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Integration of Biological Control Methods in Pest Management

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Apart from use of cultural methods of pest control and resistant varieties of plants, biological control agents play an important role in pest management even in the agro-ecosystem disturbed by human activity. Importation of exotic natural enemies to control introduced pests, augmentation and periodic colonization are the important approaches currently followed in biological control. Various factors known to reduce the effectiveness of natural enemies are yet to be identified for different regions. However, use of kairomones to increase the effectiveness of natural enemies and microbial insecticides in place of highly toxic synthetic insecticides to conserve the natural enemies is advocated. For monitoring regular use of sex pheromone traps is suggested. For suppression of lepidopterous pests use of egg parasites *Trichogramma* spp. followed by release of larval parasites, use of nuclear polyhedrosis viruses (NPV), granulosis viruses (GV) alone or in combination may prove effective. To compete with the established pesticide industry it is necessary to have economically viable mass production units in different parts of the country so as to make available to the farmers predators, parasites and pathogens for periodic colonization. The current status of work done on biological control of crop pests and weeds in India is reviewed.

Introduction

Out of 30 lakh species of insects only 10,000 are considered as pest of crops, man and domestic animals (Sailer 1969). Every species of insect is exploited by predators, parasites and diseases. Naturally occurring biological control however is seldom recognised. We mainly appreciate the type of biological control in which we introduce natural enemy in the agro-ecosystem modified or disturbed by human activity. Cultural method of control, limited and selective use of insecticides, use of resistant cultivars, all these methods individually or in combination increase the effectiveness of biological pest management. But in our country biological control has been used as an end in itself rather than synergistic component of integrated pest management. In this paper current status of work on biological control of important insect pests of different crops is

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reviewed briefly. The integration of biological control methods is also suggested wherever information is available.

Sugarcane Pests

The major pests involved in the biocontrol programme are the moth borers, *Chilo auricilius* (Dudgn.), *C. infuscatellus* Snell., *C. sacchariphagus indicus* (Kapur), *Acigona steniella* (Hampson), *Tryporyza nivella* (Fabr.), the scale insect *Melanaspis glomerata* (Green) and *Pyrilla perpusella* (Walker).

Basic information on common parasites of borers such as *Trichogramma* spp. *Sturmiopsis inferens* Tns. and *Isotima javensis* (Rohwar) has been obtained, which would enable manipulation and augmentation of the parasite populations to obtain better control. Exotic parasite *Paratheresia claripalpis* Wulp. failed to establish in Punjab (Maninder & Verma 1983) but it was recovered from *A. steniella* in Haryana (Prasad & Pawar 1980) and U.P. (Prasad & Pawar 1983). Another exotic parasite, *Diatraeophaga striatalis* Tns. was recovered from Pugalur area of Tamil Nadu (Easwaramoorthy et al. 1980). The role of these diptron parasites in suppression of the pest population to economic level is yet to be determined. Efforts are also made to introduce some parasites restricted to certain parts of the country into other regions where they may prove useful.

The use of *Trichogramma* against moth borers has been attempted by number of workers. Against internode borer *C. sacchariphagus indicus* Sithanantham et al. (1973) released 20,000 *T. chilonis* Ishii per acre each week from 4th to 11th month of planting. Encouraging results were obtained by releasing *Trichogramma* over 3000 acres (Solayappan 1980) and by 12 releases of *T. chilonis* at 5000/release/acre in Tamil Nadu (Varadharajan 1980). Similarly Lakshminarayana (1980) achieved good results by releasing 50,000 *T. chilonis* per acre in many spots for proper distribution. It is generally believed that release of 100,000 *T. chilonis* in 2-3 batches against *C. infuscatellus*, *C. auricilius* and *A. steniella* and same dosage of *T. japonicum* against *T. nivella* will prove effective. However, the role of different species of *Trichogramma* in parasitising different moth borer eggs, method of release (inoculative, inundative or flooding) has to be identified in different agro-climatic zones of our country. More and more modern *Trichogramma* factories are required for meeting the demand of farmers throughout the country. In the absence of any effective indigenous natural enemy of sugarcane scale insect *M. glomerata* a number of exotic species were introduced of these only *Sticholotis madagassa* Weise was recovered from A.P. (Sankaran & Mahadeva 1974). U.P. and North Bihar (Misra et al. 1981). Mass multiplication of indigenous parasite *Anabrolepis mayurai* Subba Rao, and predators *Pharoscymnus horni* Weise and *Chilocorus nigritus* Fab. and their inundative release may prove useful. Efforts should be made to distribute the eggs of the predators so that the hatching grubs feed in the places of release and the subsequent generation multiplies there. Efforts were made at the main centre, Bangalore to introduce exotic parasites of allied species of *Melanaspis* from Brazil. Initial laboratory trials with *Signiphora* sp., *S. lutea*, *S. flavopallidata*, *Physcus flavoflagellata* indicated that they will not accept the Indian scale but row additional material i.e., *Neococcidencyrtus* sp. and *Aphytis* spp. has been received for testing. These species have accepted *M. glomerata*. These parasites are now being supplied to different centres for testing.

The most outstanding success has been achieved with *Epipyrops melanoleuca* Fletcher, the parasite of *Pyrilla perpusalla* (Walker). Introductions into West Bengal, Karnataka, Madhya Pradesh, Maharashtra and Rajasthan besides other areas have proven success-

ful (Pawar 1979). The parasite has therefore demonstrated its adaptability to a wide range of ecological conditions.

A buildup of natural enemies as a result of lowered insecticide application is generally recorded in sugarcane fields.

Cotton Bollworms

Indigenous parasites of bollworms [*Pectinophora gossypiella* (Saunders), *Earias insulana* Boisduval and *E. vittella* F.] have been studied in different cotton growing regions (Khan & Rao 1970, Chabra & Jai Singh 1977, Das & Basu 1977, and Sekhon & Varma 1983). The relative role of native parasites in pesticide applied and pesticide free fields of cotton is yet to be assessed.

Exotic parasites have been tested in the field and *Chelonus blackburni* Cam. from *E. vittella* in Dharwar district of Karnataka (Thontadarya & Jai Rao 1977) and *Bracon kirkpatricki* Walk. from different parts of Haryana have been recovered (Pawar & Prasad 1983). Mere establishment may not solve the problem the real test of their effectiveness in the released area will be the economic gains obtained by the establishment of these parasites in different regions. Recently, Gujarat Agricultural University has tested a number of parasites and predators for the control of bollworms near Surat and obtained quite encouraging results (Anon 1980). Exotic egg parasite *T. brasiliensis* (Ashm.) has also been recovered from *P. gossypiella* eggs in Punjab (Varma et al. 1980) and Haryana (Pawar et al. 1980). Earlier Sangwan et al. (1972) released *T. brasiliensis* on cotton at 7–10 days interval throughout the oviposition period of bollworm resulting in 35% increase in yield of cotton at the end of experiment. There is every possibility of achieving success in biological control of cotton bollworm by releasing at least 1,50,000 *T. brasiliensis* and 3000 *Bracon kirkpatricki* per hectare as well encouraging by the different methods, local parasites like *Bracon hebator* Say and predator *Chrysopa scelestes* Banks. Nuclear polyhedrosis virus and Granulosis of *Spodoptera litura* Fabr. and *Heliothis armigera* Hbn. can also be tried individually or in combination. Interaction between the viruses and the parasites are also being studied as the parasites could serve a useful role in transmitting and disseminating the pathogens in the field.

Recently one more parasite *Apanteles marginiventris* Cress. has been imported from the West Indies for trial against *H. armigera* and *S. litura*. Laboratory trials have indicated that it accepts both these hosts and field trials are being conducted. Large scale field trials are however necessary in different agro-climatic regions of the country.

Phosalone (0.05%) was found safe for parasites *Apanteles angaleti* and *Bracon kirkpatricki* (Mani & Nagarkatti 1983). A waiting period of 6 days was recommended for colonising *T. brasiliensis* on endosulfan treated plants (Awate et al. 1977).

Integrated pest management for cotton resulted in increase in the natural incidence of parasites, predators and yield. A saving of Rs. 250 per hactare on plant protection operations was achieved (Menon & Srinivasan 1978).

Rice Pests

Work on rice pests is mainly confined to study the indigenous natural enemies. Natural enemies of brown plant hopper (BPH) *Nilaparvata lugens* (Stal.) include a coccinellid, anthocorid, mirids, ants, a frog and a fungal pathogen (Manjunath et al. 1978a and 1978b); and drynids *Haplogonatopus* sp. and *Ecthrodelphax fairchildi* Perkins. Eggs were parasitised by *Oligosita* sp., *Tetrastichus* sp. (Samal & Misra 1978b) and *Anagrus* spp. *Cyrtorhinus lividipennis* Rent and *Coccinella arcuata* F. were identified as important predators (Abraham et al. 1973, Kalode 1976, Datta 1977, Manoranjan & Jayaraj 1979)

and *Verticillium lecanii* (Zemm.) as important pathogen of BPH (Balasubramanian 1979). Two entomophilic nematodes *Hexamermis* spp. (Manjunath 1978), 20 species of predatory spiders including salticids, lycosids and oxopids (Samal & Misra 1975) and a crabid predator, *Casnoidea indica* (Thunb.) (Samal & Misra 1978b) were recorded on BPH. Lot of information has been collected on *C. lividipennis* by the workers of All India Coordinated Rice Improvement Project, Hyderabad. Since breeding of BPH on caged rice plants and also of the egg parasites and predatory bug is possible, mass multiplication of the natural enemies for release in BPH out-break areas seems feasible.

Natural enemies of rice stem borer, *Scirpophaga incertulas* (Walk.) have been identified (Nath & Hakim 1979). Egg parasites, *Telenomus rowani* Gah., *Telenomus* sp. and *Tetrastichus schoenobii* Ferr. have been studied (Rao & Ali 1975). It was also shown that *Sturmiopsis parasitica* Curr. successfully develops in *C. auricilius, C. partellus* (Swinh.) and *S. inferens* (Walk.) (Nagarkatti & Rao 1975). Efforts are being made to import parasites of *S. incertulas* including those of *Rupela albinilla* a rice borer from Surinam. Conservation of indigenous natural enemies and augmentation of egg parasite *T. japonicum* (release of 150,000 parasites in 2-3 batches) during the active period of the pest may be tried.

Parasites *Platygaster* sp., *Neanastatus grallarjus* (Masi), *Tetrastichus* sp., *Gelix areator* (Panz.) and unidentified ceratopogonids have been isolated from rice gall midge (Rai et al. 1975). Conservation of indigenous natural enemies by regulating the pesticide application may help to some extent but the use of gall midge resistant varieties will prevail in the long run.

Pulse Pests

Polyphagous pest *Heliothis armigera* (Hubn). is a serions limiting factor in pulse production in our country. Natural enemies of this pest were studied by the Indian Station of Commonwealth Institute of Biological Control (Anon. 1974), ICRISAT (Bhatnagar & Devies 1978) and I.I.H.R., Bangalore. Efforts have also been made to utilise *T. chilonis* (Thontadarya et al. 1978), *Chelonus heliopae* Gupta and *Campoletis chlorideae* Uchida for the control of *H. armigera.* Exotic parasite *Eucelatoria bryani* Sabrosky has been recovered from Bangalore (Mani 1980, Anon 1980), Hyderabad (Sithanantham & Reed 1980) and eastern Uttar Pradesh (Misra et al. 1982). An all out effort should be made to control this pest by utilising egg parasites *Trichogramma* and larval parasites like *Bracon hebetor* Say because both of these can be easily multiplied. Exotic larval parasites, *Apanteles kazak* Tel. and *Hyposoter didymator* Thunb. which are available in USSR (Singh 1972) and other East European countries are likely to be introduced soon. *H. didymator* was recorded as the most important population regulatory factor in Krassnodar, USSR (Singh 1972) Use of nuclear polyhedrosis viruses (NPV) or Granulosis virus (GV) or both in combination may also be encouraged by organising commercial production of these viruses.

Oil Seed Pests

In Andhra Pradesh *Achaea janata* L. is a serious pest on castor. Egg parasite, *Telenomus proditor* Nixon seems to have given quite promising results (Thobbi et al. 1960, Narasimharao 1980). In Andhra Pradesh four factories are producing *T. proditor* for use against *A. janata* which shows the prospects of biological control against this pest. However, due to continuous laboratory rearing it is suspected that the culture of the parasite is highly inbred which needs replacement. The use of NPV of this pest should also be encouraged.

Tobacco Pests

The two major insect pests of tobacco against which biocontrol agents are being tried are *Spodoptera litura* Fabr. the caterpillars of which destroys the crop in the nursery stage and the aphid *Myzus persicae* Sulz. which affects the planted crop. Exotic egg parasite *Telenomus remus* Nixon has given encouraging results by inundative releases for the control of *S. litura* (Anon 1980). The Central Tobacco Research Institute, Rajahmundry is making renewed efforts to use *T. remus* which is now known to be established in some parts of the country. Excessive use of insecticides in tobacco nurseries, however, appears to have prevented the widespread establishment of the parasite and prevented it from demonstrating its full impact on the pest. However, the efforts of C.T.R.I. staff to use this egg parasite and a general predator *Chrysopa scelestes* supplied by I.I.H.R., Bangalore on a pilot scale have given encouraging results. Similarly NPV of *S. litura* should be produced on commercial scale for use on large areas. Exotic parasite *Apantales marginiventris* has been introduced and laboratory trials indicate the ability of this parasite to attack and develop in *S. litura*. As regards *M. persicae* its natural enemy component is known. Some of the indigenous natural enemies such as the coccinellid *Menochilus sexmaculatus* appear to be suitable for commercial multiplication and inundative field releases.

Coconut Pests

The major pests involved in biological control programme are *Opisina arenosella* Wlk. and *Oryctes rhinoceros* (L.). From *O. arenosella* five parasites viz., *Parasierola nephantidis* (Musse), *Elasmus nephantidis* Rohow, *Brachymeria nephantidis* Gah., *Bracon brevicornis* Wesmael and *Trichospilus pupivora* have been recorded causing 29.4% parasitism (George et al. 1977). But these parasites on their own do not regulate the population of this pest and frequent outbreaks right from the western coastal belt from Karwar down to Kerala as well as from interior districts of Karnataka have been observed. The population of the pest is also fairly high in Gujarat and Orissa. Some basic work has been done at IIHR, Bangalore where an artificial diet has been developed for laboratory rearing of *O. arenosella* (Jayanth & Nagarkatti 1980). This in turn has facilitated mass rearing of some host specific indigenous parasites such as *E. nephantidis*. Work conducted by C.P.C.R.I., Kayangulam indicate that exotic parasites *Spoggosia bezziana* (Bur.) and *Bessa remota* (Ald.) from Sri Lanka and Malaysia respectively were unable to establish under field conditions. Under the circumstances inundative release of native parasites, *Parasierola nephantidis* and *Bracon brevicornis* at 3000 and 4500 per hectare in two to three batches should be continued.

Against *O. rhinoceros*, releases of the exotic predatory bug *Platymaris laevicollis* Distant have shown considerable promise, resulting in reduced leaf and spathe attack as well as fresh incidence (Anon 1980). A baculovirus has also been found in natural population of adult beestles collected in Kerala (Anon. 1980). Wild beetles are infected by allowing them to swim in a glucose-virus suspension for 30 minutes. The beetles are kept for 24 hrs and then released in the field, they carry the disease to the breeding sites and continue disseminate the disease for their entire life (Mohan 1983). Methods have been developed to culture the fungal pathogen *Metarhizium anisopliae* (Metch.) Sorokin on cheap media, such as tapioca chips and rice bran amended with fish waste extract or urea, in specially designed large aluminium vessels (Mohan & Pillai 1982a). Similarly the persistence of the pathogen in manure heaps has been studied by using selective medium (Mohan & Pillai 1982b).

Fruit and Vegetable Crop Pests

Extensive surveys have been made for natural enemies of citrus pests, especially citrus butterfly, diaspidid and lecanine scales, mealy bugs, aphids, mites, leaf-miner etc. (Singh 1980). Methods have been standardised for mass rearing the coccinellid *Cryptolaemus montrouzieri* Mulls. (a predator of Australian origin) and colonization in mealy bug infested mixed plantations of citrus and coffee where chemical control has not been satisfactory (Singh 1978b). It is now possible to undertake commercial scale production and colonization of the predators. Growers have also been trained in multiplication and colonization methods (Singh 1980). However, since this will be required to be done as and when citrus mealybug populations build up in a given area, efforts are continuing to introduce host specific parasites with superior searching ability which will not require to be bred and released periodically but rather will act in a typical density-dependent manner. *Leptomastix dactylopii* How. which was introduced recently has already been recovered from citrus mealybug *Planococcus citri* Risso. at Chethalli and Bangalore. Dipel, a commercial formulation of the bacterium *Bacillus thuringiensis* Berl. has been found to be very effective against the citrus butterfly at 0.05% concentration but its use will be limited in Karnataka in view of the prohibitory orders in the state against use of *B. thuringiensis* which is highly toxic to mulberry silkworms (Singh 1980). At the main centre a protozoan (*Nosema* sp.) has been isolated from the citrus butterfly larvae (Anon 1980). The feasibility of using sprays of the fungal pathogen *Verticillium lecanii* Zemm. against greenscale, *Coccus viridis* (Green) has been explored at CHES, Chethalli. A combination of the fungal suspension containing 16×10^6 spores/ml and one-tenth of the recommended dose of quinalphos have been found to give effective control of the scale insect (Singh 1980).

Foliar application of the NPV against *S. litura* on banana in Madurai district showed that sprays of 1.2×10^{12} PIB/ha gave effective pest control but persistence was only for one day (Santharam et al. 1978). Srivastava (1978) used *Neoaplectana carpocapsae* (Dutky at a dose of 600,000 nematodes per tree 63.33% kill of third instar and 67.67% mortality of fourth and fifth instar larvae were obtained.

At the Central Mango Research Station, Lucknow, surveys for natural enemies of mango pests such as hoppers, mealybugs, leaf webber, shoot borer and scale insects have been made and evaluation of the important ones is in progress. A number of coccinellids and spiders have been found preying on mango hoppers and mealybugs. At least some of the coccinellids could conceivably be multiplied and utilised for controlling these pests. Several fungal and bacterial pathogens are being investigated from the stand-point of field application. Loss of virulence of the fungal pathogens after continued culturing on artificial substrates poses one of the major difficulties in their field use, besides the fact that sporulation of the fungi is greatly influenced by environmental factors such as temperature and humidity.

The Department of Horticulture, Jammu and Kashmir and Sher-e-Kashmir University of Science and Technology, Srinagar has been continuing multiplication and colonization of parasites of San Jose scale on apple and other deciduous fruit trees. There is abundant evidence now that the exotic hymenopterous parasites *Encarsia* (*Prospaltella*) *perniciosi* Tower and *Aphytis diaspidis* (How.) are well established (Anon. 1980). In view of this it is necessary to now review the situation and determine whether the usual agricultural oil-sprays or pesticide sprays are needed at all.

Integrated pest control programme have been developed for apple pests in Europe, Australia, the United States and other parts of the world (Gonzelez 1973).

Surveys for natural enemies of *Lymantria obfuscata* have been in progress in Kashmir. A number of parasites have been recorded but reasons for outbreaks of this pest which cause serious defoliation of several species of broad leaved trees are yet to be determined. Exotic parasites *Trichogramma cacoeciae pallida* Mayer and *T. embryophagum* Htg. were found promising against codling moth (Pawar et al. 1980). However, for monitoring codling moth and other lepidopterous pests sex pheromone traps may be used extensively.

Insect pests of vegetable crops are primarily being investigated by the main centre at Bangalore. The pests under study are: *Heliothis armigera* on tomato, *Plutella xylostella* (L.) and other lepidopterous and aphid pests of cabbage, phytophagous mites attacking okra and brinjal, epilachna beetle and shoot and fruit borer of brinjal and shoot and fruit borer of okra. The population dynamics of the different pests and their natural enemies in different seasons have been studied and possibilities of manipulating natural enemy populations to enable better control of the pests are being investigated. Sampling techniques, life-tables etc. have been developed for some of these. The dipterous parasite *Eucelatoria bryani* (origin: Southern USA) has been colonised against *Heliothis* on tomato and recoveries have been obtained in and around Bangalore (Mani & Krishnamoorthy 1983). The most outstanding results have been obtained with cabbage, where it has been found that the plants can tolerate a fairly high level of *Plutella* population (Nagarkatti & Jayanth 1982) and that the parasites *Apanteles plutellae* Kurdj and *Tetrastichus sokolowskii* Kurdj can effectively suppress the diamond back moth while aphids are checked by coccinellid and syrphid predators in the absence of pesticide interference. Similarly the epilachna beetle is effectively suppressed by *Pediobius foveolatus*, a native parasite as determined through life table studies.

Methods to mass-rear the predatory mite *Amblyseius tetranychivorus* (Gupta) have been perfected using castor pollen which would facilitate colonization of this mite against the pest species *Tetranychus ludeni* Zacher on okra and brinjal (Krishnamoorthy 1982a). The bio-ecology of this predatory mite has also been studied (Krishnamoorthy 1982b).

Mass rearing technique for neuropteron *Chrysopa scelestes*, a general predator of lepidopterous eggs and young larvae and other soft-bodied insects has been standardised (Krishnamoorthy & Nagarkatti 1981). An artificial diet for *C. binotalis* and *Hellula undalis* Fb. has also been evolved (Jayanth & Nagarkatti 1981a).

Surveys for indigenous natural enemies of important insect pests of potato have been made by the Central Potato Research Institute. Cutworms *Agrotis ipsilon* (Hfn.) and *A. segetum* (D & S) were parasitised by entomophilic nematode *Neoaplectana* sp. at Jullundhur in irrigated potato fields (Singh 1977). *A. segetum* and *A. spinifera* Hb. were also parasitised by this nematode at Rasalpur (Singh 1982). The most effective parasite of *A. segetum* at Simla was *Macrocentrus collaris* (Spin.) (Saxena et al. 1980, Singh 1982). The entomopathogenic fungus *Metarhizium anisopliae* (Metch.) Sorkin has been found causing 20% mortality of scarabaeid larvae in potato fields (Singh 1978a). A. *Nesoma* sp. has been reported from larvae of *A. ipsilon* (Srivastava & Ramakrishnan 1977). Since indigenous parasites of PTM are ineffective, four hymenopterous parasites have been imported and supplied by the main centre to the Central Potato Research Institute. These are *Orgilus jennieae* Marsh. and *Chelonus kellieae* Marsh from Costa

Rica, *C. blackburni* Cameron from Hawaii and *Apanteles subandinus* Blanchard. from Argentina. It is reported that all the parasites have been recovered from release areas in Maharashtra around Rajgurunagar (Saxena et al. 1980) and *C. blackburni* from Bangalore (Divakar & Pawar 1979) but whether establishment is permanent or not and to what extent PTM infestation can be kept in check by the parasites will have to be watched over the next few years. It is conjectured that *A. subandinus* may prove superior to all the others as it has become established in most countries where it was earlier introduced and shows ability to adapt to a wide range of agro-climatic conditions.

Weeds

After the successful control of *Opuntia dillenii* (Ker-Crawler) Howarath and *O. eliator* Muller by introduction of *Dactylopius opuntiae* Lictenstein in 1925 (Sankaran 1973) a new hope was raised for the biological control of weeds. *Procecidochares utilis* (Stone) introduced against *Eupatorium adenophorum* Sprengal has also established.

The Central Horticultural Experiment Station at Chethalli has made initial trials with the leaf-eating caterpillar *Pareuchaetus pseudoinsulata* (previously called *Ammalo insulata*) for control of the weed *Chromolaena* (=*Eupatorium*) *odorata* (Singh 1980). This insect was introduced from West Indies into Sri Lanka where it caused extensive defoliation of the weed. Encouraged by these results, a nucleus culture was obtained from Sri Lanka mass bred at Chethalli and released in three different locations in Coorg district. The insect has failed to establish but the precise reasons are not known. It is conjectured that a virus disease and/or predators may be responsible for this. A fresh stock has been imported from the West Indies and it is proposed to make releases in different agro-climatic regions including Kerala where the weed is widespread. Stocks of a seed feeding weevil *Apion brunneoniorum* which is also specific to *Chromolaena* are expected to be received from the West Indies. The *Lantana* bug *Telenomia scrupulosa* is suppressing Lantana weed successfully in some areas. For the biological control of *Parthenium*, *Zygogramma bicolorata* and *Smicronyx lutulentus* have been imported. Host specificity tests in respect of *Z. bicolorata* have been completed. Limited field trials are in progress (Anon 1984).

At the Kerala Agricultural University, cultures of the grasshopper *Paulinia acuminata*, imported earlier from Trinidad was studied with regard to control of the aquatic weed *Salvinia molesta*. Although establishment was initially observed in two districts, the grasshopper does not appear to perform well under Kerala conditions and is also valunerable to predation by spiders, frogs and catfishes. Therefore, the main centre obtained host-specific weevil *Cyrtobagous* sp. for trials. This weevil is already established at Bangalore (Karnataka) and Trichur (Kerala) (Anon. 1984). For the suppression of water hyacinth three natural enemies viz., *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* have been introduced by the main centre. Host specificity tests have been completed and the results of limited field trials indicate that *N. eichhorniae* and *N. bruchi* hold good promise. *O. terebrantis* is yet to be tried under field conditions (Anon. 1984).

Plant Pathogens and Nematodes

The LD50 value of methyl bromide is twice as great for *Trichoderma* antagonist as for the root pathogen *Armillaria mellea* Vahl exfr. on citrus (Ohr et al. 1973) indicating that the biocontrol agent is more tolerant to the chemical used for control of pathogen.

At low concentrations (21 μg/ml) of EDB (1, 2-diphromoethane), there was a slight but significant increase in the growth of

namatode trapping fungus *Arthrobotrys* sp. (Mankau 1968).

General Remarks

The above evidence suggests that in future a high proportion of pest problems will be met by use of biological control agents as components of integrated pest management systems. The determination of economic thresholds by monitoring, use of resistant cultivars, use of entomopathogenic organisms in place of highly toxic insecticides, introduction of suitable exotic natural enemies by cultural, nutritional and pheromone manipulations, discouraging insecticidal sprays to increase the effectiveness of indigenous natural enemies and predatory mites, spot treatment of orchards and strip treatment of field crops and use of insecticide resistant predators are some of the strategies utilised in integrated pest management.

Trichogramma spp. are widely used in the USSR and China for the control of lepidopterous pests. The monitoring of the moth population by means of sex pheromone traps provides useful information for deciding the *Trichogramma* releases. The releases should synchronise with the egg laying in the field. The efficacy of *Trichogramma* can however be increased by using Kairomones (host seeking stimulus). As per requirement, the releases of *Trichogramma* should be supplimented by use of effective larval parasites and/or nuclear polyhedrosis viruses (NPV) and Granulosis viruses (GV) individually or in combination.

It may be possible to follow an integrated approach for management of key pests of different crops with least disturbance to the ecosystem.

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