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Some Success Stories in Classical Biological Control of Agricultural Pests in India




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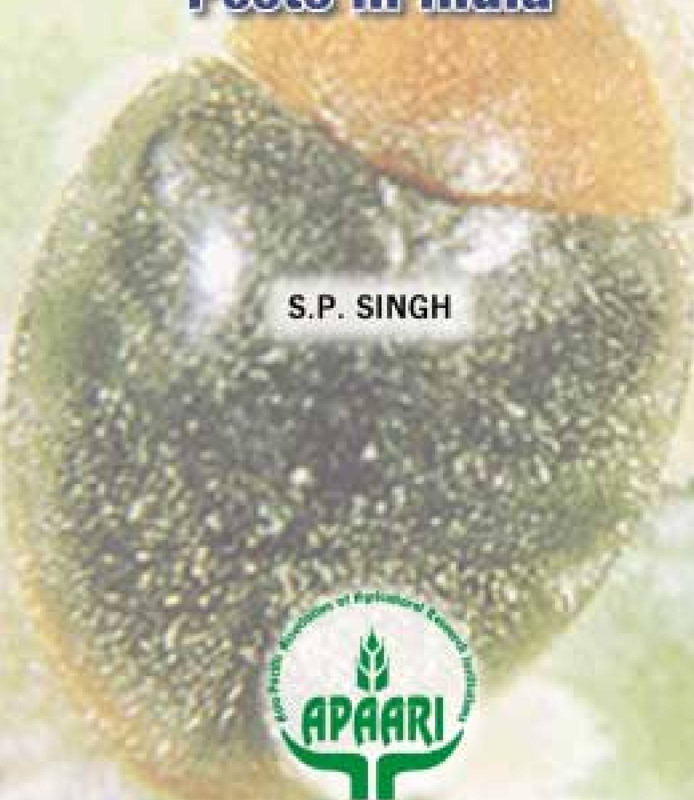

S.P. SINGH

Asia-Pacific Association of Agricultural Research Institutions
FAO Regional Office for Asia and the Pacific
Bangkok, Thailand

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Foreword

Natural biological control by predators, parasites and pathogens of agricultural pests has been occurring since the beginning of evolutionary process of crop plants. It was shortly after the Second World War, the success of chemical pesticides such as DDT and 2, 4-D became known. The public eventually got interested in having better pesticides for effective control of various pests and diseases. Since then, synthetic pesticides development and their extensive use in agriculture went up. However, the public perception gradually changed regarding their use, especially after the publication of Rachel Carson's "Silent Spring" in 1962 and several related reports on the deleterious effects of pesticides in agriculture. Later, since Earth Summit in 1992, Agenda 21 clearly defined the need for corrective measures to contain the use of pesticides for attaining sustainable agriculture and environmental safety.

During the past two decades, the Asia-Pacific Region is making steady progress in safeguarding its crops from pests through the use and manipulation of biological control agents. Accordingly, there has been growing interest lately towards search for predators, parasites and pathogens. It is also clear that a particular biological control agent may not always respond in the same way and the response may vary with the environment, habitat and the level of pest population. Hence, for each of the biological control agent, a detailed scientific study for increased efficiency is rather essential.

In this context, several classical biological control agents have been scientifically examined and introduced by many countries.

Information concerning progress in this discipline has, therefore, become very important both for the scientists and the farmers. It is also important for both the developed and developing countries to lay greater emphasis on large scale demonstrations of biological control methods as a part of an integrated pest management (IPM) strategy.

In view of the above, the Asia-Pacific Association of Agricultural Research Institutions (APAARI) has been playing pro-active role in collating information in vital areas of agriculture through publication of Success Stories. It is in this context that information on research and extension activities on some very useful biological control agents, used lately in India, has been compiled in this Success Story. I thank Dr. S.P. Singh for having undertaken this assignment for APAARI. I hope that the concerned readers would find this publication quite useful and interesting.

R.S. Paroda
Executive Secretary
APAARI

Bangkok, Thailand
October 2004

INTRODUCTION

Pests and diseases adversely affect crop productivity and the stability of production in the tropics. In India, the annual losses amount to Rs. 45,000 crore. Recently, annual crop loss due to Old World bollworm, *Helicoverpa armigera* in India has been estimated at around Rs. 2,000 crore despite the use of insecticides worth Rs. 500 crore in 1998. With the new liberal trade policies several exotic insect pests have entered the country viz., subabul psyllid, *Heteropsylla cubana* on subabul, *Leucaena leucocephala* (1988); leaf miner, *Liriomyza trifolii* complex on several plants (1990); coffee berry borer, *Hypothenemus hampei* on coffee (1991); spiralling whitefly, *Aleurodicus dispersus* on several plants (1993); coconut eriophyid mite, *Aceria guerreronis* on coconut (1998) and whitefly, *Bemisia argentifolii* (1999) on tomato and other hosts.

Alien species are recognized as the second largest threat to biological diversity, the first being habitat destruction. The exotic pests in the absence of their natural antagonists, which they leave in their original home, cause unprecedented damage. Economic impact of invasive pests is tremendous. Exotic weeds (aquatic, terrestrial and parasitic) interfere with cultivation of crops, loss of biodiversity (native plant species are displaced) and ecosystem resilience, loss of potentially productive land, loss of grazing and livestock production, poisoning of humans and livestock, erosion following fires in heavily invaded areas, choking of navigational and irrigation canals and reduction of available water in water bodies. The Convention on Biological Diversity (CBD), as an outcome of the 1992 Rio Summit, recognizes the risk posed by the alien species and requests contracting parties to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species" (Article 8.h.).

Biological control, i.e. conservation, augmentation and introduction of exotic natural enemies, has been accepted as an effective, environmentally non-degrading, technically appropriate, economically viable and socially acceptable method of pest management.

This publication has been prepared with a view to elucidate the information on classical biological control in India. It will be very useful for a large majority of readers of scientific literature, policy makers and scientists. The publication will serve as important reference to the members of APPARI countries and encourage adopting this system of pest management for exotic pests.

History of Biological Control and Organizational Set Up

The history of biological control dates back to the seventeenth century and since then a great deal of success has been achieved in biological methods of pest control. In India, organized and systematic biological control research began with the establishment of the Indian station of Commonwealth Institute of Biological Control (CIBC) at Bangalore in 1957 with need based substations at Srinagar (Jammu & Kashmir), Dalhausi, Kulu and Shimla (Himachal Pradesh), Ludhiana (Punjab), Sriganganagar (Rajasthan), Lucknow (Uttar Pradesh), Dehra Dun (Uttaranchal), Bhopal (Madhya Pradesh), Parbani (Maharashtra), Surat (Gujarat), Motipur (Bihar), Bhubaneshwar (Orissa), Plassey (West Bengal), Jorhat and Gauhati (Assam), Gangtok (Sikkim), Shillong (Meghalaya), Ambajipet and Ramachandrapuram (Andhra Pradesh), Coimbatore (Tamil Nadu), Mandya (Karnataka) and Palghat (Kerala). These substations were temporary to complete a definite project (The duration of substations varied from few months to 3-5 years). The All-India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds (AICRP) was established in 1977 with 10 centres under the aegis of the Indian Council of Agricultural Research (ICAR) for carrying out biological control research in different parts of the country. The centres included, Indian Institute of Horticultural Research, Bangalore (Karnataka), Sugarcane Breeding Institute, Coimbatore (Tamil Nadu), Central Rice Research Institute, Cuttack (Orissa), Central Tobacco Research Institute, Rajahmundry (Andhra Pradesh), Central Plantation Crops Research Institute, Kayangulam (Kerala), Central Potato Research Institute, Shimla (Himachal Pradesh), Indian Agricultural Research Institute, New Delhi (Delhi), Gujarat Agricultural University, Anand (Gujarat), Punjab Agricultural University, Ludhiana (Punjab) and Kerala Agricultural University, Thrissur (Kerala).

The AICRP was elevated to Project Directorate of Biological Control in 1993. The details of the centres are provided below (see box).

Project Directorate of Biological Control (Bangalore) and its centres in different regions
Eastern region
• Assam Agricultural University (AAU), Jorhat (Assam)
Southern region
• Acharya N.G. Ranga Agricultural University (ANGRAU), Hyderabad (Andhra Pradesh) • Central Tobacco Research Institute (CTRI), Rajahmundry (Andhra Pradesh) • Indian Institute of Horticultural Research (IIHR), Bangalore (Karnataka) • Sugarcane Breeding Institute (SBI), Coimbatore (Tamil Nadu) • Tamil Nadu Agricultural University (TNAU), Coimbatore (Tamil Nadu) • Central Plantation Crops Research Institute (CPCRI), Kayangulam (Kerala) • Kerala Agricultural University (KAU), Thrissur (Kerala)
Western region
• Mahatama Phule Krishi Vidyapeeth (MPKV), Rahuri, College of Agriculture, Pune (Maharashtra) • Gujarat Agricultural University (GAU), Anand (Gujarat)

Project Directorate of Biological Control (Bangalore) and its centres in different regions *(continued)*
Northern region
• Sher-e-Kashmir University of Agricultural Sciences & Technology (SKUAS & T), Srinagar (Jammu & Kashmir)
• Dr. Y.S. Parmar University of Horticulture & Forestry (YSPUH & F), Nauni-Solan (Himachal Pradesh)
• Punjab Agricultural University (PAU), Ludhiana (Punjab)
• Indian Agricultural Research Institute (IARI), New Delhi (Delhi)
• Indian Institute of Sugarcane Research (IISR), Lucknow (Uttar Pradesh)
• G.B. Pant University of Agriculture & Technology (GBPUA & T), Pantnagar (Uttaranchal)

The PDBC is the nodal agency in India for organizing research on biological control of pests of agricultural importance. It coordinates 16 centres spread across the country (Map 1), which forms a strong network for field studies on biological control of pests of crops such as sugarcane, rice, cotton, pulses, oilseeds, tobacco, coconut, fruits and vegetables as well as weeds. It conducts basic research on biological control agents and provides advanced training in biological control. Other organizations involved in biological control research include other crop-based ICAR Research Institutes, state Agricultural Universities, traditional universities, and others.

Map 1. Project Directorate of Biological Control (Bangalore) and its network of centres

Classical Biological Control: Success Stories

Classical biological control aims at introducing the exotic natural enemies of inadvertently introduced alien organisms (which have become pests in the absence of natural checks in the new environment) in order to re-establish the balance between the pests and natural enemies. Introduction of host-specific organisms from the country of origin of the pests offers some highly effective and environmentally friendly solutions to the problem of invading alien pests.

Introduction of Material; Methodologies/Approaches adopted

Correct identification of the introduced exotic pest is determined. Literature is surveyed and information on the origin and distribution of the exotic pest determined. In fact complete dossiers are prepared on the pest and its natural enemies. Based on information collected, the decision for introduction of suitable natural enemy (ies) is made. Letters are addressed to international and national institutes of the country from where the natural enemy is intended to be imported. The terms and conditions and the time schedule are fixed. Once the concent and complete information from the exporter is received, application along with dossiers and full justification is sent to the Plant Protection Advisor to the Government of India for processing and grant of import permit. After obtaining the permit, a copy of it is supplied to the exporter with necessary information for fast track receipt of natural enemy. The natural enemy on receipt is quarantined and multiplied for one or two generations and then evaluated in the net house and field. For non-specific pathogens, and weed killers elaborate host specificity tests are required to be conducted in the quarantine before the natural enemy is declared fit for field test. Even the field tests are not conducted directly; first these are evaluated in glass/net house and then in a specified area. Finally if it passes the entire set of tests it is permitted for field-testing. This is just a brief outline but a detailed procedure is available in the country, which is followed for trouble free introduction of exotic natural enemies of crop pests and weeds. By and large similar procedure is followed in other countries with slight variations to meet the local needs.

Material Introduced

In India, so far 166 exotic biological control agents have been introduced of which 33 could not be released in the field, 71 recovered after release, 6 providing excellent control, 7 substantial control and 4 partial control. The details are presented in Appendix 1.

SUCCESSES ACHIEVED: SIGNIFICANT FINDINGS

Significant research and development efforts over a long period, have led to several successful case studies that have provided great impact in classical biological control. Results achieved in fifteen such notable case studies have been presented in detail.

A. Providing Excellent Control

Biological Control of Prickly Pear, *Opuntia elatior* Miller, *O. stricta* (Haworth) and *O. vulgaris* Miller (Cactaceae)

The Problem

Prickly pear cacti, *Opuntia* spp. (origin: New World) were deliberately introduced into India in conjunction with the cochineal trade. These plants are also known for their edible fruits, drought resistance and emergency forage value of certain spineless forms, as botanical curiosities as well as garden ornamentals. *Opuntia* spp. escaped from the intentionally cultivated fields and progressively occupied large areas of valuable grazing-lands. In 1787, *O. vulgaris*, a native of the coastal areas of southern Brazil and Uruguay, originally introduced by traders for production of cochineal dye was observed growing wild in south India. *O. stricta* (= *O. dillenii*) (Origin: Florida, USA and West Indies) and *O. elatior* (Origin: tropical South America) were also introduced for similar purpose and became serious agricultural pests in south India.

Experiments conducted and results achieved

The first successful classical biological control was achieved in India when cochineal insect, *Dactylopius ceylonicus* was introduced from Brazil in 1795 in the mistaken belief that it was the true carmine dye producing insect, *D. coccus*.

Fig. 1. *Dactylopius opuntiae* feeding on prickly pear cactus, *Opuntia stricta*

D. ceylonicus was multiplied on cultivated spineless pear cactus, *Opuntia ficus* (= *O. indica*). *D. ceylonicus* later readily established on drooping prickly pear, *Opuntia vulgaris* (its natural host) in north and central India bringing about spectacular suppression of *O. vulgaris.* Areas that were wholly impenetrable on account of cactus bushes became fit for cultivation within 6 years. Subsequently the insect spread to southern India during 1836-1838 and Sri Lanka in 1865 and the successful control of *O. vulgaris* there constituted the first intentional transfer of a natural enemy for biological control of weeds. *D. ceylonicus*, being restricted to *O. vulgaris*, proved a failure when introduced and distributed in south India to suppress *O. stricta*.

In 1926, *D. opuntiae*, a North American species, was imported from Sri Lanka and its colonization resulted in spectacular suppression of *O. stricta* and related *O. elatior*. More than 40,000 ha area was cleared of *O. stricta* within five to six years.

Currently *D. ceylonicus* continues to successfully control *O. vulgaris*, reducing it from a state of widespread abundance to that of virtual extinction in southern India and northern Sri Lanka and a relatively uncommon weed in the northern parts of India. Similarly for *O. stricta* and *O. elatior*, which are less preferred by *D. ceylonicus, D. opuntiae* is giving good and substantial control, respectively. *D. ceylonicus and D. opuntiae* have reduced the population of *O. vulgaris*, *O. stricta* and *O. elatior* to non-pest level.

Biological Control of Water Fern, *Salvinia molesta* D.S. Mitchell (Salviniaceae)

The Problem

Water fern, *Salvinia molesta*, a native of southeastern Brazil has invaded many water bodies of Asia, Africa and Australia. It was introduced into India through Botanical gardens. *Salvinia*, first observed in 1955 in Vole Lake (Kerala) has assumed pest status since 1964 and affects the lives of 5 million people. In Kuttanad area alone, which is considered the rice bowl of Kerala, some 75,000 acres of canals and another 75,000 acres of paddy fields are affected by this weed. It choked rivers, canals, lagoons, and covered Kakki and Idukki reservoirs; navigation, irrigation, fishing, shell collection and other operations were hindered. In some areas cultivation of paddy had to be abandoned on account of *Salvinia* infestation.

Experiments conducted and results achieved

For the biological suppression of *S. molesta*, the weevil, *Cyrtobagous salviniae,* native to Brazil, was imported from Australia in 1982. More than 75 economically important plants belonging to 41 families were tested for host specificity. It was declared safe for field releases.

Exotic weevil, *C. salviniae* was released for the control of water fern, *Salvinia molesta* in a lily pond in Bangalore in 1983-84. Within 11 months of the release of the weevil in the lily pond the salvinia plants collapsed and the lily growth, which was suppressed by competition from salvinia resurrected.

Three shipments consisting of 600 adults of *C. salviniae* were supplied to Kerala Agricultural University (KAU), Thrissur, for multiplication and field release in Kerala in 1983. Subsequently, a total of 1820 adults of the weevils was supplied to Central Biological Control Stations at Srinagar (Jammu & Kashmir), Bhubaneshwar (Orissa), Hyderabad (Andhra Pradesh) and Bangalore (Karnataka) and also to Vector Control Research Centre at Shertallai (Kerala).

Releases in Kerala, resulted in establishment of the weevils in ponds/tanks at Panancherry, Elanjikulam, at Vembanad lake and canals such as Ahirampuza and Moncompu. Maniyamparampu-Thyalayolaparampu canal extending for a streatch of about 15 km and once thickly clogged with salvinia is now clear of salvinia and navigable. The population of salvinia was drastically reduced in irrigation canals in Thrissur and Thiruvananthapuram to Shernur canal. Kerala Agricultural University, Thrissur, and the Department of Agriculture, Kerala, distributed country boatloads of weevil infested weed mats in all parts of Kuttanad for hastening biological control of *S. molesta* in Kerala. Within a span of 3 years after release and establishment of *C. salviniae,* most of the canals abandoned due to the weed menace have become navigable once again. There is considerable saving in the time taken for navigation through canals and amount of fuel consumed by motorboats. Population of the weed is thin and scanty in most of the paddy fields in the release areas. Already about 2,000 sq km area of the weed has been cleared by *C. salviniae*. By 1988 in the case of paddy cultivation, where Rs. 235 had to be spent per hectare for manual removal, the savings on account of labour alone were about Rs. 6.8 million annually. The control of salvinia has brought back the aquatic flora of Kerala back to the pre-salvinia days.

Fig. 2.
Top to bottom: Athirampuzha-mannam canal in Kerela before the start of biological control (the canal was fully occupied by water fern, *Salvinia molesta*), Weevil-*Cyrtobagous salviniae* (this weevil has controlled *S. molesta* in Bangalore (Karnataka) and several water bodies in Kerala), Athirampuzha-mannam canal in Kerela 8 months after the release of *C. salviniae* (the lush green *S. molesta* turned brown), Athirampuzha-mannam canal in Kerela 16 months after the release of *C. salviniae* (the brown mat of *S. molesta* collapsed rendering the canal fit for navigation)

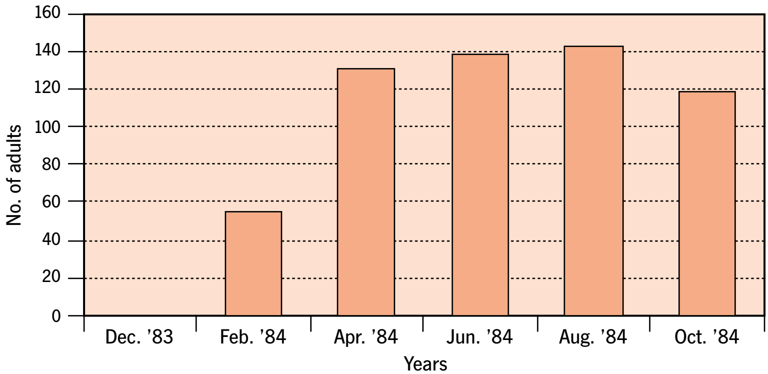

Fig. 3. The effect of release of weevil, *Cyrtobagous salviniae* on water fern, *Salvinia molesta* at Bangalore, Karnataka

Biological Control of Water Hyacinth, *Eichhornia crassipes* (Martius) Solms-Laubach (Pontederiaceae)

The Problem

Water hyacinth, *Eichhornia crassipes*, a free floating aquatic weed of South American origin, ranks among the top ten weeds worldwide. It is one of the most noxious weeds known to man and has spread to at least 50 countries around the globe. First introduced into Bengal around 1896 as an ornamental plant, it has spread throughout India and occupies over 200,000 ha of water surface. Water hyacinth is considered to be the most damaging aquatic weed in India. It now occurs in fresh water ponds, tanks, lakes, reservoirs, streams, rivers and irrigation channels. Water hyacinth has also become a serious menace in flooded rice fields, considerably reducing the yield. It has even encroached into major river systems – Brahmaputra, Cauvery, Ganges, Godavari, Satluj and Beas. Due to construction of dams on major river systems water hyacinth is no longer flushed out to sea. It interferes with the production of hydro-electricity, blocks water flow in irrigation projects (40 to 95% reduction), prevents the free movement of navigation vessels, interferes with fishing and fish culture and facilitates breeding of mosquitoes, besides fostering water-borne diseases. Also, water loss (1.26 to 9.84%) due to evapo-transpiration from the luxuriant foliage of water hyacinth is a major concern where fresh water shortages have become chronic. Besides, it is not possible to suppress the explosive growth potential of the weed by utilisation, which on the contrary may help promote growth and maintenance of large weed stands. The rate of organic matter production is so high that it leads to silting and gradual drying up of water bodies.

Water hyacinth propagates by vegetative and sexual methods. The seeds of water hyacinth sink to the bottom of mud where they can remain viable for as long as 20 years. Under ideal conditions water hyacinth plants can double their number in 10 days. With its extra ordinarily high growth rate and its ability to propagate vegetatively, it defies most control methods. In view of the high cost of manual control and water pollution problems associated with use of herbicides, attention has now been turned to biological control.

Experiments conducted and results achieved

Three exotic natural enemies were introduced in India viz., hydrophilic weevils – *Neochetina bruchi* (Ex. Argentina) and *N. eichhorniae* (Ex. Argentina) and galumnid mite *Orthogalumna terebrantis* (Ex. Sout h America) from their original home via USA in 1982 for the biological suppression of water hyacinth. Detailed host-specificity tests involving 76 species of plants belonging to 42 families with the weevils and 88 species of plants belonging to 42 families with the mite confirmed their safety to cultivated plants in India. Ten pairs of adults and their larval progeny per 0.58-m^2 area reduced plant growth within one insect generation.

For the biological suppression of water hyacinth, starting from October 1983, field releases of mass bred weevils *N. eichhorniae* and *N. bruchi* in different water tanks in Karnataka located at Byramangala (500 ha), Bellandur (344 ha), Varthuru (40 ha), Hebbal (20 ha), Nagavara (20 ha), Agram (20 ha) and others from October 1983 to December 1986; in an 8 ha tank at Nacharam in Hyderabad (Andhra Pradesh) in 1987; Ramgarh lake near Gorakhpur (Uttar Pradesh) in 1988; in 43 km peripheral Surha lake, Balia (Uttar Pradesh) in 1990 and Lakhaibill (Alengmore), Assam in 2000 resulted in suppression of water hyacinth within 4 years. The weevils have cleared Tocklai River and are proving very effective in most of the water bodies in Assam. Weevil *N. eichhorniae* was successfully released and established in 1983 on water hyacinth in Kerala at Ernakulum, Alleppey, Kottayam and Thrissur districts. More than 450,000 weevils have been released at different locations in 15 states viz., Andhra Pradesh, Assam, Gujarat, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Manipur, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal, including Loktak Lake, Manipur; Indira Gandhi canal, Rajasthan; Mula Mutha River, Pune; Pichola Lake, Udaipur; etc. These efforts have resulted in establishment of the weevils in different parts of the country. During 1982 Bangalore City Corporation had allocated Rs. 3.5 lakhs for clearing water hyacinth from Bellandur tank. After the establishment of weevils this recurring expenditure has been saved. The annual savings due to suppression of the weed by the weevils was estimated to be Rs. 11.2 lakhs in Bangalore alone. The saving is on mechanical/manual removal of the weed.

Releases of the water hyacinth mite, *O. terebrantis* which confines to water hyacinth were initiated in 1986 at Bangalore, Karnataka. About 25,000 adults were released in Agram, Kengeri and Byramangala tanks. Establishment was obtained within 6 months in all the tanks. In Kerala, field releases of *O. terebrantis* commenced during 1990. It was released at Alleppey, Botjetty, Chakka, Kokkalai, Kottayam, Kumarakom, Moncompu, Marathodu, Thrissur, and Thiruvananthapuram in different spots at each of the water bodies. *O. terebrantis* has established all over the release sites and is spreading on its own. It has spread far and wide across the vast stretches of

Kuttanad backwaters of Kerala. The mite was more efficient in water bodies where weevils, *Neochetina* spp. have established. *O. terebrantis* has established in Kerala and Karnataka and it complements the two exotic weevils in hastening the collapse of water hyacinth. Under field conditions 200,000 galleries per m^2 (or 10,000 per plant) caused serious damage to water hyacinth in some tanks in Kerala and Karnataka. But in Kerala where *N. eichhorniae*

Fig. 4. Left to right clockwise: Profuse growth of water hyacinth in 344 hectare Bellandur tank (Bangalore, Karnataka) before initiating biological control, weevil – *Neochetina bruchi* and its feeding marks on water hyacinth leaves, hydrophilic mite – *Orthogalumna terebrantis* & its feeding marks on *E. crassipes,* exotic weevils – *N. eichhorniae* & *N. bruchi* and hydrophilic mite – *O. terebrantis* multiplied on *E. crassipes* for innoculative releases, water hyacinth infested Ballandur tank (Bangalore, Karnataka) 4 years after release of weevils showing clearance of water body, water hyacinth infested Ballandur tank (Bangalore, Karnataka) 2 years after release of weevils showing substantial clearance of water body

and *N. bruchi* are slow in managing water hyacinth, *O. terebrantis* on its own is providing effective suppression of water hyacinth in certain areas. The impact is more pronounced in partially shaded areas or under bridges.

Biological Control of Cottony Cushion Scale, *Icerya purchasi* Maskell (Margarodidae)

The Problem

Icerya purchasi (Origin: Australia) was probably introduced on imported orchard stock or flowering plants from Sri Lanka and it spread to cultivated wattles, rose-bushes and citrus. It was first reported from Nilgiris (Tamil Nadu) in 1928 as a pest of cultivated wattle, *Acacia decurrens* and other *Acacia* spp. With the spread of the pest in Karnataka, Kerala and Maharashtra, the citrus crop of these states was seriously threatened. It has been recorded from 117 host plants.

As the pest posed a serious threat to fruit and other trees of economic importance, steps were taken to control it biologically, since chemical methods of control were either ineffective or too expensive.

Experiments conducted and results achieved

The coccinellid beetle, *Rodolia cardinalis* (Origin: Australia), which has an excellent track record for the suppression of cottony cushion scale, *I. purchasi* was introduced to India in 1926 via USA (California) and South Africa and in 1930 via Egypt for the control of *I. purchasi.* The beetle was released in the Nilgiris in 1930 and it successfuly controlled *I. purchasi.* In 1941, the pest assumed serious proportions and spread to upper Palni hills (Tamil Nadu), but was brought under control by releasing *R. cardinalis.* As *I. purchasi* threatened citrus in Maharashtra, Karnataka and Kerala, *R. cardinalis* was obtained from the Nilgiris and New Zealand, multiplied and released in infested localities resulting in satisfactory control.

Fig. 5. Coccinellid beetle, *Rodolia cardinalis* feeding on cottony cushion scale, *Icerya purchasi* (successful biological control of this pest has been achieved in all the places wherever the beetle was released)

R. cardinalis was also liberated against *I. purchasi* on casuarina in Nileshwar (Kerala) resulting in quick control.

This predator has been effective against *Icerya aegyptiaca* and *I. seychellarum* on some of the Pacific Islands and it would be easy to introduce it wherever *Icerya* spp. have spread and the predator is absent. Release of 8-10 beetles on each of the moderately infested plant has been suggested whenever required.

B. Providing Substantial Control

Biological Control of Mealybugs

The Problem

Mealybugs-common mealybug (*Planococcus citri*), grape mealybug (*Maconellicoccus hirsutus*), mango mealybug (*Rastrococcus iceryoides*), spherical mealybug (*Nipaecoccus viridis*), striped mealybug (*Ferrisia virgata*), oriental mealybug (*Planococcus lilacinus,* *P. pacificus, P. robustus*) and pineapple mealybug (*Dysmicoccus brevipes*) are soft-bodied sucking insects which cause serious damage and decrease the productivity and marketability of the produce.

They are 'hard to kill pests' that live in protected areas such as cracks and crevices of bark, underside of leaves, at bases of leaf petioles and inside bunches/berries or near the fruit stalk. The damage is caused by sap sucking and secreting copious amount of honeydew on which black sooty mould fungus develops.

Eggs of the mealybugs, protected by waxy filamentous secretions of ovisacs are almost impossible to reach with insecticides. Late instar nymphs and adult female mealybugs are not affected by foliar application of insecticides since they are covered with waxy coating. Some mealybugs have been able to develop resistance to insecticides. However, mealybugs, being sessile insects, are quite amenable to biological control.

Experiments conducted and results achieved

As far as biological control of crop pests in India is concerned, perhaps the first intentionally introduced beneficial was the coccinellid predator, *Cryptolaemus montrouzieri* which was introduced in June 1898 by Mr. H.O. Newport, an amateur entomologist and coffee planter of Palni hills (Tamil Nadu). The predator did not control soft green scale *Coccus viridis,* which was its specific target, but in July 1951, *C. montrouzieri* was observed for the first time in large numbers on *Araucaria* trees infested with *Eriococcus araucariae* around Bangalore (Karnataka). It has established on a variety of mealybugs infesting fruit crops, coffee, ornamentals, etc. in south India. *C. montrouzieri* is now commercially produced and utilized for the management of a variety of mealy bugs and sac forming scale insects.

In 1977, an insectary was established at the Central Horticultural Experiment Station, Chethalli, Kodagu (Karnataka), for the

Fig. 6. Coccinellid beetle, *Cryptolaemus montrouzieri* adult feeding on mealybugs (it suppresses several species of mealybugs on horticultural and plantation crops)

multiplication of *C. montrouzieri*. Its propagation, field evaluation and pilot trials were conducted from 1977 to 1983. *C. montrouzieri* was propagated on common mealybug, *Planococcus citri* infested pumpkins. Beetles can also be reared on *Corcyra cephalonica* eggs, but in the absence of chemical stimuli that is present on the wax filaments of the mealybug, empty ovisacs of *Planococcus citri* are to be kept for inducing egg laying by the beetles. The beetles are also multiplied on a semi-synthetic freeze-dried beef liver based diet. Each cycle is completed in 1-1.5 months. The adult beetles lived and dispersed for 1.5 to 2 months and consumed 300-500 mealybugs. The production cost of 100 beetles in some private companies is Rs. 70.

Eight commercial insectaries are supplying *C. montrouzieri* to the growers. Biocontrol Research Laboratory of Pest Control India (P.) Ltd. established in Bangalore in 1981, has been producing and supplying this predator since inception. A total of 1,171,050 *Cryptolaemus* was supplied to the growers during 1999-2003 April (K.P. Jayanth, personal communication).

In 1977-78, 43,500 beetles were released and under ICAR lab to land phase 1 programme 85,000 beetles were released during 1979-81 in the mealybug infested mixed planted orchards (citrus and coffee) of 125 adopted small and marginal farming families. 5,900 beetles were supplied/released on grape mealybug *Maconellicoccus hirsutus* around Hyderabad.

The predator is found effective in suppressing the mealybugs on citrus, guava, grapes, mulberry, coffee, mango, pomegranate, custard apple, ber, etc. and green shield scale on sapota, mango, guava, brinjal and crotons in Karnataka. It did not seriously impair the efficiency of local biocontrol agents. The results are briefed in Table 1.

Table 1. Biological control of mealybugs and other sucking pests with *Cryptolaemus montrouzieri*

Crop	Species	Place	Result
Fruits			
Citrus	*Planococcus citri* and *Nipaecoccus viridis*	Karnataka	Suppressed successfully
Custard apple	*Maconellicoccus hirsutus*, *P. citri*, *P. lilacinus*, *Ferrisia virgata* and *N. viridis*	Karnataka and Andhra Pradesh	Suppressed
Grapevine	*Maconellicoccus hirsutus* and *P. citri*	Karnataka and Andhra Pradesh	Suppressed successfully
Guava	*Pulvinaria psidii*, *Drepanococcus chiton*, *F. virgata*, *P. citri* and *P. lilacinus*	Karnataka and Tamil Nadu	Suppressed successfully
Mango	*Pulvinaria polygonata*, *F. virgata*, *P. citri*, *Rastrococcus iceryoides* and *R. invadens*	Karnataka	Suppressed
Pomegranate	*Siphoninus phyllireae*, *M. hirsutus*, *P. citri*, *P. lilacinus*, *F. virgata* and *N. viridis*	Karnataka	Suppressed
Sapota	*Coccus viridis* and *P. citri*	Karnataka	Suppressed
Ber	*Nipaecoccus viridis*, *P. lilacinus*, *P. citri*, *M. hirsutus* and *D. chiton*	Karnataka	Suppressed

Table 1. *(continued)*

Crop	Species	Place	Result
Vegetables			
Brinjal	*Coccidohystrix insolita*	Karnataka	Suppressed
Tomato	*Planococcus citri*	Karnataka	Suppressed
Chow-chow	*Planococcus lilacinus*	Karnataka	Suppressed
Ornamentals			
Crotons	*Planococcus minor*	Karnataka	Brings down the population
Hibiscus	*Aphis gossypii*	Karnataka	Suppressed
Jacaranda	*Saissetia hemisphaerica*	Karnataka	Suppressed
Jasmine	*Pseudococcus longispinus*	Karnataka	Kept under check
Mussaenda	*Orthezia insignis*	Karnataka	Suppressed
Others			
Araucaria	*Eriococcus araucariae*	Karnataka	Completely wiped out
Ficus	*Pulvinaria psidii*	Karnataka	Managed successfully
Mulberry	*Ferrisia virgata*	Karnataka	Suppressed
Neem	*Megapulvinaria maxima*	Karnataka	Kept under check
Coffee	*Planococcus* spp.	Karnataka	Suppressed successfully

Biological Control of Common Mealybug, *Planococcus citri* (Risso) (Pseudococcidae)

The Problem

Planococcus citri was described from citrus in southern France. From its origional home it has spread to many countries of the world. In India, it is a pest of citrus, coffee, passionfruit, cut flowers and many other fruit crops and wild plants. Continuous drought causes outbreak of this pest. The damage caused by mealybug is similar to that caused by other soft scale insects, but this pest prefers to feed on the fruit stalk or on the berries resulting in their drop.

Experiments conducted and results achieved

The encyrtid parasitoid *Leptomastix dactylopii* (Origin: Brazil) was introduced into India in 1983 from Trinidad, West Indies. It is capable of parasitising *Planococcus citri* and *P. lilacinus*. It was produced on ripe pumpkins infested with 15-20 day-old *P. citri* by exposing to 1-2 day old *L. dactylopii* females in the host parasitoid ratio of 40:1. In the laboratory it could be produced on several species of mealybugs; however, in the field it proved to be a specific parasitoid of *P. citri*. The parasitoid colonized on *P. citri* infested citrus orchards has already been recovered from Bangalore and Kodagu districts of Karnataka. On coorg mandarin and coffee, it parasitized up to 100% nymphs of *P. citri*. *L. dactylopii* was released in a lime orchard in Karnataka. Prior to release, infestation by *P. citri* ranged from 38 to 65%, but establishment of *L. dactylopii* led to excellent control within 4 months and no insecticides were required in the following season. The effectivenes of *L. dactylopii* has been demonstrated in Karnataka and Tamil Nadu. It has also spread to Kerala. It was found be very effective in controlling *P. citri* on acid lime, lemon, mandarins, sweet oranges, guava, coffee, etc. It was recovered in same locations even after 20 years of release. In lime and lemon orchards, *L. dactylopii* was found to be highly compatible with indigenous parasitoid *Coccidoxenoides peregrinus* preferentially attacking the later instars and leaving the early instars for *C. peregrinus*.

Fig. 7. Parasitoid, *Leptomastix dactylopii* has established permanently in India on *Planococcus citri* infesting several horticultural and plantation crops

Biological Control of San Jose Scale, *Quadraspidiotus perniciosus* (Comstock) (Diaspididae)

The Problem

Quadraspidiotus perniciosus is a polyphagous pest of Oriental origin. Its native home is believed to be somewhere in the general area of northern China, the Far East, and North Korea. It is a serious pest of apple in northwestern India. It also attacks other deciduous trees, poplars and willows. About 50 hosts have been recorded in India. The scale insect colonizes all parts of the plant. Young tree bark when attacked shows characteristic deep red or purplish stain. The bark of old tree develops cracks and exudes large amount of gummy substance. The fruits attacked may also develop reddish spots around the scale infestations. In case of severe infestation the attacked tree may get defoliated. Such trees do not bear any fruits. The overwintering nymphs become active in mid-March; the males emerge in April. The life cycle is completed in 35-40 days. The scale insect passes through 4-5 generations before mid-October when hibernation starts.

Experiments conducted and results achieved

Aphelinid parasitoid *Encarsia perniciosi* (Origin: Far East) strain from California was introduced in 1958 and Illinois, Chinese and Russian strains were introduced in 1960 for the biological suppression of San Jose scale. Russian strain gave 89 per cent parasitism in Himachal Pradesh. In Kashmir, the Russian and Chinese strains appeared to be superior to Californian and Illinois strains. American (Illinois) and Chinese strains were also released in Kumaon hills of Uttar Pradesh; the population of *Q. perniciosus* was reduced by about 95 per cent. *E. perniciosi* has established in many areas where the population of San Jose scale is low. But due to frequent sprays in apple orchards, mass multiplication and release of *E. perniciosi* as well as *Aphytis* sp. *proclia* group at the beginning of the season is recommended.

Biological Control of Woolly Aphid, *Eriosoma lanigerum* (Hausmann) (Aphididae)

The Problem

Eriosoma lanigerum is a native of Eastern United States. It was probably accidentally introduced to India from England as indicated from its record in Shimla district of Himachal Pradesh where nursery stocks were imported. Currently it has spread to all the apple-growing areas of the country. The aphids prefer to feed on the new bark at pruning and wound scars on the trunk and branches. The aphids feeding on the roots cause maximum direct injury, although large numbers may be found on the aerial parts of the tree. The aphid sucks sap from the bark of the trunk and the roots. It also infests fruit stalks and calyx end. The infested twigs shrivel and die. The nursery plants when attacked suffer the most. Points on the stems and roots where the aphids crowd together and feed develop gall-like swellings.

Experiments conducted and results achieved

For the control of woolly aphid, exotic aphelinid parasitoid, *Aphelinus mali*, a native of North America, was introduced from UK at Saharanpur (Uttar Pradesh). The parasitoid failed to establish and provide effective control of woolly aphid in the Kumaon hills because of the intense activity of coccinellid beetle, *Coccinella septempunctata* which fed indiscriminately on parasitized as well as unparasitized woolly aphids. *C. septempunctata* however provided satisfactory control of the pest. The parasitoid could control woolly aphid in Kullu valley (Himachal Pradesh) and has spread to Kashmir valley. *A. mali* was transferred to Coonoor (Tamil Nadu) from Kullu where it established. The parasitoid was sent to Shillong (Meghalaya) from Coonoor in 1961 and Kullu in 1963 and establishment was achieved after periodic releases. At present, it has established in all apple growing areas of the country, but is more effective in valleys rather than on mountain slopes. During the period of activity of other predators the population of this exotic parasitoid is diminished. In general, *A. mali* has emerged as a key population regulatory agent of *E. lanigerum* in the areas of its successful establishment.

Biological Control of Spiralling Whitefly, *Aleurodicus dispersus* Russell (Aleyrodidae)

The Problem

Spiralling whitefly, *Aleurodicus dispersus*, a native of Carribbean region and Central America was introduced into India in 1995. First reported from Kerala, it has spread to all the southern states causing serious damage to several plants. It attacks over 253 plant species belonging to 176 genera and 60 families. It causes serious damage to avocado, banana, cassava, guava, papaya and mango, besides sevaral ornamental and avenue trees. Severe infestations cause yellowing, crinkling and curling, and premature fall of leaves. The nuisance created by the wind borne, copious white waxy flocculent material and the flying adults are very telling. The whitefly is suspected to be a possible vector of lethal yellow disease.

Experiments conducted and results achieved

Exotic aphelinid parasitoids, *Encarsia guadeloupae* and *E.* sp. nr. *meritoria* (Origin: Carribbean region/Central America) collected from Minicoy Island of Lakshadweep and brought to main land have established well, causing perceptible reduction in pest population. Parasitism levels due to both parasitoids vary from 29-70% and exceed 90% during some parts of the year. Wherever parasitism was heavy, the pest population was substantially reduced subsequently. *E. guadeloupae* is performing better than *E.* sp. nr. *meritoria* and has displaced it almost completely in Bangalore. It has established in Kerala, Karnataka and several parts of Andhra Pradesh, where it was earlier absent.

Fig. 8. Top: Adult parasitoid, *Encarsia guadeloupae* parasitising spiraling whitefly, *Aleurodicus dispersus*, Bottom: emergence holes of *E. guadeloupae* from *A. dispersus* are seen (*Encarsia guadeloupae* has established against *A. dispersus* providing over 90% parasitism in some areas of Karnataka

Biological Control of Subabul Psyllid, *Heteropsylla cubana* Crawford (Psyllidae)

The Problem

Subabul, *Leucaena leucocephala* was introduced into India to strengthen social forestry programme. It is considered to be an important new input for cattle feed, and fuel for use of the rural population where fuel wood is still preferred over modern substitutes. Leucaena psyllid *Heteropsylla cubana*, a native of South America invaded subabul in 1988. It devastated subabul plantations in Karnataka, Kerala, Tamil Nadu and Andhra Pradesh. It has since spread allover the country. Adults and nymphs of the psyllid attack tender shoots and severe infestations caused complete defoliation. *H. cubana* females laid about 400 eggs in the tender terminal shoots, completed life cycle in 10-11 days and had 8-10 overlapping generations in a year.

Experiments conducted and results achieved

Efforts to import suitable exotic natural enemies were initiated immediately after the pest was detected. The coccinellid predator, *Curinus coeruleus* (origin: South America) was obtained from Thailand in 1988 for the biological suppression of *H. cubana*. *C. coeruleus* was produced on bouquets of *H. cubana* infested twigs, the eggs were deposited by the females on small strips of cardboard cartons provided. A generation was completed in about 35 days. By keeping 30 cages, which required about 2-man hrs/day for handling and providing food, 8,000-10,000 adults were obtained in 60 days. *C. coeruleus* was also produced successfully on *Ferrisia virgata.*

In November 1988, *C. coeruleus* was successfuly colonized on subabul around Bangalore. The predator established well in the field and in about four months after release 20-30 adults per tree was recorded. The grubs consumed 10,630 eggs and 3,500 nymphs during

Fig. 9. Coccinellid beetle, *Curinus coeruleus* reared on mealybug, *Ferrisia virgata* in the insectary and released against subabul psyllid has saved the subabul plantations from *Heteropsylla cubana*

their lifetime. In the field at Bangalore the predator population started building up in May and reached its peak in December to February and the pest population declined from November and remained so up to March. The predator has spread on its own to the area of more than 20 sq km in Bangalore district. In about two years after release the population of the psyllid was drastically reduced and the predator firmly established in the release sites. Subsequently by releasing 20 adults per tree twice during July and October or about 1,000 to 5,000 beetles per hectare of subabul trees followed by reduction of psyllid population on 20 marked trees/ha and recovery of *C. coeruleus* at each weekly observation proved the superiority of *C. coeruleus* at different release sites. It provided control on par with monocrotophos sprays at fortnightly interval. The beetles have since then been released in many other parts of Karnataka, Kerala, Andhra Pradesh, Tamil Nadu and Manipur where they have established and are providing efficient, cost effective and environmentally safe control of *H. cubana* on a sustainable basis.

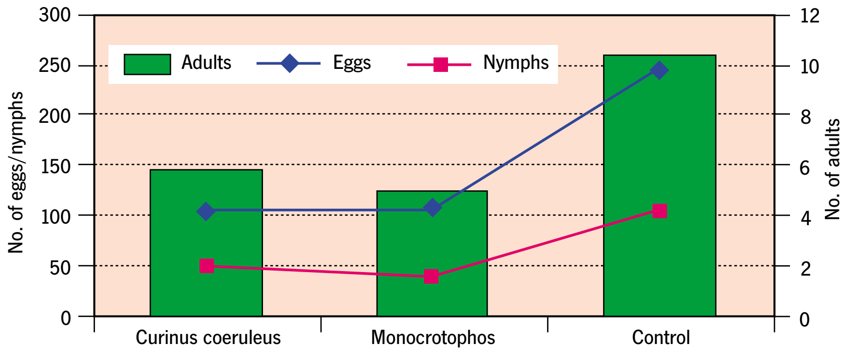

Fig. 10. Coccinellid beetle, *Curinus coeruleus* released against subabul psyllid, *Heteropsylla cubana* has proved superior to monocrotophos, which unlike *C. coeruleus* requires repeated sprays

Biological Control of Carrot Weed, *Parthenium hysterophorus* Linnaeus (Asteraceae)

The Problem

Parthenium hysterophorus, also known as white top and congress grass, is native to the area around Gulf of Mexico including the West Indies, and central South America. It has accidentally been introduced, over the past five decades, into many countries including Australia, China, India, Israel, Madagascar, Mozambique, Nepal, South America and Vietnam. In India, it was recorded from Pune in 1955. It has spread all over India covering most of the vacant and marginal lands. *P. hysterophorus* is known to suppress local vegetation by release of growth inhibitors through leaching, exudation of roots, decay of residues, etc. It not only covers wasteland but also invades cultivated fields and poses a threat to crops such as cereals, vegetables, fruits, oil seeds, etc. It also inhibits fruit set in crops like tomato, brinjal, beans and capsicum when its pollen grains are deposited on the stigmatic surfaces. The health hazards caused by *Parthenium* are also well known and there is considerable documentation on contact dermatitis and rhinitis due to airborne pollen, which constituted 66.18% of the total annual pollen catch in Bangalore. In India a number of indigenous insects have successfully transferred to *Parthenium*, but none of them causes any appreciable damage to the weed, and utilize parthenium as a breeding ground and then shift to the cultivated crops.

Due to the absence of effective natural enemies that keep it under check in its native home, combined with its allelopathic properties, *Parthenium* grows in pure stands in almost all the states, where climatic conditions are congenial for its growth, suppressing local vegetation and threatening natural diversity. It has occupied fallow land along roadside and railway tracks, pastures and is a serious health hazard to susceptible individuals and cattle.

Manual and mechanical methods of control, which have been advocated for the control of this weed are expensive and provide only short-term control, requiring repeated applications.

Experiments conducted and results achieved

In 1983, a chrysomelid beetle *Zygogramma bicolorata* was imported from Mexico for the management of parthenium. Host specificity tests were conducted with 40 plant species belonging to 25 families and the insect was declared to be safe to economic plants.

Adults and larvae of *Z. bicolorata* feed on *Parthenium* leaves. The early stage larvae feed on the terminal and auxiliary buds and move on to the leaf blades as they grow. The full-grown larvae enter the soil and pupate. An insect density of one adult per plant caused skeletonization of leaves within 4-8 weeks provided this density is achieved early in the rainy season.

The releases of *Z. bicolorata* commenced in June/August 1984. The initial releases were made in Bangalore (Karnataka) at Hessaraghatta, Tumkur road, Bannerghatta road and Sultanpalya road.

Maximum releases were made in Sultanpalya. Early sign of establishment was evident at Sultanpalya. The insect undergoes diapause from November to June. But if optimum moisture and green plants are available, part of the insect population remains active even during otherwise dry period. The insect however failed to show any dramatic result up to 1988. In September 1988, about 5 ha parthenium area was defoliated and the beetles had dispersed up to 2 sq km area. By October 1988, *Z. bicolorata* had spread over 5 sq km area, mainly in north and east Bangalore. By October 1989, it had covered about 400 sq km and 5,000, 20,000 and 50,000 sq km by the same period in 1990, 1991 and 1992 respectively. *Z. bicolorata* has spread over more than 200,000 km^2 in and around Bangalore, causing defoliation of *P. hysterophorus* and encouraging the growth of vegetation formerly suppressed by this weed.

At Bangalore, 40 different species of plants, including eight grasses, were observed to grow in the areas vacated by parthenium due to defoliation by *Z. bicolorata*. Parthenium plants produce an average

Fig. 11. *Zygogramma bicolorata* adults have established and cleared large areas of parthenium weed, *Parthenium hysterophorus*

of 5,925.5 inflorescence per plant, which release enormous quantities of pollen (624 million/plant) into the atmosphere. Defoliation of parthenium in extensive areas in and around Bangalore city has caused an overall reduction in flower production by the weed, which in turn has reduced its pollen density in the atmosphere. This will benefit the people suffering from nasobronchial allergy. The ability of *Z. bicolorata* to bring down flowering in *P. hysterophorus* is also encouraging from the point of view of biological control, as it can reduce weed density over a period of time and encourage the growth of vegetation formerly suppressed by this weed.

Initially, the adults move from a defoliated weed stand to adjacent healthy plants. Once all parthenium plants in a particular area are defoliated, they disperse by flight. Surface winds over Bangalore have a clear-cut seasonal character, with the westerly components predominating between May and September and the easterly components during November-March. Correspondingly, the insect was noticed to migrate mainly towards the east up to September and in a westerly direction during October and early November.

The beetles were supplied to 14 Indian states. Recently it has also established in Jammu (Jammu & Kashmir), Madhya Pradesh, Punjab, Haryana and Himachal Pradesh. The beetle has already spread naturally in entire Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala. Field activity of *Z. bicolorata* coincides with receipt of 1.5 mm rainfall. It may therefore, perform better in well-distributed heavy rainfall areas. When *Z. bicolorata* numbers are very large, related plants such as *Xanthium occidentale* (=*X. strumarium*) and *Lagascea mollis* are also attacked, but these are both weeds and the damage caused does not cause any problem.

C. Providing Partial Control

Biological Control of Lantana, *Lantana camara* Linnaeus (Verbenaceae)

The Problem

Lantana camara, a central and South American weed was introduced into India in 1809 as an ornamental plant. It spread soon into open areas in forestland, and pastures forming dense thickets. It is a perennial, straggling shrub with prickly stems, spreading by seed, but regrowing vigorously after cutting. It competes with young trees in the forest area and in plantations thus not allowing them to grow. *Lantana* flowers throughout the year in warm areas. The seeds are eaten by birds, which facilitate the rapid dispersal of the plant. Apart from several drawbacks of this plant such as competitive displacement, it has been reported to be a symptomless carrier of sandal spike disease. In India it has by now spread everywhere. It is very difficult to manage with herbicides. *L. camara* has several varieties or forms, which has complicated the introduction and establishment of exotic insects.

Experiments conducted and results achieved

In 1921, the agromyzid seedfly, *Ophiomyia lantanae* was introduced from Hawaii (origin: Mexico) and released in south India for the suppression of *L. camara.* Though established, it did not provide spectacular suppression. It is now widely distributed in India.

Tingid lace bug, *Teleonemia scrupulosa,* a native of Mexico, was introduced from Australia in 1941. However, the insect was reported to feed on teak flowers in quarantine at Dehra Dun, Uttar Pradesh, and hence the culture was destroyed in the quarantine. But the insect 'escaped' quarantine and by now it has spread to all the lantana stands in the country. *Teleonemia scrupulosa* does not attack teak or any other economic plant in India under field conditions. In 1951 it was recovered at a distance of 40 km from Dehra Dun (evidently escaped

Fig. 12. Lace bug, *Teleonemia scrupulosa* feeding on lantana, *Lantana camara*

from the laboratory stock, before it was destroyed). It was reported to attack and kill lantana on a fairly large scale in Bhimtal, Nainital (Uttaranchal) and also along the sub-Himalayan tracts.

The insect was further redistributed by the Forest Research Institute in the Dharampur/Kasauli area in 1972, Bhopal in 1975 and Shillong in 1976. *T. scrupulosa* has also established in the southern parts of the country in Kerala, Karnataka, Andhra Pradesh, Pondicherry and Tamil Nadu. Sustained attack by many bugs resulted in severe defoliation and reduced vigour of the attacked plants in some parts of the country. Buds and flowers attacked by adults usually abort, affecting seed production. If sufficient population of *T. scrupulosa* is available, it does not allow lantana to overgrow, which can be neglected if growing over cultivable barren land because it cannot propagate or hamper agricultural operations.

Heavy mortality during the cold winter months in the Kumaon region, low temperatures, high humidity and heavy rainfall in the Maruthamalai hills of the Palghat gap and high temperatures and low humidity at Hyderabad and heavy parasitism (up to 85%) of *T. scrupulosa* eggs by *Erythmelus teleonemiae* in Bangalore impair the population build up of *T. scrupulosa*.

Several other host specific insects such *Diastema tigris*, *Salbia* (*Syngamia*) *haemorrhoidalis*, *Uroplata girardi*, *Octotoma scabripennis* and *Epinotia lantanae* have been introduced from time to time for the biological suppression of lantana. *U. girardi* and *O. scabripennis* have established in India. Similarly *E. lantanae* has established in certain pockets of south India. *E. lantanae* in combination with *O. lantanae* affects 95% of the fruits of lantana in Bangalore.

Biological Control of Siam Weed, *Chromolaena odorata* (Linnaeus) R. King & H. Robinson (Asteraceae)

The Problem

Chromolaena odorata, a native of West Indies and continental America, is a serious weed of pastures, forests, orchards and commercial plantations in south and north-east India. It migrated to Assam during the First World War (1914-18) where it is locally known as Assam-lata or Assam-lota. It is also known as German bane, because of its introduction during German war! After it spread to entire northeastern region, in 1924-25 it further spread to West Bengal. By 1932-33, it invaded the major forestlands. From West Bengal it also spread to Orissa. From eastern region it spread to Kerala in 1942 by the seeds stuck to the belongings of workers returning from Assam front. From Kerala the weed has spread rapidly to all the southern states. It is now well distributed in northeastern and southern states, particularly in Assam, West Bengal, Orissa, Karnataka, Maharashtra, Tamil Nadu and Kerala. The distribution of the weed is limited to areas receiving rainfall of 150 cm and above.

It has occupied pastures, marginal lands and open areas. It has become a menace in coconut, cocoa, cashew, rubber, oil palm, tea, teak, coffee, cardamom, citrus and other plantation, orchards and forests. It impedes the access to crop and wild life management programmes. In forest ecosystem, it decreases the value of timber, forest seed, increases the cost of seedling production in nurseries, hampers the harvesting operations in the forest and affects the overall productivity of the forest ecosystem. During the dry season, it can be a serious fire risk in the forests.

Experiments conducted and results achieved

The CIBC Indian Station introduced *Pareuchaetes pseudoinsulata* from Trinidad, which failed to establish on *C. odorata*. However information on host specificity with 85 species of plants representing 46 families was obtained by adopting choice and no choice tests. The insect was declared safe for field release.

In September 1984, about 70 field-collected larvae of *P. pseudoinsulata* were obtained by the Project Coordinator, All India Coordinated Research Project on Biological Control through the CIBC Indian station, from Sri Lanka (*P. pseudoinsulata* had established in Sri Lanka after releases were initiated in 1973, causing defoliation of the weed).

During October 1984 a nucleus culture of about 500 larvae of the Sri Lankan strain of *P. pseudoinsulata* was supplied to Kerala Agricultural University (KAU), Thrissur for multiplication and releases in Kerala. Releases of about 40,000 larvae and 400 adults resulted in establishment and partial control of the weed in a rubber plantation in the campus of the College of Agriculture, KAU, and clearance of the weed in an area of about two hectares during 1985. The typical yellowing and larval feeding injury symptoms were common. The Sri Lankan strain of *P. pseudoinsulata* was also supplied to the University of Guam through the CIBC Indian Station. Field releases of this insect in Guam resulted in immediate establishment and

Fig. 13. Lepidopteran, *Pareuchaetes pseudoinsulata* adults and eggs on Siam weed, *Chromolaena odorata* (The larvae of *C. odorata* defoliate and suppress the weed)

extensive defoliation. By 1989, *C. odorata* was reported to have lost its status as the predominant weed in Guam.

Between October 1984 and December 1987, a total of 61,345 larvae of *P. pseudoinsulata* were multiplied in the laboratory at Indian Institute of Horticultural Research (IIHR), Bangalore, and released at different locations in Bangalore, Chickmagalur, Dakshina Kannada, Kodagu, Mysore and Shimoga districts in Karnataka. Since the release spots, other than in Bangalore district, were located more than 250 km away, young larvae were produced and stored at 15°C in a B.O.D. incubator for up to 45 days to accumulate larvae for carrying out large-scale releases at distant locations.

Among the release spots in Karnataka, establishment of *P. pseudoinsulata* was noticed in July 1988, about 9 months after releases, at Kamela in Suliya taluk of Dakshina Kannada district.

The insect was noticed to cause large-scale defoliation of *C. odorata* in a one-hectare area, fully infested by *C. odorata*, in a private estate growing rubber, arecanut and black pepper. Defoliation by the insect was found to prevent flower production by the weed. About 75% reduction in weed cover and increases in the growth of local vegetation were noticed by October 1990. *P. pseudoinsulata* had dispersed sporadically over more than 400 sq km area, causing defoliation of the weed in several pockets. Area of dispersal had increased to about 1,000 sq km by January 1993. Large scale defoliation extending over several km along the road was noticed in areas around Subramanya, in reserve forests as well as rubber and cashew plantations.

In Dakshina Kannada, where this insect has established, only about 10,000 larvae had been released. Dakshina Kannada district is located in the high rainfall area (about 2,000 mm) of Western Ghats. Initial releases of only about 10,000 larvae were made in an undisturbed area, adjacent to a perennial mountain stream, where green leaves were available throughout the year for sustaining a population of the insect. *P. pseudoinsulata* has established here, disperses from this focal point to the surrounding areas during the rainy season and causes extensive defoliation if the rainfall is well distributed. *P. pseudoinsulata* has also been recovered from Tamil Nadu. *P. pseudoinsulata* can effectively suppress the weed in areas that receive well distributed rainfall almost round the year, so that leaves of the weed are available to it for feeding.

Biological Control of Crofton Weed, *Ageratina adenophora* (Sprengel) R. King & H. Robinson (Asteraceae)

The Problem

Ageratina adenophora, a native of Mexico, has spread to the hilly areas of north and south India, forming dense thickets up to some 3 meters on valuable grazing land. The weed has also occupied vacant places in tea, teak, rubber and other forest plantations.

Experiments conducted and results achieved

The gallfly, *Procecidochares utilis* (origin: Mexico) was introduced from New Zealand in 1963 and released in the Nilgiris (Tamil Nadu), Darjeeling and Kalimpong areas (West Bengal) for biological control of *A. adenophora*. The insect has established and is spreading naturally. Its effectiveness is hampered by attack of indigenous parasitoids. *P. utilis* has spread into Nepal, where it has become well-distributed.

Biological Control of Submerged Aquatic Weeds

The Problem

Submerged aquatic weeds cause serious navigational problems in different water bodies particularly in lakes, which attract large numbers of tourists.

Experiments conducted and results achieved

The grass carp *Ctenopharyngodon idella*, a native of Siberia, Manchuria and China, was introduced from Japan in 1959 to control submerged aquatic weeds such as *Vallisneria* spp. and *Hydrilla verticillata* in fish ponds and it has since been distributed to different parts of the country.

Maximum degree of success with classical biological control agents in India has been achieved in biological control of aquatic weeds (55.5%) followed by homopterous pests (46.7%) and terrestrial weeds (23.8%).

Transfer of Parasitoids within the Country for the Biological Control of Sugarcane Pests

The Problem

There are several crop pests in India which are serious in one region but under effective natural check in the other. India is a large country and collection of a key parasitoid or predator from one area and its release in another geographically separated area serves a sort of classical biological control.

Experiments conducted and results achieved

Epiricania melanoleuca is an important parasitoid of *Pyrilla perpusilla.* The redistribution of *E. melanoleuca* for the management of sugarcane pyrilla has proved a notable success. It was introduced into Gujarat, in 1982, from Maharashtra and Haryana, for the control of *Pyrilla* on sugarcane; even after 15 years, it suppresses the population and provides 72% parasitism. The pyrilla population starts declining and within 30 days a balance is struck when the population becomes less injurious (i.e. below ETL level). Similarly, the ichneumonid, *Isotima javensis* is a key parasitoid of sugarcane top borer, *Scirpophaga excerptalis* in northern India. It has been successfuly colonized in southern India and plays an important role in the suppression of this pest.

Regional and Global Impact of Study, Transfer of Technology and Material

A critical review of work carried out in this field since distant past points to the following significant achievements/findings:

Way back in 1762, the Indian myna bird, *Acridotheres tristis* was introduced to Mauritius where it successfully controlled the red locust, *Nomadacris septemfasciata.* After this first success in the world forty-six natural enemies from India have established in other countries and 26 are contributing extensively in improving the economy of the recipient countries on a recurring basis in addition to environment protection and enhancement of biodiversity. There are several outstanding examples worth mentioning. *Neodusmetia sangwani* was successfully colonized for the control of *Antonina graminis* in the USA, Bermuda, northern Brazil and other countries. It gave complete control, and Texas economy has benefited by $177 million annually. *Gyranusoidea tebygi* controlled mango mealy bug, *Rastrococcus invadens* in Central and West Africa saving several horticultural crops from disaster. *Aphytis* sp. (*proclia* group) has been successfully colonized against San Jose scale in Russia, where it is providing significant control of this pest. *Tamarixia radiata* provided exellent control of Asian citrus psylla, *Diaphorina citri* and the greening disease in Reunion Island.

Cotesia flavipes has established in Barbados on sugarcane borer, *Diatraea saccharalis* resulting in additional yields valued at £315,000 and £405,000 for the years 1969 and 1970, respectively and continue to provide these benefits. Early establishment of citrus blackfly parasitoids (*Amitus hesperidum*, *Eretmocerus serius, Encarsia clypealis* and *E. opulenta*) in Mexico stimulated the initiation of a collection and distribution programme unequaled in magnitude by any other biological control project in the world. A special gasoline tax was levied to defray the main costs and at one time about 1,600 men were engaged on various phases of the work.

India also has benefited from the introduction of natural enemies from other parts of the world. So far, 166 exotic natural enemies have been studied for utilization against various crop pests and weeds. Of the 71 species recovered after release, four provided partial control, seven substantial and six excellent control resulting in recurring economic and environmental benefits. Maximum degree of success

(55.5%) has been achieved in biological control of aquatic weeds followed by homopterous pests (46.7%) and terrestrial weeds (23.8%).

As far as biological control of crop pests in India is concerned, perhaps the first intentionally introduced beneficial was the coccinellid predator, *Cryptolaemus montrouzieri* which was introduced in June 1898. It has established on a variety of mealybugs (*Planococcus citri, P. lilacinus, Ferrisia virgata, Maconellicoccus hirsutus*) infesting fruit crops, coffee, ornamentals, etc. in south India. This is the first predator disseminated to small and marginal farming families through ICAR lab to land phase 1 programme during 1979-81. The predator is found effective in suppressing the mealybugs on citrus, guava, grapes, mulberry, coffee, mango, pomegranate, custard apple, ber, etc. and green shield scale (*Pulvinaria* spp.) on sapota, mango, guava, brinjal and crotons. *C. montrouzieri* is now commercially produced and utilized for the management of a variety of mealybugs and sac forming scale insects. Release of coccinellid beetle, *Rodolia cardinalis* in 1930 & 1941 provided excellent control of cottony cushion scale, *Icerya purchasi* on citrus, casuar inas, wattle and other *Acacia* spp. Parasitoid, *Leptomastix dactylopii* colonized in 1983 successfully manages common mealy bug, *Planococcus citri* in orchards, coffee, ornamentals and others on continued basis. Since 2001, exotic aphelinid parasitoid *Encarsia guadeloupae* has been successfully colonized against spiralling white fly, *Aleurodicus dispersus* in Kerala, Karnataka and several parts of Andhra Pradesh, where it is providing perceptible reduction in pest population.

In November 1988, coccinellid beetle, *Curinus coeruleus* was successfully colonized against subabul psyllid, *Heteropsylla cubana* on subabul around Bangalore. The predator established well in the field and provided control of psyllid on par with monocrotophos sprays at fortnightly interval. The beetles have since then been released and established in Karnataka, Kerala, Andhra Pradesh, Tamil Nadu and

Manipur, providing efficient, cost effective and environmentally safe control of *H. cubana* on a sustainable basis.

Incidentally the first successful classical biological control of a weed (Prickly pear) was achieved in India when cochineal insect, *Dactylopius ceylonicus* was introduced from Brazil. *D. ceylonicus* readily established on drooping prickly pear, *Opuntia vulgaris* (its natural host) in north and central India bringing about spectacular suppression of *O. vulgaris.* From 1863 to 1868 it was introduced to southern India, where it brought about the first successful intentional use of an insect to control a weed. In 1926, *D. opuntiae,* a North American species, was imported from Sri Lanka and its colonization resulted in spectacular suppression of *Opuntia stricta* and related *O. elatior.*

In 1983, a chrysomelid beetle, *Zygogramma bicolorata* was imported from Mexico for the biological suppression of parthenium, *Parthenium hysterophorus.* The releases of *Z. bicolorata* commenced in 1984. But real defoliation of parthenium was evident only in September 1988. *Z. bicolorata* has spread over more than 200,000 km^2 in and around Bangalore, causing defoliation of *P. hysterophorus* and encouraging the growth of vegetation formerly suppressed by this weed. The beetles have established in entire Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Kerala, Jammu, Madhya Pradesh, Punjab, Haryana and Himachal Pradesh.

For the biological suppression of water hyacinth, *Eichhornia crassipes,* exotic weevils *Neochetina eichhorniae* and *N. bruchi* were successfully colonized since 1983 in different water bodies in Andhra Pradesh, Assam, Gujarat, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Manipur, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal, including Loktak Lake, Manipur; Indira Gandhi canal, Rajasthan; Tocklai River, Assam; Mula Mutha River, Pune, Maharashtra; Pichola Lake, Udaipur. These efforts have resulted in establishment of the weevils in different parts of the country. The annual savings due to suppression of the weed by the weevils was estimated to be Rs. 11.2 lakhs in Bangalore alone.

Exotic weevil, *Cyrtobagous salviniae* was first colonized successfully on water fern, *Salvinia molesta* in a lily pond in Bangalore in 1983-84. Within 11 months of the release of the weevil in the lily pond the salvinia plants collapsed and the lily growth, which was suppressed by competition from Salvinia resurrected. Subsequent releases in Kerala, resulted in establishment of the weevils in ponds/ tanks/canals/lakes and within a span of 3 years, most of the canals abandoned due to the weed menace have become navigable once again. Already about 2,000 sq km area of the weed has been cleared by *C. salviniae*. By 1988 in the case of paddy cultivation, where Rs. 235 had to be spent per hectare for manual removal, the savings on account of labour alone were about Rs. 6.8 million annually.

Successes Achieved in Classical Biological Control in other Countries using Indian Biological Control Agents

- In 1762, the Indian myna bird, *Acridotheres tristis* was introduced to Mauritius where it successfully controlled the red locust, *Nomadacris septemfasciata,* historically this was this was the first successful example of classical biological in the world
- Forty-six natural enemies from India have established in other countries and 26 are contributing extensively in improving the economy of the recipient countries on a recurring basis.
- Braconid parasitoid *Aphidius smithi* introduced into USA in 1958 and released from 1958 to 1961 successfully controlled the pea aphid *Acyrthosiphon pisum* in pea and alfalfa fields.
- The parasitoid, *Aphidius smithi* after becoming well established on *Acyrthosiphon pisum* in several of the coastal valleys, spread to many of the interior valleys, including the desert regions of southern California.
- The parasitoid *Aphidius smithi* was released and recovered from *Acyrthosiphon pisum* in centr al valleys and eastern states, central Mexico and Maui, Hawaii (USA). It spread from eastern USA to southern Ontario in Canada.

- The braconid larval parasitoid, *Cotesia flavipes* introduced in 1966 and 1967 in Barbados became well established on sugarcane tissue borer, *Diatraea saccharalis*. It spread rapidly all over the island both naturally and aided by artificial releases and soon gave complete suppression of the pest. It was estimated that this successful campaign costing about £60,000 gave additional yields valued at £315,000 and £405,000 for the years 1969 and 1970, respectively.
- *Cotesia flavipes* has successfully established on sugarcane tissue borer, *Diatraea saccharalis* in Florida (USA), providing recurring annual benefits.
- Release of *Cotesia flavipes* in 1966 in Mauritius against *Etiella zinckenella* infesting pigeon pea provided complete suppression of this pest. Recurring benefits are accrued annually.
- The encyrtid parasitoid *Neodusmetia sangwani* attacking the Rhodes grass mealybug, *Antonina graminis* was introduced to the USA in 1959 and released in southern Texas during 1959-60. This became well established and gave complete control of *Antonina graminis*. By 1976 the parasitoid saved $17 million annually in management costs.
- In 1968, *Neodusmetia sangwani* was also successfully introduced into Bermuda and northern Brazil where it has not only established but is also providing very good suppression of the pest.
- In 1865, *Dactylopius ceylonicus* was transferred from India to Sri Lanka, which resulted in the successful control of *Opuntia vulgaris* throughout the island.
- In 1969, the parasitoid *Encarsia lahorensis* was introduced in California (USA) where it successfully established on citrus white fly, *Dialeurodes citri*. It was also introduced and established in Georgia (former USSR Republic) on *D. citri.*
- Early establishment of citrus blackfly, *Aleurocanthus woglumi* parasitoids (*Amitus hesperidum*, *Eretmocerus serius, Encarsia clypealis* and *E. opulenta*) in Mexico during 1948-50 stimulated the initiation of a collection and distribution programme unequaled in magnitude by any other biological control project in the world. A special gasoline tax was levied to defray the main costs and at one time about 1,600 men were engaged on various phases of the work.
- *Aphytis melinus* introduced in 1956-57 provides considerable suppression of *Aonidiella aurantii* on citrus in Texas and California (USA). *Aphytis melinus* has performed better in Greece, where it gives satisfactory to complete suppression in certain areas.
- Introduction of *Aphytis melinus* in 1961 provided complete suppression of *Chrysomphalus dictyospermi* in Greece and California (USA). The 1964 introduction to Sicily (Italy) was also satisfactory.

- From 1960 to 1963, *Aphytis melinus* along with several other *Aphytis* spp., *Comperiella bifasciata* and coccinellid beetles, *Chilocorus* spp. were successfully introduced to western Australia for the suppression of *Aonidiella aurantii*.
- Coccinellid predator *Chilocorus nigrita* introduced to Seychelles in 1938, successfully suppressed *Chrysomphalus aonidum* in citrus orchard areas, it also controlled the scale insect *Ischnaspis longirostris* on coconut palm.
- The parasitoid *Gyranusoidea tebygi* introduced in 1987 has established in Togo, West Africa and spread to provide successful suppression of mealybug, *Rastrococcus invadens* on several horticultural crops.
- Releases of eulophid larval parasitoid *Pediobius foveolatus* against Mexician bean beetle in major soybean areas of Maryland during the summer of 1973 resulted in high parasitism ranging between 80 and 100 percent. The parasitoid spread naturally to distance exceeding 100 kms from the released sites. Currently the pest is successfully managed by annual inoculative releases.
- The braconid larval parasitoid *Opius fletcheri* shipped to Hawaii, USA in 1916 got established on fruit fly, *Bactrocera cucurbitae* and provided considerable suppression of this pest infesting the small fruits of the balsam apple *Momordica balsamina*.
- In 1950, a braconid larvo-pupal parasitoid *Biosteres oophilus* was successfully shipped to Hawaii where it provides substantial suppression of oriental fruit fly, *Bactrocera dorsalis* on several fruit plants.
- Exellent control of Asian citrus psylla, *Diaphorina citri* was achieved by release of eulophid parasitoid, *Tamarixia radiata* into Reunion Island in 1978, the vector of greening disease was nearly eliminated and the disease controlled.

FUTURE CHALLENGES

For systematic studies and promotion of biological control a national and regional network is essential. APPARI member countries should be encouraged to set up national mechanisms (where not yet available) to co-ordinate, promote and monitor the implementation of biological control programmes including quarantine activities. Such national mechanisms should determine and chart the direction of national biological control activities, encourage and enhance the development and use of biological control in the country, support the development of technology for the production of biological control agents by farmers, farmer co-operatives and the private sector, publicize the environmental and social benefits of biological control through the mass media, establish rapport with relevant professional bodies and non-governmental organizations and secure support from these organizations to jointly act to create greater awareness among government policy makers on the need to support biological control for sustainable agriculture.

Regional collaboration and networking

A formal regional linkage should be established to provide freer exchange of literature, technology, resources, information, exchange visits and training between countries. The countries in the region, which have already well developed national system, should assist other countries, which do not have national set-ups to establish their own national co-ordinating bodies in biological control. The regional set up should solicit financial and technical support from international donor agencies for specific projects identified for regional implementation, organize regional workshops, produce and disseminate databases, other literature in printed and electronic form and serve as a clearinghouse for all member countries.

Collaboration among countries in the region, which have similar problems in pest management and share common borders, can maximise the use of resources in biological control and related quarantine activities by sharing information, expertise and resources through regional collaboration. Moreover, some countries face several problems such as lack of infrastructure, trained manpower, budgetary support, etc. and hence regional cooperation is vital. Mechanism for regional collaboration should be put in place.

Capacity building and HRD

For building and enhancing the capabilities joint projects can be envisaged at the regional level. This will lead to the establishment of model biological control systems in selected crops in the participating countries. Experiences of other countries would be helpful in developing and implementing appropriate biological control technologies as part of IPM at the farmers' level for major insect pests and invasive weeds. International standard quarantine facility wherever available could be used by the scientists from different countries.

For strengthening skills in biological control, human resource development and training needs (identification of biocontrol agent, procedures for exploratory surveys & quarantine, field release & assessment procedures, transfer of technology & interaction with the farmers) in the region should be assessed.

Networking and need to develop a database

In this Internet age, it is essential to have a mechanism in place to ensure dissemination of information related to biological control in different countries through networking of individual researchers and national research bodies.

There is a definite need for developing database. Personnel should be trained on the need, relevance, the programmes, protocols and linkages required for creating databases. The first and foremost job is to prepare dossiers of the target pests & weeds and their natural enemies. The gaps identified in the knowledge of target pests and natural enemies should be filled. The database should also be developed on the availability and standard of quarantine facilities available in different countries. It will determine the need and type of net works or joint projects required in the region.

Farmers' participation

Lack of farmer involvement and understanding may severely reduce the impact of introduced biological control agents in many cropping systems. Educating the public and farmers about biological control programmes is essential to promote biological control. By properly educating the farmers, their understanding of biocontrol can be improved. It is desirable to adopt non-conventional methods of training and extension, and innovative programmes using discovery-learning methods with farmers to make better use of biological control such as the Farmers' Field School (FFS) approach. Smallholder farmers could organize into weekly FFS facilitated by extension specialists. In FFS, farmers conduct observations and analyze the components of the ecosystem to discover for themselves the role of parasitoids and predators in controlling pests, improve understanding of pest-natural enemy interactions and factors affecting the natural enemies. The farmers trained in the initial stage become master trainers and pest control decision makers themselves, and pass their experience to their neighbours and relatives. This core force of master trainers acquires capabilities of conducting on-farm research through FFS in the region and provides appropriate input regarding the establishment and spread of exotic natural enemies.

Epilogue

Being a mega diversity country, India has contributed significantly in classical biological control at global level by providing Indian biological control agents to other countries. In fact classical biological control has its beginning in India.

The build up of research infrastructure and coordination of R&D programme keeping national perspectives in view, discussed in the foregoing account, particularly highlighting the success achieved in fifteen case studies has provided valuable impact. The successes can be translated/adopted suitably by other national programmes in APPARI following the kind of measures adopted and transfer of technology advocated. Over all, as has been stressed, the classical biological control offers some highly effective and environmentally friendly solutions to the problem of invading alien pests. A strong national and regional policy is required to accelerate the effective implementation of biological control programmes.

As would be evident from Appendex 1, some pest species are widely distributed in different continents, but their natural enemies are effective in one area and absent in others, hence suitable species could be considered for study and introduction from one area to another.

Exchange of experiences and information among countries will help in developing techniques/procedures for the safe movement and use of biocontrol agents. The existing quarantine facilities, if not adequate, can be improved and an information base for the development and refinement of protocols/guidelines for introduction and registration of bioagents, etc. can be created by closer collaboration among APPARI countries.

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Appendix 1

Exotic natural enemies introduced in India

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
Recovered and established			
1.	*Aphelinus mali* (Hymenoptera: Aphelinidae)	USA via UK, 1936 -1937	Introduced at Saharanpur (Uttar Pradesh) for the control of woolly aphid, *Eriosoma lanigerum* on apple. Subsequently established in Kullu valley (Himachal Pradesh), Kashmir valley (Jammu and Kashmir), Coonoor (Tamil Nadu), Shillong (Meghalaya), and all the apple-growing areas of India. More effective in valleys than on mountain slopes.
2.	*Encarsia perniciosi* (Hymenoptera: Aphelinidae)	California, USA, 1958, 1959; Illinois, USA, 1960; China via Switzerland, 1960; Russia via France, 1960	All strains introduced for the biological suppression of San Jose scale, *Quadraspidiotus perniciosus* performed well, providing 89-95 per cent parasitism in Himachal Pradesh, Jammu & Kashmir and Uttaranchal. Presently established in many areas where the scale population is low.
3.	*Rodolia cardinalis* (Coleoptera: Coccinellidae)	Australia via South Africa & via California, USA, 1926; via Egypt, 1930	Released against cottony cushion scale, *Icerya purchasi* in the Nilgiris (Tamil Nadu) in 1930, upper Palni hills (Tamil Nadu) in 1941, in Maharashtra, Karnataka and in Nileshwar (Kerala) on citrus, casuarinas, wattle and other *Acacia* spp. with excellent results.
4.	*Cryptolaemus montrouzieri* (Coleoptera: Coccinellidae)	Australia, 1898, 1980	Introduced in June 1898 and presently established on a variety of mealybugs infesting fruit crops, coffee, ornamentals, etc. in south India. Commercially produced and widely utilized for the management of a variety of mealybugs and sac forming scale insects.

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
5.	*Leptomastix dactylopii* (Hymenoptera: Encyrtidae)	Trinidad, West Indies, 1983	Introduced for the control of *Planococcus citri* Established in Karnataka, Tamil Nadu and Kerala.
6.	*Curinus coeruleus* (Coleoptera: Coccinellidae)	Mexico via Thailand, 1988	First released in Bangalore (Karnataka) on subabul psyllid, *Heteropsylla cubana*. Later released and established in other parts of Karnataka, Kerala, Andhra Pradesh, Tamil Nadu and Manipur and successfully established.
7.	*Telenomus alecto* (Hymenoptera: Scelionidae)	Colombia, 1966;Trinidad, West Indies, 1982	Released in Plassey (West Bengal) and recovered from Plassey borer, *Chilo tumidicostalis*. Also released in Motipur (Bihar) and Golagokarnath (Uttar Pradesh), recovered from Motipur and established at Golagokarnath.
8.	*Bracon kirkpatricki* (Hymenoptera: Braconidae)	Africa via USA, 1969	Recovered from pink bollworm, *Pectinophora gossypiella* on cotton, okra and hollyhock in Gujarat seven years after release indicating its establishment.
9.	*Eucelotoria bryani* (Diptera: Tachinidae)	Arizona, USA, 1978	Colonized in 1979-80 and recovered from Old World bollworm, *Helicoverpa armigera* on tomatoes & cotton in Bangalore & Dharwad (Karnataka), pigeonpea in Hyderabad & tobacco in Rajahmundry (Andhra Pradesh), tomatoes, cotton & lucerne in Mogar (Gujarat) and tomato, pigeonpea and lab-lab in Paiyur (Tamil Nadu).
10.	*Steinernema carpocapsae* (Rhabditida: Steinernematidae)	Czech Rebublic, 1980	Released and recovered from tobacco caterpillar, *Spodoptera litura* infesting tobacco nurseries and cruciferous vegetables in Rajahmundry (Andhra Pradesh).

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
11.	*Dactylopius ceylonicus* (Hemiptera: Dactylopiidae)	Brazil, 1795	Introduced in the mistaken belief that it was the true carmine dye producing insect *D. coccus*. Later readily established on drooping prickly pear, *Opuntia vulgaris* (its natural host) in north and central India bringing about spectacular suppression. Introduced in South India during 1863-1868 with excellent control of prickly pear.
12.	*Dactylopius opuntiae* (Hemiptera: Dactylopiidae)	USA via Sri Lanka via Australia, 1926	Gave spectacular suppression of *Opuntia stricta* and related *O. elatior.*
13.	*Pareuchaetus pseudoinsulata* (Lepidoptera: Arctiidae)	Trinidad, West Indies via Sri Lanka, 1984	Established in 1988 in Dakshina Kannada district (Karnataka). About 75% reductions in weed cover and increase in the growth of local vegetation noticed by October 1990. Also recovered from Kerala and Tamil Nadu.
14.	*Procecidochares utilis* (Diptera: Tephritidae)	Mexico via Hawaii, USA via Australia via New Zealand, 1963	Released in the Nilgiris (Tamil Nadu), Darjeeling and Kalimpong areas (West Bengal) against Crofton weed, *Ageratina adenophora*. Established and is spreading naturally, but efficacy hampered by indigenous parasitoids. Has spread to Nepal, where it has become well distributed.
15.	*Zygogramma bicolorata* (Coleoptera; Chrysomelidae)	Mexico, 1983	Released for the control of *Parthenium hysterophorus* from June/August, 1984 and established by 1988. Naturally spread to entire Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala. Established in Jammu (Jammu & Kashmir), Madhya Pradesh, Punjab, Haryana and Himachal Pradesh.

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
16.	*Neochetina bruchi* (Coleoptera: Curculionidae)	Argentina via USA, 1982/1983	Released and established on water hyacinth, *Eichhornia crassipes*. Spread to different parts of the country.
17.	*Neochetina eichhorniae* (Coleoptera: Curculionidae)	Argentina via USA, 1983	Released in different water tanks in Karnataka during October 1983-December 1986; Nacharam, Hyderabad (Andhra Pradesh) in 1987; Ramgarh lake near Gorakhpur (Uttar Pradesh) in 1988; Surha lake, Balia (Uttar Pradesh) in 1990; Lakhaibill (Alengmore), Assam in 2000; Ernakulum, Alleppey, Kottayam and Thrissur districts (Kerala). More than 450,000 weevils have been released in 15 states viz., Andhra Pradesh, Assam, Gujarat, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Manipur, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Presently established in different parts of the country.
18.	*Orthogalumna terebrantis* (Acari: Orthogalumnidae)	Argentina via USA, 1982/1986	Released for the control of water hyacinth in 1986 at Bangalore (Karnataka) and later in Kerala. Has established in all released sites and is spreading on its own.
19.	*Epinotia lantanae* (Lepidoptera: Tortricidae)	Mexico, unintentional accidental introduction, 1919	Established on lantana, *Lantana camara* in several places.
20.	*Lantanophaga pusillidactyla* (Lepidoptera: Pterophoridae)	Mexico, unintentional accidental introduction, 1919	Established on lantana.

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
21.	*Octotoma scabripennis* (Coleoptera: Chrysomelidae)	Mexico via Hawaii via Australia, 1971	Established on lantana.
22.	*Ophiomyia lantanae* (Diptera: Agromyzidae)	Mexico via Hawaii, 1921	Established on lantana in several places.
23.	*Orthezia insignis* (Hemiptera: Ortheziidae)	Mexico, unintentional accidental introduction, 1915	Established on lantana in several places.
24.	*Teleonemia scrupulosa* (Hemiptera: Tingidae)	Mexico via Hawaii via Australia, 1941	Reported to feed on teak flowers in quarantine at Dehra Dun (Uttaranchal) and hence culture was destroyed in quarantine. But the insect 'escaped' quarantine and presently found on all lantana stands in India.
25.	*Uroplata girardi* (Coleoptera: Chrysomelidae)	Brazil via Hawaii via Australia, 1969 to 1971	Established on lantana.
26.	*Cyrtobagous salviniae* (Coleoptera: Curculionidae)	Brazil via Australia, 1982/1983	Released for the control of water fern, *Salvinia molesta* in Bangalore in 1983-84. Later released and established in Kuttanad, Kerala, with excellent results.
27.	*Ctenopharyngod-on idella* (Pisces: Cyprinidae)	China via Hong Kong & Japan, 1959/1962	Introduced to control submerged aquatic weeds such as *Vallisneria* spp. and *Hydrilla verticillata* in fishponds. Established in different parts of the country.
28.	*Hypophthalmich-thys molitrix* (Pisces: Cyprinidae)	China via Hong Kong & Japan, 1959/1962	Released and established in different water bodies and feeds on various aquatic weeds and algae.

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
29.	*Oreochromis mossambicus* (Pisces: Cichlidae)	Africa, 1953	Released and established in different water bodies and feeds on various aquatic weeds and algae.
30.	*Osphronemus goramy* (Pisces: Osphronemidae)	Java, Indonesia; Mauritius, 1916	Released and established in different water bodies and feeds on various aquatic weeds and algae.
31.	*Cephalonomia stephanoderis* (Hymenoptera: Bethylidae)	Mexico, 1995	Released in the field from 1998 to 2001. Established in several areas of Kodagu district (Karnataka), Wyanad (Kerala) and Lower Palanis (Tamil Nadu).
32.	*Encarsia guadeloupae* (Hymenoptera: Aphelinidae)	Caribbean region & Central America, serendipitously introduced via Lakshadweep Island, 2000	Brought from Minicoy Island of Lakshadweep to main land for the control of spiralling white fly, *Aleurodicus dispersus*. Established in Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh.
33.	*Encarsia* sp. nr. *meritoria* (Hymenoptera: Aphelinidae)	Caribbean region & Central America, serendipitously introduced via Lakshadweep Island, 2000	A parasitoid of spiralling whitefly, fortuitously introduced. Present in several parts of south India, but displaced by *E. guadeloupae* in several areas and population remains low.
Recovered			
34.	*Sticholotis madagassa* (Coleoptera: Coccinellidae)	Mauritius & Reunion via East Africa, 1973	Colonized on sugarcane scale insect, *Melanaspis glomerata* and recovered from Shakar Nagar (Andhra Pradesh).
35.	*Aphytis* sp. nr. *diaspidis* (Hymenoptera: Aphelinidae)	Japan via USA, 1966	Colonized on San Jose scale, *Quadraspidiotus perniciosus* on apple and several other deciduous fruits and recovered from Kashmir (Jammu & Kashmir).

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36.	*Allorhogas pyralophagus* (Hymenoptera: Braconidae)	Mexico, 1983	Released against sugarcane tissue borers and cocoons recovered from Lucknow (Uttar Pradesh) at the time of the harvest during 1983-1984. Also recovered subsequently from adjacent maize fields from maize borer, *Chilo partellus* and sugarcane tissue borers-stalk borer, *C. auricilius* and shoot borer, *C. infuscatellus*; and top borer, *Scirpophaga excerptalis* at Lucknow & Simbhaoli (Uttar Pradesh) and Ladda (Punjab).
37.	*Cotesia flavipes* (Hymenoptera: Braconidae)	Indonesia, 1991	Released in sugarcane fields and recovered from *Chilo auricilius* larvae in Uttar Pradesh.
38.	*Diatraeophaga striatalis* (Diptera: Tachinidae)	Indonesia via Malagasy, 1965; via Reunion, 1970	Released and recovered from sugarcane stem borer, *Chilo sacchariphagus indicus* during 1979 in Pugalur (Tamil Nadu).
39.	*Lixophaga diatraeae* (Diptera: Tachinidae)	Trinidad, West Indies via Taiwan, 1963-64	Released in sugarcane fields and recovered from *Chilo* spp. larvae/ pupae from Karnataka and Uttar Pradesh.
40.	*Telenomus* sp. (Hymenoptera: Scelionidae)	Bolivia, 1983	Released in sugarcane fields and recovered from eggs of *Chilo* spp.
41.	*Trichogramma australicum* (Hymenoptera: Trichogrammatidae)	Taiwan, 1963; Trinidad, West Indies, 1981	Released in sugarcane fields in Pugalur (Tamil Nadu) and recovered from eggs of sugarcane stem borer, *Chilo sacchariphagus indicus* and other *Chilo* spp.
42.	*Trichogramma brasiliense* (Hymenoptera: Trichogrammatidae)	South America via California, USA, 1968	Released and recovered from sugarcane tissue borers; *Helicoverpa armigera* on tomatoes, cotton and several other hosts; pink bollworm, *Pectinophora gossypiella* on cotton, okra and hollyhock in Punjab.

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
43.	*Trichogramma fasciatum* (Hymenoptera: Trichogrammatidae)	Barbados, 1965	Released in sugarcane fields and recovered from eggs of *Chilo* spp. and *Scirpophaga excerptalis.*
44.	*Trichogramma japonicum* (Hymenoptera: Trichogrammatidae)	Trinidad, West Indies, 1979	Released in sugarcane fields and recovered from eggs of Gurdaspur borer, *Acigona steniellus*; *Chilo infuscatellus, Chilo* spp. and *Scirpophaga* spp.
45.	*Trichogramma perkinsi* (Hymenoptera: Trichogrammatidae)	Colombia, 1966	Introduced against tissue borers of sugarcane, recovered from eggs of *Chilo tumidicostalis* from Plassey (West Bengal) and *Chilo auricillius.*
46.	*Trichogramma* sp. (Hymenoptera: Trichogrammatidae)	Trinidad, West Indies, 1983	Released in sugarcane fields against sugarcane tissue borers and recovered from *Chilo* spp.
47.	*Trichogramma-toidea eldanae* (Hymenoptera: Trichogrammatidae)	Trinidad, West Indies, 1983	Released in sugarcane fields and recovered from eggs of *Chilo infuscatellus* at Shakar Nagar (Andhra Pradesh) and *Chilo* spp. at Pravaranagar (Maharashtra) and Lucknow (Uttar Pradesh).
48.	*Trichogramma-toidea bactrae* (Hymenoptera: Trichogrammatidae)	Taiwan, 1992	Released and recovered from diamond back moth, *Plutella xylostella.*
49.	*Cotesia chilonis* (Hymenoptera: Braconidae)	Indonesia, 1977	Released in sugarcane fields and recovered from the larvae of sugarcane tissue borers in Punjab.
50.	*Trichogramma embryophagum* (Hymenoptera: Trichogrammatidae)	Rumania, 1978; Germany, 1988	Released and recovered from codling moth, *Cydia pomonella* on apple in Ladakh region of Jammu & Kashmir state.

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51.	*Trichogramma cacoeciae* (Hymenoptera: Trichogrammatidae)	France, 1978	Released and recovered from *Cydia pomonella* on apple in Ladakh region of Jammu & Kashmir state.
52.	*Chelonus blackburni* (Hymenoptera: Braconidae)	Hawaii via Arizona, USA, 1976; Hawaii, USA, 1980	Released and recovered from *Pectinophora gossypiella* on cotton, okra and hollyhock in Punjab; and *Phthorimaea operculella* on potato in Bangalore (Karnataka) and Rajgurunagar (Maharashtra); and from *Helicoverpa armigera* on tomatoes, chickpea, cotton and several other hosts.
53.	*Agathis unicolorata* (Hymenoptera: Braconidae)	South America, 1944-45	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra) and Chickballapur and Hassan (Karnataka).
54.	*Apanteles subandinus* (Hymenoptera: Braconidae)	South America, 1944-45	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra) and Chickballapur and Hassan (Karnataka).
55.	*Bracon gelechiae* (Hymenoptera: Braconidae)	Canada, 1944-45	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra) and Chickballapur and Bangalore (Karnataka).
56.	*Copidosoma desantisi* (Hymenoptera: Braconidae)	Peru, 1990	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra).
57.	*Copidosoma koehleri* (Hymenoptera: Braconidae)	South America via California, USA, 1965; Peru, 1990	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra) and Chickballapur and Hassan (Karnataka).
58.	*Diadegma turcator* (Hymenoptera: Braconidae)	Cyprus, 1968	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra).

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59.	*Orgilus jennieae* (Hymenoptera: Braconidae)	South America via Trinidad, West Indies, 1980	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra).
60.	*Orgilus lepidus* (Hymenoptera: Braconidae)	South America via California, 1965; South America via Trinidad, West Indies, 1980	Released and recovered from potato tuber moth on potato in Rajgurunagar (Maharashtra) and Chickballapur and Hassan (Karnataka).
61.	*Telenomus remus* (Hymenoptera: Scelionidae)	New Guinea, 1963	Released and recovered from castor semilooper, *Achaea janata* on castor in Andhra Pradesh; *Spodoptera litura* on papaya, cabbage and tobacco nursery in Rajahmundry (Andhra Pradesh) and on lucerne and cauliflower from Gujarat.
62.	*Telenomus* sp. (probably *Telenomus proditor*) (Hymenoptera: Scelionidae)	New Guinea, 1964	Released against *Achaea janata* in Hyderabad (Andhra Pradesh) and recovered, with 60-80% parasitism.
63.	*Stomatomyia bezziana* (Diptera: Tachinidae)	Sri Lanka, 1960	Released and recovered from coconut leaf eating caterpillar, *Opisina arenosella* in the west coast of Kerala.
64.	Trichogramma pretiosum (Hymenoptera: Trichogrammatidae)	USA, 1964; Mexico, 1968	Released and recovered from *Helicoverpa armigera* on tomatoes, cotton, and several other hosts in Bangalore (Karnataka).
65.	*Cotesia marginiventris* (Hymenoptera: Braconidae)	Arizona, USA, 1969	Released and recovered from *Spodoptera litura* on tobacco nurseries and cruciferous vegetables in Rajahmundry (Andhra Pradesh) and *Helicoverpa armigera* in Bangalore (Karnataka).

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66.	*Platymeris laevicollis* (Hemiptera: Reduviidae)	Zanzibar (Tanzania) via Malaysia, Pakistan & Western Samoa, 1965; East Africa, 1979	Released to control *Oryctes rhinoceros* on coconut in 1968 in the Lakshadweep and later in large numbers at Pandalam (Kerala), Androth island (Lakshadweep) and Vittal (Karnataka), recovered with good results. Frequently recovered from Vittal.
67.	*Amblyseius chilenensis* (Acari: Phytoseiidae)	USA, 1984	Released and recovered from spider mites, *Tetranychus* spp. on various crops such as beans, okra and strawberry.
68.	*Phytoseiulus persimilis* (Acari: Phytoseiidae)	Chile via Switzerland, 1965; UK, 1984	Released and recovered from spider mites, *Tetranychus* spp. on various crops such as citrus, beans, okra and strawberry.
69.	*Paulinia acuminata* (Orthoptera: Acrididae)	West Indies, 1983	Released and recovered from water fern, *Salvinia molesta* in Thiruvananthapuram (Kerala).
70.	*Phymastichus coffea* (Hymenoptera: Eulophidae)	Colombia, 1999-2001	Field released against coffee berry borer and recovered in south India.
71.	*Prorops nasuta* (Hymenoptera: Bethylidae)	Mexico, 1995; Colombia, 1999	Introduced against coffee berry borer. Recovered in field cages.
Not recovered/established			
72.	*Lysiphlebus testaceipes* (Hymenoptera: Braconidae)	USA, 1966	Cowpea aphid, *Aphis craccivora.*
73.	*Adelencyrtus mayurai* (Hymenoptera: Encyrtidae)	Trinidad, West Indies, 1972	Sugarcane scale insect, *Melanaspis glomerata.*

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74.	*Aphytis mytilaspidis* (Hymenoptera: Aphelinidae)	Mauritius, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
75.	*Aphytis* sp. (Hymenoptera: Aphelinidae)	Australia, 1972-1973	Sugarcane scale insect, *Melanaspis glomerata.*
76.	*Aphytis* sp. (Hymenoptera: Aphelinidae)	Mauritius, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
77.	*Chilocorus cacti* (Coleoptera: Coccinellidae)	Trinidad, West Indies, 1972, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
78.	*Chilocorus distigma* (Coleoptera: Coccinellidae)	Uganda, 1969	Sugarcane scale insect, *Melanaspis glomerata.*
79.	*Chilocorus schioedtei* (Coleoptera: Coccinellidae)	Uganda, 1969; Ghana, 1973	Sugarcane scale insect, *Melanaspis glomerata.*
80.	*Coccidophilus citricola* (Coleoptera: Coccinellidae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
81.	*Cryptognatha nodiceps* (Coleoptera: Coccinellidae)	West Indies, 1982	Sugarcane scale insect, *Melanaspis glomerata.*
82.	Indet. encyrtid (Hymenoptera: Encyrtidae)	Brazil, 1981	Sugarcane scale insect, *Melanaspis glomerata.*
83.	*Microweisea suturalis* (Coleoptera: Coccinellidae)	California, USA via Bermuda, 1972	Sugarcane scale insect, *Melanaspis glomerata.*

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84.	*Neococcidencyrtus* sp. (Hymenoptera: Encyrtidae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
85.	*Coccobius subflavus* (Hymenoptera: Aphelinidae)	East Africa, 1972	Sugarcane scale insect, *Melanaspis glomerata.*
86.	*Coccobius* sp. (Hymenoptera: Aphelinidae)	Australia, 1972-1973	Sugarcane scale insect, *Melanaspis glomerata.*
87.	*Coccobius* sp. (Hymenoptera: Aphelinidae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
88.	*Pseudoazya trinitalis* (Coleoptera: Coccinellidae)	Trinidad, West Indies, 1982	Sugarcane scale insect, *Melanaspis glomerata.*
89.	*Pseudoscymnus anomalus* (Coleoptera: Coccinellidae)	Guam, USA, 1972	Sugarcane scale insect, *Melanaspis glomerata.*
90.	*Rhyzobius lophanthae* (Coleoptera: Coccinellidae)	Australia, directly & via Bermuda, East Africa, Reunion & West Indies, 1972	Sugarcane scale insect, *Melanaspis glomerata.*
91.	*Rhyzobius pulchellus* (Coleoptera: Coccinellidae)	New Caledonia via Trinidad, West Indies, 1972	Sugarcane scale insect, *Melanaspis glomerata.*
92.	*Aphytis diaspidis* (Hymenoptera: Aphelinidae)	USA, 1960	San Jose scale, *Quadraspidiotus perniciosus.*
93.	*Aphytis mytilaspidis* (Hymenoptera: Aphelinidae)	USA, 1966	San Jose scale, *Quadraspidiotus perniciosus.*

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94.	*Chilocorus kuwanae* (Coleoptera: Coccinellidae)	Japan via Trinidad, West Indies, 1959	San Jose scale, *Quadraspidiotus perniciosus.*
95.	*Cybocephalus gibbulus* (Coleoptera: Coccinellidae)	Japan via Trinidad, West Indies, 1959	San Jose scale, *Quadraspidiotus perniciosus.*
96.	*Hyperaspis trilineata* (Coleoptera: Coccinellidae)	Barbados, 1970	Sugarcane mealybug, *Saccharicoccus sacchari.*
97.	*Cryptochaetum iceryae* (Diptera: Cryptochaetidae)	California, USA, 1947, 1948	Cottony cushion scale, *Icerya purchasi.*
98.	*Agathis* sp. (Hymenoptera: Braconidae)	Bolivia, 1983	Sugarcane tissue borers.
99.	*Cotesia chilonis* (Hymenoptera: Braconidae)	Japan, 1965	Sugarcane tissue borers.
100.	*Cotesia sesamiae* (Hymenoptera: Braconidae)	Uganda, 1967	Sugarcane tissue borers. Maize borer, *Chilo partellus.*
101.	*Diadegma lineatus* (Hymenoptera: Ichneumonidae)	Taiwan, 1965	Sugarcane tissue borers.
102.	*Itoplectis naranyae* (Hymenoptera: Ichneumonidae)	Japan, 1970	Sugarcane tissue borers.
103.	*Lathromeris ovicida* (Hymenoptera: Trichogrammatidae)	Ghana, 1972	Sugarcane tissue borers.

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104.	*Macrocentrus grandii* (Hymenoptera: Braconidae)	USA, 1969	Sugarcane tissue borers.
105.	*Metagonistylum minense* (Diptera: Tachinidae)	Trinidad, 1959-1960	Sugarcane tissue borers.
106.	*Palpozenillia* sp. (Diptera: Tachinidae)	Bolivia via Trinidad, West Indies, 1968-1969	Sugarcane tissue borers.
107.	*Paratheresia claripalpis* (Diptera: Tachinidae)	Mexico via Trinidad, West Indies, 1958-1960; Columbia, 1980	Sugarcane tissue borers.
108.	*Pediobius furvus* (Hymenoptera: Eulophidae)	Uganda, 1969	Sugarcane tissue borers.
109.	*Telenomus nephele* (Hymenoptera: Scelionidae)	Ghana, 1972	Sugarcane tissue borers.
110.	*Tetrastichus inferens* (Hymenoptera: Eulophidae)	Taiwan, 1969	Sugarcane tissue borers.
111.	*Tetrastichus* sp. (Hymenoptera: Eulophidae)	Thailand, 1969	Sugarcane tissue borers.
112.	*Trichogram-matoidea* sp. (Hymenoptera: Trichogrammatidae)	Trinidad, West Indies, 1983	Sugarcane tissue borers.
113.	*Trichogramma* sp. (Hymenoptera: Trichogrammatidae)	Italy, 1991	Sugarcane tissue borers.

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114.	*Trichogramma semifumatum* (Hymenoptera: Trichogrammatidae)	Hawaii, USA, 1973 Mexico, 1973	Sugarcane tissue borers. Old World bollworm, *Helicoverpa armigera.*
115.	*Trichogramma evanescens* (Hymenoptera: Trichogrammatidae)	Germany, 1991	Sugarcane tissue borers. Old World bollworm, *Helicoverpa armigera.*
116.	*Campoplex haywardi* (Hymenoptera: Ichneumonidae)	South America, 1944-1945; South America via California, USA, 1965	Potato tuber moth, *Phthorimaea operculella.*
117.	*Chelonus kellieae* (Hymenoptera: Braconidae)	Costa Rica, 1980	Potato tuber moth, *Phthorimaea operculella.*
118.	*Diadegma stellenboschense* (Hymenoptera: Ichneumonidae)	South Africa, 1966	Potato tuber moth, *Phthorimaea operculella.*
119.	*Illidops scutellaris* (Hymenoptera: Braconidae)	USA, 1965	Potato tuber moth, *Phthorimaea operculella.*
120.	*Orgilus parcus* (Hymenoptera: Braconidae)	South Africa, 1966	Potato tuber moth, *Phthorimaea operculella.*
121.	*Temelucha* sp. (Hymenoptera: Ichneumonidae)	South Africa, 1966	Potato tuber moth, *Phthorimaea operculella.*
122.	*Telenomus nawai* (Hymenoptera: Scelionidae)	New Guinea, 1963	Castor semilooper, *Achaea janata.*
123.	*Bessa remota* (Diptera: Tachinidae)	Myanmar, 1937-1938; Malaysia, 1981	Teak leaf skeletonizer, *Eutectona machaeralis.* Coconut leaf eating caterpillar, *Opisina arenosella.*

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124.	*Hyposoter didymator* (Hymenoptera: Ichneumonidae)	Switzerland, 1985	Old World bollworm, *Helicoverpa armigera.*
125.	*Lespesia archippivora* (Diptera: Tachinidae)	USA, 1969-1970	Old World bollworm, *Helicoverpa armigera.*
126.	*Baculovirus oryctes* (Virales: Baculoviridae)	Malaysia via Western Samoa, 1971	Rhinoceros beetle, *Oryctes rhinoceros.*
127.	*Amblyseius newsami* (Acarina: Phytoseiidae)	Malaysia, 1961	Tea mite, *Bravipalpus californicus.*
128.	*Stethorus vagans* (Coleoptera: Coccinellidae)	Australia, 1961	Tea mite, *Oligonychus coffeae.*
129.	*Euglandina rosea* (Stylommatophora: Oleacinidae)	Hawaii, USA directly & via Bermuda, 1962-1973	Gaint African snail, *Achatina fulica.*
130.	*Gonaxis* sp. (Stylommatophora: Streptaxidae)	East Africa directly & via Guam, Hawaii, Sri Lanka & Trinidad, West Indies, 1964-1973	Gaint African snail, *Achatina fulica.*
131.	*Dactylopius confuses* (Hemiptera: Dactylopiidae)	South America via South Africa, 1836	Drooping prickly pear, *Opuntia vulgaris.*
132.	*Apion brunneonigrum* (Coleoptera: Apionidae)	Trinidad, West Indies, 1972-1983	Siam weed, *Chromolaena odorata.*

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133.	*Salbia haemorrhoidalis* (Lepidoptera: Pyralidae)	Trinidad, West Indies, 1972-1983	Lantana, *Lantana camara.*
Not released			
134.	*Coccobius flavoflagellatus* (Hymenoptera: Aphelinidae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
135.	*Encarsia ectophaga* (Hymenoptera: Aphelinidae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
136.	*Signiphora flavopalliata* (Hymenoptera: Signiphoridae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
137.	*Signiphora lutea* (Hymenoptera: Signiphoridae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
138.	*Signiphora* sp. (Hymenoptera: Signiphoridae)	Brazil, 1983	Sugarcane scale insect, *Melanaspis glomerata.*
139.	*Leptomastidea abnormis* (Hymenoptera: Encyrtidae)	Trinidad, West Indies, 1985	Common mealybug, *Planococcus citri.*
140.	*Agathis stigmatera* (Hymenoptera: Braconidae)	South America via USA, 1964, 1972; South America via West Indies, 1981	Sugarcane tissue borers.
141.	*Cotesia diatraeae* (Hymenoptera: Braconidae)	Trinidad, West Indies, 1959, 1969, 1972	Sugarcane tissue borers.

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142.	*Dentichasmias busseolae* (Diptera: Tachinidae)	Uganda, 1970	Sugarcane tissue borers.
143.	*Descampsina sesamiae* (Diptera: Tachinidae)	United Kingdom, 1985	Sugarcane tissue borers.
144.	*Lydella thompsoni* (Diptera: Tachinidae)	USA, 1991	Sugarcane tissue borers.
145.	*Ipobracon puberuloides* (Hymenoptera: Braconidae)	Trinidad, West Indies, 1959	Sugarcane tissue borers.
146.	*Ipobracon* sp. (Hymenoptera: Braconidae)	Bolivia, 1983	Sugarcane tissue borers.
147.	*Jaynesleskia jaynesi* (Diptera: Tachinidae)	Colombia, 1985	Sugarcane tissue borers.
148.	*Trichogramma dendrolimi* (Hymenoptera: Trichogrammatidae)	Germany, 1990	Sugarcane tissue borers.
149.	*Trichogramma minutum* (Hymenoptera: Trichogrammatidae)	Florida, USA, 1964	Sugarcane tissue borers.
150.	*Dactylosternum hydrophiloides* (Coleoptera: Hydrophilidae)	Malaysia, 1948	Banana weevil borer, *Cosmopolites sordidus.*
151.	*Apanteles malevolus* (Hymenoptera: Braconidae)	Myanmar, 1937-1938	Teak leaf skeletonizer, *Eutectona machaeralis.*

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152.	*Apanteles hyblaeae* (Hymenoptera: Braconidae)	Myanmar, 1937-1938	Teak leaf skeletonizer, *Eutectona machaeralis.*
153.	*Carcelia kockiana* (Diptera: Tachinidae)	Myanmar, 1937-1938	Teak leaf skeletonizer, *Eutectona machaeralis.*
154.	*Trichogram-matoidea nana* (Hymenoptera: Trichogrammatidae)	Myanmar, 1937-1938	Teak leaf skeletonizer, *Eutectona machaeralis.*
155.	*Diadegma semiclausum* (Hymenoptera: Ichneumonidae)	Taiwan, 1992	Diamond back moth, *Plutella xylostella.*
156.	Nucleopoly-hedrovirus (Virales; Baculoviridae)	United Kingdom, 1969	Diamond back moth, *Plutella xylostella.*
157.	*Campoletis flavicincta* (Hymenoptera: Braconidae)	Trinidad, West Indies, 1981	Old World bollworm, *Helicoverpa armigera.* Armyworm, *Spodoptera litura.*
158.	*Chelonus insularis* (Hymenoptera: Braconidae)	USA via Trinidad, West Indies, 1982-1983	Old World bollworm, *Helicoverpa armigera.* Armyworm, *Spodoptera litura.*
159.	*Cotesia kazak* (Hymenoptera: Braconidae)	Greece, 1985	Old World bollworm, *Helicoverpa armigera.*
160.	*Mescinia parvula* (Lepidoptera: Pyralidae)	Trinidad, West Indies, 1986	Siam weed, *Chromolaena odorata.*
161.	*Epiblema strenuana* (Lepidoptera: Tortricidae)	Mexico via Australia, 1985	Parthenium, *Parthenium hysterophorus.*

Sl. No.	Natural enemy (Order: Family)	Source/year of introduction/ release	Pest/crop/status
162.	*Smicronyx lutulentus* (Coleoptera: Curculionidae)	Mexico, 1983	Parthenium, *Parthenium hysterophorus.*
163.	*Leptobyrsa decora* (Hemiptera: Tingidae)	Peru & Colombia via Australia, 1971	Lantana, *Lantana camara.*
164.	*Phytomyza orobanchia* (Diptera: Agromyzidae)	Yugoslavia, 1982	Broomrape, *Orobanche* sp.
165.	*Diglyphus begini* (Hymenoptera: Eulophidae)	USA, 1997	Leafminer, *Liriomyza trifolii.*
166.	*Cecidochares connexa* (Diptera: Tephritidae)	South America via Indonesia, 2003	Siam weed, *Chromolaena odorata* (Not released till June, 2004).