Int. J. Indust. Entomol. Vol. 4, No. 2, 2002, pp. 83~91

Review

International Journal of
Industrial Entomology

Biological Control of Pests of Non-Mulberry Silkworms and Its Host Plants in India

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(Received 18 March 2002; Accepted 26 April 2002)

The protection of silkworm and its host plants from various kinds of pest, parasite and predator is a chronic problem in sericulture. Silkworms and its primary food plants are heavily damaged by large number of pest. The major pests of primary tasar food plants (*Terminalia arjuna* and *Terminalia tomentosa*) are the gall insect (*Trioza fletcheri minor*). Various species of aphids (*Eutrichosiphum* sp.) have been recorded to damage oak tasar food plants whereas muga silkworm host plants (*Machilus bombycina* and *Litsaea polyantha*) are generally attacked by stem borer (*Zeuzera multistrigata*). Castor (*Ricinus communis*) is one of the primary host plant of eri silkworm and extensive damage is caused by the castor white fly (*Trialeurodes ricini*). Insects pests are major enemies of silkworms. Parasites (*Blepharipa zebina, Exorista bombycis, Apateles glomeratus*), predators (*Canthecona furcellata, Sycanus collaris, Hierodulla bipapilla*), wasps (*Vespa orientalis*) and ants (*Oecophylla smargdina*) continues to cause damage to silk industry. It is estimated that the losses due to parasites and predators are to an extent of 15 - 20 percent and varies from crop to crop. The complexities in the behaviour and life cycle of pest population existing in seri ecosystem warrant a special attention for their effective management specially in changing scenario for our modern sericulture. 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. Biological control is one of the most important method which can be used to control the pests, parasites and predators population in sericulture. Various potential parasitoids, which can be utilized as an agent of biological control in sericulture have been screened. The natural enemies of the uzi fly (*E. bombycis* and *B. zebina*) are already present in the nature. *Nesolynx thymus, Trichopria* sp., *Splangia endius, Dirhinus* sp., *Trichopria* sp., *Trichomalopsis apanteloctena* and *Pediobius* sp. are the major parasitoids effective against uzi fly pupa. The scelionid *Psix striaticeps* and *Trissolcus* sp. are the potential egg parasitoids against stink bug (*Canthecona furcellata*). Various other native natural potential parasitoids have been screened and suitable strategies have been developed to check the population of pest insect in sericulture.

Key words : Biological control, Pest, Non-mulberry silkworm, Parasitoid

Introduction

With the increasing of the importance of sustainable sericulture, the concept of biological control for sustainable development has emerged. In the recent past, plant protection scientists, as well as the farmers have identified pest management methods, which are ecologically non-disrupting and stable. Biological control in sericulture is not very popular at present. Non-mulberry silkworms are largely comprised of the saturniids. Saturniidae comprises the largest group of sericigenous insects belonging to the genus *Antheraea, Philosamia*, and *Attacus*. Non-mulberry silkworms are polyphagous. Tussah (*Antheraea*) caterpillars provide the world with the majority of wild silk. Tropical tasar silkworm (*Antheraea mylitta* Drury) is reared on the food plants arjun (*Terminalia arjuna* Bedd.) and asan (*T. tomentosa*). Wild cocoons of tasar occasionally are collected by tribal from sal (*Shorea robusta* Roxb.) from forests. Oak tasar (*Antheraea proylei* Jolly) is a synthesized hybrid from the inter-specific hybridization between

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an indigenous species *Antheraea roylei* and its Chinese counterpart *Antheraea pernyi* G. M. The food plants of temperate tasar silkworm are mainly of the genus *Quercus* Linn. (Oak). *Quercus incana* Roxb (banj), *Q. semicarpifolia* Smith (kharshu), and *Q. himalayana* Bahadur (moru) are exploited for rearing in north western region whereas in north eastern region *Q. serrata* Thunb (uyung), *Q. semiserrata* Roxb and *Q. dealbata* Hook & Thomas are commonly used. Muga, the golden yellow silk, is produced by *Antheraea assama* Westwood. It is multivoltine and polyphagous insect largely reared on commercial scale in Assam, India. The polyphagous muga silkworm feeds primarily on the leaves of *Machilus bombycina* King (som) and *Litsaea polyantha* Juss (soalu). Eri silkworm (*Philosamia ricini* Boisduval) is found mostly in north-eastern India. It feeds mainly on castor (*Ricinus communis*) (bharendra or castor-oil plant). The important secondary food plants are *Heteropanax fragrans* Seem (Kesseru), *Manihot utilissima* Phol (Simul-alu), *Carica papaya* L. (Papita), *Evodia fraxinifolia* Hook (Payam), and *Ailanthus excelsa* Roxb (Maharukh).

Silkworm and its food plants are closely associated with each other for production of silk. Much of the attempts have been made to increase the silk productivity but still there are several constraints, which needs immediate attention for increasing silk production in India (Thangavelu and Singh, 1994). One of the main reasons for low production of silk is the pest problem associated with food plants and silkworms (Thangavelu and Singh 1991; Singh *et al.*, 1992a). More than hundred insects pests are known to attack host plants during different growth stages, of which about 20 have major significance. Seven to ten insects have been reported as parasites and predators of silkworm larvae (Singh and Thangavelu, 1994a). The population dynamics of these pests varies from crop to crop and the pest status is also altered due to various factors.

Pest complex of non-mulberry silkworm and its host plants

One of the major impediments in tropical and temperate non-mulberry sericulture is the serious depredation caused by certain pests of non-mulberry silkworms and its host plants. There is no precise yield loss estimation in non-mulberry sericulture. Insect pests are known to interfere considerably with all the phases of sericultural practice, *viz.*, host plant propogation, silkworm rearing and egg production (Singh *et al.*, 1989; Singh and Thangavelu, 1994a). In the tropical tasar region of India, the key pest of tasar food plants are the gall insect (*Trioza fletcheri minor* Cwarf), stem borer (*Psiloptera fastuosa* and *Aeolesthes holocericea*), tussock moth (*Notolophus antiqua*), weevils (*Crinorrhinus nebulosus*), beetles (*Anomala blanchardi*), termites and several soil inhibiting insects whereas the prominent pests of silkworm during pre-cocoon and post cocoon stages are *Blepharipa zebina* (Walk.) and *Dermestes* sp., respectively. Besides the above pests, sporadic occurrence of the Bihar hairy caterpillar, *Spilosoma obliqua,* causes extensive damage to *Terminalia* plantation in certain areas of Jharkhand. Unilateral control measures against *T. fletcheri minor, P. fastuosa* and *N. antiqua* mainly include the application of chemical insecticides. Adoption of chemical measure means a time leads to failure of silkworm rearing due to residual toxicity/drift residues. Further, frequent use of insecticides may lead to the development of resistance by these pest insects besides causing environmental pollution. Above all, their use does not provide the desired level of pest control. Some effective control measures against *Blepharipa zebina* and *Xanthopimpla predator* are required to control the parasites population in non-mulberry sericulture. Apart from this predators like stink bug (*Canthecona furcellata*), praying mantis (*Hierodulla bipapilla*) and wasp (*Vespa orientalis*) caused a severe loss to early staged larvae of tasar silkworms.

Oak tasar silkworm, *Antheraea proylei,* and its host plants are attacked by various pests which reduces the quality and quantity of the oak tasar food plants. The major categories of insect destroyers of oak have been grouped as sap sucking, defoliating, meristem feeding, acorn feeding and gall forming insects. Among sap sucking insects aphids, leaf hoppers, bugs, scales white flies, thrips, mites and cicada are very common. The adults and nymphs cluster on the plant parts and sucks the sap of the leaves. This scolytid insect infest acorns of *Q. acutissima* and *Q. griffithii* in north-eastern India. Among gall forming insects seven species of cynipid wasps are so far known to infest the oaks in India *viz., Callirhytis, Neuroterus* sp., *Cynips* sp., *Neosynergus* sp., and *Saphonicrus* sp., are most common (Singh *et al.*, 2000).

Muga silkworms and its food plants are attacked by large number of pests and predators. Pest attacks from nursery to mature plants. Carpenter moth (*Zeuzera multistrigata* Moore), amphutikani, (*Cricula trifenestra* Helf), stem borer (*Xylotrichus* sp.), hairy caterpillar, (*Euproctis* sp.), leaf minor (*Phytomyza* sp.), gall insect (*Pauropsylla besooni),* gall midges (*Asphondylia* sp), white ants or termite (*Odontotermes assamensis* Heilm) are major pests of food plants whereas silkworms larvae are generally attacked by various parasites and predators. The most important among them are uzi fly, apantalis, mantis, wasp and bugs. Wild eri silkworm, *Philosamia cynthia*, occurs in nature and freely crosses with the domesticated *Philosamia ricini* and produces cocoons. It prefers to feed on the castor plants. Castor plants are attacked by large number of pests throughout the year and it needs regular attention to increase the leaf and fruit yield. The castor white fly (*Trialeurodes ricini*), castor semi looper (*Achea janata*), castor hairy caterpillar (*Euproctis lunata*), castor seed capsule borer (*Dichocrocis punctiferalis*), thrips (*Thrips tabaci*), jassid (*Ambrosa bagatelle*) and castor leaf hopper (*Empoasca flavescens*) are the major pests.

Insect populations have a tendency to fluctuate as a 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. In order to reduce pest population and resulting plant damage, several methods are known but due to easiness in application farmers prefer to apply synthetic insecticides. The anti pest strategy, primarily involved unilateral use of pesticides, which had many short comings.

Pest resurgence

The repeated and frequent application of modern synthetic insecticide has created problems of pest resurgence and outbreak, insecticide residues, development of insecticides resistant strains, phytotoxicity and hazards to non target species including natural enemies and other beneficial organisms, alteration in the pest species population dynamics, environmental degradation and disruption of natural balance. In view of these drawbacks associated with over reliance on chemical control, the concept of integrated pest management (IPM), which combines all possible manners in a compatible and harmonious manner has gained prominence. Biological control is considered as an essential component of IPM as it is economical, effective, and eco friendly. Natural enemy plays an important role in the suppression of pest population in sericulture. Whenever suitable conditions prevail for their survival, development, conservation and multiplication, parasitoid population increases and this resulted in the decrease of natural pest population. Some biological control agents, when used alone in combination with less persistent insecticides and botanicals have provided better results than insecticides.

Reason for biological control

Generally, pest population is controlled by application of pesticide. The pesticides consumption is excessively high and also expensive. The importance of pesticides in sericulture needs no emphasis. Since the pesticides are poisonous, their use poses heavy silkworm mortality and environmental problems. Sometimes indiscriminate uses of hard pesticides promote speedier evolution of insect pests, affect non-target species, convert formerly innocuous species into pests, and leave undesirable residues in silkworm. Now more than ever, therefore, the onus is on developing an alternative method of pest control, to step in and fill the void resulting in shifting of importance from the chemical based protection to the adoption of an integrated approach based primarily on use of biocontrol measures and need based application of botanicals, and safer pesticides. Such an approach may lead to reduction of residues and ancillary problems associated with pesticide application (Singh *et al.*, 1993a). Pesticides disrupt interaction between phytophage insects and their natural enemies, the essential ecological processes operating in nature that contribute to the regulation of insect population. Whenever this interaction between phytophage and entomophage insect is disrupted, the population of phytophage increased tremendously and they attain pest status because they become free from the constraints imposed by the entomophages. The realization that conventional pesticide could cause problem resulted in the idea that it might be use to caution with these toxic chemicals. Biological control strategies are under utilized rather than the alternative, 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 de Bosch, 1981). Being so long forgotten and dominated by the use of agrochemicals, biological control is now identified and considered as the alternative methods of insect control, together with other non pesticidal or biologically 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 system is the first step toward their conservation, augmentation and manipulation. Classical biological control program is generally less perused in developing countries like India, where there exists a need to thoroughly explore and evaluate their native natural enemies which may be or are more likely not yet identified as promising biological control agent. Fortunately, in India, the native natural enemies have a little probability of extermination caused by synthetic poisons due to commonly expressed views by the media such as lack of pesticides, or not having enough pesticides or pesticides not available, or pesticides of poor quality. It is, therefore, obvious that such prevailing situation in India will lead to more conducive environment for implementation of the biological control program design for the native pests, or even for introduction programmes involving the utilization of exotic natural enemies (Napompeth, 1987). The current revival of interest in biological control is also driven by a change from pest control approaches that aim to maximize productivity and to approaches that emphasize efficiency that the long term sustainability of seri 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 as a corner stone of many Integrated Pest Management (IPM) programmes. The philosophy of modern insect pest management is based on the management of entire pest population not just located ones where a single control technique is employed. In IPM, emphasis is placed on the use of combination of methods, aimed at providing cheap but long term reliability with the minimum of harmful side effects. The philosophy and ideology of modern IPM programme is thus compatible with the philosophy and methodology of biological control; indeed biological control has been a central core around which IPM has been developed. The reason for this is that natural enemies constitute the major natural control factors that can be manipulated. The parasitoids can be utilized in three major ways *viz.*, imposition of exotic species and their establishment in new habitat, augmentation of established species through direct manipulation of their population by insectary mass population and periodic colonization and their conservation through the deliberate manipulation of environmental factors to enhance their activity (DeBach, 1974).

Applicability of biological control

In biological control, parasitoids were favored 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 Lateren, 1986). The parasitoids have been used more frequently than predators in the biological control programmes and about 80% of all biological control programme 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 the biological controls are very meagre as compared to synthetic pesticides. Fewer amounts have been invested on the biological control programme. The basic reason for the relative neglect is that the biological control is widely perceived as un reliable. Biological control has enormous undeveloped potential that is capable of being exploited through improved procedure (Beine, 1984).

Parasitoid complex

Sericulture is a agro based industry. Therefore, large number of native natural parasitoid fauna are available. Various parasitoids of uzifly and stink bug in seri eco system has been reported and their parasitization potential has been determined (Thangavelu and Singh, 1992; Singh and Thangavelu 1995; Singh, *et al.*, 2000). Most commom among them belong to the family scelionidae, eulophidae, trigrammatidae and pteromalidae and found to be highly potential against various parasites and predators of silkworm (Table 1). It is essential to have information on existing natural enemies and their role in natural control.

Scelionid parasitoids

The search for effective biological control agents against bugs of the superfamily Pentatomidea (Heteroptera) has often focussed on their egg parasitoids, and in particular on the species of the subfamily Telenominae (Hymenoptera: Scelionidae; Jonson and Masner, 1985; Braman and Yeargan, 1989). Biological and systematic research on these wasps has focussed on the large genera *Telenomus* sp. and *Trissolcus* sp. (Johnson and Mesner, 1985). Thangavelu and Singh (1992) reported that *Psix striaticeps, P. lucanatus* and *Trissoculs* sp. are important egg parasitoids of stink bug, *Canthecona furcellata,* which is an important predator of early stage larvae of tasar silkworm, severely damaging to Indian silk industry. Life-table studies of *P. striaticeps* indicate that the female parasitoid survives 12 days and oviposits intensively for 3.5 days. The net reproductive rate representing the total female births was 38.30. The population decreased with an inifinitesimal rate of 0.275 and finite rate of 1.32 per female per day. One generation was completed in 13.25 days (Singh *et al.*, 1995d). Biological characteristics of the parasitoid indicates preponderance of females due to solitary parasitism and a balanced sex ratio due to superparasitism. The superparasitism and a higher female progeny appears to be a reproductive adaptation of this parasitoid to utilize less suitable hosts for the production of females (Singh and Sinha 1995a; Singh *et al.*, 1996a). The study conducted on density responsiveness behaviour indicate that *P.striaticeps* has a density dependent relationship with its host. It has been found capable of attacking 80% of the stink bug eggs within 10 minutes of exposure period, indicating its high searching capacity *i. e.*, the ability to find the hosts in the higher reproductive potential (Singh *et al.*,1996, 1994a; Singh and Thangav-

Table1. Parasitoid and their host in sericulture

Parasitoid	Host	References
Egg parasitoids		
Psix striaticeps	*Canthecona furcellata*	Singh *et al.*, 1992,1995,1996
Psix lucanatus	*C. furcellata*	Singh *et al.*, 1992
Trissolcus sp.	*C. furcellata*	Singh *et al.*, 1991
Telenomus sp	*C. furcellata*	Singh *et al.*, *1992*
Trichogramma chelonis	*Achaea janata*	Singh and Jalal, 1994
Szelenyiola batocerae	*Psiloptera fastuosa*	Singh *et al.*, 1 1994
Podagrion sp.	*Hierodulla bipapilla*	Singh *et al.*, 1994
Larval/Pupal parasitoids		
Nesolynx thymus	*Blepharipa zebina*	Singh *et al.*, 1993
Nesolynx thymus	*Tricholyga bombycis*	Kumar *et al.*, 1986
Pediobius sp	*Blepharipa zebina*	Singh *et al.*, 1994
Trichomalopsis apanteloctena	*B .zebina*	Singh *et al.*, 1995,1996
Spalangia endius	*B. zebina*	Singh *et al.*, 1999
Nasonea vitripennis	*B. zebina*	Singh *et al.*, *1999*
Theronea maskeliyae	*B. zebina*	Singh *et al.*, 1995
Brachymeria lasus	*B. zebina*	Singh *et al.*, 1995, 1995
Trichopria sp.	*Trycholyga bombysis*	Kishor *et al.*, 1987
Spilomicrus karnatakensis	*T. bombysis*	Kumar *et al.*, 1988
Exoristobia philippinensis	*T. bombysis*	Kumar *et al.*, 1989
Trechnites secundus	*Trioza fletcheri minor*	Singh *et al.*, 1996
Aprostocetus niger	*T. fletcheri minor*	Singh *et al.*, 1996
Amblystomus gutula	*P. fastuosa*	Singh *et al.*, 1994

elu, 1994b). The reduction in the incidence of *C. furcellata* is 48 - 62 percent by colonizing *Psix striaticeps* and *Trissolcus* spp. at 10,000 wasps/acre at 10 days interval from July to October.

Uzifly parasitoids

Uzifly is a major parasite of silkworm larvae in tropical region of India (Singh *et al.*, 1993b). Therefore, it becomes essential to control the uzifly population in the silk growing area. One key to successful biological control, based primarily on use of entomophagous arthropods, is retention of adequate numbers of appropriate augmented or naturally occurring entomophagous parasitoids within target area. *Trichomalopsis apanteloctena, Nesolynx thymus, Pediobius* sp., *Spalangia,* sp., *Brachymeria lasus,* and *Theronea maskeliyae* are predominantly available in the field during certain period (Singh and Thangavelu, 1992; Singh *et al.,* 1995a, b). But due to unknown reason, it fails to contain the pest population. *T. apanteloctena* is a gregarious ecto-pupal parasitoid of uzifly, *B. zebina* (Singh and Thangavelu, 1996). In order to find out the possibility of using this parasitoid in the biological control of *B. zebina,* the biological characteristics, age specific survival, age specific fecundity, intrinsic rate of population increase and sex ratio under laboratory conditions were reported by Singh and Thangavelu (1996, 1997b). The number of female progeny produced by *T. apanteloctena* was 41.76 and the sex ratio was 1 : 4.5 in favour of females on the pupae of *B. zebina* and did not vary significantly with maternal age (Singh and Thangavelu, 1999). Each female usually parasitized about four hosts (ranged from 1 to 6) daily until one or two days before death and laid 8 - 14 eggs on each host. The number of adult emerged per female was more than 40. Fertilized females produced about 90% female progeny if low host parasitoid ratio (1 : 5) had been maintained during oviposition (Singh *et al.,* 1997b). Wylie (1976) reported similar observation between host parasitoid ratio of *Nasonia vitripennis* and some other common species of pteromalidae that parasitise muscoid flies. The developmental ability of host discrimination in *T. apanteloctena* is very high. The results show that inexperienced parasitoids (those which have never been in contact with the hosts) do superparasitize significantly more host than experienced ones, and the former improve upon the discriminatory ability by adaptive learning as a result of practice (Singh *et al.*, 1994c). Besides this, *Pediobius* sp. an eulophid wasp was found to kill the pupae of *B.zebina* (Singh *et al.*, 1994b). Longevity of the female parasitoid was greater than that of the male. Behavioural response indicates that the frequency of the host contact, prick, oviposition, first escape time and total retention period with host increased exponentially. The parasitoid prefers to parasitise on early pupae of *B. zebina*. Age of the parasitoid has no significant influence on the rate of parasitism and progeny production (Singh and Thangavelu, 1997a, b, 1999). The overall performance of these parasitoids clearly indicate that they possess most of the desired attributes and therefore, may be used as tool in the biological control of uzifly, *B. zebina*. Laboratory studies indicate that all these parasitoids of uzi fly, have tremendous reproductive potential, high searching ability and female biased sex ratio. Singh *et al.* (2001) reported that *T. apanteloctena, Pediobius* and *N. thymus* are the potential parasitoids in tasar sericulture and appears in the field in the 3rd week of October, parasitizing 45.32% of uzifly pupae. The parasitoids remain in the field and search more and more hosts and build up their population. It resulted in the suppression of uzifly population in the rearing field (Thangavelu and Singh, 1993, 1994). Sex ratio of most of the parasitoid is female biased. (Singh *et al.*, 1994a). This behaviour of reproduction in nature helps in successful establishment of parasitoid because it is the female parasitoid which produces the desired level of mortality.

Nesolynx thymus (Girault) (Hymenoptera: Eulophidae) has been reported as a pupal endoparasitoid of *Exorista sorbillans* (Kumar *et al.*, 1986). The life cycle is completed in 10 to 12 days. Longevity of the adult parasitoid varies from 6 - 8 days. The mated female oviposits on the 1 - 5 days old puparia and completes her life cycle in the body of uzifly pupae. The adult emerges after 6 - 7 days and mates again after 10 - 12 hrs of the emergency. The host searching ability of the parasitoid is very high and, therefore, the parasitization potential is also very high and it is useful for biocontrol of uzifly population. Among the various biological and physical characteristic study of developmental stages, fecundity, longevity and tolerance limit of the parasitoid species to temperature and humidity play an important role in determining mass culture (Kumar *et al.*, 1989; Singh and Sinha, 1996). The age of host has significant effect though that of parasitoid does not have any significant influence on the parasitization and progeny production of *N. thymus*.

Trichopria (Hymenoptera: Diapriidae) has also been reported as a potential parasitoid of *Exorista sorbillans*, a common uzifly in mulberry sericulture. Adults of *Trichopria* sp. mated soon after eclosion. Mated female oviposits on the uzifly puparia after one day and oviposits for 2 - 3 days continuously. The female survives longer than male. The parasitoids prefer to parasitise 1 - 4 days puparia, though it has been reported to develop successfully on the uzifly puparia which were up to 8 days old. 50 - 70 adults emerge from a single puparium. Mean progeny production by a single female was 115 individual with male to female ratio of 1: 3 (Kishore and Kumar, 1990). The parasitoid culture can be maintained successfully on the puparia of house fly also. The parasitization potential of this parasitoid can be tried against the *Blepharipa zebina* puparia and the parasitoid colony has already been maintained on the *Musca domestica* puparia.

Other parasitoids

Mantis (*Hierodulla bipapilla)* is an important predator of tasar and muga silkworm larvae. The ootheca of mantis is parasitized by *Podagrion* sp. A single mated female parasitizes the complete ootheca of mantis. Host and parasitoid both inhabit the same ecological situations and seek similar ecological requirements. Therefore, *Podagrion* is expected to have a better ecological compatibility with the Ootheca of mantis. *Podagrion* has a high reproductive potential by having high fecundity and a short life cycle.
To minimise the population of lepidopterous pests over tasar food plants, mass culture of *Trichogramma chilonis* has been maintained in the laboratory. *T. chilonis* were received from Central Biocontrol Stations from time to time. These were multiplied in the laboratory on the eggs of *Corcyra cephalonica* Staintin at 27 + 2°C and 70 + 10% R. H. Trichocards were released in the field. Release of laboratory reared parasitoids at 20,000 wasps/acre twice in a month were made after recording the presence of shoot borer and defoliators egg in the field. Recovery tests were made after one month of releases. The parasitization by this species varied between 33.25 and 93.75% at different localities, depending upon the period of activity which was at its peak in the month of July - August. A single egg of vapourer tussock moth was found to host 2 - 4 individuals of the parasitoid (Singh and Jallali, 1991).

Recently, some important parasitoids of gall insect (*Trioza fletcheri minor)* were screened. They were identified as *Trechnites secundus* (Encystidae) and *Aprostocetus niger* (Eulophidae) (Singh *et al.*, 1995c). The females of *T. secundus* and *A. niger* developed successfully on the galls of *T. arjuna* and *T. tomentosa*. It prefers to parasitize 6 days old gall and yielded 80 - 90 percent adult parasitoids within an average of 10 - 12 days. In both the species the sex ratio is female biased, which is positively advantageous from biological control point of view. Its immediate and potential value as important components of pest management has been confirmed. Most of the major pests have their natural enemies in the field itself and that is needed to be identified and screened for suppressing the pest population in tasar eco-system. It is possible to suppress pest population by means of conservation and manipulation of natural enemies. Therefore, identification, augmentation and large scale progeny production of natural enemies existing in tasar ecosystem will be the best method to combat with the pest population.

The practice of biological control

Many diverse methods have been developed for practicing biological control but most programmes have a common thread. They all seek to reduce pest status by increasing pest mortality, and, very often, this is done for increasing existing parasitoid to host ratio. Biological control involves three phases: introduction, augmentation, and conservation but any of the practice may be used in a single biological control programme.

Introduction

Introduction is often considered as the classical practice in biological control because most early programme used this approach. The basis for this practice is to identify the natural enemies that regulate a pest in its original location and introduce these into the pests; thus natural enemies are reassociated with their hosts. The hope is that the natural enemies, once introduced, will become established and permanently reduce the pests to the general equillibrium position (average population level) below the economic injury level.

Augmentation

Augmentation is a biological control practice that includes any activity designed to increase numbers or effect of existing natural enemies. These objective may be achieved by releasing additional numbers of a natural enemy into a system or modifying the environment in a such way so as to promote greater numbers or effectiveness. Releasing additional numbers of a natural enemy is similar to the introduction practices, except that augmentative releases are expected to result only in temporary suppression. Therefore, the ecological result of these is most likely the dampening of pest population peaks, rather than the general equilibrium position. Because of their temporary effect, these releases must be made periodically. Periodic releases may be considered as either inundative or inoculative.

Inundative release: These release depend on propogation of massive numbers of natural enemies and their wide spread distribution. Subsequently, the release of the actual enemies suppress the pest population, with little or no impact expected from progeny of the released individuals. Massive release has been attempted in several programmes involving natural enemies like *Trichogramma* species, a tiny wasp that parasitises insect eggs, and general parasitoid *Psix striaticeps* against the eggs of *C. furcellatta.* Several of these natural enemies are available abundantly in the field and after successful augmentation in the laboratory it can be released into the field.

Inoculative releases: These releases differ from inundative releases in that once they occur, the natural enemies is expected to colonise and spread throughout an area naturally. An inoculation is often made only once in the growing season and it is the progeny of the released individuals that have the most significant impact on the pest population. One of the most successful programmes utilizing this approach with predators and parasitoids has been reported from the project, Directorate of Biological Control, Bangalore.

Conservation

This is the most widely practiced form of biological control. The objective of the conservation is to protect and maintain these existing natural populations, particularly the parasitoids. It involves the maintenance of existing parasitoids by avoiding harmful practices. Basically, this approach requires knowledge about all aspects of the natural enemy community, including species present, population numbers, phenology, and impact on pest populations. The life-table analysis provides vital information for maintaining the parasitoids population in a given area. With this knowledge, pest management practices are modified to avoid natural enemy destruction. All these studies indicate that the natural enemies of pests of tasar food plants and silkworm play very vital role in the pest control but above it there is always danger of their mortality due to indiscriminate use of insecticides.

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