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Current Status and Future Projections for Biological Control of Insect Pests in India

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While the biocontrol programmes of the first half of this century resulted in a few notable successes in many areas, such as the suppression of the woolly aphid of apple *Eriosoma lanigerum* by the North American hymenopterous parasite *Aphelinus mali* and of the polyphagous fluted scale insect *Icerya purchasi* by the Australian lady-bird beetle predator *Rodolia cardinalis*, the use of parasites, predators and pathogens on an adequate scale in the field to maximise the benefits from biological control, could not be extended to other crop pests in various parts of the country for want of sufficient monetary, man-power and material resources.

Several exotic parasites are established in the country and, together with native species, are contributing to a decline in pest population levels. The indiscriminate use of chemical insecticides has interfered with biological control in some areas. Hence the need for proper pest management practices that help and do not hamper the activity of beneficial organisms. On account of delays and difficulties in importing other, possibly more promising, parasites and predators some of the introduced species, such as the egg parasite *Telenomus remus* and the predator *Cryptolaemus montrouzieri*, are mass-produced and used in inundative releases in the same way as native species. For certain serious pests, for example sugarcane pyrilla and coconut leaf caterpillar, the main approach to control at present is conservation and augmentation of the already existing complex of parasites. This has proved rewarding, without the need for insecticide applications. Inundative releases of *Trichogramma* spp. continue to play a major role in biocontrol of sugarcane borers.

The forest ecosystem offers very favourable conditions for classical biological control and there are some very suitable target insect pests of forest trees that warrant attention.

Basic research in insect taxonomy, ecology and other disciplines that support biocontrol approaches is also carried out in Indian Universities. Efforts to evaluate biocontrol agents need to be intensified and improved. Microbial control of insect pests has made little progress in India although several potentially valuable pathogens have been studied and are available for practical use.

With increasing awareness of the merits of biological control it is expected that this method will be adopted on an expanded scale in the coming decades. The future possibilities are discussed.

Introduction

Biological control of pests aims at suppression of insect pests of crops or other harmful organisms by using their natural enemies (parasites, predators or pathogens) which form part of the biotic environment. This method has proved economical and effective in dealing with several pest problems all over the world and does not have the disadvantages of chemical pesticides. The natural enemies are either introduced from one area to another (classical biological control) or those that are already present in an area are enabled to improve their performance by manipulation, augmentation or other means. Natural enemies are valuable tools in pest management (Sankaran 1977).

In India the earliest deliberate and successful introduction of a natural enemy against an insect pest was the coccinellid beetle *Cryptolaemus montrouzieri* (Muls.) from Australia in 1898. Although it became established it failed to control the target pest, the coffee green scale *Coccus viridis* (Green), but it is now a common mealybug predator in South India. It is also mass-produced and released in the field to control mealybugs on citrus, grapevine and other crops. Two alien insect pests have been kept under effective biological control by introduced natural enemies for some decades now, the apple woolly aphid *Eriosoma lanigerum* (Hausm.) by the North American eulophid parasite *Aphelinus mali* (Hald.) introduced from England in 1937, and the polyphagous cottony cushion scale *Icerya purchasi* Mask. by the Australian ladybird beetle *Rodolia cardinalis* (Muls.) obtained from the USA in 1929 and from Egypt in 1930.

These successess and also many others elsewhere have prompted entomologists in India to pay more attention to biological control as a promising alternative to chemical control. This trend was evident even during the decade following the Second World War when synthetic organic pesticides strongly swayed the decisions and actions of plant protection specialists and agricultural administrative agencies. The establishment of the CIBC Indian Station in 1957 paved the way for more concerted exploratory surveys for natural enemies of crop pests and introduction of and evaluation of exotic biocontrol agents against some of the important pests. The natural enemies introduced into India from other areas of the world and the field releases and results known until 1969 were reviewed by Rao et al. (1971). Sankaran (1974) listed the subsequent introductions and discussed the results up to 1973. Biological control of sugarcane borers in India has been reviewed comprehensively by various authors (Sithanantham & Solayappan 1980). The present paper highlights the major developments of the last one decade, reviews the current progress and comments on the future possibilities. Biological control of weeds and of insects of medical and veterinary importance is not considered here.

Surveys for and Basic Studies on Natural Enemies

One of the prerequisites for biocontrol programmes is adequate information on the presence or absence of natural enemies of target pests in the area where control is needed and also in other areas where the same pests or related species occur and which may therefore be sources of possibly more effective natural enemies. Such information should include the correct identifications, detailed biologies and population dynamics of natural enemies as well as of pests. Surveys carried out by CIBC in India have greatly added to our knowledge of indigenous parasites and predators of a wide range of insect pests of crops and forest trees. The results are documented in the reports of the institute. These cover rice insect pests, sugarcane stem borers,

coconut rhinoceros beetle, pine shoot borers, aphids and diaspine scale insects, *Coccus viridis*, *Cryptophlebia ombrodelta*, *Heliothis* spp., *Hypsipyla robusta*, *Lymantria obfuscata* and *Procontarinia matteiane*.

Taxonomic studies on Indian parasitic groups such as Chalcidoidea, Ichneumonoidea, Proctotrupoidea and Tachinidae, have made significant advances in recent years, as may be seen from the revisionary studies of Joseph et al. (1973), Crosskey (1976), Gupta and Tikar (1976), Nagarkatti and Nagaraja (1977), Mani and Sharma (1982), and Noyes and Hayat (1984). Some predaceous groups have also been studied in considerable detail, for instance Anthocoridae by Muraleedharan and Ananthakrishnan (1978).

These surveys and taxonomic studies serve as an essential base for more detailed biological and ecological research on individual species as agents for evaluation in practical control attempts. For example, *Apanteles flavipes* Cameron is an important native parasite of *Chilo* spp. in India but it is unable to prevent borer populations from increasing because of its inability to tolerate wide variations in temperature and humidity. Recent studies on this parasite by Balraj Singh and Anand (1982) confirmed that even short exposures to unfavourable temperatures and humidities reduced adult survival and rate of parasitism and hampered larval development. When transferred to Barbados and other neotropical areas having optimum climatic conditions the parasite gave spectacular control of sugarcane borers there. We have sufficient data on natural enemies of *Heliothis armigera* in India and elsewhere to formulate and carry out a pest management programme (Greathead & Girling 1982, Sudha Nagarkatti 1982). However, detailed studies are lacking for most other insect pests. Recent interest in developing a pest management programme for coffee plantations in south India revealed how some basic aspects of even the biology, behaviour and habits of a major pest, such as the coffee white stem borer *Xylotreches quadripes* Cher., are still unknown, not to mention the lack of such information on its natural enemies. Similarly, while the sugarcane scale *Melanaspis glomerata* (Green) has a complex of native parasites and predators no serious attempts have been made to find out why they are unable to exercise adequate control of the pest. The fact that parasites and predators, native or exotic, such as the species attacking the coconut leaf caterpillar *Opisina arenosella* Wlk. and *M. glomerata*, could be bred on these insects in the laboratory but they fail to maintain their populations at effective levels when released in the field, points to the need for critical evaluation of the complex of factors that affect their performance. This would help in selecting species or strains of natural enemies that may overcome these limitations and prove useful in biological control or pest management.

Introduction and Evaluation of Exotic Natural Enemies

During the last ten years the Directorate of Plant Protection, Quarantine & Storage, Ministry of Agriculture, Govt. of India, set up a network of Central Biological Control Stations, with a main unit at Faridabad and a parasite/predator multiplication centre at Bangalore. These stations availed of CIBC's expertise and facilities at Bangalore for importation and initial laboratory breeding of a number of exotic parasites and predators. Prior to the establishment of these stations most of the work of distributing stocks of imported natural enemies within the country was handled by the CIBC station at Bangalore with its limited funding and staff. A major constraint for the Central Biological Control Stations was lack of adequate foreign exchange allocations for natural enemy introductions from other areas of the world. Therefore, the Indian Council of Agricultural

Research (ICAR) stepped in to launch an All India Co-ordinated Research Project on Biological Control of Crop Pests, with a diverse and more widespread network of collaborating units that included some of the agricultural universities. These units deal separately with different crops. Initially CIBC provided quarantine and other facilities at Bangalore for maintaining the imported stocks of biotic agents and for testing them but the ICAR project co-ordinator and all other staff are now based at the Indian Institute of Horticultural Research, Hessarghatta, Bangalore. The detailed technical programmes and progress of these units are discussed and future plans formulated at periodical workshops, the fourth of which was held in 1983. The Central Biological Control Stations mainly play an important extension role, promoting the use of already available exotic and native natural enemies.

Sudha Nagarkatti and Jayanth (1981) have summarised the recent work and achievements. Sugarcane borers and scale insects are among the main pests for which suitable exotic natural enemies are still being sought since none of the earlier introductions has met with success. However, the larval tachinid parasite *Diatraeophaga striatalis* Tns. has shown promise of establishment in south India. CIBC is arranging to provide additional species through its stations in Kenya and Trinidad. As regards cotton, the egg parasites *Trichogramma brasiliensis* (Ashm.) and *T. chilonis* Ishii and larval parasites *Bracon kirkpatricki* Wlk. and *Chelonus blackburni* are reported to be established in some areas. In parts of Gujarat, substantial reduction in bollworm infestations is attributed to the action of these parasites. The rice stem borer *Scirpophaga incertulas* (Wlk.) and gall midge *Orseolia oryzae* (Wood-Mason) continue to be of major importance for which the possibilities of introducing effective parasites are still wide open. The introduction of several species of African and neotropical parasites of graminaceous borers is under way. *Telenomus remus* Nixon has proved effective against *Spodoptera litura* (F.) when used in inundative releases, complementing the native predator *Chrysopa scelestes* Banks. The larval parasite *Eucelatoria bryani* Sabrosky and egg parasite *Trichogramma brasiliensis* are of considerable value in controlling *Heliothis armigera* (Hb.) on tomato in some areas. The predaceous bug *Platymeris laevicollis* Dist. attacking *Oryctes rhinoceros* (L.) is established in Kerala, giving a reduction in leaf and spathe damage. *Baculorirus oryctes* (Huger) has recently been introduced into the Laksahdweep Islands to suppress the rhinoceros beetle. Of the exotic parasites of the potato tuber moth *Phthorimaea operculella* Zeller released in Maharashtra only *Copidosoma koehleri* Blanch., *Chelonus blackburni, C. kelliae* Marsh and *Orgilus jeniae* Marsh have been recovered. However, some promising species, notably *Apanteles subandinus* Blanch., should be released more extensively in different areas to evaluate their potential.

Trichogramma cacoeciae Marchal and *T. embryophagum* (Htg.) are effective in inundative releases against the apple codling moth *Cydia pomonella* (L.) in Ladakh.

Use of Indigenous Natural Enemies and Pest Management Studies

As already mentioned, native parasites and predators are successfully used in India against several highly destructive insect pests that include borers, pyrilla (*Pyrilla perpusilla* Wlk.) and scale insect on sugarcane, castor semilooper (*Achaea janata* L.), coconut leaf caterpillar (*Opisina arenosella*) and tobacco caterpillar (*Spodoptera litura*). Yet there is very little reliable information on the cost of production and field releases of indigenous natural enemies and on the economic benefits accruing therefrom, except for *Trichogramma* used against sugarcane borers. A private pest control organisation runs a commercial

insectary at Bangalore for mass-producing parasites and predators and selling them to farmers and others. Since the cost of releasing a parasite or predator per unit crop area is known from a commercial supplier it should be possible to obtain reliable cost/benefit data to demonstrate the value of biological control.

Large scale production of host/prey organisms in the insectary to enable natural enemy colonies to be increased and made available on the required scale is often hampered by diseases, secondary parasites, predators etc. Genetic deterioration of highly inbred stocks, preponderance of one sex in colonies of bisexual species, and other problems are also frequently encountered. These can only be overcome by research and by constant efforts to improve the techniques in the light of advances in knowledge and experience. Artificial diets are known for a number of species of insects. There is scope for their commercial production in India to meet the needs of several laboratories that use insects like *Heliothis*, *Spodoptera* and *Corcyra* for their work.

Introduction of natural enemies from one area to another for biological control of pests, in the classical sense of the term, is mainly intended for inoculative releases in the expectation that such species would thrive very well in the new area and suppress the target pests. If an introduced species is no better than native species that are present the level of control of the pest may not improve and there is no greater advantage in mass producing and releasing it than with already existing natural enemies for inundation and augmentation. This could even turn out to be a disincentive to further attempts to look for and try other promising exotic natural enemies. There is a risk of this happening in countries like India where classical biological control needs much greater support than it receives at present.

The available data on natural enemies of some Indian insect pests of crops are already being used in integrated control recommendations. For instance, Sharma and Sarup (1980) have studied the feasibility of integrated control of *Chilo partellus* (Swinh.) on maize, permitting the utmost effectiveness of native parasites and predators. Nadarajan and Channa Basavanna (1980) have dealt with *Opisina arenosella* on a more comprehensive basis. The requirements for pest management in cabbage, cotton and pulses have also been outlined (Sudha Nagarkatti & Jayanth 1982, Nagarkatti & Sankaran 1982, Sithanantham 1983). With many other pests the existing knowledge of their natural enemies has hardly been applied in the field. For pests of seasonal crops, such as the groundnut leaf-miner *Stomopteryx subsecivella* Zeller, which have a complex of parasites that build up high populations some weeks after pest attack starts, any early control measures should be carefully selected and judiciously applied so as not to impair parasite activity. It is relevant here to point out that some natural enemies favour the same host/prey occurring on certain host plants but not on others. Such affinities are of practical significance.

Pest management or integrated control recommendations have to take into account the total crop (and pest) situation in a specified area and not be confined to individual pest species at a fixed time or over a crop season. Otherwise, a target pest may be controlled but a different key pest may emerge and vitiate the results as it happened with cotton pests in Western Australia (Woods 1981).

Insect Pathogens for Pest Control

Recent advances in the study of insect pathogens in India are reviewed by Ramakrishnan and Kumar (1981). Viruses, bacteria, fungi and parasitic nematodes have

received more attention than other groups of microbial organisms with potential use for pest control. Nuclear polyhedral viruses attacking *Amsacta albistriga* Wlk., *Heliothis armigera* and *Spodoptera litura* have shown encouraging results in preliminary field trials. *Bacillus popilliae* Dutky has been demonstrated to be promising against white grubs (*Holotrichia* spp.). *Bacillus thuringiensis* Berl. is effective against a wide range of pests on several different crops but it is feared to be detrimental to the progress of sericulture. Its popularity and use in other silk-producing countries like China and Japan should dispel the bias. The entomogenous fungus *Verticillium lecanii* (Zimm.) is another pathogen of proved value against a number of coccoid and aphid pests. *Beauveria bassiana* (Bals.) Vuill. *B. brongniartii* Tenella, *Entomophthora* spp., *Metarrhizium anisopliae* (Metch.) and *Nomuraea rileyi* (Farlow) have all been investigated generally but scarcely used in the field on any large scale. Commercial production of selected insect pathogens merits official support for extended use in agriculture. Readily available formulations can be used when temperature and humidity are favourable. The practice of collecting diseased material from the field and preparing water suspensions for spraying and dissemination of the pathogen has serious limitations and is not the best way of promoting microbial control.

The Rhabditid nematode *Neoaplectana carpocapsae* Weiser (DD 136) has been successfully tried on rice stem borers. A low cost method of mass production of this nematode developed in Australia (Bedding 1981) could make it available for ready use against several pests. However, recent investigations elsewhere have shown that the nematode adversely affects certain braconid and ichneumonid parasites (Kaya & Hotchkin 1981). This again brings out the need for detailed study of the interactions of different biotic agents in any given situation.

Baculovirus oryctes was imported by CIBC Indian Station from Western Samoa in 1971 and supplied to one of the collaborating laboratories in India. Since the virus is easily disseminated by infected media like sawdust the author believes that its subsequent collection from *Oryctes rhinoceros* populations in Kerala was the result of the introduction and that the virus was not present in India earlier. Moreover, surveys carried out by CIBC and other scientists in India prior to 1971 had not shown the presence of the virus in natural populations.

Pests of Forest and Shade Trees

Forest and shade trees are attacked by several species of major insect pests, notably defoliators and borers. Recent advances in their control are reviewed by Sen-Sharma and Thapa (1981). Many of these pests have a large complex of natural enemies but proper surveys and biological and related studies of individual species have been carried out only in a few instances (Chatterjee & Misra 1974, Sankaran 1976). Some of the pests, such as *Dioryctria abietella* Denis & Schiff. *Hyblaea puera* Cram., and *Hypsipyla robusta* Moore, occur over a wide geographical area or have related species in other areas in the tropics that open up possibilities of introduction of suitable parasites into India. Others like *Calopepla leayana* Latr. and *Tonica niviferana* Wlk. have a restricted distribution in the Indian subcontinent. The natural enemies of these warrant more detailed study with a view to their use in pest management.

Exchange of parasites of teak defoliators, *Hapalia machaeralis* (Wlk.) and *Hyblaea puera*, between India and Burma during the 1940's did not have much effect on the pest populations. Breeding and release of native parasites of *Plecoptera reflexa* Guen. also proved to be futile.

Limited trials have been carried out with aerial spraying of forest plantations with chemical insecticides but the long-term effect of these insecticides on natural enemy populations of forest pests has not been investigated. It is advisable to avoid large-scale use of non-selective insecticides, and to evolve guidelines for pest management practices in forests, allowing natural enemies to exert maximum control. The use of microbial agents is especially valuable in checking forest insect pests.

Training in Biological Control

Dearth of adequately trained scientists to operate biocontrol programmes and to carry out basic and applied research studies on natural enemies of pests both in the laboratory and in the field was a major constraint until ten years ago. Most of the main staff engaged in current biocontrol projects in India have been trained for various periods of time at the CIBC station in Bangalore. Training of staff and also of post-graduate students of entomology in the principles and practice of biological control is arranged by CIBC by prior consultation. CIBC has so far held three international training courses and a special course for scientists of the FAO inter-country rice pest management programme in South-east Asia. Candidates from India have participated in these courses. Some of the agricultural universities have included courses in biocontrol in their regular syllabus.

Discussion and Future Projections

From the foregoing account it may be seen that substantial progress has been made over the last one decade in building up a self-reliant infrastructure of basic facilities and trained personnel to expand biological control work in India, with the Indian Council of Agricultural Research now taking a leading role in these developments at a national level. The importance of encouraging commercial insectaries is recognised. Mass production of native parasites, predators and pathogens is best organised and promoted by private agencies, which will relieve biocontrol workers in Government laboratories and universities to devote their time and limited resources to research and development tasks and to evaluate field programmes. Native biotic agents will continue to be employed against several key pests and therefore further research efforts should aim at more efficient and cost-effective production and utilisation, keeping in view the need for qualitative improvements. The developments of pesticide-resistant strains and of those that show improved tolerance to temperature and humidity variations is also possible.

Introduced natural enemies have much more to contribute to biological control of insect pests in India than what has been witnessed to date. However, Indian agencies have hardly supported any major exploratory surveys for natural enemies or detailed studies in other parts of the world but have almost always looked for readily available species of biotic agents that would cost nothing or little to import. Moreover, the present procedures for obtaining authorisation to import natural enemies are cumbersome and protracted. A more realistic and positive system is needed to enable biocontrol scientists to introduce and evaluate a large number of potentially valuable exotic beneficial organisms. Even where good candidates are known and can be introduced, such as larval parasites of *Cydia pomonella* from Europe and of *Lymantria dispar* (L.) from Europe and the USA (to control *L. obfuscata*), lack of funds has prevented their importation and trial. In some instances, as with the parasites of *Quadraspidiotus perniciosus* (Comst.) already introduced and well established in the apple-growing areas of northern India, the use of chemical insecticides has to be

reduced and properly integrated with the use of natural enemies.

Biological control of forest insect pests is largely neglected at present and warrants the establishment of a separate central co-ordinating unit working in close collaboration with international organisations and state forest departments.

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