte when subjected to critical tests, was found to be ineffective in killing the Uzi eggs (Siddappaji and Kotikal, 1988).

Review of literature reveals that gamma radiation has been used successfully to induce sterility in several dipterans like Mexican fruit fly, *Anastrepha ludens* Loew (Rhode *et al.*, 1961). Melon fly, *Dacus cucubitae* Coquillett (Steiner *et al.*, 1965), House fly *Musca domestica* L. (Kilgore and Doutt, 1967) etc. In all these

studies late age pupae were irradiated with gamma rays, the doses ranging between 5000 to 10,000 r.

Radiosensitivity is a basic requirement for radiation disinfestation of agricultural products. It is measured by determining the lethal or sterilizing effects on the stage of the insect involved. Occasionally, behavioural effects are determined, such as cessation of feeding or movement of the affected insect. Typically, lethality is gauged by determining the emergence of adults from the irradiated pre-adult stages or determining the survival of metamorphic stages from previous stages that were irradiated (Hasan *et al.*, 1989).

The preceeding paragraphs have brought to light certain lacunae in our knowledge on various aspects of the biology and control of the Uzi fly as well as some areas where further endeavours are solicited.

CHAPTER TWO

SEASONAL INCIDENCE AND DISTRIBUTION OF *E. SORBILLANS* IN THE LARVAE OF *B. MORI* IN DIFFERENT COMMERCIAL AREAS

2.I. Introduction

E. sorbillans poses a potential threat to the sericulture industry of Bangladesh like in many parts of the world. The fly takes a heavy toll of silkworm larvae during different rearing seasons of the year. Economic losses due to the Uzi infestation had been reported from time to time by several workers. Cotes (1889a) estimated the loss due to this parasitoid in the then Bengal to be ranging from £ 2000,000 to £ 3000,000 annually, and the fly destroyed up to 90% of *B. mori* larvae in the rearing. Crop loss due to the attack of the Uzi fly was also reported by De (1914) and Maxwell- Lefroy (1917). In India crop losses ranged from 40-80% due to the Uzi fly infestations (Sriharan *et al.*, 1971b; Kumar *et al.*, 1983b). In Bangladesh damage caused by *E. sorbillans* goes up to 80% when the farmers rear silkworm in unprotected conditions Even in careful rearings about 15-20% loss is noticed in summer and rainy rearing seasons (Rahman and Rahman, 1976,1978). However, no systematic field studies have been carried out in the sericulture areas of Bangladesh on the incidence of the Uzi fly in different rearing areas. Varied agroclimatic and rearing conditions do not reflect a comprehensive picture of the fly infestation. Knowledge on the incidence and distribution of pests like that of *E. sorbillans* in relation to seasons and regions, is a prerequisite in any pest control programme in a given area.

The present investigation deals with the incidence of the Uzi fly infestation in three major sericultural areas, e.g. Bholahat, Mirgonj and Paba, in different rearing seasons, viz. Agrahayoni (Oct.- Nov.), Chaita (Feb.- Mar.), Jaistha (Apr.-May) and Bhaduri (Jul.-Aug.) of 1994-1995.

2.II. Materials and Methods

Three traditional silkworm rearing areas, namely Bholahat, Mirgonj and Paba, located in Chapai Nawabgonj and Rajshahi districts were visited periodically from Agrahayoni season'94 to Bhaduri season'1995. The silkworm rearing conducted by the farmers were subjected to random sampling. Two thousand four hundred randomly selected larvae of an individual farmer were examined at the rate of 400 larvae from each rearing busket. Larval infestation was recorded based on the number of silkworm larvae having either the Uzi eggs or bearing scars caused by penetration of the integument of the host body by newly emerged maggots from the eggs of the Uzi flies laid on the body of silkworms. Fifth instar silkworm larvae were examined. Different rearing batches were examined throughout the period of survey comprising four rearing seasons, namely Agrahayoni(Oct.-Nov.'94), Chaita(Feb.-Mar.'95), Jaistha(Apr.-May'95) and Bhaduri(Jul.-Aug. '95). This investigation was conducted at 40 Bosoni's (rearer's) house in each rearing area and each season. Each investigation was divided into four blocks in each locality. Each block was considered as a replication in this experiment.

2.III. Results and Discussion

Incidence of the Uzi fly, *E. sorbillans* infestation was recorded in the silkworm rearings of 160 farmer's drawn from three traditional silkworm rearing localities of Nawabgonj and Rajshahi districts of Bangladesh in four rearing seasons. During the study, damages of silkworm corps due to the Uzi fly infestation were observed in the rearing area. The maximum fly infestation was observed at Mirgonj and the minimum at Paba (Table 3). The seasonal incidence of *E. sorbillans* in *B. mori* larvae is shown in Fig. 1. The maximum and minimum fly infestation occurred during the Bhaduri and Chaita rearing seasons respectively.

Analyses of variance for two-way classified data show that both localities and seasons produced singnificant effects on the incidence of *E. sorbillans* and the season x locality interaction was significant ($P< 0.001$) (Appendix Table 1). The warm, humid climate during the Bhaduri season is conducive to the growth and development of the flies which accounts for their greatest infestation during this rearing season. On the other hand, the dry, cold climate during the Chaita commercial season reduces their infestation. Govindaraju *et al.*(1990), and Kumar and Sengupta (1992) also reported seasonal effects on the incidence of the Uzi flies.

Silkworms are intensively reared at the farmer's level at Mirgonj and Bholahat with little or no protection against the Uzi flies. This is apparently the cause for a greater fly infestations at these localities. However, climatic factors, field temperature and relative humidity, may play an important role in this regard.

Table 3. Seasonal incidence and distribution of *E. sorbillans* in the larvae of *B. mori* in some sericultural areas

Rearing season	Location	No. of rearer's house sampled	Total no. of larvae examined	Infested larvae Mean ± SE	Rate of infestation (%)
Agrahayoni Oct.- Nov. 1994	Bholahat	40	96000	115.27±16.88	4.80 (12.66)
	Mirgonj	40	96000	788.40±82.62	32.85(34.97)
	Paba	40	96000	107.82±9.17	4.49 (12.24)
Chaita Feb.- Mar. 1995	Bholahat	40	96000	51.85±4.73	2.16 (8.45)
	Mirgonj	40	96000	3.32 ± 0.54	0.14 (2.14)
	Paba	40	96000	23.70±2.27	0.99 (5.71)
Jaistha Apr.- May 1995	Bholahat	40	96000	61.35±5.60	2.57 (9.23)
	Mirgonj	40	96000	69.35±5.42	2.89 (9.80)
	Paba	40	96000	43.50±4.45	1.81 (7.73)
Bhaduri Jul.- Aug. 1995	Bholahat	40	96000	165.20±21.29	6.88 (15.22)
	Mirgonj	40	96000	988.00±74.64	41.17(39.91)
	Paba	40	96000	109.67±13.40	4.57 (12.35)

Note: Figures in the parentheses indicate the angular transformation values

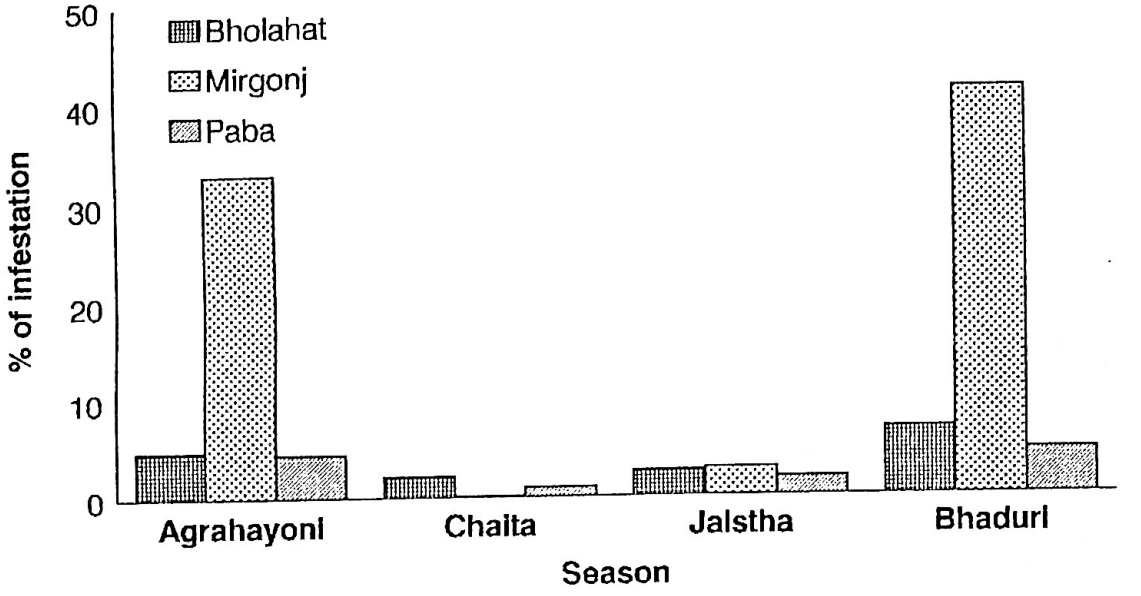

Fig. 1. Seasonal incidence of *E. sorbillans* in the larvae of *B. mori* in some sericultural areas

CHAPTER THREE

STUDIES ON THE GROWTH AND DEVELOPMENT, AND BIOTIC POTENCY OF THE UZI FLY, *EXORISTA SORBILLANS* WIEDEMANN ON *BOMBYX MORI* L.

3.I. Introduction

The Uzi fly, *Exorista sorbillans* Wiedemann (Diptera: Tachinidae) is one of the most important endoparasitoids of silkworm, *Bombyx mori* L. producing its offsprings oviparously. The fly spreads in Eastern Asia including the states of West Bengal, Bihar and Assam of India extending up to Burma (now Myanmar) and Siam (Mukherjee, 1919; Jameson, 1922; Ghosh, 1949). It still continues to be threat to silkworms in this region, especially in the district of Rajshahi and Chapai Nawabgonj in Bangladesh, and Malda and Murshidabad of West Bengal in India. Every year serious quantitative and qualitative losses in silk production is caused by the fly (Kumar *et al.*, 1985; Kumar and Jolly, 1986). Thus, fly menace pose a serious threat to the existence of sericulture industry of Bangladesh.

The information on the biotic potency of the Uzi fly is primarily available from the studies of Indian researchers. A pioneering account of some aspects on the biotic potency of the Indian Uzi fly (*Exorista bombycis*) has been provided by Cotes (1889a). Jameson (1922) gave further details of the maggots, their emergence from the host larvae and cocoon, etc. Among the recent workers on the life-history of the fly, the name of Datta and Mukherjee (1978a) may be mentioned, who described the egg, larva, pupa and adult. Sriharan *et al.* (1971a) gave a detailed account based on the laboratory studies which contributed to our knowledge

of the life-history of the Uzi fly. More recently Siddappaji(1985), and Patil and Govindan (1986) provided results on the biotic potency of the Indian Uzi fly under laboratory condition.

The ovipositional preference of the fly, *E. sorbillans* on different species of Lepidopteran larvae were different (Kumar and Jolly, 1986). The biotic potential of insects is importance in building up of the population. The population build up of a particular insect depends on its reproductive potential. In addition, the survival rate of offsprings, availability of food, competition with natural enemies, conducive atmosphere, etc. play an important role in selecting the host (Kumar and Jolly, 1986; Veeranna and Prasad, 1993). A thorough knowledge of the aspects of biotic potency is very much essential prior to any control measure. The present investigation was undertaken to study the ovipositional preference and some of the biological parameters of *E. sorbillans* on some races of silkworm which could provide valuable information on mass rearing and give a better perception of the successful control programme of this notorious pest.

3.II. Materials and Methods

Disease-free layings of five races of *B. mori* L., viz. *Nistari, Urboshi, 85/3, Dong 34* and *Ziangshu* were used in this experiment. *Nistari* is the local multivoltine, *Urboshi* and *85/3* are improved multivoltine whilst *Dong 34* and *Ziangshu* are bivoltine races. These races were collected from the Germplasm Bank of Bangladesh Sericulture Research and Training Institute, Rajshahi and were reared in the Entomology Laboratory, Institute of Biological Sciences, Rajshahi University. Fifth instar larvae of each race were placed in the rearing cage (25 x 25 x 25 cm) where three pairs of four-day old gravid female fly were confined. After 24 hours, the larvae were removed from the cage, examined and the eggs laid were counted. One egg was retained on the body of each larva while the rest were removed using a fine camel-hair brush. Infested larvae were reared on rearing trays (40 x 30 x 5 cm) kept in the wire-netted cabinets for observation. There were three replications with larvae for each race. During the experiment the average room temperature was recorded as 28±0.3°C.

Five pairs of the fly were collected randomly from each replication. To record the pre-oviposition period, mated females were introduced into a separate beaker covered with mosquito-net at the top. After recording the pre-oviposition period, females were left inside the beaker and new silkworm larvae were introduced

in the beaker after every 24 hours to record their oviposition period.

Infested silkworm larvae of each race were reared on the rearing trays. A black scar or spot on the site of infestation appears when the Uzi-egg hatches and starts to bore inside the body of the host larva. From the record of the black scar appearance, incubation period was recorded. The fecundity and fertility of the flies on larvae from different silkworm races were recorded. The larval duration of *E. sorbillans* was noted. The weight of the maggots and pupae were recorded using an electronic balance. The pupal period was noted and the pupae were measured for their length and breath. The longevity of the male and female flies were also recorded.

3.III. Results and Discussion

Data on the ovipositional preference of *E. sorbillans* on various silkworm races in 24 hours have been presented in Table 4. Both *Nistari* and *Urboshi* races were highly preferred by the flies than the other races and *Dong 34* race was the least preferred. Some physical characteristics lick moisture, smell, texture of the skin and physical obstruction play an important role in guiding an insect in selecting the host (Kumar and Jolly, 1986). Results on the performance of different biological parameters on five different races of *B. mori* L. have been presented in Tables 5-11 and their statistical analysis in Appendix Tables 2-14.

Females oviposited directly on the integument throughout the host body although more eggs appeared on the inter-segmental region of the worms, rested on the plant twigs and attempted to escape. In general, female fly starts to lay eggs on the second day after emergence. But the maximum eggs were laid between 3rd and 5th day (Singh *et al.*, 1993). The range of pre-oviposition and oviposition period varied in different races (Table 5). The highest pre-oviposition period (2.33±0.22 days) was recorded in *Ziangshu* and the lowest (1.92±0.08 days) in *Nistari*. The highest oviposition period was 11.42±0.51 days in *Nistari* and the lowest, 10.07±0.44 days in *Dong 34* race (Table 5). The data of these two traits showed that the effect of race on them was significant ($P<0.05$) (Appendix Tables 2-3).

The egg of the Uzi fly is microtype creamy-white and oval. It can be seen with the naked eye on the infested worm (Fig. 2). At the time of deposition, the egg is provided with a sticky material causing it to adhere on to the host surface. The highest fecundity (409.55±36.32) was recorded in *Nistari* and the lowest (230.82±6.12) in *Ziangshu*. The highest fertility of the eggs was 98.61±0.79 in *Nistari* and the lowest was 85.36±5.38 in *Dong 34* (Table 6). Both the fecundity and fertility showed that these characters are significantly influenced by racial differences (Appendix Tables 4 and 5).

The incubation period varied in different races. The maximum incubation period of 2.50 days in *85/3, Dong 34* and *Ziangshu* races and the minimum of 2.10 days were observed in *Nistari* and *Urboshi* races (Table 7). The incubation period in different races were found to vary significantly ($P<0.01$) (Appendix Table 6).

After emergence from the egg, the maggot or larva generally faces the silkworm body, bores into the host tissues. A small black scar developed on the skin at the point of entrance (Fig. 3) and it increases in size day by day (Devaiah *et al.*, 1993; Patil and Govindan, 1984c). The scar was very prominent towards the period of maggot emergence from the host. The maggots are yellowish-white in colour (Fig. 4). The maggot feeds mostly on fat bodies and muscles and all the internal organs except the salivary glands of the host body. The highest and lowest larval periods were 4.43±0.19 and 4.13±0.09 days in *Dong 34* and *Nistari* respectively (Table 8). The

larval weight of *E. sorbillans* in different races were also found to significantly vary ($P<0.01$) (Appendix Table 8). The highest and lowest larval weight were recorded as 0.0952±0.0018 and 0.0883± 0.0028 g on *Nistari* and *Dong 34* respectively (Table 8).

The freshly-formed puparium was yellowish-brown in colour. In course of time, the colour changed to dark red and brownish black. The puparium was barrel-shaped with narrow rounded anterior and broadly rounded posterior end (Fig. 5). The dark colour indicate the emergence of the Uzi fly. The pupal period was also found to vary on different races (Table 9). The pupal period ranged from 9.40 to 10.80 days in different races (Appendix Table 9).

The pupal weight, length and breadth were also found to vary on different silkworm races (Table 10 and Appendix Tables 10-12). The pupal weight was the maximum (0.0866±0.003 g) in *Urboshi* and the minimum (0.0825±0.0004 g) in *85/3*. The highest pupal length was 0.99±0.009 cm in *Nistari* and *Urboshi*, and the lowest was 0.92±0.014 cm in *Dong 34*. The maximum pupal breadth of 0.50±0.006 cm was observed in *Nistari* and *Urboshi*, and the minimum of 0.46±0.012 cm was recorded in *Dong 34*.

Adults of *E. sorbillans* are blackish-grey in colour (Fig. 6). The male is longer than the female. The head is triangular in shape. On the dorsal side of the thorax, there are four longitudinal black bands. The abdomen is conical. Of the abdominal segments, the first one is black and the rest are greyish-yellow.

Males can be distinguished from the females by the presence of external genitalia covered with brownish-orange hairs on the ventral side of the abdominal tip. The lateral regions of the abdomen are covered with bristles more dense in male than in female, and in the latter are restricted mostly to last two segments. The width of the fronts of the male fly is narrower than that of the female. Longitudinal lines on the dorsum of the thorax of the male are more vivid than the female. The pulvilli of male are larger than that of females. The present studies showed that the highest longevity in males and females were 12.03±0.48 and 13.12±0.46 days respectively in *Nistari* and the lowest were 10.70±0.40 and 11.68±0.26 days respectively in *Dong 34* (Table 11). The longevity of males and females varied according to race and sex (Appendix Tables 13 and 14).

Various biological parameters of the Uzi fly vary significantly among the silkworm races-some races are more suitable for the growth and development of the fly than the others. The present study on the biotic potency of *E. sorbillans* has concentrated on some of the critical issues regarding the reproduction, development and survival of this pest species under laboratory conditions. These information could be utilized in an effective control programme for the pest.

Table 4. Preference of different races of *B. mori* L. for oviposition by the Uzi fly, *Exorista sorbillans* (N=15)

Race	No. of worms provided	Parasitised		No. of eggs laid	Mean±SE
		No.	Percentage		
Nistari	60	60	100.00(90.00)‡	537	8.95±0.74
Urboshi	60	60	100.00(90.00)	577	9.62±0.59
85/3	60	51	85.00(67.21)	767	12.78±1.26
Dong 34	60	50	83.33(65.90)	479	7.98±0.92
Ziangshu	60	53	88.33(70.03)	540	9.00±1.02

‡Note: Figures in the parentheses indicate the angular transformation values

Table 5. Pre-oviposition and oviposition periods of *E. sorbillans* on different races of *B. mori* L. (days) (N=15 for each race for each character)

Race	Pre-oviposition period Mean±SE	Oviposition period Mean±SE
Nistari	1.92±0.08	11.42±0.51
Urboshi	1.96±0.04	10.72±0.15
85/3	2.08±0.08	10.33±0.63
Dong 34	2.08±0.08	10.07±0.44
Ziangshu	2.33±0.22	10.17±0.25

Table 6. Fecundity and fertility(%) of *E. sorbillans* on different races of *B. mori* L.

Race	Fecundity Mean±SE	No. of females	Fertility(%) Mean±SE	No. of eggs
Nistari	409.55±36.32	15	98.61±0.79(84.54±2.84)[t]	1000
Urboshi	365.99±20.48	15	96.73±1.93(81.61±4.42)	1000
85/3	355.69±9.99	15	89.66±3.01(71.72±3.10)	1000
Dong 34	273.99±13.66	15	85.36±5.38(68.19±4.40)	1000
Ziangshu	230.82±6.12	15	87.22±7.44(70.49±6.12)	1000

Note: Figures in the parentheses indicate the angular transformation values

Table 7. Incubation period of *E. sorbillans* on different races of *B. mori* L. (days) (N=1000 eggs for each race)

Race	Incubation period Mean±SE	Minimum incubation period	Maximum incubation period
Nistari	2.23±0.09	2.10	2.40
Urboshi	2.23±0.09	2.10	2.40
85/3	2.35±0.08	2.25	2.50
Dong 34	2.40±0.06	2.30	2.50
Ziangshu	2.40±0.06	2.30	2.50

Table 8. Larval period and larval weight of *E. sorbillans* on different races of *B. mori* L. (N=100 for each race for each character)

Race	Larval period (days) Mean±SE	Larval weight (g) Mean±SE
Nistari	4.13±0.09	0.0952±0.0018
Urboshi	4.22±0.13	0.0971±0.0021
85/3	4.27±0.12	0.0932±0.0003
Dong 34	4.43±0.19	0.0883±0.0028
Ziangshu	4.30±0.15	0.0892±0.0019

Table 9. Pupal period of *E. sorbillans* on different races of *B. mori* L. (days) (N=100 for each character for each race)

Race	Pupal period Mean±SE	Minimum pupal period	Maximum pupal period
Nistari	10.20±0.15	10.00	10.50
Urboshi	9.87±0.18	9.60	10.20
85/3	10.10±0.21	9.80	10.50
Dong 34	9.75±0.30	9.40	10.35
Ziangshu	10.52±0.16	10.25	10.80

Table 10. Pupal weight, length and breadth of *E. sorbillans* on different races of *B. mori* L. (N=100 for each character for each race)

Race	Pupal weight(g) Mean±SE	Pupal length(cm) Mean±SE	Pupal breadth(cm) Mean±SE
Nistari	0.0856±0.002	0.99±0.009	0.50±0.006
Urboshi	0.0866±0.003	0.99±0.034	0.50±0.015
85/3	0.0825±0.0008	0.95±0.024	0.47±0.014
Dong 34	0.0827±0.002	0.92±0.014	0.46±0.012
Ziangshu	0.0854±0.001	0.94±0.021	0.48±0.012

Table 11. Adult longevity of *E. sorbillans* on different races of *B. mori* L. (days) (N=100)

Race	Male longevity Mean±SE	Female longevity Mean±SE
Nistari	12.03±0.48	13.25±0.46
Urboshi	11.50±0.35	12.49±0.14
85/3	11.23±0.29	12.21±0.64
Dong 34	10.70±0.40	11.68±0.26
Ziangshu	11.08±1.13	12.13±0.38

Fig. 2. *E. sorbillans* eggs on *B. mori* larva

Fig. 3. Black scar on the body of *B. mori* larva showing Uzi fly infestation

Fig. 4. Maggots of *E. sorbillans*

Fig. 5. Puparia of *E. sorbillans*

Fig. 6. Adult *E. sorbillans*

CHAPTER FOUR

EFFECT OF ULTRA-VIOLET RADIATION ON THE PUPAE OF *EXORISTA SORBILLANS* WIEDEMANN

4.I. Introduction

Exorista sorbillans Wiedemann, the Uzi fly, is a wellknown serious endoparasitoid of the mulberry silkworm, *Bombyx mori* L. The incidence of this fly is very high in the tropical and sub-tropical countries (Nahar *et al.*, 1992). Farmers in Bangladesh are not very much aware of the attack of this fly pest and therefore, they do not normally pay much attention to the control of their infestation in the rearing house. Instead, they have no suitable technique at hand to combat this fly effectively. At present it is advised to create certain physical barriers by providing wire-mesh in the doors and windows of the rearing rooms or mosquito-net curtains around the rearing stands. Although these methods have been found to be quite effective in preventing the Uzi fly females from getting access to the silkworms, the farmers in our country are not in a position to spend as much money at a time as in required to cover this doors and windows or rearing stands with protective devices.

The problems of the continued wide-spread use of pesticides, and particularly, the incorporation of the words "environmental pollution" into common vocabulary, have caused scientists to look seriously at any ideas for pest control which do not involve traditional insecticides. The control of this menacing fly is almost impossible through chemical measures due to its close association with silkworms. Application of chemosterilants on the

Uzi fly may cause some health hazards (Rahman, 1989). The nonavailability of the natural enemies of *E. sorbillans* was one of the major constrains for biological control of the fly (Mukherjee, 1919; Jameson, 1922; Ghose, 1949; Das Gupta, 1962; Datta *et al.*, 1979). However, in recent years a number of hyperparasites of the Uzi fly have been identified such as *Nesolynx thymus* Girault, *Trichopria* spp., *Exoristobia philippinensis* Ashmead, *Dirhinus himalayanus* Westwood, *Brachymeria lugubris* Walker, *Spilomicrus karnatakensis* Sharma, *Spalangia cameroni* Perkins and *Pachycrepoideus vindimmae* Rondani (Sengupta *et al.*, 1990). Successful biological programmes with these hyperparasites of the Uzi fly are not recommended till to date since the mass culture techniques of the hyperparasites has not yet been developed.

Differential sensitivity to radiation in different species and individuals of the same species of certain insects has been well documented (Subramanya *et al.*, 1993). It is also interesting to note that such marked sensitivity to radiation is also manifested in various stages of metamorphosis. In general, sensitivity to radiation is very high in the early developmental stages. There is a gradual decline with regard to sensitivity through development from egg to adult (Tazima, 1978).

Researches on the mutagenic action of ultra-violet (UV) rays started soon after the discovery of X-ray mutagenesis. Altenburg (1934) was first to discover the mutagenic effect of UV rays on the

polar cap cells in *Drosophila melanogaster* Meigen. UV rays are readily absorbed by certain substances like nitrogen bases (purines and pyrimidines) of the nucleic acids, which then enter a more reactive or excited stage. The absorbed energy can cause alterations in the bond characteristics of the nitrogen bases: pyrimidines are found to be more liable to such changes than purines. One of the consequence of the altered bond characteristics is the formation of covalent bonds between adjacent pyrimidines of the same DNA polynucleotide strand. The linked pyrimidines are called dimers. Dimerization interferes with the proper base pairing of thymine and adenine and may result in thymine pairing with guanine. This will produce a T-A to C-G transition. However, because of their lower energy UV rays are reported to penetrate living tissues only slightly, usually only the surface layer of cells in multicellular organisms (Islam *et al.*, 1992). The relationship between mutation rate and UV dosage is highly variable, depending on the type of mutation, the organism and conditions employed (Gardner and Snustad, 1981). The most important of these, is dose, the amount of radiation administered and whether it is fractionated or in one dose. Because a high dose of radiation often results in mortality or adverse physiological changes, researchers have investigated the feasibility of partial sterilization (North, 1975). The offspring of partially sterilized individuals are also partially sterile, probably from heritable chromosome rearrangements (North and Holt, 1968).

Though a good deal of researches on the effects of gamma radiation on several dipterans like the Mexican fruit fly, *Anastrepha ludens* Loew (Rhode *et al.*, 1961), Melon fly, *Dacus cucurbitae* Coquillett (Steiner *et al.*, 1965), house fly, *Musca domestica* L. (Kilgore and Doutt, 1967), etc. In all these studies late age pupae were irradiated with gamma rays, the doses ranging between 5 to 10 krad (Kumar *et al.*, 1990b).

The use of UV radiations as a controlling agent of *E. sorbillans* is comparatively a new approach. The pupal stage of insects is recommended for irradiation since it minimizes the handling problem. Keeping in view the importance of *E. sorbillans* as a pest of *B. mori* and prospects for its control by UV radiation, the present experiment was conducted under laboratory conditions to determine the effects of different doses of UV irradiation on the pupal stage of *E. sorbillans* inducing sterility under different mating systems.

4.II. Materials and Methods

Healthy pupae of *E. sorbillans* were collected from the stock culture of the Uzi fly maintained at the Entomology Laboratory, Institute of Biological Sciences, Rajshahi University, for the present investigation. Three day old papae were irradiated with UV rays of different doses, viz. 30, 60, 120 and 240 seconds in experiment with a Ultraviolet lamp of 254 nm wavelength installed at the Genetic Engineering Laboratory, Department of Zoology, Rajshahi University. The distance between the lamp and surface was 12cm, and the length and width of the surface was 20.50 sq.cm. The length and width of the lamp were 20 and 4 cm respectively. For each dose 45 pupae were irradiated in separate petridishes (7cm diam.). Three replications were made for each treatment. Equal numbers of untreated males and females of similar age as those of treated batches were maintained at the laboratory for different crossing schedules as control.

The irradiated pupae of different doses were kept separately in wire-mesh cages (25 x 25 x 25 cm). When the adult flies emerged from the pupae, they were sorted out according to their sexes by examining their genitalia. For individual crossing schedules, five pairs of males and females were introduced in beakers (500ml) covered with fine mosquito-net tied with rubber bands. The following reciprocal crossing for each dose separately was

performed:

1. Control male (C♂) x control female (C♀);
2. Treated male (T♂) x treated female (T♀);
3. Treated male (T♂) x control female (C♀); and
4. Control male (C♂) x treated female (T♀).

The flies were supplied with a 10% glucose solution soaked in cottonwool placed on the mosquito-net. For recording the fecundity and fertility of the females, fifth instar silkworm larvae were provided in the beakers . The procedure of replacement of silkworm larvae in the beakers after 24 hour intervals was repeated till the death of the females. The parasitized *B. mori* larvae were examined daily to record the number of eggs laid by the females. The larvae which were infested in this way were reared in separate rearing trays in a wire-netted rearing cabinet to avoid further infestation by the natural flies. Hatching of the eggs was recorded daily by observing the black scars on the host body. Observations on the oviposition period, fecundity, fertility, percentage of adult recovery and adult longevity were noted and analyzed statistically. The experiment was conducted at 30°C and 75% R.H.

4.III. Results and Discussion

The mean performance on oviposition period, fecundity percentage of egg-hatch, adult longevity and adult recovery(%) of *E. sorbillans* resulting from pupae exposed to UV radiation are shown in Table 12. The data with their statistical analyses are shown in Appendix Tables 15-35.

Results on the oviposition period of the fly indicate that the effect of UV irradiation was to significantly reduce its duration ($P<0.01$).

UV irradiation for 30, 60 and 120 seconds did not affect the fecundity of the female flies, but 240 second treatment significantly affected this parameter ($P<0.05$). It is evident from the results that the treated females mated to treated males had the lowest fecundity.

The effect of different doses of UV radiation was found to significantly lower the fertility of the female flies when compared with that of the controls. Again, T♂ x T♀ produced the least egg ablity.

Only the higher UV doses (e.g. 120 and 240 second treatments) significantly reduced the longevity of the male flies but the

longevity of the female flies was significantly decreased at all the treatments.

The percentage of adult emergence from the irradiated pupae was found to be decreased as the dose of irradiation was increased ($P<0.001$). The lowest adult recovery (77.50±2.54%) was noted at 4-minute exposure to UV rays.

Ionizing radiations appear to be a potential agent for the control of *E. sorbillans* (Kumar *et al.*,1990b; Jahan, 1993). Gardner and Snustad (1981) noted that the maximum absorbtion of UV radiations by DNA molecule was at wavelength of 254 nm and the maximum mutagenecity also occurred at this dose, suggesting that UV- induced mutation process is mediated directly by absorption of UV rays by the nitrogen bases. Earlier, Swanson(1957) reported that the 254 nm of UV rays was the most productive in increasing the mutation rate in corn pollen. By using two doses of UV, Haque(1989) found that 254 nm of UV induced a more drastic effect on the fecundity and fertility of *Musca domestica* L. than those induced by 366 nm. From an experiment with *Haemophilus influenzae* , Deering and Setlow (1983) reported that 280 nm and 240 nm of UV radiations were capable of inducing 70% and 30% breakage of dimers, respectively in DNA molecule. These results contrast with those reported by Haque (1989) which might be due to the variation in the experimental organisms.

Odum (1959) suggested that radiosensitivity was correlated with the size of insects. The effect of pupal age at the time of treatment was most strikingly evident in the differences that occurred in the numbers of eggs oviposited and percent hatch for each group. Researchers (Bushland and Hopkins, 1953; Jaynes and Godwin, 1957; Donnelly, 1960) working with pupae and adults of insects, have reported that sterilizing doses of ionising radiation will reduce adult longevity and this is the prime factor for the success of sterilization techniques. Doubtless, in some insects the relationship between fertility and longevity will be influenced by the time of irradiation (Proverbs and Newton, 1962). They also added that the doses of gamma radiation required to cause complete or almost complete sexual sterility in the codling moth were appreciably greater than the doses of gamma or X-radiation required to sterilize most other species of insects that have been investigated in many Diptera (Plough, 1952; Lindquist, 1955; Steiner and Christenson, 1956; Potts, 1958; Davis *et al.*, 1959; Rhode *et al.*, 1961).

Unfortunately, no comparable data could be found. However, further experiments with various dose combinations are suggested. The present findings are encouraging and suggest that UV radiations could be utilized in the control of this notorious pest.

Table 12. Effect of UV radiation on the pupae of *E. sorbillans*

Treatment	Oviposition period(days) Mean±SE	Fecundity Mean±SE	Hatchability(%) Mean±SE	Adult longevity (days) Mean±SE		Adult recovery(%)
				Male	Female	
C♂ x C♀	14.26±0.60	361.08±64.80	88.55±2.93(70.52±2.64)*2	11.58±1.14	16.00±0.72	95.00±1.55(77.46±2.26)
30 Second						
T♂ x T♀	10.07±1.21	278.17±7.09	70.64±1.74(57.20±1.09)	9.03±1.24	10.83±0.66	93.75±1.49(75.73±1.80)
T♂ x C♀	11.64±0.51	317.43±27.02	77.37±2.27(61.64±1.56)	8.50±1.04	12.10±1.01	
C♂ x T♀	11.31±0.81	295.33±14.25	75.00±2.72(60.07±1.81)	9.60±0.95	11.53±0.99	
LSD*1						
5%	-	-	6.76	-	2.57	
1%	2.52		-	-	-	
60 Second						
T♂ x T♀	9.50±0.63	265.38±18.79	61.11±2.06(51.43±1.21)	9.02±0.59	10.01±0.90	92.50±0.72(74.14±0.79)
T♂ x C♀	10.49±0.95	313.57±20.24	71.50±2.98(57.79±1.92)	8.27±1.19	11.67±0.74	
C♂ x T♀	10.27±0.45	281.90±10.03	64.01±2.94(53.16±1.74)	8.70±1.39	10.66±0.99	
LSD						
5%	-	-	-	-	3.16	
1%	2.37	-	7.94	-	-	
120 Second						
T♂ x T♀	9.46±0.44	260.51±17.18	37.10±3.75(37.47±2.24)	8.53±1.02	9.80±0.98	85.00±1.38(67.25±1.12)
T♂ x C♀	10.21±0.78	300.53±13.13	53.39±4.57(46.95±2.64)	8.23±0.94	10.86±0.74	
C♂ x T♀	9.65±0.32	275.66±21.57	42.31±5.90(40.52±3.44)	8.19±0.85	10.00±0.97	
LSD						
5%	-	-	-	-	-	
1%	3.19	-	15.50	2.71	4.15	
240 Second						
T♂ x T♀	9.07±1.21	174.64±28.06	15.42±3.59(22.87±2.78)	8.43±1.16	9.20±1.31	77.50±2.54(61.76±1.76)
T♂ x C♀	9.12±0.33	287.03±23.30	26.16±5.67(30.51±3.69)	8.02±0.85	10.27±1.20	
C♂ x T♀	7.16±0.78	245.50±21.81	18.70±5.01(25.26±3.62)	8.07±0.93	8.93±1.65	
LSD						
5%	-	109.86	-	-	3.75	
1%	3.12	-	9.39	2.08	-	

*1 Least significant difference. *2 Angular transformation values.

CHAPTER FIVE

Summary

References

Appendices

Summary

The present investigation was to explore the incidence and distribution in different rearing season, biotic potency and control with UV radiation of the Uzi fly , *Exorista sorbillans* Wiedemann, an important endoparasitoid of the silkworm, *Bombyx mori* L.

The incidence of the Uzi fly infestation in three major sericultural areas, e.g. Bholahat in Chapai Nawabgonj, and Mirgonj and Paba in Rajshahi districts was observed in different rearing seasons, viz. Agrahayoni (Oct.-Nov.), Chaita (Feb.-Mar.), Jaistha (Apr.-May) and Bhaduri (Jul.-Aug.) of 1994-1995. This investigation was conducted at rearer's houses in each rearing area and each season. Each investigation was divided into four blocks in each area. The maximum fly infestation (41.17%) at Mirganj and the minimum (0.99%) at Paba were observed during the Bhaduri and Chaita rearing seasons respectively.

The ovipositional preference and some biological aspects of *E. sorbillans* on some races of silkworm, viz. *Nistari, Urboshi, 85/3, Dong 34 and Ziangshu* were studied. Both *Nistari* and *Urboshi* were highly preferred by the flies than the other races and *Dong 34* was the least preferred for oviposition.

The maximum and minimum pre-oviposition period were 2.33±0.22 and 1.92±0.08 days in *Ziangshu* and *Nistari* respectively. The highest oviposition period was 11.42±0.51 days in *Nistari* and the lowest 10.07±0.44 days in Dong 34. The highest egg laying/female of 409.55±36.32 was observed in *Nistari* and the lowest of 230.82±6.12 in *Ziangshu*. The highest fertility(%) was 98.61±0.79 in *Nistari* and the lowest 85.36±5.38 in *Dong 34*. Incubation period varied depending on the races. The maximum period of 2.50 days was observed in *85/3, Dong 34* and *Ziangshu*, and the minimum of 2.10 days was observed in *Nistari* and *Urboshi*. Maggot stage ranged from 4.13-4.43 days in different races. The highest and lowest larval weight of *E. sorbillans* were recorded as 0.0952±0.0018 and 0.0883±0.0028 g on *Nistari* and *Dong 34* respectively. The pupal period ranged from 9.40-10.80 days in different races. The pupal weight was the maximum (0.0866±0.003 g) in *Urboshi* and the minimum (0.0825±0.0004 g) in 85/3. The highest pupal length was 0.99±0.009 cm in *Nistari* and *Urboshi*, and the lowest was 0.92±0.014 cm in *Dong 34*. The maximum pupal breadth of 0.50±0.006 cm was observed in *Nistari* and *Urboshi*, and the minimum of 0.46±0.012 cm was recorded in *Dong 34*. The highest longevity in males and females were 12.03±0.48 and 13.12±0.46 days respectively in *Nistari* and the lowest were 10.70±0.40 and 11.68±0.26 days respectively in *Dong 34*.

The use of UV radiation as a controlling agent of *E. sorbillans* is comparatively a new approach. Three-day old pupae were irradiated with UV rays of different doses, viz. 30, 60, 120

and 240 seconds with a Ultraviolet lamp of 254 nm wavelength, under different mating systems. The effect of UV irradiation was to significantly reduce the oviposition period. Irradiation with UV rays for 30, 60 and 120 seconds did not affect the fecundity of the female flies, but 240 second treatment significantly affected the fecundity of females. Irradiated females mated to treated males had the lowest fecundity. UV irradiation significantly reduced the egg-viability in *E. sorbillans*. The emergence and longevity of flies from the irradiated pupae were also significantly reduced. These effects were dependent on the doses of UV irradiation employed.

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Appendix Table 1. Seasonal incidence and distribution of *E. sorbillans* in different sericultural areas

Season	Bholahat					Mirgonj					Paba				
	R_1	R_2	R_3	R_4	Total	R_1	R_2	R_3	R_4	Total	R_1	R_2	R_3	R_4	Total
Agrahayoni'94	2993	1276	424	218	4611	14497	10219	5425	1394	31536	1922	1165	798	428	4313
Chaita'95	879	635	423	137	2074	85	34	14	-	133	421	296	181	50	948
Jaistha'95	1075	737	496	155	2463	1136	768	579	291	2774	791	555	325	69	1740
Bhaduri'95	3581	1955	893	179	6608	15900	11495	8286	3839	39520	2306	1086	718	277	4387

Total sum of squares (TSS) = 627074059.50
Season sum of squares {SSS(S)} = 140979418.10
Locality sum of squares {LSS(L)} = 152557602.00
Replication sum of squares {RSS(R)}= 66879630.23
Total sum of squares {TSS(SxL)} = 163774449.60
Error sum of squares (ESS) = 102882959.60

Analysis of variance (ANOVA) Table

Source of variation	Degrees of freedom(DF)	Sum of squares(SS)	Mean squares(MS)	Variance ratio (F)
Localities (L)	2	152557602.00	76278801.00	24.47**
Seasons (S)	3	140979418.10	46993139.37	15.07**
S x L	6	163774449.60	27295741.60	8.75**
Replication	3	66879630.23	22293210.08	7.15**
Error	33	102882959.60	3117665.44	
Total	47			

** Significant at 1% level

Appendix Table 2. Pre-oviposition period of *E. sorbillans* on different races of *B. mori* L.(days)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	1.75	2.00	2.00	1.92±0.08
Urboshi	1.88	2.00	2.00	1.96±0.04
85/3	2.00	2.00	2.25	2.08±0.08
Dong 34	2.00	2.00	2.25	2.08±0.08
Ziangshu	2.00	2.25	2.75	2.33±0.22

Total sum of squares= 0.7418
Treatment sum of squares= 0.3155
Replication sum of squares= 0.2672
Error sum of squares= 0.1591

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	0.2672	0.1336	6.71*
Treatment	4	0.3155	0.0789	3.96*
Error	8	0.1591	0.0199	
Total	14			

* Significance at 5% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.0199)/3\}}$
= 0.115
and t = 2.31

Therefore, LSD at 5% = 0.115 x 2.31
= 0.27

Appendix Table 3. Oviposition period of *E. sorbillans* on different races of *B. mori* L.(days)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	10.50	11.50	12.25	11.42±0.51
Urboshi	10.50	10.67	11.00	10.72±0.15
85/3	9.16	10.50	11.33	10.33±0.63
Dong 34	9.20	10.33	10.67	10.07±0.44
Ziangshu	9.67	10.33	10.50	10.17±0.25

Total sum of squares= 9.27
Treatment sum of squares= 3.63
Replication sum of squares= 4.63
Error sum of squares= 1.01

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	4.63	2.31	17.81‡‡
Treatment	4	3.63	0.91	7.00‡
Error	8	1.01	0.13	
Total	14			

‡‡ and ‡ indicates the significance at 1% and 5% level respectively

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.13)/3\}}$
= 0.29
and t= 2.31

Therefore, LSD at 5%= 0.29 x 2.31
= 0.67

Appendix Table 4. Fecundity of *E. sorbillans* on different races of *B. mori* L.

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	396.67	354.16	477.83	409.55±36.32
Urboshi	328.66	370.16	399.16	365.99±20.48
85/3	344.25	347.25	375.58	355.69±9.99
Dong 34	255.67	265.64	300.66	273.99±13.66
Ziangshu	219.54	232.37	240.54	230.82±6.12

Total sum of squares= 76005.49
Treatment sum of squares= 63659.74
Replication sum of squares= 7524.45
Error sum of squares= 4821.30

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	7524.45	3762.22	6.24*
Treatment	4	63659.74	15914.93	26.41**
Error	8	4821.30	602.66	
Total	14			

** and * indicates the significance at 1% and 5% level respectively

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 602.66)/3\}}$
= 20.04
and t= 3.36

Therefore, LSD at 1%= 20.04 x 3.36
= 67.33

Appendix Table 5. Fertility(%) of eggs of *E. sorbillans* on different races of *B. mori* L.

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	97.27 (80.49)	98.57 (83.12)	100.00 (90.00)	98.61±0.79 (84.54±2.84)
Urboshi	93.33 (75.03)	96.87 (79.81)	100.00 (90.00)	96.73±1.93 (81.61±4.42)
85/3	85.71 (67.79)	87.72 (69.53)	95.56 (77.83)	89.66±3.01 (71.72±3.10)
Dong 34	75.22 (60.14)	87.33 (69.15)	93.54 (75.28)	85.36±5.38 (68.19±4.40)
Ziangshu	72.38 (58.30)	93.99 (75.70)	95.29 (77.47)	87.22±7.44 (70.49±6.12)

Note: Figures in the parentheses indicate the angular transformation values

Total sum of squares= 1198.29
Treatment sum of squares= 635.11
Replication sum of squares= 473.93
Error sum of squares= 89.25

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	473.93	236.96	21.23**
Treatment	4	635.11	158.78	14.23**
Error	8	89.25	11.16	
Total	14			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 11.16)/3\}}$
= 2.73
and t= 3.36

Therefore, LSD at 1%= 2.73 x 3.36
= 9.17

Appendix Table 6. Incubation period of *E. sorbillans* on different races of *B. mori* L. (days)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	2.10	2.20	2.40	2.23±0.09
Urboshi	2.10	2.18	2.40	2.23±0.09
85/3	2.25	2.30	2.50	2.35±0.08
Dong 34	2.30	2.40	2.50	2.40±0.06
Ziangshu	2.30	2.41	2.50	2.40±0.06

Total sum of squares= 0.2613
Treatment sum of squares= 0.0913
Replication sum of squares= 0.1608
Error sum of squares= 0.0092

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	0.1608	0.0804	73.09**
Treatment	4	0.0913	0.0228	20.75**
Error	8	0.0092	0.0011	
Total	14			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.0011)/3\}}$
= 0.027
and t= 3.36

Therefore, LSD at 1%= 0.027 x 3.36
= 0.091

Appendix Table 7. Larval period of *E. sorbillans* on different races of *B. mori* L. (days)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	4.00	4.10	4.30	4.13±0.09
Urboshi	4.00	4.20	4.45	4.22±0.13
85/3	4.10	4.20	4.50	4.27±0.12
Dong 34	4.20	4.30	4.80	4.43±0.19
Ziangshu	4.10	4.20	4.60	4.30±0.15

Total sum of squares= 0.729
Treatment sum of squares= 0.147
Replication sum of squares= 0.543
Error sum of squares= 0.039

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	0.543	0.271	54.20**
Treatment	4	0.147	0.037	7.40**
Error	8	0.039	0.005	
Total	14			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.005)/3\}}$
= 0.058
and t= 3.36

Therefore, LSD at 1%= 0.058 x 3.36
= 0.195

Appendix Table 8. Larval weight of *E. sorbillans* on different races of *B. mori* L. (g)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	0.0930	0.0937	0.0988	0.0952±0.0018
Urboshi	0.0930	0.0983	0.1000	0.0971±0.0021
85/3	0.0926	0.0933	0.0937	0.0932±0.0003
Dong 34	0.0829	0.0896	0.0924	0.0883±0.0028
Ziangshu	0.0855	0.0903	0.0919	0.0892±0.0019

Total sum of squares= 0.00029
Treatment sum of squares= 0.00017
Replication sum of squares= 0.00009
Error sum of squares= 0.00003

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	0.00009	0.000045	11.25††
Treatment	4	0.00017	0.0000425	10.62††
Error	8	0.00003	0.000004	
Total	14			

†† Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.000004)/3\}}$
= 0.001633
and t= 3.36

Therefore, LSD at 1%= 0.001633 x 3.36
= 0.0055

Appendix Table 9. Pupal period of *E. sorbillans* on different races of *B. mori* L. (days)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	10.00	10.10	10.50	10.20±0.15
Urboshi	9.60	9.80	10.20	9.87±0.18
85/3	9.80	10.00	10.50	10.10±0.21
Dong 34	9.40	9.50	10.35	9.75±0.30
Ziangshu	10.25	10.50	10.80	10.52±0.16

Total sum of squares= 2.36
Treatment sum of squares= 1.08
Replication sum of squares= 1.17
Error sum of squares= 0.11

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	1.17	0.585	48.75††
Treatment	4	1.08	0.27	22.50††
Error	8	0.11	0.012	
Total	14			

†† Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.012)/3\}}$
= 0.089
and t= 3.36

Therefore, LSD at 1%= 0.089 x 3.36
= 0.30

Appendix Table 10. Pupal weight of *E. sorbillans* on different races of *B. mori* L. (g)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	0.0889	0.0848	0.0831	0.0856±0.002
Urboshi	0.0919	0.0869	0.0811	0.0866±0.003
85/3	0.0834	0.0821	0.0820	0.0825±0.0004
Dong 34	0.0858	0.0829	0.0794	0.0827±0.002
Ziangshu	0.0872	0.0862	0.0829	0.0854±0.001

Total sum of squares= 0.00015
Treatment sum of squares= 0.00008
Replication sum of squares= 0.00005
Error sum of squares= 0.00002

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	0.00008	0.00004	16.00**
Treatment	4	0.00005	0.0000125	5.00*
Error	8	0.00002	0.0000025	
Total	14			

** and * indicates the significance at 1% and 5% levels respectively

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.0000025)/3\}}$
= 0.0013
and t= 2.31

Therefore, LSD at 5%= 0.0013 x 2.31
= 0.0030

Appendix Table 11. Pupal length of *E. sorbillans* on different races of *B. mori* L. (cm)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	1.01	0.99	0.98	0.99±0.009
Urboshi	1.06	0.97	0.95	0.99±0.034
85/3	0.98	0.96	0.90	0.95±0.024
Dong 34	0.95	0.92	0.90	0.92±0.014
Ziangshu	0.98	0.93	0.91	0.94±0.021

Total sum of squares= 0.0271
Treatment sum of squares= 0.0124
Replication sum of squares= 0.0118
Error sum of squares= 0.0029

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	0.0118	0.0059	14.75**
Treatment	4	0.0124	0.0031	7.75**
Error	8	0.0029	0.0004	
Total	14			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.0004)/3\}}$
= 0.016
and t= 3.36

Therefore, LSD at 1%= 0.016 x 3.36
= 0.054

Appendix Table 12. Pupal breadth of *E. sorbillans* on different races of *B. mori* L. (cm)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	0.51	0.50	0.49	0.50±0.006
Urboshi	0.52	0.51	0.47	0.50±0.015
85/3	0.50	0.47	0.45	0.47±0.014
Dong 34	0.48	0.45	0.44	0.46±0.012
Ziangshu	0.50	0.47	0.46	0.48±0.012

Total sum of squares= 0.0088
Treatment sum of squares= 0.0042
Replication sum of squares= 0.0040
Error sum of squares= 0.0006

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	0.0040	0.0020	26.67**
Treatment	4	0.0042	0.00105	14.00**
Error	8	0.0006	0.000075	
Total	14			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.000075)/3\}}$
= 0.0071
and t= 3.36

Therefore, LSD at 1%= 0.0071 x 3.36
= 0.024

Appendix Table 13. Adult longevity (male) of *E. sorbillans* on different races of *B. mori* L. (days)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	11.10	12.33	12.67	12.03±0.48
Urboshi	10.83	11.67	12.00	11.50±0.35
85/3	10.75	11.20	11.75	11.23±0.29
Dong 34	10.00	10.71	11.40	10.70±0.40
Ziangshu	10.90	11.00	11.33	11.08±0.13

Total sum of squares= 6.64
Treatment sum of squares= 2.96
Replication sum of squares= 3.14
Error sum of squares= 0.54

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	3.14	1.57	19.62**
Treatment	4	2.96	0.74	9.25**
Error	8	0.54	0.08	
Total	14			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.08)/3\}}$
= 0.23
and t= 3.36

Therefore, LSD at 1%= 0.23 x 3.36
= 0.77

Appendix Table 14. Adult longevity (female) of *E. sorbillans* on different races of *B. mori* L. (days)

Race	Replication			Mean±SE
	R_1	R_2	R_3	
Nistari	12.33	13.67	13.75	13.25±0.46
Urboshi	12.20	12.60	12.66	12.49±0.14
85/3	11.10	12.20	13.33	12.21±0.64
Dong 34	11.20	11.75	12.10	11.68±0.26
Ziangshu	11.71	11.80	12.89	12.13±0.38

Total sum of squares= 9.18
Treatment sum of squares= 4.02
Replication sum of squares= 3.85
Error sum of squares= 1.31

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	3.85	1.925	12.03**
Treatment	4	4.02	1.005	6.28*
Error	8	1.31	0.16	
Total	14			

** and * indicates the significance at 1% and 5% levels respectively

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.16)/3\}}$
= 0.33
and t= 2.31

Therefore, LSD at 5%= 0.33 x 2.31
= 0.76

Appendix Table 15. Effect of UV radiation on the adult recovery(%) of *E. sorbillans*

Treatment	Replication			Mean±SE
	R_1	R_2	R_3	
Control	92.80 (74.44)	94.20 (76.06)	98.00 (81.87)	95.00±1.55 (77.46±2.26)
30 sec.	91.50 (73.05)	93.30 (75.00)	96.45 (79.14)	93.75±1.49 (75.73±1.80)
60 sec.	91.20 (72.74)	92.60 (74.21)	93.70 (75.46)	92.50±0.72 (74.14±0.79)
120 sec.	82.90 (65.57)	84.50 (66.81)	87.60 (69.38)	85.00±1.38 (67.25±1.12)
240 sec.	73.20 (58.82)	77.30 (61.55)	82.00 (64.90)	77.50±2.54 (61.76±1.76)

Note: Figures in the parentheses indicate the angular transformation values

Total sum of squares= 598.74
Treatment sum of squares= 519.06
Replication sum of squares= 70.47
Error sum of squares= 9.21

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	70.47	35.20	30.61***
Treatment	4	519.06	129.765	112.84***
Error	8	9.21	1.15	
Total	11			

*** Significance at 0.1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 1.15)/3\}}$
= 0.88
and t= 5.04

Therefore, LSD at 0.1%= 0.88 x 5.04
= 4.435

Appendix Table 16. Effect of UV radiation on the oviposition periods of *E. sorbillans* (days)

Treatment	Dose 30 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.19	14.33	15.27	14.26±0.60
T♂xT♀	8.21	9.67	12.33	10.07±1.21
T♂xC♀	11.67	10.75	12.50	11.64±0.51
C♂xT♀	9.75	11.67	12.50	11.31±0.81

Total sum of squares= 44.39
Treatment sum of squares= 27.98
Replication sum of squares= 12.23
Error sum of squares= 4.18

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	12.23	6.11	8.73*
Treatment	3	27.98	9.33	13.32**
Error	6	4.18	0.70	
Total	11			

** and * indicates the significance at 1% and 5% level respectively

LSD for treatment= SE x t

Here, SE= √{(2 x ms)/r}
= √{(2 x 0.70)/3}
= 0.68
and t= 3.71

Therefore, LSD at 1%= 0.68 x 3.71
= 2.52

Appendix Table 17. Effect of UV radiation on the oviposition periods of *E. sorbillans* (days)

Treatment	Dose 60 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.19	14.33	15.27	14.26±0.60
T♂xT♀	9.67	8.33	10.50	9.50±0.63
T♂xC♀	11.20	8.60	11.67	10.49±0.95
C♂xT♀	10.19	9.53	11.09	10.27±0.45

Total sum of squares= 52.13
Treatment sum of squares= 40.87
Replication sum of squares= 7.52
Error sum of squares= 3.74

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	7.52	3.76	6.06*
Treatment	3	40.87	13.62	21.97**
Error	6	3.74	0.62	
Total	11			

** and * indicates the significance at 1% and 5% level respectively

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.62)/3\}}$
= 0.64
and t= 3.71

Therefore, LSD at 1%= 0.64 x 3.71
= 2.37

Appendix Table 18. Effect of UV radiation on the oviposition periods of *E. sorbillans* (days)

Treatment	Dose 120 second Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.19	14.33	15.27	14.26±0.60
T♂xT♀	8.67	10.20	9.50	9.46±0.44
T♂xC♀	10.77	11.19	8.67	10.21±0.78
C♂xT♀	10.27	9.50	9.19	9.65±0.32

Total sum of squares= 53.88
Treatment sum of squares= 46.28
Replication sum of squares= 1.01
Error sum of squares= 6.59

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	1.01	0.505	0.46
Treatment	3	46.28	15.43	14.02‡‡
Error	6	6.59	1.10	
Total	11			

‡‡ Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 1.10)/3\}}$
= 0.86
and t= 3.71

Therefore, LSD at 1%= 0.86 x 3.71
= 3.19

Appendix Table 19. Effect of UV radiation on the oviposition periods of *E. sorbillans* (days)

Treatment	Dose 240 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.19	14.33	15.27	14.26±0.60
T♂xT♀	7.21	8.67	11.33	9.07±1.21
T♂xC♀	9.65	8.50	9.20	9.12±0.33
C♂xT♀	5.67	7.50	8.32	7.16±0.78

Total sum of squares= 98.74
Treatment sum of squares= 83.49
Replication sum of squares= 8.96
Error sum of squares= 6.29

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	8.96	4.48	4.27
Treatment	3	83.49	27.83	26.50**
Error	6	6.29	1.05	
Total	11			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 1.05)/3\}}$
= 0.84
and t= 3.71

Therefore, LSD at 1%= 0.84 x 3.71
= 3.12

Appendix Table 20. Effect of UV radiation on the fecundity of *E. sorbillans*

Treatment	Dose 30 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	306.75	490.00	286.50	361.08±64.80
T♂xXT♀	290.33	265.80	278.37	278.17±7.09
T♂xC♀	300.29	281.67	370.33	317.43±27.02
C♂xT♀	295.30	320.00	270.70	295.33±14.25

Total sum of squares= 42592.74
Treatment sum of squares= 11571.31
Replication sum of squares= 4192.29
Error sum of squares= 26829.14

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	4192.29	2096.14	0.47
Treatment	3	11571.31	3857.10	0.86
Error	6	26829.14	4471.52	
Total	11			

Appendix Table 21. Effect of UV radiation on the fecundity of *E. sorbillans*

Treatment	Dose 60 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	306.75	490.00	286.50	361.08±64.80
T♂xT♀	230.80	270.00	295.33	265.38±18.79
T♂xC♀	280.29	350.10	310.33	313.57±20.24
C♂xT♀	280.29	265.41	300.00	281.90±10.03

Total sum of squares= 46267.61
Treatment sum of squares= 15964.58
Replication sum of squares= 9949.88
Error sum of squares= 20353.15

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	9949.88	4974.94	1.47
Treatment	3	15964.58	5321.53	1.57
Error	6	20353.15	3392.19	
Total	11			

Appendix Table 22. Effect of UV radiation on the fecundity of *E. sorbillans*

Treatment	Dose 120 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	306.75	490.00	286.50	361.08±64.80
T♂xT♀	290.33	230.88	260.33	260.51±17.18
T♂xC♀	280.88	325.40	295.30	300.53±13.13
C♂xT♀	270.29	315.80	240.88	275.66±21.57

Total sum of squares= 48429.23
Treatment sum of squares= 17646.04
Replication sum of squares= 10654.97
Error sum of squares= 20128.22

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	10654.97	5327.48	1.59
Treatment	3	17646.04	5882.01	1.75
Error	6	20128.22	3354.70	
Total	11			

Appendix Table 23. Effect of UV radiation on the fecundity of *E. sorbillans*

Treatment	Dose 240 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	306.75	490.00	286.50	361.08±64.80
T♂xT♀	123.50	220.10	180.33	174.64±28.06
T♂xC♀	280.29	330.29	250.50	287.03±23.30
C♂xT♀	210.30	240.88	285.33	245.50±21.81

Total sum of squares= 90680.44
Treatment sum of squares= 54733.75
Replication sum of squares= 17852.32
Error sum of squares= 18094.37

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	17852.32	8926.16	2.96
Treatment	3	54733.75	18244.58	6.05*
Error	6	18094.37	3015.73	
Total	11			

* Significance at 5% level

LSD for treatment= SE x t

Here, $SE=\sqrt{\{(2 \times ms)/r\}}$
$= \sqrt{\{(2 \times 3015.73)/3\}}$
$= 44.84$
and $t= 2.45$

Therefore, LSD at 5%= 44.84 x 2.45
= 109.86

Appendix Table 24. Effect of UV radiation on the fertility(%) of eggs of *E. sorbillans*

Treatment	Dose 30 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	89.30 (70.91)	93.20 (74.88)	83.15 (65.76)	88.55±2.93 (70.52±2.64)
T♂xT♀	67.29 (55.11)	71.52 (57.74)	73.10 (58.76)	70.64±1.74 (57.20±1.09)
T♂xC♀	81.33 (64.39)	77.29 (61.54)	73.48 (59.00)	77.37±2.27 (61.64±1.56)
C♂xT♀	79.80 (63.29)	70.40 (57.04)	74.81 (59.87)	75.00±2.72 (60.07±1.81)

Note: Figures in the parentheses indicate the angular transformation values

Total sum of squares= 379.73
Treatment sum of squares= 296.69
Replication sum of squares= 14.46
Error sum of squares= 68.58

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	14.46	7.23	0.63
Treatment	3	296.69	98.90	8.65*
Error	6	68.58	11.43	
Total	11			

* Significance at 5% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 11.43)/3\}}$
= 2.76
and t= 2.45

Therefore, LSD at 5%= 2.76 x 2.45
= 6.76

Appendix Table 25. Effect of UV radiation on the fertility(%) of eggs of *E. sorbillans*

Treatment	Dose 60 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	89.30 (70.91)	93.20 (74.88)	83.15 (65.76)	88.55±2.93 (70.52±2.64)
T♂xT♀	64.40 (53.37)	61.60 (51.71)	57.33 (49.22)	61.11±2.06 (51.43±1.21)
T♂xC♀	77.29 (61.54)	67.40 (55.18)	69.80 (56.66)	71.50±2.98 (57.79±1.92)
C♂xT♀	65.30 (53.91)	68.33 (55.74)	58.40 (49.84)	64.01±2.94 (53.16±1.74)

Note: Figures in the parentheses indicate the angular transformation values

Total sum of squares= 759.99
Treatment sum of squares= 669.05
Replication sum of squares= 49.58
Error sum of squares= 41.36

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	49.58	24.79	3.60
Treatment	3	669.05	223.02	32.37**
Error	6	41.36	6.89	
Total	11			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 6.89)/3\}}$
= 2.14
and t= 3.71

Therefore, LSD at 1%= 2.14 x 3.71
= 7.94

Appendix Table 26. Effect of UV radiation on the fertility(%) of eggs of *E. sorbillans*

Treatment	Dose 120 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	89.30 (70.91)	93.20 (74.88)	83.15 (65.76)	88.55±2.93 (70.52±2.64)
T♂xT♀	42.90 (40.92)	30.10 (33.27)	38.30 (38.23)	37.10±3.75 (37.47±2.24)
T♂xC♀	44.67 (41.92)	60.10 (50.83)	55.40 (48.10)	53.39±4.57 (46.95±2.64)
C♂xT♀	53.30 (46.89)	40.54 (39.55)	33.10 (35.12)	42.31±5.90 (40.52±3.44)

Note: Figures in the parentheses indicate the angular transformation values

Total sum of squares= 2199.91
Treatment sum of squares= 2015.61
Replication sum of squares= 26.10
Error sum of squares= 158.20

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	26.10	13.05	0.49
Treatment	3	2015.61	671.87	25.48**
Error	6	158.20	26.37	
Total	11			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 26.37)/3\}}$
= 4.19
and t= 3.71

Therefore, LSD at 1%= 4.19 x 3.71
= 15.54

Appendix Table 27. Effect of UV radiation on the fertility(%) of eggs of *E. sorbillans*

Treatment	Dose 240 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	89.30 (70.91)	93.20 (74.88)	83.15 (65.76)	88.55±2.93 (70.52±2.64)
T♂xT♀	22.50 (28.32)	12.90 (21.05)	10.85 (19.23)	15.42±3.59 (22.87±2.78)
T♂xC♀	36.75 (37.32)	24.33 (29.55)	17.40 (24.65)	26.16±5.67 (30.51±3.69)
C♂xT♀	28.45 (32.23)	15.80 (23.42)	11.85 (20.13)	18.70±5.01 (25.26±3.62)

Note: Figures in the parentheses indicate the angular transformation values

Total sum of squares= 4756.34
Treatment sum of squares= 4508.33
Replication sum of squares= 190.24
Error sum of squares= 57.77

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	190.24	95.12	9.88*
Treatment	3	4508.33	1502.78	156.05**
Error	6	57.77	9.63	
Total	11			

** and * indicates the significance at 1% and 5% level respectively

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 9.63)/3\}}$
= 2.53
and t= 3.71

Therefore, LSD at 1%= 2.53 x 3.71
= 9.39

Appendix Table 28. Effect of UV radiation on the longevity males of *E. sorbillans* (days)

Treatment	Dose 30 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.67	9.75	11.33	11.58±1.14
T♂xT♀	11.50	8.00	7.60	9.03±1.24
T♂xC♀	10.50	7.00	8.00	8.50±1.04
C♂xT♀	7.80	10.00	11.00	9.60±0.95

Total sum of squares= 45.16
Treatment sum of squares= 16.32
Replication sum of squares= 9.74
Error sum of squares= 19.10

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	9.74	4.87	1.53
Treatment	3	16.32	5.44	1.71
Error	6	19.10	3.18	
Total	11			

Appendix Table 29. Effect of UV radiation on the longevity males of *E. sorbillans* (days)

Treatment	Dose 60 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.67	9.75	11.33	11.58±1.14
T♂xT♀	9.00	8.00	10.05	9.02±0.59
T♂xC♀	6.42	7.90	10.50	8.27±1.19
C♂xT♀	6.00	9.50	10.60	8.70±1.39

Total sum of squares= 49.97
Treatment sum of squares= 20.02
Replication sum of squares= 9.03
Error sum of squares= 20.92

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	9.03	4.51	1.29
Treatment	3	20.02	6.67	1.91
Error	6	20.92	3.49	
Total	11			

Appendix Table 30. Effect of UV radiation on the longevity males of *E. sorbillans* (days)

Treatment	Dose 120 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.67	9.75	11.33	11.58±1.14
T♂xT♀	9.50	7.60	8.50	8.53±0.55
T♂xC♀	9.00	8.40	7.30	8.23±0.50
C♂xT♀	8.10	7.50	8.98	8.19±0.43

Total sum of squares= 36.35
Treatment sum of squares= 24.17
Replication sum of squares= 6.23
Error sum of squares= 5.95

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	6.23	3.11	3.15
Treatment	3	24.17	8.06	8.14*
Error	6	5.95	0.99	
Total	11			

* Significance at 5% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 0.99)/3\}}$
= 0.81
and t= 2.45

Therefore, LSD at 5%= 0.81 x 2.45
= 1.98

Appendix Table 31. Effect of UV radiation on the longevity males of *E. sorbillans* (days)

Treatment	Dose 240 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	13.67	9.75	11.33	11.58±1.14
T♂xT♀	10.30	8.67	6.32	8.48±1.16
T♂xC♀	9.66	7.60	6.80	8.02±0.85
C♂xT♀	9.55	6.37	8.30	8.07±0.93

Total sum of squares= 51.72
Treatment sum of squares= 26.44
Replication sum of squares= 18.78
Error sum of squares= 6.50

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	18.78	9.39	8.69*
Treatment	3	26.44	8.81	8.16*
Error	6	6.50	1.08	
Total	11			

* Significance at 5% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 1.08)/3\}}$
= 0.85
and t= 2.45

Therefore, LSD at 5%= 0.85 x 2.45
= 2.08

Appendix Table 32. Effect of UV radiation on the adult longevity females of *E. sorbillans* (days)

Treatment	Dose 30 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	14.80	17.30	15.90	16.00±0.72
T♂xT♀	12.00	10.80	9.70	10.83±0.66
T♂xC♀	14.10	11.30	10.90	12.10±1.01
C♂xT♀	13.10	11.80	9.70	11.53±0.99

Total sum of squares= 65.96
Treatment sum of squares= 48.20
Replication sum of squares= 7.81
Error sum of squares= 9.95

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	7.81	3.90	2.35
Treatment	3	48.20	16.07	9.68[t]
Error	6	9.95	1.66	
Total	11			

[t] Significance at 5% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 1.66)/3\}}$
= 1.05
and t= 2.45

Therefore, LSD at 5%= 1.05 x 2.45
= 2.57

Appendix Table 33. Effect of UV radiation on the adult longevity females of *E. sorbillans* (days)

Treatment	Dose 60 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	14.80	17.30	15.90	16.00±0.72
T♂xT♀	9.33	8.90	11.80	10.01±0.90
T♂xC♀	13.10	10.60	11.30	11.67±0.74
C♂xT♀	12.50	9.10	10.40	10.66±0.99

Total sum of squares= 82.71
Treatment sum of squares= 65.46
Replication sum of squares= 2.25
Error sum of squares= 15.00

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	2.25	1.12	0.45
Treatment	3	65.46	21.82	8.73*
Error	6	15.00	2.50	
Total	11			

* Significance at 5% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 2.50)/3\}}$
= 1.29
and t= 2.45

Therefore, LSD at 5%= 1.29 x 2.45
= 3.16

Appendix Table 34. Effect of UV radiation on the adult longevity females of *E. sorbillans* (days)

Treatment	Dose 120 second			
	Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	14.80	17.30	15.90	16.00±0.72
T♂xT♀	9.80	11.50	8.10	9.80±0.98
T♂xC♀	12.30	10.50	9.80	10.86±0.74
C♂xT♀	11.50	9.40	9.10	10.00±0.97

Total sum of squares= 92.71
Treatment sum of squares= 77.04
Replication sum of squares= 5.33
Error sum of squares= 10.34

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	5.33	2.66	1.55
Treatment	3	77.04	25.68	14.93**
Error	6	10.34	1.72	
Total	11			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 1.72)/3\}}$
= 1.07
and t= 3.71

Therefore, LSD at 1%= 1.07 x 3.71
= 3.97

Appendix Table 35. Effect of UV radiation on the adult longevity females of *E. sorbillans* (days)

Treatment	Dose 140 second Replication			Mean±SE
	R_1	R_2	R_3	
C♂xC♀	14.80	17.30	15.90	16.00±0.72
T♂xT♀	10.10	7.70	9.80	9.20±1.31
T♂xC♀	11.50	9.40	9.90	10.27±1.20
C♂xT♀	11.80	8.90	6.10	8.93±1.65

Total sum of squares= 124.24
Treatment sum of squares= 99.03
Replication sum of squares= 5.73
Error sum of squares= 19.48

ANOVA Table

Source of variation	DF	SS	MS	F
Replication	2	5.73	2.86	0.88
Treatment	3	99.03	33.01	10.16**
Error	6	19.48	3.25	
Total	11			

** Significance at 1% level

LSD for treatment= SE x t

Here, SE= $\sqrt{\{(2 \times ms)/r\}}$
= $\sqrt{\{(2 \times 3.25)/3\}}$
= 1.47
and t= 3.71

Therefore, LSD at 1%= 1.47 x 3.71
= 5.45