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Review

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Biological Control of the Pentatomid Stink Bug, *Eocanthecona furcellata* (Wolff.), by using their Parasitoid, *Psix striaticeps* Dodd, in Sericulture

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Stink bug, *Canthecona furcellatta* (Hemiptera: Pentatomidae), is an important predator of silkworm larvae. Nymphs and adult attack the early stage silkworm larvae and causes about 10 – 15 per cent loss to silk industry. Synthetic organic pesticides has tremendous impact on minimizing the pest population but repeated and frequent use has created problems of residual toxicity, development of resistance to insecticides, pest resurgence and out break, phyto-toxicity and hazards to non target species and beneficial organism. Silkworms are very sensitive to pesticides; therefore, attempt has made to control the bug population through introduction of its native natural enemies in the silkworm-rearing field. Biological control has tremendous scope in sericulture because it is eco-friendly in nature and non-harmful farmers. Native natural enemies have been screened. *Psix striaticeps*, *Trissolcus* spp. and *Telenomus* spp. have been recorded as the most potential parasitoid against pentatomid bug. Life cycle, sex ratio and other various attributes of the parasitoids have been recorded. The parasitization potential of the parasitoid is very high and they have the ability to discriminate between parasitized and unparasitized host. Mass propopagation technique under laboratory condition has been standardized.

Key words: Biological control, *Canthecona furcellatta, Psix striaticeps,* Sex ratio, Parasitization

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Introduction

The pentatomid *Eocanthecona* (= *Canthecona*) *furcellata* (Wolff.) (Pentatomidae: Hemiptera) has been documented as a predator of several pests of agricultural crops in south - eastern Asia (Cherian, 1917; Pant, 1960; Chu, 1975; Rai 1978; Gope 1981; Chien *et al.,* 1984; Rani, 1992; Rani and Wakamura, 1993). In India, it has been recorded as a serious predator of tropical tasar silkworm (*Antheraea mylitta*) causing considerable loss to silk industry in India (Jolly, 1967; Singh *et al.*, 1992a). It was also found preying on the temperate tasar silkworms, *A. proylei* and *A. roylei.* Sen *et al.* (1971) described the biology and population dynamics of *Canthecona furcellata* in tasar eco system. The insect completes its lifecycle in 35 to 40 days and is multivoltine in nature with 6 – 7 broods per year. There are five nymphal instars and the fifth moult takes place on the 19th day (12 mm) transforming into an adult which develops fully by 20th or 21st day. The adults are bronzy in colour. The mating takes place 3 – 4 days after the last nymphal moult. A single female lays about 200 to 300 eggs extending for about 8 days. The incubation and nymphal period lasts for 6 – 15 days, respectively. The adults are dimorphic with thoracic marks. The females are broader than male caries mid ventrally a pink spot on the 5th sternal segment near the anterior margin. In the male the marks extend slightly to the fourth sternite in the form of a faint pink line. An adult lives for about 13 to 19 days.

The survey results indicate that the pest makes its appearance in the last week of April and increases above economic injury level by the second week of May. The population increases till September and rises abruptly to its peak by the middle of October. After mid October the population starts declining and the bug goes under hibernation between December and February (Singh *et al.*, 2000). The feeding behaviour of stink bug is interesting. The bug approaches its prey slowly and suddenly pierces its proboscis inside the body of silkworm into the central nervous system. They generally attack the middle of the body of the prey so that the efforts of the prey to get rid of the enemy fail. After piercing, the feeding process continues for about 15 minutes at a stretch. Generally the first and second instars larvae are killed with one prick while later instars can survive 4 – 5 pricks. The predatory potential of the *C. furcellata* is very high. A single predator can feed and kill 130 to 225 tasar larvae of 1^{st} to 3^{rd} instars.

Several control methods (chemical, mechanical, and cultural) are known to minimize the pentatomid bug population, but farmers prefer to use synthetic insecticides due to the ease in application. Though use of synthetic insecticides has provided us with effective control of almost all major pests and predators, yet their undesirable side effects limit their continued use. However, repeated and frequent application of modern synthetic insecticide has created problems of residual toxicity, development of resistance to insecticides, pest resurgence and out break, phytotoxicity and hazards to non target species including natural enemies and other beneficial organisms, alternation in pest species population dynamics, environmental degradation and disruption of natural balance. In view of these drawbacks associated with excessive dependency on chemical control, the concept of "Integrated Pest Management (IPM)", which combines all possible measures into a compatible and harmonious package, has gained prominence (De Bach, 1974). Biological control is considered as an essential component of IPM as it is economical, effective and eco-friendly. Natural enemies play an important role in suppressing pest population in the crop whenever suitable conditions prevail for their survival, development, conservation, and multiplication in any agro-ecosystem. The complexities in the behaviour and life cycle of pentatomid bugs warrant a special attention for their effective management especially in view of the changing practices in sericulture. For a sustained development in all spheres of life, sustainable sericulture has become a significant topic of discussion. Conservation of our natural resources, air, soil and water, stands at top priority and hence IPM strategies should aim at the approaches, which do not lead to degradation, depletion or pollution of natures gifts. Thus it is high time that we may lay more emphasis on evolving eco-friendly non-chemical approaches for pest management. Biological control is one of the most important methods, which can be used to control the undesirable pests and predators. Various potential parasitoids have been screened which can be utilized as an agent of biological control in sericulture (Thangavelu and Singh, 1992). The use of bio-control agents has many advantages. Biological studies of *Psix striaticeps* revealed its importance as a promising biological control agent against the stink bug *C. furcellata* (Singh and Thangavelu, 1996; Singh *et al.*, 1992b, Singh and Sinha, 1995).

Host location and habitat selection

Host location and preference using chemical cues constitute the first step leading to successful parasitization. Chemical signals have a significant role in organizing the host, pest and parasitoid complexes. Semiochemicals help natural enemies to locate and recognize their hosts through many inter and intra specific interactions. The host plant, the insect, predator or parasite, all release exudates, and these chemicals serve as mediators in host selection. These volatile chemicals affect behaviour of not only the host insect, but also the parasitoid. Studies on the enhancement of tropical tasar silk production through manipulation of host plant-insect herbivory interactions indicate that chemical constituent of host plants play a key role in effective manipulation of communication system involved in allelochemical web of triotrophic interaction in sericulture (Babu and Chauhan, 1994; Som, 1996; Roger and Hassell, 1974). Similar observations on insect plant interactions were reported earlier by Bragg (1974), Ladden (1970), Price *et al.* (1980) and Elzen *et al.* (1983).

Earlier studies were conducted on two tropic levels only, plants and their herbivores. But the recent researches on the biological control reveals that it is intimately linked with the allelochemical web of plant-pest-parasitoid/predator, resulting in a tritrophic or sometimes a tetratrophic level of interaction (Elzen, 1983; Price, 1981; Schltz, 1983; Muller, 1983). Our studies of allelochemcilcal interactions among silkworm host plants and its associated herbivores and parasitoids were designed to determine how these three trophic level system operates in the light of the biological problems outlined above. Chemicals mediating parasitoid-host-plant interactions are classified as kairomones, allomones, and synomones (Lewis *et al.*, 1982) and appear to be key factors determining host location and governing the range of hosts attacked by parasitoids. One major task faced by a female parasitoid is location of the habitat harbouring host insect. Initially a parasitoid may seek certain environment regardless of presence or absence of the hosts (Doutt, 1964). The host, however, remains only in specific locations within that environment, and a female parasitoid must locate those locations of the habitat most likely to yield their hosts. Factors attracting the parasitoid to a plant and retain it in the area have a positive selection value for the plant due to parasitoids beneficial effects in reducing herbivore survival and fitness (Sauls *et al.*, 1979). The foraging activity of the parasitoids may be influenced by a number of factors in the plants or hosts.

Plant may produce chemicals that attract and retain parasitoids (Nettles, 1979; Vinson, 1975) or provide nutrition (Sahajahan, 1974) and thereby attracts parasitoids. A few attractants have been identified in pioneering studies of parasitoid-plant interactions (Read *et al.*, 1970; Camors and Payne, 1972; Elzen, 1983; Elzen *et al.* 1984a, 1984b; Lecomte and Thibout, 1984). Parasitoids are more often attracted to plants on which their host feeds (Thorpe and Caudle, 1939; Monteith, 1955, 1964; Arthur, 1962; Madden, 1970). Damaged plants may provide stimuli for increased parasitoid searching (Nishida, 1956; Bragg, 1974; Vinson, 1975). Some parasitoids are be attracted by fruits and flowers (Nordlund and Lewis, 1976; Voronin, 1981) or other specific parts (Nishida, 1956). Plants also may influence the general attraction of the herbivore (Muller, 1983) or kairomonal activity of the herbivores frass (Sauls *et al.*, 1979; Nordlund and Sauls, 1981; Elzen *et al.*, 1984b) and host reared on different plants may vary in attractiveness (Nordlund and Sauls, 1981). Retention of beneficial insect on the plant may require sources of nutrition, refuge sites and host insects (Lewis *et al.*, 1982) besides chemical cues. Our experiments on plant produced attractants for beneficial insects and effects of plant defence compounds on the quality of herbivore as reproductive resource for parasitoids focused on *Terminalia.* It was chosen because of its economic importance in sericulture and availability of many related species as well as data on *Terminalia* volatiles. Babu and Chauhan (1994) studied the volatile compounds in *T. arjuna* and *T. tomentosa* leaves and its effect on the growth and development of silkworm larvae.

Reason for biological control

Insect populations have a tendency to fluctuate as result of their inherent characteristics as influenced by the environmental factors. The magnitude of the increase and decrease in numbers is governed by the degree of influence of various environmental factors. The rate of change in pest population is determined by the fecundity, rate of development and survival among its members. The same factor may be favourable in case of one population but may become unfavourable for another. It is thus necessary to consider the influence of various factors with reference to a particular pest population (Beine, 1984). The pest control strategy, primarily involved unilateral use of pesticides which had many shortcomings and hence the emphasis on Integrated Pest Control/ Pest management.

The control of various pests and predators in sericulture is a complicated process due to the close association of silkworms and their food plants. The requirement of pesticides is high. Since the pesticides are poisonous, their use poses a threat to silkworms as well. Sometimes indiscriminate uses of hard pesticides promote speedier evolution of insect pests, affect non-target species, convert formerly innocuous species into noxious pests, and leave undesirable residues in silkworm and their host-plants. Therefore, the focus now has been shifted from chemical control to other alternative methods of pest control or adoption of an integrated approach based primarily on use of bio control application of botanicals, and safer pesticides. Such an approach may lead to reduction of residues and ancillary problems associated with pesticide application (Huffaker *et al.*, 1971). Pesticides disrupt interaction between phytophagous insects and their natural enemies, the essential ecological processes operating in nature that contribute to the regulation of insect population. Whenever this interaction between phytophagous and entomophagous insects is disrupted, the population of phytophages, increase tremendously and they attain pest status because they become free form the constraints imposed by the entomophages. The realization that conventional pesticides could cause problem came up from the idea that it might even kill the beneficial insects controlling the pests bringing an imbalance leading to a surge in the pest population due to lack of their bio-control agents. Biological control strategies are under utilized and it can not be a total alternative for chemical control, judging from the fact that many of the successful causes of the pest control achieved through biological control predated the era of agrochemicals (Flint and Van den Bosch, 1981). Being forgotten so long and dominated by the use of agrochemicals, biological control is now identified and considered as an alternative method of insect control, together with other non-conventional or plant based control measures (Upadhyay *et al.*, 1997, 1998).

Biological control refers to management and regulation of natural biotic forces to suppress pest populations to a level below the economic injury. Identification of many naturally occurring predators, parasitoids and pathogens prevalent in sericulture ecosystem is the first step towards their conservation, augmentation and manipulation. Classical biological control program is generally less pursued in developing countries like India, where there exists a need to thoroughly explore and evaluate their native natural enemies, which may be potential biological control agents. Fortunately, in India, the native natural enemies have a little probability of extermination caused by synthetic pesticides due to lack of sufficient pesticides or the poor quality of pesticides. It is, therefore, obvious that the conditions prevailing in India can lead to more conducive environment for implementation of the biological control programme by using native or introduced bio control agents (Davis, 1967; Napompeth, 1987). The current revival of interest in biological control is also driven by a change from pest control approaches to maximize productivity to the long-term sustainability of the sericulture ecosystems. The biological control of the pests tends to be a long lasting, often can be implemented at little direct cost to producers and consumers. For these reasons, biological control is considered a corner stone for many Integrated Pest Management (IPM) programmes. The philo- sophy of modern insect pest management is based on the management of entire pest population, unlike in the past where separate techniques are employed for each individual pest. In IPM, emphasis is laid on the use of combination of methods, aimed at providing cheap and dependable long-term approach with reduced side effects. The philosophy of modern IPM programme is thus compatible with the philosophy of biological control; indeed biological control has been the core around which IPM has been developed. The reason for this is that natural enemies constitute the major pest control factors those can be manipulated. The parasitoids can be utilized in three major ways. (i) Imposition of exotic species and their establishment in new habitat, (ii) augmentation of established species through direct manipulation of their population by mass population in insectaria and periodic colonization and (iii) their conservation through deliberate manipulation of environmental factors to enhance their activity (DeBach, 1974; Kumar and Mukerji, 1996)

Applicability of biological control

In biological control parasitoids were favoured over predators because they were most host specific, better adapted and synchronized in interrelationships, have lower food requirement per individual thereby maintaining a balance with their host species at their lower host densities and their larvae do not need to search for food (Van Leteren, 1986). The parasitoids have been used more frequently than predators in the biological control programmes and about 80% of all biological control programmes are because of them (Hokkanen, 1985). Biocontrol agents are now managing more than 300 agricultural and urban insect pests in more than 100 countries. Indeed, the research and development efforts on biological control are very meagre as compared to control by synthetic pesticides. Very little is being invested on the biological control programmes. The basic reason for the relative neglect is that the biological control is widely perceived as unreliable. Biological control has enormous untapped potential capable of being exploited much.

Methods for developing biological control

Van Lenteren (1983) outlined the method for searching and testing natural enemies for biological control, which is followed by many workers. The steps involved are outlined as follows:

- A detailed project is made, covering the pests correct identification, biology and development, together with economic damage it causes.
- The second step is finding and assessing various data about the pests natural enemies.
- An inventory of the effective natural enemies will have to be made.
- General information on the features of the habitat, its associates, its enemies, etc., which controls the population dynamics of the pests is collected.
- An initial selection is of the natural enemies is made in their natural habitat and their associates is studied.
- The initial selection is followed by a detailed study of the most promising species. The study includes reproductive capacity, climatic adaptability, host specificity and discrimination ability and the internal and external synchronization of the natural enemies with the host, etc. The species to be used for field-testing are selected on the basis of these parameters.
- The first field tests are carried out in the experimental areas. If found satisfactory, field tests are repeated with commercial growers. The main purpose of this stage is to determine the migration and host searching ability of the natural enemies, their capacity to establish and colonise within the target environment, and its capacity to suppress the pest below economic threshold level.
- Once a natural enemy satisfies the above conditions, mass cultivation can be started if sufficient organisms can be collected in the original habitat. The collected and cultivated organisms are released into the crop environment.
- Depending on the duration of each brood, the population of the parasitoids and the target pests have to be studied to check for the utility of the parasitoid.

Native natural parasitoid of stink bug

The search for effective biological control agents against bugs of the super family Pentatomidae (Heteroptera) has been focused on their egg parasitoids and in particular, on the species of the subfamily Telenominae (Hymenoptera: Scelionidae) (Joronin, 1981; Wylie, 1982). *Psix straiticeps* Dodd. (Scelionidae: Hymenoptera) parasitizes egg mass of stink bug *C. furcellata*, a major predator of early stage tasar silkworm larvae (Thangavelu and Singh, 1992). Biological and systematic research on those wasps has focused on the large genera *Telenomus* sp. and *Trissolcus* sp. However, in tasar culture, *Psix striaticeps*, *Telenomus* and *Trissolcus* are abundantly available which are highly effective against pentatomid bug and play an important role in the biological control of some economically important predators (Chua, 1979; Singh *et al.*, 2000; Wilson, 1960; Okuda and Yeargan, 1988a, 1988b; Yeargon, 1982).

Psix is most diverse in the Ethiopian oriental and Australian regions. Its distribution also extends into southern reaches of the pale artic and for one species, the new world. The genus characteristically found in relatively arid climates typical of south-western Asia, central Australia and the savannas of Africa. *Psix*, however, is not entirely restricted to these biomass; species have also been collected from the humid forests of South-western India, Southeast Asia, Taiwan and both northern and eastern Australia. The few host records available indicate that the species are egg parasitoids of bugs in the family Pentatomidae, Scentallenidae and Coreidae. Biological information on this genus is scarce. The scelionidae is the largest family of Proctodontoidea, with more than 70 genera distributed among three sub families and more than 20 tribes. *Telenomus* is cosmopolitan, eurytopic genus, with more than 500 nominal species. Several species show some degree of specificity, primly parasitizing only the eggs of host species from which they are reared (Bosuqe and Rabinovich, 1979). Parasitization by a single species of *Telenomus* of insect in more than one order is uncommon (Johnson and Masner, 1985). Biological control in the field has been achieved in some parts of tropical tasar region of India, because their parasitoids have great potential in managing their populations in spite of certain limitations (Singh and Thangavelu, 1991). Navasero and Oatman (1989) reported similar observation for *Telenomus solitus*. The parasitoids become established in 20 out of 25 attempts. The eggs of *C. furcellata* (0 – 24 hrs old) on the eggs card were exposed for one hour to fertilized *P. striaticeps* female confined inside oviposition unit. The development of the parasitoid was recorded by mounting parasitized host eggs in Hoyer, s medium on glass microscope slides: every 2 – 4 hrs on first day; every 6 hrs in second day; and every 24 hrs in thereafter until adult parasitoids emerged from the unmounted eggs. The immature parasitoid stage within the host eggs were examined and measured, using a compound light microscope with an eyepiece micrometer.

Life history

Age-specific survival and fecundity of *P. striaticeps* on *C. furcellata* has been reported (Singh *et al.*, 1995). At 25 ± 2°C, the development of *P. striaticeps* from egg to adult took 12 days. The total duration of immature stages was 10.75 days. The first mortality within the cohort occurred on the fourth day and increased thereafter. The number of females produced by one female *P. striaticeps* ranged from 35 to 52. Egg laying continues for about 7 days and the parasitoid lays maximum number of eggs on the 3rd day. The population increased with an infinitesimal rate (r_m) of 0.275 and finite rate (λ) of 1.32 per female per day. One generation is completed in 13.25 days (T). The weekly multiplication of the population was 6.85 times. The mean sex ratio (male: female) was 1:4.5 (Singh *et al.*, 1995). *P. striaticeps* is a solitary parasitoid but high incidence of super-parasitism was observed under laboratory condition. Two or three individuals emerge from the super-parasitized eggs of *C. furcellata* but with reduced body size. The fecundity of scelionid parasitoids in general was reported to be 30 – 85. Similar observation was made by Braman and Yeargan (1989) in *T. euschisti*, a common wasp parasitizing stink bug.

Sex ratio

The knowledge of sex ratio of parasitoids play a very significant role in biological control (King, 1961). It helps us to understand the reproductive strategies of the parasitoids. A significant variation in sex ratio was observed in parasitic hymenoptera. Fisher (1930) postulated an equilibrium ratio of equal numbers of male and female offspring for randomly mating parasitic species. Hamilton (1967) was the first to show that optimal sex ratios could vary from 0.5 if the assumption of panmixis (= random mating) was relaxed. He constructed the 'local mate competition' (LMC) model for a situation where female placed offspring in discrete patches of resource, and those offspring mated randomly within their patch before female offspring disperse to colonize elsewhere. This situation is found mainly among small gregarious and often parasitic species (Waage and Lane, 1984). The LMC model permits the production of significantly higher number of females than males, each batch of offspring containing at least one male. The males emerge earlier than females and are polygynous. The sex ratio ranges from a slight male bias to entirely female broods (Waage, 1986). Sex ratio of the stink bug parasitoid, *P. striaticeps*, was found to be female biased

(Singh *et al.*, 1994). The predominance of females over males was observed in each sample of *P. striaticeps* collected in adults form or larvae parasitizing egg masses of *C. furcellata*. The mean proportion of females was 75%, which deviated significantly (P=0.001, X^2 test) from an expected sex ratio of 50:50. About 95 percent of the females were mated, which exhibited local mate finding mechanism. Males emerged earlier, remained at the place of emergence to mate with subsequently emerging females. The sex ratio varied during different season.

Parasitization potential

The parasitization efficiency of the parasitoid determines its potentiality against the pest in the target areas. In a population, the number of hosts parasitized per time unit depends upon the number of parasitoids present and the ability of individual parasitoids to locate and parasitize variable number of hosts. Usually *C. furcellata* oviposites enmass on the under surface of the leaves of plants and hence their parasitoids also distributed in patches or groups. The overall parasitization rate depends on the individual performance within a patch of certain host densities (Hassell, 1986). Thus a parasitoid responds to increased host density by increasing the number of hosts each individual destroys (functional response) or by increasing their own numbers (numerical response) while the host destruction per parasitoid remains same (Solomon, 1949). Numerical response is one of the two essential ingredients in modelling any prey-predator or host parasitic interactions, which are descriptions of the entomophages density responses (Hassel, 1986). This response is usually of more interest than the functional response because it is more often responsible for suppressing the host population although it has attracted much less modelling effort (Huffier and Kennett, 1969; Hassell, 1978; Hassell and May, 1974). A rapid and strong numerical response is the most important attributes of a successful agent for pest control (Coppel and Mertins, 1977). The study of numerical interactions between parasitoids and host population also provides the data for calculating the number of parasitoids needed to regulate the estimated pest population (Knipling and Gilmore, 1971). Numerical response was described for few parasitoids (Griffiths, 1977; Yamada, 1987; Hassell, 1971, 1978; Stinner, 1976; Chua, 1979). Excessive release of the parasitoids in large numbers at a time shall not ensure proportional multiplication of the parasitoid (Alphen and Vet, 1986). This was due to non-availability of sufficient number of hosts.

Host discrimination

The subject, ability of host discrimination among parasitic hymenoptera had not attracted the attention of biologists in past. Host discrimination ability is a desirable attribute of potential parasitoids and plays a significant role in their establishment and utility in biological pest management. "Discrimination" in this context means preference or specificity to a particular species of host.

Host discrimination ability of the parasitoid has been reported as one reason for superparasitism (Lenteren and Bakker, 1978; Lenterren, 1981; Singh and Thangavelu, 1994). The ability to reject parasitized hosts is a desirable feature of successful bio-control agents, as it provides an opportunity to infest and destroy more number of host species within the environment, thereby preventing the wastage of energy, potential eggs and searching time, which help in the speedier establishment of the parasitoid. Earlier findings showed that *P. striaticeps*, was a potential egg parasitoid of *C. furcellata* (Singh *et al.*, 1992, 1995; Singh and Thangavelu, 1994; Singh and Sinha, 1995). It has been reported that *P. striaticeps* can discriminate between parasitized and healthy host, a desirable trait also exhibited by some other parasitoid species (Vinson, 1975, 1981). Even then, this cannot completely prevent super parasitism in *P. striaticeps*. Two to four male individuals emerge from a single super parasitized egg where they show reduced body size and mating efficiency. The pre-attack time is longer in in-experienced parasitoids (those which have never come in contact with the host) than the experienced ones. The inexperienced females however superparasitize significantly more hosts than the experienced females (Singh and Thangavelu, 1996). The experienced females reject heavily parasitized egg masses.

Mass propagation

Standardisation of mass multiplication of bio-control agents forms the pre-requisite for using any parasitoid for pest control. Alternate hosts in place of target organisms for multiplication of parasitoids in the laboratory forms a better option since we can avoid multiplication of harmful organisms which can form a great risk even with the slightest negligence or mistake. Secondly, the bio-control agents should be as readily available as chemical pesticides without which, biological control remains a subject of academic interest with no practical role (Manjunath, 1986). Probably less than 2% of the known species of pentatomid egg parasitoids have been reared in the laboratory (Singh and Jalali, 1991). This mainly includes species of *Telenomus, Microphanurus, Aporophlebus,* *Trissolcus,* and *Psix,* which have been used in the biological control of various economically important pests or parasitoids. The culture environment, diet provided to the free-living adult, the size of the host required for the parasitic stages, the capability of the strain etc., are the main factors determining the success of the mass culture programme. Of many factors that can influence the outcome of the rearing programme, the nutritional requirement of the parasitoid is among the most important one (House, 1977). Bosque and Robinnovich (1979) mass reared *Telenomus fariai* on their natural hosts. Yeargan (1982) developed methods for mass rearing, storage and release of *Telenomus podisi* and *Trissolcus eusachisti*. Davis (1967) described this progress in the biological control of the southern green sting bug, *Nazera viridula* variety *smargdula.*

Biological control in the present days is regarded as most effective method of pest control in a very stable ecosystem. But its application needs a thorough understanding of the bio-control agent and its environment and a careful handling. It is also regarded as the most important component of an Integrated Pest Management, but a caution is needed since the chemical pesticides can equally damage the bio-control agents, if not planned properly. Further, a great caution is needed to balance its ecosystem without disturbing beyond certain limits, lest it can become pest of other useful organisms. In silkworm ecosystems use of bio-control agents stand a clear edge over chemical pesticides, since chemicals can cause equal damage to the silkworm, the most wanted.

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