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Welcome to Biological Control of Rice Insect Pests

Welcome to the Integrated Pest Management (IPM) reference guide, Biological Control of Rice Insect Pests. Use the links on the left side of the screen to navigate the content contained in this reference guide, or use the Index and Search features to help you find specific content.

Biological Control

History of Biological Control

The development of biological control followed no master plan, but surged or stagnated at the whim of insights, luck, personal endeavor and, in more recent decades, institutional momentum. Biological control efforts can be traced back to the Renaissance period (8th and 9th centuries) when farmers were making use of predacious arthropods. In China and Yemen, ant colonies were purposely moved among citrus and date trees to control pests. These practices, dating back several thousand years, were developed by farmers through direct observation of predators. The striking success in the control of the cottony cushion scale insect pest of citrus in California through the introduction of the Vidalia beetle from Australia in the late 1880s marked the beginning of intensive activities in this field in the 20th century.

Biological control was first used to control insect, mite and weed pests. Over time, the method was applied to control other invertebrates and plant pathogens. Even vertebrates are now considered as possible targets.

What is biological control?

Biological control may be defined as the action of predators, parasitoids, pathogens, antagonists, or competitor populations to suppress a pest population, making it less abundant and less damaging than it would otherwise be. In other words, biological control is a population-leveling process in which one species' population lowers the numbers of another species by mechanisms such as predation, parasitism, pathogenicity or competition. Biological control has proven relatively successful and safe. It can be an economical and environmentally benign solution to severe pest problems.

Biological Control Agents

Predators

Predators

A predator is an animal that depends on predation for its food. In other words, predators sustain life by killing and consuming animals of other species.

Characteristics of a predator

- A predator generally feeds on many different species of prey, thus being a generalist or polyphagous in nature.
- A single predator kills and eats large numbers of prey in its lifetime.
- Predators kill and consume their prey quickly, usually via extra oral digestion.

- Usually, immatures and adults of both sexes attack prey.

- Predators are very efficient in hunting their prey.

- Predators develop separately from their prey but may live in the same habitat or adjacent habitats.

Predators of insects

The predatory behavior is widespread among insects, spiders and mites. There are more than 40 families of insect predators that are significant for pest suppression in agriculture and forestry (Table 1). Of these, the Anthocoridae, Pentatomidae, Reduviidae, Carabidae, Coccinellidae, Staphylinidae, Chrysopidae, Cecidomyiidae, Syrphidae, Formicidae, Gerridae, Miridae, Vellidae and Dytiscidae are most commonly found preying on pest species in crop fields.

Virtually all members of all the 60 families of spiders (Araneae) are predators. Of the 27 or more families of order Acari (mites) that prey on or parasitze other invertebrates, eight are significant for biological control. Vertebrate predators that attack insect pests include birds, small mammals (bats), lizards, amphibians (frogs and toads), and fishes.

Table 1. Important families/groups of predacious arthropods and vertebrates (adopted from Driesche and Bellows, 1996).

Thrips: Thysanoptera	• Chrysopidae
• Aleolothripidae	• Hemerobiidae (brown lacewings)
• Phlaeothripidae	• Coniopterygidae
Mantids and grasshoppers: Orthoptera	**True flies: Diptera**
• Gryllidae	• Cecidomyiidae (gall flies)
• Mantidae	• Chamaemyiidae (aphid flies)
• Tettigoniidae	• Sciomyzidae (marsh flies)
True bugs: Hemiptera	• Syrphidae (flower flies)
• Anthocoridae	**Ants and wasps: Hymenoptera:**
• Belostomatidae	• Formicidae
• Gerridae	• Sphecidae
• Lygaeidae	• Vespidae
• Miridae	**Moths and butterflies: Lepidoptera**
• Nabidae	• Blastobasidae
• Naucoridae	• Heliodinidae
• Nepidae	• Lycaenidae
• Notonectidae	• Noctuidae
• Pentatomidae	• Olethreutidae
• Pheidae	• Psychidae
• Physmatidae	• Pyralidae
• Reduviidae	**Mites: ACARI (27 families predator/parasite)**
• Veliidae	• Anystidae
Beetles: Coleoptera	• Bdellidae
• Cantharidae	• Cheyletidae
• Carabidae	• Hemisarcoptidae
• Cicindelidae	• Laelapidae
• Cleridae	• Macrochelidae
• Coccinellidae	• Phytoseiidae
• Cybocephalidae	• Stigmaeidae
• Dytiscidae	**Spiders: Aranaea (all 60 families)**
• Gyrinidae	**Birds**
• Histeridae	**Fish**
• Staphylinidae	**Bats: Small Mammals**
	Frog and toads: Amphibians

Parasites

Parasites

A parasite is an organism living in or on another living organism, obtaining from it part or all of its organic nutrients, resulting in death for the host or altered growth, development and reproduction.

Approximately 10% of all insect species can be classified as parasitoids. The main difference between parasites and parasitoids is that parasites may not kill their hosts but parasitoids do. Parasitoids play a key role in the biological control of insect pests. About 75% of the parasitoids are Hymenoptera, the remaining 25% is composed of Diptera and some Strepsiptera, Neuroptera, Coleoptera and Lepidoptera.

Characteristics of parasitoids

- Specific parasitoid species usually attack specific insect species (specialist or monophagous) or a few closely related species (oligophagous).

- Parasitoids are host stage specific - some parasitize eggs while others parasitize larvae/pupae.

- Only the female parasitoid is involved in the act of parasitism. Many of them have a highly developed long ovipositor to lay eggs in their host body and in some cases they attack hosts that are inside plant tissue.

- Only the larval stage of the parasitoid is parasitic; adults are free living and feed on nectar, honeydew or host insect body fluid.

- Female parasitoids lay a single egg or several eggs in, on, or near the host body. Newly emerged parasitoid larvae feed inside the host body, and gradually destroy the host as it develops.

- Pupation of parasitoids can take place either inside or outside the host body.

- A parasitoid completes its development on one host individual.

Parasitism terminology

Different parasitoids may attack the various growth stages of a pest. Thus, there may be egg, larval, pupal, nymphal and adult parasitoids. Parasitoid species may be solitary (only a single parasitoid can develop on a single host) or gregarious (several parasitoids of a single species can develop on a single host).

In some species, adults deposit a single egg per host, which subsequently divides into many cells, each of which develops independently. This process is called polyembryony. If more eggs are deposited by a single species in a host than can survive, the result is termed superparasitism. If two or more species of parasitoids attack the same host, the resultant condition is described as multiparasitism.

Parasitoids that insert their eggs into hosts are called endoparasitoids; those that lay their eggs externally and whose larvae develop externally are called ectoparasitoids. Parasitoids of non-parasitoid hosts are primary parasitoids. Parasitoids that attack other species of parasitoids are hyperparasitoids.

Parasitoids of insect pests

Parasitoids are a very important component of the natural enemy complex of insect pests and have been the most common type of natural enemy introduced for biological control of insects. Members of 43 families of the order Hymenoptera are parasitoids. Twelve families of Diptera contain some species whose larvae are parasitoids of arthropods and snails. Of these, only the Tachinidae have been of major significance in biological control as introduced natural enemies.

So far, parasitoids of 26 families have been used in biological control. The most frequently used groups in the Hymenoptera are Braconidae, Ichneumonidae, Eulophidae, Pteromalidae, Encrytidae and Aphelinidae. Some parasitoids are also found in the insect order Strepsiptera, Lepidoptera and Coleoptera, although parasitism is not typical of the Lepidoptera and Coleoptera.

Table 2. Parasitoid orders and families (developed from - Driesche and Bellows, 1996).

Flies: DIPTERA	• Ibaliidae	*Ceraphronoidea*
• Acroceridae	• Eucoilidae	• Ceraphronidae
• Bombyliidae	• Figitidae	• Megaspilidae
• Calliphoridae	• Charipidae	*Stephanoidea*
• Conopidae	*Chalcidoidea*	• Stephanidae
• Cryptochetidae	• Leucospidae	*Ichneumonoidea*
• Nemestrinidae	• Chalcididae	• Ichneumonidae
• Phoridae	• Eurytomidae	• Braconidae
• Pipunculidae	• Torymidae	Aculeata
• Pyrgotidae	• Ormyridae	*Chrysidoidea*
• Sciomyzidae	• Pteromalidae	• Dryinidae
• Sarcophagidae	• Eucharitidae	• Bethylidae
• Tachinidae	• Perilampidae	• Chrysididae
Wasps: HYMENOPTERA	• Tetracampidae	*Vespoidea*
Symphyta	• Eupelmidae	• Tiphiidae
• Orussidae	• Encyrtidae	• Mutillidae
Apocrita	• Signiphoridae	• Scoliidae
Parasitica	• Eulophidae	• Sphecidae
Trigonalyoidea	• Aphelinidae	Moths and Butterflies: LEPIDOPTERA
• Trigonalidae	• Trichogrammatidae	• Epipyropidae
Evanioidea	• Mymaridae	Beetles: COLEOPTERA
• Aulacidae	*Proctotrupoidea*	• Meloidae
• Evaniidae	• Proctotrupidae	• Rhipiphoridae
• Gasteruptiidae	• Diapriidae	STREPSIPTERA (small order – all members are parasites)
Cynipoidea	• Scelionidae	
• Cynipidae	• Platygasteridae	

Pathogens

Pathogens attacking Arthropods

More than 1500 species of pathogens are known to attack arthropods. These include bacteria, viruses, fungi, protozoa and nematodes. Some pathogens have been formulated as micro-biological insecticides. Others have been genetically engineered but none have been commercialized.

Bacteria

Among the various pathogen groups, bacteria have been the group most successfully brought into commercial use. Three species of spore-forming bacteria in the genus Bacillus are currently used for the control of several groups of pests, the most widely used of which is Bacillus thuringiensis (Bt.). About 30 subspecies of Bacillus thuringiensis and more than 700 strains have been identified. Bt. products are available for control of lepidoptera, coleoptera and diptera.

Viruses

At least 16 families of viruses have been found to be pathogens of insects. Members of Baculoviridae frequently cause lethal infections and are only known to cause disease in insects.

Few viruses have been marketed as commercial products because their production costs are high and they have narrow host specificity.

Fungi

More than 400 species of entomopathogenic fungi have been recognized. These fungi are found under five subdivisions: Mastigomycotina, Zygomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina. Fungal epidemics occur periodically and can cause high levels of mortality in affected arthropod populations. Successful development of fungal pesticides has been limited because of narrow host range, and high humidity requirements for germination or sporulation, but have great potential for use in humid climates or moist environments such as soil.

Protozoa

Protozoa infecting insects include micro-sporidians and the eugergarines. Some have been considered for use as microbial insecticides. Species of Nosema are potential biocontrol agents for grasshoppers.

Nematodes

Nematodes that have shown potential for the control of agricultural pests are members of the families Steinernematidae and Heterorhabditidae, which are mutualistically associated with bacteria that kill the nematode’s host. Nematodes in some other families also kill their host insect through their growth, as do parasitoids. These include mermithidae, phaenopsitylenchidae, iotonchiidae, sphaerulariidae and tetradonematidae.

Approaches of Biological Control

Introduction to approaches of biological control

Large numbers of biological control agents are active in the field and are naturally performing biological control functions. This phenomenon is known as naturally occurring biological control or natural biological control. Natural biological control is the most important component of pest management in crop fields. In its absence, crop production would be extremely difficult.

Natural biological control is often limited by factors such as low plant diversity and its consequences for natural enemy populations - pesticide use or highly seasonal planting of field crops. As pests enter crops early in the season, and start to grow rapidly on abundant food, it is difficult for natural enemies to keep up with them.

Therefore, in order to create favorable situations for natural enemies, interventions are often necessary. There are three major interventions:

1. conservation
2. augmentation and
3. introduction or classical biological control.

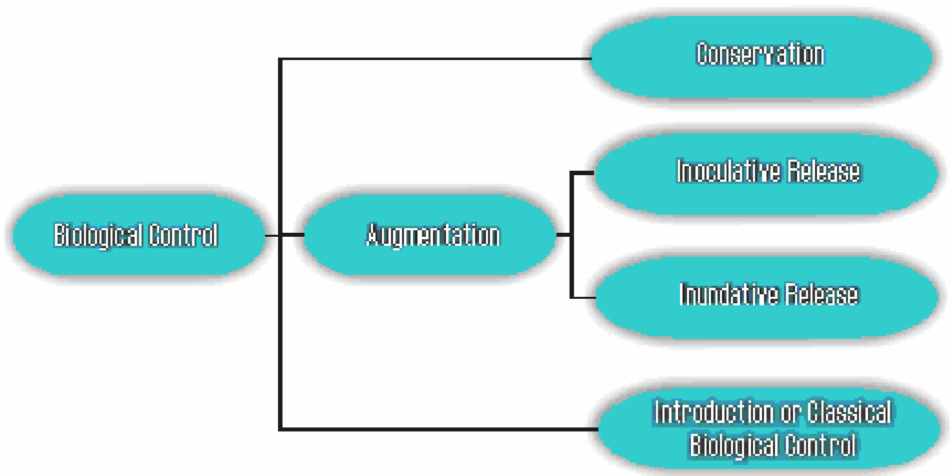

Figure 1. Approaches of biological control.

Conservation

What is conservation?

Conservation involves the modification of environment and judicious use of pesticides in order to conserve natural enemies to enhance biological control of target organism(s). Fundamental to biological control through conservation is the assumption that certain locally existing natural enemies have the potential to effectively suppress pests if given the opportunity to do so.

Conservation methods

Conservation methods depend primarily on knowledge of the effectiveness of a particular conservation practice under local conditions. Positive forms of conservation include efforts to enhance the environmental requisites that natural enemies need to flourish in a system. Such environmental requisites for natural enemies, including:

- Supplementary foods – alternate hosts or prey, or in some cases pollen.
- Complementary foods – honeydew, pollen, nectar for adult parasitoids.
- Modified climate – windbreakers.
- Over-wintering or nesting habitat.
- Shelter and/or food – adjacent non-crop vegetation provides food and shelter during off-season.

Conservation is perhaps the most cost effective and universal form of biological control.

Reduced pesticide use

Chemical pesticides are potentially harmful to natural enemies of both target and non-target pests. When this occurs, secondary pests such as scale insects, mealy bugs, and whitefly can become a problem. Natural enemies are more susceptible to insecticides than insects because:

- They are smaller in size;
- They have greater mobility on plants (host/prey searching behavior);
- Their habits are less concealed; and
- They have less ability to detoxify chemical poisons.

Consequently, attempts to conserve natural enemies commonly involve reducing pesticide use.

Other factors that can impact negatively on natural enemies include dust on foliage, ants that actively defend some insect pests (aphids or scales) for honeydew, date and manner of tillage, destruction of crop residues, and removal of natural enemy over-wintering sites such as hedgerows.

Augmentation

What is augmentation?

When natural enemies are missing, late to arrive at new plantings or too scarce to provide control, their numbers may be increased through releases. Such an approach is known as augmentation. Augmentation is the manipulation of natural enemies in order to make them more efficient regulators of pests. The principal limitations are the cost, quality and field effectiveness of the released organisms. Inoculative release and inundative release are two common augmentation approaches.

Inoculative release

An inoculative release involves releasing small numbers of a natural enemy into a crop cycle with the expectation that they will reproduce in the crop and their offspring will continue to provide pest control for an extended period of time.

Inundative release

Inundative or mass-release, is used when insufficient reproduction of released natural enemies is likely to occur, and pest control will be achieved exclusively by the released individuals themselves. However, inundation with fungi, nematodes, bacteria, virus and protozoa (bio-pesticides) are distinct from mass release of parasitoids and predators.

Introduction to Classical Biological Control

What is classical biological control?

If sufficient effective natural enemies are not present to control pests, especially introduced (exotic) pests, introduction of effective natural enemy species is necessary. This method is known as introduction or classical biological control.

Biological control was first effectively used to control the cottony cushion scale (Icerya purchasi Maskell) of citrus in California (USA) by the introduction of vedalia beetles Rodalia (formally Vedalia) cardinalis (Mulsant) from Australia in 1888-89. Since this first, successful attempt at biological control over 5000 programs of releasing exotic control agents against insect pests have been carried out, providing complete or partial control of more than 200 insect pest species. The highest success rates have been experienced with Homopteran insects - aphids, plant hoppers, scale insects and mealy bugs etc. - (Figure 2). Introduction has a major advantage over other forms of biological control in that it is self- maintaining and less expensive over the long-term.

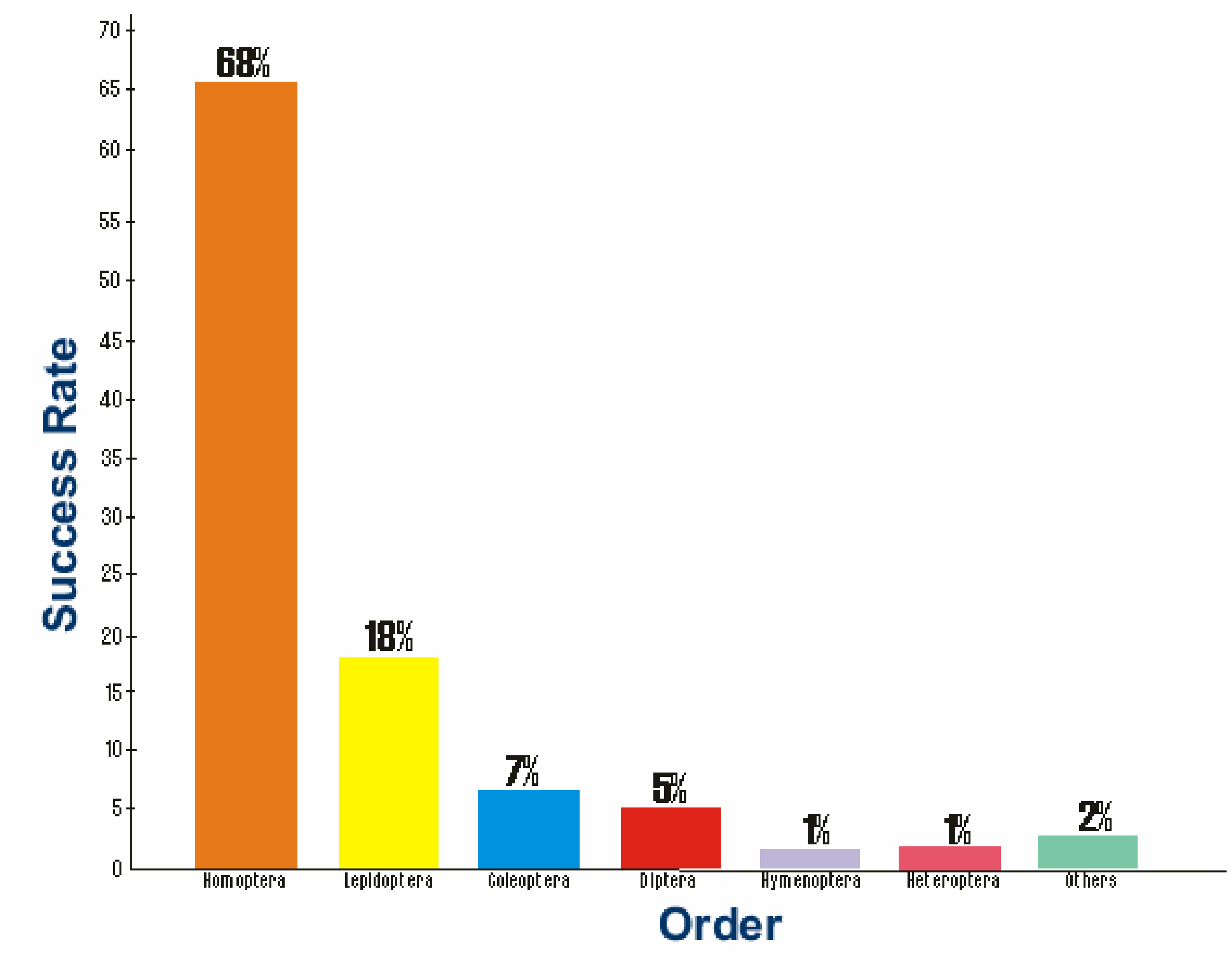

Figure 2. Relative success rate of classical biological control of insect pests by order (Greathead, 1995).

Biological Control of Rice

Background

Biological control as a method of insect pest management in rice began much later than the first success in the control of cottony cushion scale in California in the late 1880s. In fact, information - on natural enemy abundance and diversity, ecology and effectiveness as biocontrol agents, effects of pesticides and cultural practices on their populations, etc. - was very limited at the time. Considerable work has been done during the later half of the 20th century, and the practice of biological control of rice pests is constantly evolving.

Naturally occurring biological control

Rice insect pests have had long, close associations with their natural enemies, allowing stable relationships to develop. For example, predator and parasitoid guilds recorded in five irrigated rice ecosystems in the Philippines belong to ten orders and 57 families of predators and three orders comprising 40 families of parasitoids, indicating the great diversity and richness of the natural enemy community in rice. The interactions of such predators, parasitoids and insect pathogens are the cornerstone of modern integrated pest management programs in rice. The collective importance of natural enemies to pest population regulation is clearly demonstrated by observing outbreaks of insect pests after the removal of natural enemy communities by a broad-spectrum insecticide.

Conservation

Conservation

Conservation is the modification of the environment or habitat in combination with judicious use of pesticides in order to conserve natural enemies and enhance biological control. Evaluating the success of biological control is, however, a daunting problem; far different from the “spray-and-count” or “count-and-spray” evaluation methods of pesticide-based approaches. Despite this, environment management to enhance biological control has proven valuable in many settings and appears to be very important for rice insect pest management.

Conservation biological control contains two elements:

- Judicious use of insecticides.
- Modification of the environment.

Judicious use of pesticides

As mentioned earlier, insecticides are more harmful to natural enemies than to pests. There is extensive evidence that the destruction of natural enemies by broad-spectrum insecticides leads to reduced biological control and the subsequent resurgence of some pests. At the early stages of rice crop growth, abundant populations of detritus-feeding and plankton-feeding insects supports large populations of generalist predators in rice fields. The abundance of alternative prey gives the predator populations a “head start” on later developing pest populations. Therefore, insecticide overuse is most damaging early in the season. Insecticide use can also create heavy selection pressure for strains of pests that can even overcome previously resistant cultivars. Such circumstances create outbreaks of secondary pest such as brown planthopper and impair biological control of some key primary pests such as stem borers.

Recent surveys in 10 major rice-growing countries in Asia revealed that pesticide is the dominant pest control tactic of farmers, who use insecticides more frequently than herbicides and fungicides. A large proportion of farmers are still using insecticide compounds classified (by the World Health Organization) as extremely or highly hazardous to human health – namely methyl parathion, monocrotophos, and methamidophos. The mean number of insecticide sprays per season varies from 0.3 in Laos to 3.9 in Vietnam. Most of these sprays are applied during early vegetative stages mainly targeting leaf feeding insect pests, which usually do not cause economic loss.

By and large, insecticides are being misused in rice. Preventive use of insecticides in rice is common and widespread. A common tactic used by farmers to control stem borers is the use of granular insecticides as a preventive method, without any consideration of the pest population density or economic benefit. Farmers' rationales for insecticide use appear to be base on anticipated yield losses due to insect pest attack. Such attitudes are detrimental to biological control, pest management as a whole, the environment and human health. Judicious use of insecticides is essential for natural enemy conservation and for the enhancement of natural biological control.

In order to conserve indigenous natural enemies and enhance natural biological control, the following strategies for insecticide use are recommended:

- Preventive or calendar-based use of insecticides should be stopped.
- Early season spraying during the first 40 days after transplanting should be avoided.
- Selective insecticides should be used only when pest population density reaches a damaging level.
- When using insecticides, use appropriate formulations in the right dose. Apply at the optimum time of intervention following proper application methods.
- Broad-spectrum hazardous insecticides should be avoided.
- If available, use rice varieties that possess host plant resistance to major insect pests.

Modification of environment

Modification of environment

The immediate crop environment can be intentionally modified to favor natural enemies. This requires substantial knowledge of pest and natural enemy ecology, and the effects of cultural practices on them. Habitat management should be aimed at providing environmental requisites to natural enemies such as:

- Alternative hosts or prey.
- Complementary foods – honeydew, pollen, nectar.
- Over-wintering or off-season shelter.
- Modified climate – windbreak.

Some habitat management activities that have a positive influence on the abundance of the natural enemies of rice insect pests are described blow:

Rice bunds

Vegetated rice bunds support many herbivore species (including a few pests) and many species of natural enemies. They can be a very important source of natural enemy colonization in rice fields just after planting. Rice bunds are important sources of biological control agents of arthropods. Bund vegetation provides alternative and supplementary food for predators and parasitoids. Bunds are especially important for early sown crops and crucial for single-season rice crops. The importance of bund fauna on the early arrival of spiders for biological control of BPH has been demonstrated experimentally.

Bunds also provide shelter for natural enemies at critical times during harvesting, land preparation and between seasons. Puddling (tillage in presence of water) can have drastic effects on natural enemy populations. Many natural enemies take shelter on the rice bunds at puddling and the presence of vegetation on the bunds greatly increases their survival.

Manipulation of bund vegetation, particularly the enhancement of broadleaf weeds, can provide vital sources of natural enemies of rice insect pests and can reduce sources of alternate grassy hosts of some diseases such as sheath blight.

Vegetation in adjacent habitats

Generally, grasses and other vegetation in habitats adjacent to rice fields serve as habitats of natural enemies and also provide supplementary and complimentary food, over-wintering, or off-season habitats. The precise composition of plant species that will make the greatest contribution to the conservation of natural enemies of rice insect pests has not yet been determined.

Many species of arthropods, including natural enemies, exist concurrently in rice and non-rice habitats. Vegetation in these habitats serves as an important refuge for oligophagous rice parasitoids and generalist arthropod predators. One such example is Anagrus nilaparvatae (Mymaridae: Heteroptera), an important egg parasitoids of rice planthoppers, which also parasitizes the planthopper Saccharosydne procerus (Delphacidae: Homoptera) of Zizania caduciflora (Gramaineae), which is a favorite vegetable for the residents of the Yangtze Rive Delta in China. Anagrus nilaparvatae can overwinter in S. procerus eggs in Zizania fields during the off-season. Such over-wintering is crucial for the maintenance of natural enemy populations in between the seasons.

Crop mosaics and staggered planting

Some non-rice crops such as cowpea, mungbean, maize, bell pepper, garlic, onion, soybean etc. serve as important reservoirs of natural enemies of rice insect pests during the non-rice season. Appropriate crop manipulation in rice growing areas may enhance conservation of natural enemies and thus biological control of rice insect pests. In general, non-rice crop fields forming a mosaic within the rice blocks are good for natural enemy conservation. In a monoculture situation, asynchrony (staggered planting) can provide better conservation of natural enemies than strictly synchronous planting.

Cultural practices that disrupt natural enemies

Some cultural practices seriously affect natural enemies. These include:

- Burning of rice stubble and/or straw.
- Burning of rice husk on the field prior to onion cultivation (in the Philippines).
- Trimming of non-rice vegetation from rice bunds prior to tillage (puddling).
- Destruction of vegetation on the field during fallow periods.
- Strictly synchronous rice planting over a large area.

From plant nutrient and natural enemy conservation points of view, it is better to incorporate crop residues into the soil rather than burn them. If burning is essential then it should be done in heaps rather than burning residue spread all over the field.

Conservation of predatory vertebrates

In many countries insect predatory birds, toads and frogs are caught in rice fields for consumption. Conservation of insect predatory birds, frogs and toads by preventing capture from the rice environment can also enhance biological control of rice insect pests. In Bangladesh, for example, collecting frogs from the lowland rice environment during their breeding period is discouraged.

Augmentation

What is augmentation?

This method of biological control mainly refers to inundative or inoculative release of mass reared natural enemies. There have been a few attempts, mostly in China, to mass release stem borer egg parasitoids such as Trichogramma japonicum, Telenomus rowani, and Tetrastichus schoenobii. It seems that mass rearing and release is not economical in rice and that this approach has limited prospects for rice insect pest management.

Other methods of augmentation

Other methods of augmentation

Aside from inoculative and inundative release, a few other augmentation methods have been used with some success. These include the use of perches for insect predatory birds, use of ducks, and rice-fish culture.

Augmentation of insect predatory birds

Placing perches in rice fields can attract some insect predatory birds. One such bird is the black drongo, Dicrurus adsimilis (Bechstein). The black drongo is a purely insectivorous bird and very common in the rice environments of South Asia. Black drongos use perches in rice fields as prey watchtowers and resting sites between prey hunting flights. They hunt any large insects in flight and also prey on insects from the rice canopy. Their prey include, grasshoppers, crickets, moths and butterflies, large caterpillars, etc.. However, they also prey on some beneficial insects such as dragonflies. Black drongos and many other insectivorous birds concentrate in the field for insect predation at tillage, weeding and harvesting stages.

Of about 1140 species of birds known to occur in China, half are entomophagous and about 30 are common and important for pest control in agriculture and forestry. Four species of bird have proven to be effective in grassland locust control in China. These are: the rose-colored sterling Sturnus roseus; the common starling S. vulgaris porphyronotus Sharpe; the chough Pyrrhocorax pyrrhocorax (L.); and the desert wheatear Oenanthe deserti (Temminck). Constructing nest-building sites near target areas can attract these birds.

Use of ducks

Releasing domestic ducks for pest control is a common component of IPM in China and Vietnam. Ducks are generalist predators, feeding on stem borers, leaffolders, grasshoppers, planthoppers and leafhoppers etc.. Ducks have big appetites and on average one duck can consume more than 100 insects per hour. Ducks are very good at decreasing pest populations quickly, particularly in the early to mid-tillering stage, and also provide partial control of weeds. In China, rearing of ducks for pests control has been found to significantly increase income and reduce pesticide use.

Rice-fish culture

Rice and fish association is as old as the development of rice as human food. In the past, rice and free-living fish were very important resources in the lowland environments of Asia. Development of semi-dwarf modern rice plant types has dramatically changed this. In low land environments rice is now mostly grown under irrigation during the dry season. Rice-fish culture in

China is almost 2000 years old, but it suffered a setback during the green revolution due to widespread use of toxic insecticides. Increasingly, though, rice-fish culture is regaining popularity to cope with the increasing demand for fish in Asia.

Different types of carp, tilapia and catfish feed on planthoppers and leafhoppers, stem borers (moth and dispersing larvae) or other insects that fall into the water, mosquito larvae and other aquatic insects. Some fish also feed on the outer leaf of the leaf sheath, which contains planthopper and leafhopper eggs. The ecological benefits of rice-fish culture are increased soil fertility, and control of weeds, insect pests and disease. Under rice-fish systems farmers cannot use insecticides, due to potential harmful effects on the fish, which helps to protect natural enemies.

Inundative and Inoculative Release

What is inundative and inoculative release?

A few attempts have been made to control indigenous rice pests through inundative release of parasitoids, with limited success. An attempt to control the dark-headed stem borer Chilo polychrysus in Malaysia by release of Trichogramma japonicum in the early 1930s failed. Such interventions are often unsuccessful due to their high cost and the fact that the in most rice environments insect pests are already being controlled biologically by a rich and diverse group of natural enemies.

Introduction to Classical Biological control

What is classical biological control?

In only two cases did the introduction of exotic parasitoids result in successful biological control in rice production. In the first case, populations of immigrant rice leaffolder, Marasmia exigua (Butler) (Lepidoptera: Pyralidae), in the Fiji Islands were apparently reduced by the introduced larval parasitoid, Trathala flavoorbitalis (Careron) (Hymenoptera: Ichneumonidae) from Hawaii in 1928.

The second case involved the control of introduced rice striped stem borers Chilo suppressalis (Walker) (Lepidoptera: Pyralidae) in Hawaii through the introduction of an egg parasitoid – Trichogramma japonicum Ashmead (Hymenoptera: Trichogrammatidae) from Japan and two larval parasitoids – Eriborus sinicus (Holmgren)(Hymenoptera: Eulophidae) and Bracon chinensis Szepligeti (Hymenoptera: Braconidae) from China in 1929. All three parasitoids established and helped to reduce infestation of this stem borer.

Several attempts have been made to introduce exotic parasitoids to control indigenous rice insect pests in South and Southeast Asia but none was successful. One such example involved the introduction of a larval parasitoid Paratheresia claripalpis (ven der Wulp) (Diptera: Tachinidae) from Trindad to Malaysia to control the dark-headed stem borer Chilo polychrysus (Meyrick) in 1951. A more recent example involved the introduction of two egg parasitoids Psix lacunatus (Johnson and Masner) (Hymenoptera: Scelionidae) and Telenomus cyrus (Nixon) (Hymenoptera: Scelionidae) to Palawan Island from the Island of Luzon, Philippines during 1985-87 to control Malayan black bug, Scotinophara coarctata (F.) (Hemiptera: Pentatomitidae). This project was not successful.

Major Natural Enemies of Major Rice Insect Pests

What are the major natural enemies?

The species diversity and total number of natural enemies in tropical rice are impressive, but usually a few species dominate the complex. It is difficult to generalize about the precise role and relative importance of individual species.
Here three important groups of insect pests are selected to illustrate the roles that natural enemies can play in the biological control of rice insect pests. The insect pests groups are:

- Stem borers
- Leaffolders
- Leafhoppers and planthoppers

Rice stem borers

Introduction

More than one hundred species of parasitoids, predators and insect pathogens attack rice stem borers. Stem borers are most vulnerable to natural enemies at the egg, neonate larval and adult stages. On average only 1-4% of the egg population reaches adulthood and the rest perish due to biotic and abiotic stresses

Egg parasitism and predation

Parasitism and predation of stem borer eggs are usually very high and are important population regulating factors. Three groups of egg parasitoids, Telenomus spp., Tetrastichus spp. and Trichogramma spp., dominate the complex. Some of the major parasitoids are density dependent, meaning parasitism rates increase with increases in egg density, which is an important population regulation mortality factor. The most important egg parasitoids are:

- Tetrastichus schoenobii Ferriere (Hymenoptera: Eulophidae)
- Telenomus rowani (Gahan) (Hymenoptera: Scelionidae)
- Telenomus dignus (Gahan) (Hymenoptera: Scelionidae)
- Trichogramma japonicum Ashmead (Hymenoptera: Trichogrammatidae)

Two important egg predators are:

- meadow grasshoppers – Conocephalus longipennis (de Haan) (Orthoptera: Tettigoniidae); and
- crickets, Metioche vittataicollis (Stal) (Orthoptera: Gryllidae)

Larval and pupal parasitism and predation

The complex of larval and pupal parasitoids is large, but not as abundant as that of the egg parasitoids. Stem borer larvae and pupae generally suffer low levels of parasitism. Larvae and pupae are almost inaccessible to natural enemies because they remain inside the stem. A few parasitoids are equipped with highly specialized long ovipositors that they can use to probe through the rice stem to locate and parasitize stem borer larvae and pupae. The most common larval and pupal parasitoids are:

- Cotesia flavipes Cameron (Hymenoptera: Braconidae)

- Temelucha philippinensis (Ashmead) (Hymenoptera: Ichneumonidae)
- Stenobracon nicevillei (Bingham) (Hymenoptera: Braconidae)
- Bracon chinensis Szepligeti (Hymenoptera: Braconidae)
- Tropobracon schoenobii (Viereck) (Hymenoptera: Braconidae)
- Xanthopimpla stemmator (Thunberg) (Hymenoptera: Ichneumonidae)
- Tetrastichus ayyari Rohwer (Hymenoptera: Eulophidae)

However, young dispersing stem borer larvae suffer high rates of mortality due to predation and desiccation. Disappearance of young larvae is the main reason for stem borer population fluctuations. Important larval predators are:

- Lady beetles, Micraspis spp. (Coleoptera: Coccinellidae)
- Carabid beetles, Ophionea spp. (Coleoptera: Carabidae)
- Rove beetle, Paederus fuscipes Curtis (Coleoptera: Staphylinidae)
- Water bug, Microvelia douglasi atrolineata Bergroth (Hemiptera: Veliidae)
- Water bug, Mesovelia vittigera (Horvath) (Hemiptera: Mesoveliidae)
- Water bug, Limnogonus fossarum (F.) (Hemiptera: Gerridae)
- Ants (Hymenoptera: Formicidae)

Adult predation

Stem borer moths do not suffer parasitism but may suffer high mortality from a variety of insect, spider and bird predators. Reliable estimates on moth predation in the field situation are not available. The important predators are:

- Anthocorid bug – Euspudaeus sp., (Hemiptera: Anthocoridae)
- Wolf spider – Lycosa pseudoannulata (Boesenberg and Strand) (Araneae: Lycosidae)
- Black drongo – Dicrurus adsimilis (Bechstein)(Dicruridae).

Diseases

Beauveria, Cordyceps and Nomuraea are white fungi that infect stem borers. In high moisture fungal spores germinate and invade the soft tissue and body fluids of hosts and grow out of the body when ready to produce dispersing spores. Important pathogens are:

- Beauveria bassiana (Balsamo) Vuillemin (Moniliales: Moniliaceae)
- Nomuraea rileyi (Farlow) Samson (Moniliales: Moniliaceae)
- Cordyceps sp. (Entomophthoraceae)
- Bacillus thuringiensis Berliner (Bacteria)
- An unidentified nuclear polyhedrosis virus

Rice leaffolders

Introdution

Parasitoids and predators play a very important role in rice leaffolders population regulation. Unlike stem borers, leaffolders are exposed to natural enemies at all the growth stages. Although larva mostly remain inside the leaf fold, entrance of natural enemies into the leaf fold is not very difficult.

Egg parasitism and predation

Parasitism of rice leaffolder eggs is generally low but eggs may suffer high predation, mainly by crickets.

Parasitoids:

- Copidosomopsis nacoleiae (Eady) (Hymenoptera: Encyrtidae)
- Trichogramma japonicum Ashmead (Hymenoptera: Trichogrammatidae)

Predators:

- Cricket – Anaxipha longipennis (Serville) (Orthoptera: Gryllidae)
- Cricket – Metioche vittaticollis (Stal) (Orthoptera: Gryllidae)
- Mirid bug – Cyrtorhinus lividipennis Reuter (Hemiptera: Miridae)
- Lady bird beetle – Micraspis crocera Mulsant (Coleoptera: Coccinellidae)

Larval and pupal parasitism and predation

The larval and pupal parasitoid complex of rice leaffolders is rich. Several dozens of parasitoid species attack larvae and pupae. Common parasitoids are:

- Goniozus nr. trangulifar Kieffer (Hymenoptera: Bathylidae)
- Cotesia angustibasis (Gahan) (Hymenoptera: Braconidae)
- Cardiochiles philippinensis Ashmead (Hymenoptera: Braconidae)
- Macrocentrus philippinensis (Ashmead) (Hymenoptera: Braconidae)
- Trichomma cnaphalocrosis Uchida (Hymenoptera: Ichneumonidae)
- Temelucha philippinensis (Ashmead) (Hymenoptera: Ichneumonidae)
- Xanthopompla flavolineata Cameron (Hymenoptera: Ichneumonidae)
- Tetrastichus ayyari Rohwer (Hymenoptera: Eulophidae)

Reliable information on the extent of larval predation is not available. We do know, however, that the ground beetles Ophionea sp. attack leaf folder larvae.

Adult predation

Leaffolder moths do not suffer mortality from parasitoids. However, a diverse group of predatory insects, spiders and vertebrates predate on rice leaffolder moths. The extent of moth predation in nature is not known.

Disease

Entomopahogenic bacteria such as Bacillus thuringiensis Berliner and a granulosis virus cause mortality of rice leaffolder larvae.

Rice leafhoppers and planthoppers

Introduction

In general the impact of predators on rice leafhopper and planthopper populations is stronger than that of parasitoids.

Egg parasitism and predation

Egg parasitism varies considerably among hopper species and fluctuates during the season. Leafhopper and planthopper eggs are generally more heavily parasitized than are adults and nymphs. The major egg parasitoids are:

- Oligosita yasumatsui Viggiani et Subba Rao (Hymenoptera: Trichogrammatidae).
- Anagrus spp. (Hymenoptera: Mymaridae).
- Gonatocerus spp. (Hymenoptera: Mymaridae).

The most abundant predator is the green mired bug Cyrtorhinus lividipennis Reuter (Hemiptera:

Miridae), which predate on both eggs and nymphs. C. lividipennis appears to play an important role in regulation of plant and leafhopper populations.

Nymph and adult parasitism and predation

The major parasitoids of planthoppers and leafhoppers are dryinid and strepsipteran wasps. Parasitism varies between 10% and 50% depending on the season and location. Important parasitoids are:

- Pseudogonatopus spp., (Hymenoptera: Dryinidae)
- Haplogonatopus apicalis Perkins (Hymenoptera: Dryinidae)
- Echthorodelphax fairchildi Perkins (Hymenoptera: Dryinidae)
- Elenchus yasumatsui Kefune and Hirashima (Hymenoptera: Strepsiptera)
- Tomosvaryella spp. (Hymenoptera: Pipunculidae)
- Pipunculus spp. (Hymenoptera: Pipunculidae)

A complex of predators predate on nymphs and adults of rice leafhoppers and planthoppers. Among them spiders and predatory insects are important. The important predators are:

- Wolf spider – Lycosa pseudoannulata (Boesenberg and Strand) (Araneae: Lycosidae)
- Water bug – Microvelia douhlasi atrolineata Bergroth (Hemiptera: Veliidae)
- Lynx spider – Oxyopes spp. (Araneae: Oxyopidae)
- Long-jawed spider – Tetragnatha spp., (Araneae: Tetragnathidae)
- Rove beetle – Paederus fuscipes Curtis (Coleoptera: Staphylinidae)
- Ground beetle – Ophionea nigrofasciata (Schmidt-Goebel) (Coleoptera: Carabidae)

Diseases

Several fungal pathogens infect rice leafhoppers and planthoppers. Prolonged high moisture is necessary for the germination of fungal spores. The fungus grows into the body of the infected hopper; when the insect is dead, fungus grows out of the body through the joints.

One mermithid nematode also infects hoppers and after death of the insect the nematode emerges from the body. The incidence of nematode parasites is usually low, but relatively higher in the wet season than the dry season. Important pathogens are:

Fungus:

- Metarhizium anisopliae (Metchnikoff) Sorokin (Moniliales: Moniliaceae)
- Metarhizium flavoviride Gams and Roszypal (Moniliales: Moniliaceae)
- Beauveria bassiana (Balsamo) Vuillemin (Moniliales: Moniliaceae)
- Hirsutella citriformis Speare (Moniliales: Stilbaceae)
- Erynia delphacis (Hori.) (Entomophthoraceae)
- Entomophthora coronata (Constantin) Kevorkian (Entomophthoraceae)

Nematode:

- Hexamermis sp. (Mermithidae)
- Agamermis unka Kaburaki & Imamura

Selected References

Selected references

Barbosa P. (ed.) 1998. Conservation Biological Control. Academic Press, San Diego, 396p.

Bellows TS and Fisher TW (eds.) 1999. Handbook of Biological Control. Academic Press, San Diego, 1046p.

DeBach P. (ed.) 1964. Biological Control of Insect Pests and Weeds. Reinhold Publishing Corporation, New York, 844p.

Greathead, DJ. 1995. Benefits and risks of classical biological control. Pp. 53-63 In: HMT Hokkanen and JM Lynch (eds.) Biological Control: Benefits and Risks. Cambridge University Press, UK.

Halwart, M. 1995. Fish as Biocontrol Agents in Rice. Tropical Agroecology, No. 8. Margraf Verlag, Germany, 169p.

Mackay KT (ed.) 1995. Rice-Fish Culture in China. International Development Research Centre, Ottawa, 265p.

Heinrichs EA (ed.) 1994. Biology and Management of Rice Insects. International Rice Research Institute, Philippines.

Pickett CH and Bugg RL. (eds.) 1998. Enhancing Biological Control. University of California Press, Berkeley, 422p.

Thomas M and Waage J. 1996. Integration of Biological Control and Host-Plant Resistance Breeding. CAB International, UK and CTA, The Netherlands 99p.
Van Driesche RG and Bellows TS. 1996. Biological Control. Chapman & Hall, New York, 539p.

Zhang ZQ. 1992. The use of beneficial birds for biological pest control in china. BioControl News and Information 13(1), 11N-16N.

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