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[Review]

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Biological Control Strategy of Uzi Fly in Sericulture

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Uzi fly (*Exorista bombycis* Louis) is one of the major larval endo-parasitoid of silkworm (*Bombyx mori*). It causes extensive damage to sericulture industry. The application of synthetic organic pesticides has tremendous impact on minimizing pest population but their overuse and frequent misuse and high sensitivity towards the silkworms, has forced the entomologists to search for alternatives to chemical control, which is safe to silkworm, environment and farm workers. Biological control continues to offer exciting possibilities for the control of fly pest population. It is environmentally safe alternative to chemical control and offering a long-term protection. Several potential hymenopteran parasitoids have been screened. Among successful natural enemies, *Nesolynx thymus, Trichomalopsis apanteloctena, Trichopria* sp., *Brachymeria lasus, Pediobius* sp., *Spalangia* sp., *Spilomicrus karnatakensis* and *Dhirhinus* sp. are important. It is essential to predict accurately the efficacy of these natural enemies in a new habitat prior to its introduction. The important desirable attributes of these potential parasitoids *viz.*, host searching capacity, specificity, power of increase and fitness and adaptability of the parasitoid in new environment has been recorded. Results of the host parasitoid interaction indicate that the aging of the host function as a factor that influence the host finding efficiency of the parasitoid. It is highly scored with 15 - 20 hrs old pupa of the host. However, aging of the parasitoid does not significantly affect it. The sex ratio is female biased which is advantageous from biological control point of view. Biological suppression methods involving conservation and utilization of natural enemies have been discussed in detail.

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Introduction

Indian uzi fly (*Exorista bombycis* Louis) is the key parasite of mulberry silkworm (*Bombyx mori*) (Krishnaswamy *et al.*, 1964; Devaiah *et al.*, 1992). The female flies lay eggs preferably on the fourth and fifth instars silkworm (Fig. 1). The maggots after hatching enter into the body of silkworm, eat away the body contents for 4 –

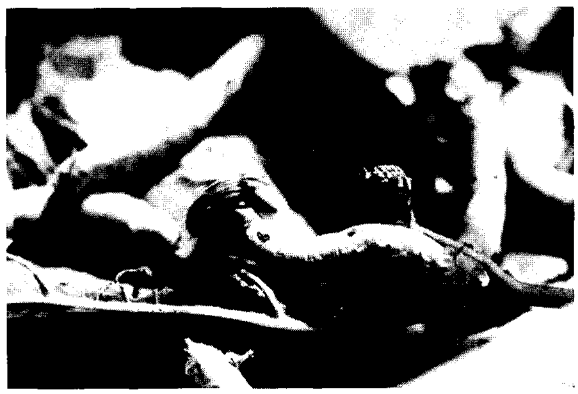

Fig. 1. Uzifly laying eggs on mulberry silkworm.

Fig. 2. Tasar silkworm showing a black scar indicating the site of penetration of the young uzi maggot.

6 days and kill the host subsequently. The infested silkworm larvae can be identified by the presence of black scar developed on the skin at the point of entrance and it increased in size day by day (Fig. 2). Besides mulberry silkworm, uzi-flies have been reported to attack tasar silkworm (*Antheraea mylitta*), Oak tasar silkworm (*Antheraea proylei, A. pernyi* and *A. yamammai*), muga silkworm (*Antheraea assama)* and eri silkworm (*Philosamia ricini*), (Singh *et al.*, 1993; Patil and Govindan, 1984). Besides these, some other lepidopteran caterpillar especially from order lymantriidae, saturnidae, and sphingidae has been reported to be an alternate host to Indian uzi fly (Singh *et al.*, 2000). Life history and biology of this Indian fly pest has been thoroughly studied and much of the information is available on the developmental stages and duration of the life cycle in various regions. The life cycle period is 16 – 23 days in hot and humid region and 15 – 25 days in dry region of south India (Datta and Mukherjee, 1978).

Several methods have been developed to control the fly pest population *viz.*, nylon net on outdoor/indoor rearing, light traps and methods based on chemical control measures like uzi trap, uzicide, uzi powder and even low concentration of diflubenzuron (Kumar *et al.*, 1986a, b). Synthetic organic pesticides have been used to control the menace of fly pest but their overuse and frequent misuse have resulted in serious worldwide problems with disastrous consequences as to the profitability of certain crops. Further, resurgence of target pest population due to development of pesticides resistance coupled with the elimination of natural enemies and competitors, the ascent of new secondary pests that often are more injurious and harder to control than the original target pests, toxicity hazards to man, plants, domestic animals and wild life, contamination of soil, water and food chains and whole sale pollution of environment (Doutt, 1964; Van den Bosch and Haramoto, 1953) have forced the entomologists to search for other control measures. Unilateral reliance on chemical pesticides is not likely to provide solution to all our pest problems. Safer, less costly alternatives to chemical control are therefore, desirable as part of an integrated interdisciplinary approach to uzi fly management.

Biological control is desirable requirement for uzi fly control in sericulture. It is an ideal form of pest management -permanent, inexpensive, non-hazardous with its firm basis in sound ecological principles. It is the most successful and most promising alternatives of chemical control. When successful the utilization of native natural enemies is an inexpensive, non-hazardous means of reducing uzi fly populations and maintaining them often permanently below established economic thresholds is applied. Therefore, it is essential to know the potential biocontrol agents and its biological attributes in the native natural habitat of silkworms and its host plants.

Natural enemies of uzi fly

Both predators and parasites are animals that feed on the other animals, but a predator consumes several host individuals during its development, where as the parasite completes its development on a single host (Singh *et al.*, 2001). A parasitoid is a special kind of predator is often the same size as its host, kills the host, and requires only one host (prey) for development into a free-living adult. Several parasitoids have been screened and their parasitization potential has been tested against uzi fly pupae. *Nesolynx thymus, Trichopria* sp., *Exoristobia philippinensis, Dirhinus* sp., *Brachymeria lugubris, Spalangia endius, Pachycrepoideus veerannai,* and *Spilomicrus karnatakensis* are the important parasitoids of uzi fly (*Exorista bombycis*) (Kumar *et al.*, 1988; 1989a, b, 1991; Samson and Ramadevi, 1985). *Nesolynx thymus* prefers to parasitize Indian uzi fly puparia where as *Trichomalopsis apanteloctena, Pediobius* sp., *Brachymaria lasus* and *Theronia maskaliya* generally parasitize tasar uzi fly puparia (Singh *et al.*, 1995; Singh and Thangavelu, 1995, 1996). Almost all are effective in minimizing uzi fly population but the parasitization potential of these parasitoids differ variably. There is a 10 – 20 percent variation in the parasitization potential of these parasitoids. Field release study has shown that even a potential parasitoid under laboratory condition does not become successful in new ecosystem, thus it needs to be standardized (Singh and Thangavelu, 1999).

Desirable attributes of natural enemies

In order to assess the usefulness of bioagents for the control of uzi fly the study of various attributes of the parasitoid has been made by the methods described by Singh and Sinha (1995). The main attribute of the effective natural enemies is searching capacity, specificity, power of increase and adaptability (Waage, 1986; Lenteren, 1983). All these attributes are of course closely related to each other and influence the population density of parasitoids in natural habitat.

Host searching ability

Searching capacity, manifested by the ability to find the host even when it is scarce, is commonly regarded as the most important attributes of effective natural enemies. The concept has been commonly expressed in terms of natural enemies area of discovery (Lenteran, 1986). A parasitoid beneficial as bioagent must successfully utilize the low-density population of the pest. *T. apanteloctena* and *N. thymus* has been found capable of attacking more than 75% of the uzi fly pupa within a six hour. It indicates its high searching capacity *i.e.*, the ability to find the hosts, when the host density is low. This is a more important attribute than a higher reproductive potential (Singh *et al.*, 1994). Studies made on the area of discovery of *Nesolynx thymus* revealed that it also has a high searching ability at higher host densities (Singh and Thangavelu, 1997). This behaviour enables the parasitoid to reproduce more rapidly such densities. The search for natural enemies are preferably carried out in undistributed environments. Backyard gardens and uncultivated tracts are sometimes more likely to yield as greater varieties of species than commercial plantations. To prevent the inadvertent introduction of any undesirable organism, including hyperparasite species, all-important material should be handled under strict quarantine.

Specificity

Although some out standing successes of biological control have been achieved in several other crops through utilization of natural enemies of related species, the empirical record of biological control studies in sericulture indicate that most success have been achieved with fairly specific natural enemies *viz.*, *N . thymus, T. apanteloctena* and *Trichopria* sp. They are attuned to the physiology, behaviour, habitat preferences, and pattern of its dispersion and phenology of uzi fly (Kumar *et al.*, 1992). These parasitoids have degree of biological adaptation to the pupa of uzi fly and also has a greater degree of direct and rapid responsiveness to density changes in the population of the uzi fly (Singh and Thangavelu, 1999). *N. thymus* is not strictly a host specific parasitoid as it is also reported to parasitize other dipteran insect. *T. apanteloctena* is another potential parasitoid and it was observed that both the species co-exist on the same host. In the laboratory both the species were more or less equally parasitizing the uzi fly pupa. It is therefore, more likely to be highly density dependent in relation to its particular host (Huffaker, 1971) than a more generalized feeder. On the other hand general feeders have the decided advantage of being able to survive even during period of scarcity of given host (Huffaker, 1971; DeBach, 1974). Most of the uzi fly parasitoids are oligophagous and many are truly polyphagous. However, the process involved in host finding and discrimination by the predators and parasitoids in nature are, of course, intimately associated with their searching behavior. They are seen as comprising a series of four restrictive steps: habitat selection, host findings, host acceptance and host suitability (Doutt, 1964).

Habitat selection is first and sometimes most important step in sequence. Before actually searching for its host, a natural enemy may seek a certain environment, a particular type of vegetation or host plant etc. In locating its preferred habitat it may respond to various chemical and physical cues, which may be related to either the host plant or the host itself or to their interaction (Hagen *et al.*, 1976; Vinson, 1981). Chalcid parasitoids usually exhibit marked host specificity and host findings and host acceptance are heavily mediated by responses to physical and chemical cues (Townes, 1972). Host suitability is another important factors to parasitoids that oviposite to other hosts. The success and failure of parasitization is largely dependent on the host suitability by such parasitoids. Oviposting parasitoids may inject venom that modifies the host and render it suitable for parasite development (Vinson, 1975). In most of the cases, the ability to recognize and avoid unsuitable host is highly desirable attribute of parasitoids. The relationship between the number of hosts parasitized and the host densities is found to be linear. There is a sharp increase in the number of host paraasitized as the host densities increases, but increase in the host density beyond the capacity of the parasitoid to parasitise it lead to decrease in the percentage of parasitization (Singh and Thangavelu, 1999).

Power of increase

A natural enemy that has received host regulation in a stable environment that has reached the hypothetical steady state would only require a power of increase sufficient for replacement of the parent population in each generation. The actual power of increase of a natural enemy in the field may be affected by its fecundity and rate of development, as well as by such other factors as its searching capacity and adaptability to the condition of the particular habitat (Singh *et al.*, 1995; Singh, 1998).

Fitness and adaptability

To be effective in a new habitat, an introduced natural enemy should preferably be pre-adapted to it. However, the possibility of possible gradual post colonization adaptation cannot be discounted. A well-adapted natural enemy should not require any essential requisites that are not present in the new habitat. It should be able to tolerate the prevailing climatic conditions, and should be effectively synchronized with the biology and phenology of its host in the habitat. Specific features required for synchronization may vary with the habitat. Diapauses for instance may be mandatory in one area, whereas in another area it may prove to be detrimental. In general precise synchronization is more likely to occur in a host specific natural enemy than in a general feeder.

Ideally, a natural enemy should be adapted to all the habitats and niches occupied by the target pest. It should frequent all the host plant and tolerate all the climatic regimes that its host does, and should equally effective in all of them. Just as the natural enemy should be well adapted to the various natural aspect of the ecosystem, it should also be adapted to cope with man made hazards, such as pesticidal treatments. (Croft and Brown, 1975; Rosen and Huffaker, 1983). Thus the factor effecting the searching behavior of natural enemies may also determines its host specificity where as searching efficiency of a population of natural enemies is also a function of number searching, hence their power of increase and their fitness (Hassell, 1978). Just as the natural enemy should be well adapted to the various natural aspect of the ecosystem, it should also be adapted to cope with man made hazards, such as pesticidal treatments. Resistance to various pesticides is known to have developed in the field in the number of predatory mites (Rogers and Hassell, 1974, Vinson, 1981) and further research is likely to discover additional cases among various natural enemies. Such resistant species strains should be regarded as highly desirable for biological control agents (Alphen, 1986). The tolerant doses of insecticides against the pupal parasitoids of uzi fly especially, *N. thymus, Trichopria* sp., *Spalangia* sp., and *T. apanteloctena* needs to be standardized for successful release in the field.

Others attributes

Various other attributes have been ascribed to effective natural enemies, but they all are regarded as manifestations of the searching capacity, specificity, power of increase and adaptability. Thus, the factors effecting the searching behavior of natural enemy may also determine its host specificity, whereas searching efficiency of a population of natural enemies is also a function of the numbers searching, hence their power of increase and their fitness (Huffaker *et al.*, 1970). It does not mean that a effective natural enemy have to be superior in all these attributes. Even in outstanding biological control successes the controlling natural enemies often exhibited deficiencies in some of them.

Competitive ability has often been mentioned as desirable. One should distinguish here between extrinsic or exploitable competition, involving efficiency in the exploitation of pest population by a population of natural enemies, and intrinsic or interference competition which, in parasites, involve competition between the larval forms or in a given individual host. Superiority in exploitative competition is largely determined by a natural enemy searching efficiency, whereas superiority in interference competition is a form of adaptive ness that may be less desirable than the capacity to discriminate parasitized hosts and avoid such completion altogether.

Utilization

In well design IPM program, the pest population is maintained at lower level by the action of parasites, predators and pathogens (DeBach and Hagen, 1964). There are three basic approaches to applied biological control: importation, conservation and augmentation.

Importation

Importation (classical biological control) has been used very successfully against a variety of pests (Clausen, 1978; DeBach, 1971). Screening of potential parasitoid is the most important factor in any successful biological control program. There are however, still many important pest species that are not amenable to the classical biological control approach (Nordulund, 1984). Many of these pests are found in disrupted environments such as annual row crop and green house agro ecosystems. These cropping systems are not generally conducive to the establishment of long term stability, which is critical to the success of a classical importation program (Lewis and Nordlund, 1980).

Importation including the search for, transfer, quarantine handling, colonization and establishment of exotic natural enemies, has been by far the most important and most promising approach to date, and has accounted for the great majority of outstanding success in applied biological control. It is also the least expensive method of natural enemy utilization. However, in certain instances an already established natural enemy, whether indigenous or introduced, may show considerable promise but fall short of fulfilling its potential due to inadequacies of its own attributes or the environment.

There are several potential parasitoids of uzi fly existing in the nature but its exploitation has not been done due to lack of sufficient information on the behavioral response of the parasitoids. Even well known natural enemies of proven high efficiency still await transfer into many areas, where uzi fly is a serious problem. There are several hymenopteran parasitoids available in the nature, which can be utilized to control the uzi fly population. These unknown species are considered as potential weapons and it can be applied as biological control tools (Kerrich, 1960; Townes, 1972). Sound systematic is an essential pre-requisite to the success of biological control program. Therefore, the correct identification of pest and parasitoids are of utmost importance (Rosen, 1978).

Conservation

Conservation involve permeated action to protect and preserve existing parasites, predators and pathogens; basically not taking actions that would be detrimental to natural enemies (Nordlund, 1984; Rabb *et al.*, 1976). IPM programs that result in a reduction in pesticide use generally contribute to conservation. Conservation and augmentation in biocontrol involves two phases, first the maintenance of existing parasitoids by avoiding harmful practices and secondly, the augmentation of parasitoids either directly releasing them in the field or by indirectly making the field environment more favorable for them. Although a number of species of eulophid parasitoids have been reported, it is rather easy to identify more effective parasitoids based on their parasitization capabilities. *Neoslynx thymus* and *Trichomalopsis apanteloctena* both multivoltine parasitoids have been identified to be such potential parasitoids. These parasitoids which appear after the arrival of uzi fly maggots in the field (Kumar *et al.,* 1990) need to be conserved from the use of pesticides which is very intensive on mulberry plants. Several authors have worked out the toxicity of popular insecticides against chalcids. Toxaphene, endosulfan and phosalane have been reported very safe, while fenthion and ethion are highly toxic. Conservation of parasitoids can be better served if systemic insecticides are encouraged. Another important aspect of conservation in the field is to find out the means to arrest the depressiveness of the parasitoids from field to field or away from the site of release. Waage (1986) reported the evidences for parasitoids movement and reasons thereof. Basically the movement is reported to be influenced by prevailing temperature ñ higher temperature induces more flight and low host density - more movement.

Augmentation

Augmentation involves actions to increase the populations of beneficial effects of parasitoids, predators or pathogens (Nordlund, 1984; Rabb *et al.*, 1976; Ridgway and Vinson, 1977).There are two basic approaches to augmentation, environmental manipulation and periodic releases (Stinner and Bradley, 1989). Periodic releases can be inoculative or inundative. Inoculative releases are releases of relatively small number of biological control agents, often on seasonal basis. The control in inoculative release programs is expected to come primarily from the progeny of these agents being released. Inundative releases are releases of relatively large numbers of biological control agents, and the control is expected to come from the released agents, not necessarily from their progeny (DeBach and Hagen, 1964). Inundative releases programs usually involve the number of releases during the season, while inoculative release programs may involve only one release. It is possible by sustained release of laboratory-reared parasitoids.

Our ability to use periodic releases of the parasitoid to control uzi fly, is to rear, transport and effectively release large number of high quality biological control agents. Periodic release requires continuous release program and thus, has commercial potential and fit IPM programs well. The growing number of commercial suppliers of biocontrol agents is evidence of this potential (Lisansky, 1990; Thomson, 1992). Adoption of biological control has had positive economic impact (Tisdell, 1990). It must be pointed out that biological control particularly augmentation and conservation does not operate in vacuum. Biological control is the most successful as part of an integrated program involving host resistance and cultural control technology.

The efficacy of such natural enemies may be sometimes enhanced through various method of augmentation, or direct manipulation of their populations, such as periodic colonization, genetic improvement, or the use of semio chemicals that affect their performance. Another possible approach is through conservation, or manipulation of the environment, either by adding of asking requisites or by mitigation of various detrimental factors.

Sex ratio

Sex ratio plays a very significant role in biological control. It helps us to understand the reproductive strategies of the parasitoids because a significant variation in the sex ratio was observed in parasitic Hymenoptera. The relative abundance of males and females commonly fluctuates when parasitic hymenoptera are propagated for several generations. The fluctuation results in part from changes in the parasitoid: host ratio at the time parasites are ovipositing. Usually an increase in the parasite: host ratio reduces the per cent age of female progeny in arrhenotokous parasite species with gregarious larvae, either by reducing the percentage of fertilized eggs, *i.e.,* female eggs that the parent females lay (Wylie, 1976), or by killing relatively more female than male parasite larvae on super parasitized host (Wilkes,1963; Benson, 1973). It has been reported that five females of *T. apanteloctena* produced relatively more female progeny from 100 hosts exposed daily than from 25 hosts ; percentage were 76.2 and 53.7 for 892 and 618 adults, respectively (Singh and Thangavelu, 1997). The results indicate that the percentage of female progeny progressively decreased as the parastioid : host ratio increased. However, in *N. thymus* it was observed that progeny production affected when 9 days old puparia were exposed to the parasitoids. The increase in the progeny production was not significant with every succeeding increase in the number of host puparia exposed to single parasitoid except when the parasitoid to host ratio was increased from 1 to 1 : 2 (Kumar, 1990). These findings therefore, suggest that maximum progeny production is obtained by providing 1 day old 5 host puparia to single parasitoid. Further, it has been reported that age of parasitoid had no significant influence on rate of parasitism and progeny production of *N. thymus*. But there is a direct and progressive relationship between the progeny production and increase in the number of host puparia. It is therefore, inferred that maximum progeny can be obtained by maintaining 1 : 4 or 1 : 5 parasitoid to host ratio. Sex ratio is affected by several biotic and abiotic factors. Apart from this, interference among the parasitoid adults, previous parastization of the host; and differential mortality of the male and female larvae on super parasitized are the important factors in the maintenance of sex ratio population in the field (Singh, 1998). The sex ratio ranges from a slight male bias to entirely female bias (Waage, 1986). The sex ratio is affected by several other biotic and a biotic factors but the mean sex ratio among the field collected samples were always female biased (Singh *et al.,* 1995).

Besides this some other basic systematic and biological information are required to be known for the potential parasitoids. Verification of primary status of natural enemy is of course, of crucial importance, but this may be done in quarantine after importation. Importation about voltanism, diapause, specificity etc. can be useful in planning; release and establishment of strategies but this too may be obtained at later stage. In any event, only reasonably well-identified primary natural enemies should be released for the control of the fly pest population in the field.

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