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Review

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An Integrated Approach in the Pest Management in Sericulture

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The success of sericulture industry in India is mainly attributed to the well-planned annual sericultural activity and the systematic implementation of pest preventive and control measures. The insect spectrum of silkworm and its food plants is complex and plays a major role in limiting the production of silk. Insects cause extensive damage to plant whereas predators and parasites either kill the silkworm larvae or force them to spin flimsy cocoons. Unilateral control measure against this pest is mainly based on the use of synthetic organic insecticides. Though these approaches initially paid rich dividends, the undesirable consequences soon surfaced. Insecticide induced resurgence of gall midges, leafhopper, leaf roller, secondary pest out breaks and development of pest biotypes has led to realization of Integrated Pest Management in sericulture. Various components of IPM, *viz.* Host plant resistance, cultural practices, biological control, chemical control and integrating them at various technological levels have been studied. Sources of host plant resistance have been identified for some of the major insect pests. High yielding mulberry variety has been propagated and their resistances towards major pests have been recorded. Cultural practices like pruning, pollarding, judicious use of nitrogen, optimum spacing and weed management have proved to be the powerful tools in containing pests. Natural control over the pest population build- up exerted by the wide range of parasitoids, predators and pathogens has been well documented with identification of natural enemies and studies on their potential. Augmentation, through inoculation or inundative releases of parasitic arthropods, is the most direct way of increasing the numbers of these beneficials in sericulture.

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Introduction

Integrated Pest Management (IPM) is the art of the possible to achieve the realistic solution of pest population without any harmful effect of human beings. Silk host plants and silkworm larvae are attacked by large number of pests and predators. The continuing incidence of pest population has confronted sericulturist with two major problems: decrease in the silk production, and the threat of environmental pollution on the other (Singh, 1989; Singh *et al.*, 1990; Mandal and Singh, 1990). It is imperative that whatever is done to alleviate one problem does not aggravate the other (Perkins, 1982; Singh *et al.*, 1989). Thus, in order to increase the silk production and to avoid environmental pollution, effective pest management program is urgently needed. IPM provides a reasonable compromise, taking into account both the desirability of biological control and necessity of some form of chemical control, in combination with judicious use of relatively selective pesticides, only when absolutely necessary and in the least disruptive modes of application (Singh and Thangavelu, 1991). Other selective tactics *viz.* cultural controls, autocidal methods or utilization of semiochemiclas is incorporated in the program wherever applicable (Teng and Heong, 1988). IPM represents a holistic approach, recognizing the unity of the ecosystem and harmonizing all available measures in an attempt to optimize pest control and crop production (Wilson and Huffaker, 1976; Apple and Smith, 1976; Rosen, 1985). Utilization of natural enemies is regarded as the backbone of any IPM program (DeBach and Hagen, 1964; Van Lenteren, 1986). The value of naturally occurring natural enemies can not be overemphasized, and their conservation is the first goal of IPM (Debach and Huffaker, 1971).

Modern sericulture is moving towards sustainability, a key development where increased emphasis is placed on the integration of many different techniques to achieve stable, long term production. The sustain view that sericultural crops could be made to produce more by usage of synthetic chemical is outdated. Disintegration of this idea has allowed the concept of IPM (Integrated Pest Management) to play a vital role in modern sericulture. Mulberry and commercially exploited non mulberry silkworms are attacked by large number of insects which causes serious depredation in silk productivity. There is much variation in the pest population and extent of damage in each variety. Mulberry silkworm (*Bombyx mori*) is completely domesticated and feeds on mulberry plant (*Morus alba*) (Rangaswamy *et al.*, 1976; Ullal and Narshimhanna, 1978). The larvae of tasar silkworm (*Antheraea mylitta*) feeds mostly on arjun (*Terminalia arjuna*), asan (*Terminalia tomentosa*) and sal (*Shorea robusta*) where as oak tasar (*Antheraea proylei*) prefers to feed on various species of *Quercus* which are abundantly available in north eastern and western region of India (Jolly *et al.*, 1979). Muga silkworm (*Antheraea assama*) is very specific to region of Assam and feeds mainly on som (*Machilus bombycina*), soalu (*Litsaea polyantha*) (Thangavelu *et al.,* 1988). Eri silkworm (*Philosamai ricini*) is a domesticated variety and multivoltine in nature. It feeds on castor (*Ricinus communis*), kesseru (*Heteropanax fragrans*), simalu (*Manihot utilissima*) and payam (*Evodia fraxinifolia*) (Sarkar, 1988).

Low yields of silk have been attributed to variety of factors, of which loss caused by insect pests has been considerable. Over 150 insect pests have been reported to attack food plants. Shoot fly, gall midges, hairy caterpillars and mealy bug occur in serious proportions to cause reduction in silk productivity. Most of the time, silkworm is also attacked by several parasites and predators. Uzi fly, Ichneumon fly and other predators cause heavy loss to silk industry. Cocoons are infested by dermestid beetle. One of the main reasons for low production of silk is the pest problems associated with silkworms and its host plants (Singh *et al.*, 2000).

IPM methodologies

- Survey will be conducted in mulberry and non mulberry sericultural areas and data will be generated on the incidence of pest population on silkworms and its food plants.
- The data from survey/ surveillance programme will be utilized regularly to decide the type and level of IPM intervention needed by the farmers.
- Biological control agents will be screened and population dynamics of host and parasitoid will be determined. Host searching ability, sex ratio and reproductive ability of the parasitoid will be determined. Culture technique of the host and parasitoid will be developed.
- To release the biological control agents based on the pest load, weather conditions, cultivation practices and cropping systems suitable technology will be developed.
- The efficiency of IPM will be assessed by conducting survey before and after the treatment of each IPM tactic.
- Residual toxicity of the pesticides in the various crops will be assessed and bioremediation of pesticide pollution problems will be studied.
- IPM technology package will be refined and fine-tuned to meet the local and seasonal requirement of the area. Soundness of the technology will be tested and compared with farmers practice from socio-economic and environment points of view.
- Sustainable sericultural IPM practices will be developed and greater productivity improved silk quality and enhanced income and profitability will be achieved.

Pest incidence

The major insect orders known to be the pests of mulberry and non mulberry silkworm host plants are lepidoptera, hemiptera, coleoptera, thysanoptera, orthoptera and isoptera (Sengupta *et al.*, 1990). Mealy bug, *Maconellicoccus hirsutus* (Green) (Hemiptera, Pseudococcidae) causes Tukra disease in mulberry. The leaf roller, *Diaphania pulverulentalis* (Lepidoptera: Pyralidae), has been noticed as a severe pest of mulberry, *Morus alba* (Geetha Bai *et al.*, 1997; Marimadaiah and Geethabai, 2000). The Bihar hairy caterpillar, *Spilosoma obliqua* Walker (Lepidoptera, Arctiidae) is a polyphagous pest and sporadic in nature. The tiny caterpillars of first two instars feed gregariously, but as they grow older, they disperse widely in search of food. The cutworm, *Spodoptera litura* is a polyphagous pest infesting several crops including mulberry. Unilateral control measures against *M. hirsutus, S. obliqua* and *D. pulverulantalis* mainly include the application of chemical insecticides. The major insect pests belonging to the order coleoptera reported causing damage to mulberry are *Sthenias grisator*, *Apriona* spp., *Baris deplanta, Myllocerus* spp. etc. Coleopteran white grub, *Holotrichia serrata* was reported to damage mulberry root extensively. The larvae feed on the roots and under ground portion of stalk while the adults feed on the foliage of trees and shrubs. The affetcted shoot dries up, resulting heavy losses to mulberry. The wingless grasshopper, *Neorthacris acuticeps nilgiriensis* Uvarov (Orthoptera, Acrididae) is a serious pest in rain fed mulberry plantations. About 15 species of mites belonging to families of tetranychidae and eriophydae have been reported to be key pests of mulberry (Pruthi and Mani, 1945;

Narayanaswamy *et al.,* 1996). *Tetranychus equitorium* and *Aceria mori* cause considerable damage to mulberry in India (Mohanasundaram and Sivagami, 1983).

Several polyphagous pests, which damage mulberry, tasar, oak tasar, muga and eri food plants have been reported (Singh *et al.,* 2000). All parts of the tree and all stages of tree growth are subjected to insect attack. Different insect species infest different parts, but all stages of growth are subjected to all types of insect attack. Defoliators, leaf minors and gall forming insects are considered as group cause most damage to older trees. *T. arjuna* and *T. tomentosa* leaves are generally attacked by gall insect (*Trioza fletcheri minor*) (Singh *et al.,* 1994) and stem borer (*Psiloptera fastuosa, Aeolesthes holosericea* and *Batocera* sp.) but several defoliating insects have also been reported to cause extensive damage tro leaves during rearing period. (Singh *et al.,* 1991; Singh *et al.,* 1992). Tiwary *et al.* (2000) reported cerambycid borer infestation on sal plantation in India. Oak tasar silkworm *Antheraea proylei* and its food plants are attacked by large number of pests. The major categories of insect destroyers of oaks have been grouped as sap sucking, defoliating, meristem feeding, acorn feeding and gall forming insects (Singh *et al.,* 2000).

Som (*Machilus bombycina*) and Soalu (*Litsarea polyantha*) are the primary food plant of muga silkworm and abundantly available in Assam. Pest attacks from nursery to mature plants. The biology and control measures of some of the major pests associated with som and soalu plants have already been reported (Singh and Sen, 2001). The castor white fly (*Trialeurodes ricini*), castor semi looper (*Achaea janata Linn.*) and Castor Hairy caterpillar *Euproctis lunata are* serious pest of castor plants. Apart from castor it has been reported on *Terminalia arjuna, T. totmentosa* and Muga food plants. Castor seed and capsule borer (*Dichocrocis punctiferalis*) damages the seed extensively. Thrips (*Thrips tabaci*) is world wide known insect and causing serious damage to various plants in their growing stage. It has been reported as a major pest of kesseru, Sepium and Ailanthus. Jassid (*Ambrosia bagatelle*) commonly known as leaf hopper is widely distributed in India and is the most destructive pest of castor, som and soalu plants. Castor Leaf Hopper (*Empoasca flavescens*) causes damage to the leaves (Singh *et al.,* 2000).

Silkworm natural enemies

Silkworm larvae are attacked by several predators and parasites (Singh and Thangavelu, 1994; Jolly *et al.,* 1979; Dhar *et al.,* 1989). Predator consumes several host individuals during its development, where as parasites includes its development on single host. The most important among them are stink bug (*Canthecona furcellata*), mantis (*Hierodulla bipapilla*), wasps (*Vespa orientalis*) and ants (*Oecophylla smargdina*). Predators are mostly confined in the silkworm rearing field and kills the early instars silkworm larvae. Some predators have biting or chewing mouthparts to devour their host *viz.* preying mantis, where as others such as stink bug or reduviid bug use piercing and sucking mouth parts to feed upon the body fluid of silkworm larvae. Many predators are agile ferocious hunters, actively seeking their host on the branches of silkworm host plant *viz.* wasps and ants and certain hunters have specially adapted seizing organs; such as barbed forelegs of mantids. Many species are predacious in both nymphal and adult stages, although not necessary on the same kind of host. Among parasites uzi fly (*Exorista bombycis* and *Blepharipa zebina*), Ichneumon fly (*Xanthopimpla pedator*) and *Apanteles* are the most important parasites of silkworm larvae (Singh and Thangavelu, 1991; Singh *et al.,* 1993).

Problems for plant protection

Plant protection in sericulture has all the characteristics of different phases of plant protection, *viz.* subsistence, exploitation, crises, disaster and IPM phases. Early to 1950, it can be considered as subsistence phase when plants were grown without modern plant protection chemicals. The exploitation phase started with the use of DDT and BHC sometimes after 1950 and the recommendation at that time were prophylactic schedule of insecticides treatment on the host plants. The crises phase started with the outbreak of tussock moth, Bihar hairy caterpillar, leaf roller, weevils, gall insects, stem borers and uzi fly. The serious outbreak of uzi fly in West Bengal and Karnataka were symptoms of disaster phase. In many south east Asian country it is found that insecticide use preceded out breaks of secondary pest like leaf roller. More over insecticide poisoning a farm worker become a serious issue and the chemical used against mulberry plants induced insecticide resistance in number of disease vector that breed in flooded field (Teng and Heong, 1988). The main issue here is a lack of comprehensive system for monitoring pest out breaks, area coverage, extent of loss and the case study on reason for out breaks. A structural organization with technical input and a corresponding system for documentation and subsequent retrieval and dissemination of data will go a long way in pinpointing the developments on plant protection and crop within state/country, the reason for fair out breaks and to advise the policy makers on decision making (Smith *et al.,* 1976).

Silkworms are very much sensitive to insecticides; therefore, extensive and intensive use of insecticides on silkworm host plant is harmful. Insecticides use resulted in decreases in pest population in sericulture areas but its repeated use has created resistance to several insects. However, resistance to insecticides, particularly in non-mulberry pests and poisoning of farm workers, farm animals and environmental pollution has not been clearly documented. The pollution in the drinking water was not properly assessed. The assessment of residue level in leaves and silkworm sometimes increased above economic threshold level and resulted in high mortality of silkworm larvae. Even though the danger due to insecticides has been pointed out, they have definitely contributed to the increased yields in Cocoon production and in general, insecticides have contributed their part in green revolution. The issue here is can sericulturist do away the pesticides? The farmers in sericulture are small and marginal farmers and they are more concern in saving their crop rather than worry about pollution and environmental issues. Even the loss of crop in a single season will immerse them in debts. They will continue to use pesticides no matter how dangerous they are to his health and to their live stocks. Hence the pest management strategy that has to be adopted should be sustainable and different and to make non chemical methods collectively more effective. The chemicals should be used sparingly and as a last resort.

Pesticide use pattern

Many industrialized countries have enforced stringent pesticide regulations and developed alternative pest management approaches as a result of which pesticide use in these countries has shown a declining trend. Consequently, the magnitude of contamination of food materials has also slowed down. However, many developing countries continue to use persistent pesticides in agriculture and public health programmes, and the contamination of different components of environment continues to be excessive and pervasive. Though the value of IPM has been well recognised, very little is being adopted at field level. The Ministry of Agriculture, Government of India is concerned very much with the slow progress in IPM as there is rising demand for chemical pesticides, which is estimated at 50,464 tonnes of technical grade materials in the current year as against 43,381 tonnes in the previous year. The pesticide industry has estimated the demand for the current year at over 86,460 tonnes. The trend in the use of chemical pesticides in India in the last one decade shows greater use of insecticides, which are mostly health hazardous and eco-destabilising. Hence, a wholesome technology to suit the small and marginal farmers in various agricultural regions has to be developed/improved and adopted. Chemical fertilizers and pesticides are the major chemical inputs used in farming. During the last two decades fertilizer consumption showed 195% compounding growth rate during the decennium 1980 - 1990 and another 99% during 1990 - 2000. Similarly, pesticide consumption increased by 71% and 58% respectively during the corresponding period (Table 1). The excessive and misuse of these chemicals have resulted in environmental pollution and were responsible for severe pest and disease outbreaks in many crops.

Table 1. Cost of chemical inputs used in agriculture in india (US $ Billions)

Input	1980	1990	2000
Fertilizers	4.9	13.0 (195)	25.9 (99)
Pesticides	0.7	1.2 (71)	1.9 (58)

Reason for IPM application

The pest problem has increased due to poor maintenance of food plants, use of higher doses of fertilizers and unhygienic condition of silkworms rearing. 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. However, repeated and frequent application of modern synthetic insecticides has created problems of pests resurgence and out breaks, insecticide residues, development of insecticide resistant strains, phyto-toxicity and hazards to non target species including natural enemies and other beneficial organism, alternation in pest species population dynamics, environmental degradation and dispersion of natural balances associated with over reliance on chemical control (Bartlett, 1964; Croft and Brown, 1975; Flint and Van Den Bosch, 1981).

In the last decade, much of the attempt has been made to achieve excellence in genetic potential of crops in sericulture system. Large quantity of chemical fertilizers and pesticides were used to increase leaf production and pest reduction but ultimately it led to soil degradation, water contamination and loss of biological diversity (Langeweg, 1989; DeBach, 1964a, b). Keeping in view the sensitivity many established pesticides were discarded on account of development of phenomenon of resistance in the target insect species and adverse environmental problems or health hazards which has become unacceptable, squander valuable but finite resources have generally lead to unsustainable sericulture. The findings of the earlier workers indicate that Integrated pest management (IPM) is only one solution which has got all positive attributes of an innovation and highly suitable in sericulture and it is the remedy for menace in sericulture.

IPM calls for integrating all available tools in cost effective, environmental friendly and sustainable manner (DeBach, 1974; Baker and Cook, 1974; Clausen, 1978). The philosophy and principal underlining the concept of IPM is to reduce mankind dependence on chemical pesticides by identifying, integrating and employing other methods which are cost effective, eco-friendly and lasting efficacy (Sharma and Batra, 1989). Since IPM approach is knowledge and skill oriented programme, training of the grass root level extension functionaries is the prerequisite for effective transmission of the message to the farming community. Pest monitoring through field surveys and surveillance help in tackling pest population and employment of cultural, mechanical and ecological practices ensures less utilization of pesticides (Norton and Mumford, 1983; Perkins, 1982). The application of minimum and need based pesticides instead of prophylactic spray schedule form the basis of IPM. In true sense, IPM is called for integration and utilization of biological methods of control using biocontrol agents such as parasites, predators, pathogens and eco-friendly neem based products (Huffaker, 1980; Huffaker and Smith, 1980; Singh and Maheshwari, 2002; Upadhyay *et al.*, 1997). The IPM approach encompasses adoption of all available methods, techniques, skills and strategies of pest management in a harmonious manner based on seri-ecosystem analysis and field observations. The pest surveillance and monitoring and biological control are the major components of this programme. (Hazarika *et al.*, 1994). IPM strategy involves integration of components such as genetic, chemical, botanical pesticides and socio economic factors. IPM should not mean putting together on paper a set of independent recommendations given by different scientists. IPM will be effective only if the component techniques are developed by agronomists, breeders, entomologists, plant pathologists and social scientist together (Upadhyay *et al.*, 1997; Goodwell, 1984). The IPM technology is now being extended to several crops like rice, cotton, pulses, oil seeds, sugar cane, ground nuts certain vegetables and fruit crops. The physical targets for IPM covering all activities have also been fixed.

Concept of IPM

The concept of IPM, which combines all possible manners in a compatible and harmonious manner, has gained prominence (Smith *et al.*, 1976; Van Lenteren and Woets, 1988). Natural enemies play an important role in suppressing pest population in the crop whenever suitable condition prevails for their survival, development, conservation and multiplication in any seri-ecosystem. Thus biological control is considered as an essential component of IPM as it is economical, effective and eco-friendly. Some biological control agents, when used alone or in combination with less persistent insecticides and botanicals have proved better than insecticides. With the increasing importance of sustainable sericulture, the concept of Integrated Pest Management (IPM) 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. Concurrently, mulberry varieties with at least moderate resistance/tolerance to pests and diseases have been developed and cultivated. Applying the principles of organic farming, several non-chemical methods have become popular among the farmers. Simple cultural practices like intercropping, trap cropping and crop rotation have been found to provide adequate protection from pest damage with no additional cost and without harmful effects on the environment. The farmers who glamoured for chemical pesticides in the sixties and seventies are now disillusioned with these poisonous eco-destabilizing substances; and are now on the look out for sensible and bio-rational methods of IPM.

IPM as tool

Integrated Pest Management (IPM) is an ecologically based, environmentally conscious method that combines, or integrates, biological and non biological techniques to suppress weeds, insects, and diseases (Nordlund, 1997). Successful implementation of IPM in pest management was introduced in the 1960 (Smith and Reynolds, 1965). Integration of multiple pest suppression techniques has the highest probability of sustaining long term crop protection (Kenmore, 1991; Sharma *et al.*, 1996). Much of the technologies and data analysis procedures have been developed about those strategies and tactics most appropriate for use in implementing specific IPM systems. These include economic thresholds, sampling technology, modeling, natural control, geographic distribution, effects of pest migration and movement, host resistance, and pesticides. IPMs basic framework is acknowledged to the natural controls. These include natural enemies, weather, climate, and food resources and semiochemicals. Natural enemies play an important role in regulating populations of all pest classes (Vinson, 1981).

IPM approach

In sericulture, Integrated Pest Management is a comprehensive approach to pest control that uses combined means to reduce the status of pests to tolerable levels while maintaining a quality environment. The main purpose of the IPM programme is to reduce crop losses, increase farmer income, reduce pesticide use and protect environment, reduce pesticide residues, improve ability to monitor pests, and increase involvement of farm workers in IPM decision making (Van Lenteren, 1983). It helps in maintenance of quality environment and conservation of natural ecosystem and non agricultural environment (air, water, soil, wild life and plant life). Pest management strategy has been divided in two groups *viz.* reductionist (pesticide treadmill) and holistic (IPM treadmill) (Tait and Lane, 1987; Tait, 1987).

Reductionist approach

The reductionist approach contains routine and rational pest management system. Routine pest management implies the use of pesticides as prophylactic measure, regardless of pest incidence and will probably require higher levels of pesticide use than any other strategy in a given set of circumstances. Rational pest management requires that each pesticides application be justified on scientific, technological and/or economic grounds (Tait, 1980). This will generally involves lower levels of pesticides use than a routine system under similar cropping condition.

Holistic approach

Holistic (IPM treadmill) approach is the most suitable procedure. Integrated pest management systems consider the interactions amongst the whole range of organisms with beneficial, neutral and pest status, the long term aim being to increase the level of pest suppression which is achieved by natural, as opposed to chemical means (Singh, *et al.*, 2001). Most IPM system will involve the use of pesticides but at a lower level than routine and rational pest management.

Cultural, mechanical and physical control

Cultural practices are integral part of mulberry, tasar, oak tasar and muga cultivation which include pruning, plucking, cleaning and stirring of soil around the bush during the winter (Singh, *et al.*, 2000). These practices directly influence the pest build up. Pruning and pollarding also contribute towards converting the host plant into a bush (Srivastava *et al.*, 1999). Works on impact of these practices on the activities on natural enemies are rare. However, Singh *et al.* (1992a, b) observed that these practices are much more useful for redemption of pest complex in sericulture. The use of light trap for the control and for monitoring of schafers, weevils and tussock moths has been well documented (Singh and Thangavelu, 1991; 1993 and 1994). During winter period, when the rearing of tasar silkworm is suspended, the gall infected leaves are plucked and burnt in the field. It is found to be the most convenient way to minimize the pest population. Further, some regular farming practices, *viz.* weeding, inter cultivation; pruning and pollarding ensure further reduction in gall insect population (Singh *et al.*, 1992; 1992a; Raman *et al.*, 1997). Similar cultural and mechanical practices have been adopted for vapourer tussock moth *Notolophus antique* (Singh *et al.*, 1991; Singh and Thangavelu, 1993). In order to minimize the pest population in the field, mechanical collection of egg mass and early stage caterpillar are most effective cultural control programme. Further, an attempt has made to use the light trap as one of the devices in integrated pest management in sericulture. For this purpose pest-O-flash an illumination device is used in the field to attract, weevils, stem borers, and defoliating insects. The most prominent among them are *Anomala blanchardi, Myllocerus viridinus*, and *Crinorrhinus nebulosus*. Removal of dead barks from the food plants is also effective in minimizing the schaffers beetle and stem borers population.

Biological control

Biological control utilizes natural enemies such as parasites, predators, pathogens or competitors, deriving its energy directly from the pests themselves. It is acknowledged to the best type of pest control (Lloyd, 1986). It is environmentally safe alternative to the chemical means of control. It is a very effective method of control offering a long term protection. The biological control strategies were born in a citrus grove in 1889, in the city of Los Angels, California (David, 1985). The release of 129 imported Australian Vidalia beetles resulted in dramatic reduction of the cottony cushion scale which has threatened California citrus industry. The technique of releasing an important organism that establishes itself and spread to permanently control a pest is today known as classical biological control concept (Rosen and DeBach, 1981). Successful classical biocontrol means that no further costs are required to keep the pest under control. The process of locating the place of origin of the non native pest and then finding and introducing natural enemies from its place of origin presents obvious ecological and logistical challenges. Therefore, exhaustive testing of the introduced pest, predator or parasite is essential before being release to be sure it will not harm non target organisms. Generally, even after meeting these challenges, there are certain other factors *viz.* climatic differences, pesticide use, disturbances of habitat by other agricultural operations, and or the removal of non-crop vegetation that might otherwise offer food and shelter to the natural enemies are the important factors for survival of the parasitoid population in its natural habitat (Narendran, 2001; Van Lenteren and Woets, 1988). Large number of parasitoids has been screened against all the major pests and parasites of silkworms and their food plants (Singh and Maheshwari, 2002). The coccinellid predator *Cryptolemous montrouz-*

ierie, is a voracious natural predator of the mealy bugs which are hard to be controlled by conventional insecticides. It is known to feed on about 1000 eggs or 300 – 500 mealy bugs nymphs. Psyllids are the major pest of arjun and and plant (Raman *et al.*, 1997; Singh and Thangvelu, 1994). The common parasitoids screened against them are *Aprostocetus niger* and *Tetranichus indicus* (Singh *et al.*, 1995). The eggs of stem borer, *Spiloptera fastosa* is attacked by *Szelenyiola batocerae* (Singh and Kulshreshta, 1990). Silkworms are attacked by various predators and parasites (Singh and Thangavelu, 1991a, b). The most common predator attacking tasar silkworm is *Canthecona furcellatta* (Singh and Sinha, 1989). Several scelionid egg parasitoids have been screened but *Psix striaticeps* and *Trissolcus* sp. have been recorded to be highly potential and effective in minimizing the stink bug population in the rearing field (Thangavelu and Singh, 1992). Several uzi fly parasitoids *viz. Nesolynx thymus*, *Trichopria* sp., *Dirhinus anthracia*, *D. himalayanus, Spilomicrus karnatakensis*, *Trichomalopsis apanteloctena,* and *Pediobius sp.* have been screened and field trial has been conducted to minimize uzi fly population in sericulture (Kumar *et al.*, 1992a, b, c; Ram Kishore *et al.*, 1992; Jyothi *et al.*, 1992a, b). The natural enemy complex is diverse and there is evidence to believe that pest population of plants is maintained at low levels mainly because of their regulating activities. The pupal parasitoid *Pediobius foveolatus* Crawford is an important parasitic hymenopteran that is practically used for control of uzi fly. Among chalcididae, *Brachymaria lasus* has been found to be a major natural enemies of the pupal stages of *Blapharipa zebina*, a serious parasite of tasar and muga silkworm (Singh *et al.*, 1995). Among pteromalid, *Trichomalopsis apanteloctena* has been reported as the highly potential parasitoid (Singh and Thangavelu, 1995; Singh *et al.*, 1995). All most all of them are ectoparasiotoid - feeding externally upon the host. Ectoparasitoids most frequently occur on hosts that live in some protected site a pupa in a cocoon where they are less likely to be dislodged and loose their host. Many of them also sting and paralyze the host prior to oviposition.

Chemical control

Sericulturist faced problems due to extensive and intensive use of insecticides on silkworm food plants. Insecticide use resulted in increases in pest population in mulberry and non-mulberry food plants. Resistance to synthetic insecticides against major pests *viz.* tussock moth, gall midges, leaf roller and stem borer has forced the entomologist to switch over to plant originated insecticides in sericulture. Among the plants, which are reported to be more commonly used in pest control, are Neem, Pungamia, Indian privet, Adathoda, Chrysanthemum, Turmeric, Onion, Garlic, Tobacco, Ocimum, Custard apple, Zinger and some other plants. Usually extract of whole plant or parts of the plants are prepared and sprayed, otherwise, they are dried under sunshade, powdered finely and applied as dust. Sometimes mixtures of extracts of more than a plant are made and the extracts are sprayed after allowing certain incubation period to enable them to release out the toxicant in the liquid.

Among the plants, neem is the most promising source of biopesticides. Neem owes its toxic attributes to all large number of bitter compounds called meliacins like azadirachtin, nimbin, salanin, meliantriol, etc. among which azadirachtin is the most efficient. Neem seed kernels are the richest source of meliacin and contain 0.2% - 0.3% azadirachtin and 0.4% oil though neem leaves, seeds and bark also contain these in smaller quantities. The neem product acts as insect antifeedant, repellent, growth regulator, chemosterilant and toxicant. Any pest escaping one effect may be killed by other (Vijayalakshmi *et al.*, 1995). Neem has been found effective against more than 200 species of insects like stem borers, hairy caterpillars, podborers, beetles, leafhoppers, planthoppers, aphids, mealybugs and whiteflies (Singh and Sinha, 1993). Application of azadirachtin to maggots of the uzifly, *Blepharipa zebina* completely disrupted subsequent development to pre pupae, pupae and adults. In a dose and stage dependent manner azadirachtin caused a delay and inhibition of puparium formation, loss of weight, pupal death, prevention of emergence of adults and malformation to adult structures (Singh and Thangavelu, 1996; 1998). Neem cake has manurial value to plants besides acting against nematode infestation in mulberry. Neem products are highly photodegradable ensuring their nonexistence in environment however, its action can be extended up to 3 - 7 days in the field. There is no problem of resistance and resurgence. Hence, they have characteristic suitable for IPM strategy.

Feed back in IPM

Holistic and reductionist pest management system can both be defined in terms of positive feed back. In reductionist system, pest problems are main driving forces on crop protection decision making. As they increase, or are perceive to increase, pesticide use increases, leading to decline in natural controls which in turns lead to an increase in the pest problems followed by further increase in pesticide use. In holistic system, pest control by natural factor is the controlling influence on decision making. As this increases, pest problems decline, hence pesticides use declines, leading to a further increase in pest control by natural factors. The switch from system which driven by a pest problems to one which is driven by natural controls is unlikely to be smooth one. It must involve a discontinuity of some kind to jolt the thinking of the decision maker (Tait, 1980; Van Den Bosch, 1982).

Strategies and tactics

The application of pest management concepts begin with the development of a strategy. A pest management strategy is the over all plan to eliminate or alleviate a pest problem. The particular strategy developed depends on the particular life system of the pest and the crop involved. Recently some important strategies *viz.* planting of cover crops, providing nectar- producing plants and sources of alternate hosts in and around fields, and inter planting different crops to provide habitat diversity are all management techniques that lead to the build up of natural enemy populations and result in enhanced biological control of pests.

Market potential

IPM market should be developed to avoid excessive use of pesticides. Sticky traps, pest-O-flash and pheromones lure chemicals and Tricho cards should be popularized and provided as tool for controlling various pests and parasites in sericulture. The potential for promotion of pheromone technology is an important aspect. It may be popularize at grass root level and mass awareness should be created among farmers for further transfer of technology from laboratory to land.

Future outlook

The pesticide application as prophylactic measures is very common among farmers. In most of the states, farmers very religiously follow the package of practices evolved on the application of pesticides on a prophylactic basis. These package of practices need to be reviewed immediately to incorporate components of IPM technology for the benefit of farmers. Research progress on the use of IPM strategies is being made. There is a greater potential for kairomones in contributing significantly to pest management, however, the uses of kairomones should not be considered in isolation from other control measures and component of IPM.

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