Insects as biocontrol agents

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Abstract An attractive alternative method to chemical pesticides is the insect biocontrol (MBCAs) agents. They are the natural enemies devastating the pest population with no hazard effects on human health and the environment. Like Entomopathogenic fungi has an important position among all the biocontrol agents because of its route of pathogenicity, broad host rang and its ability to control both sap sucking pests such as mosquitoes and aphids as well as pests with chewing mouthparts, yet they only cover a small percentage of the total insecticide market. Improvements are needed to fulfill the requirements for high market share. The biocontrol agent are required to eliminate the chance that the putative impact of the biocontrol agent is not confounded with other causes. Overall, we argue that well replicated and landscape-scale post release monitoring programs are required not only to evaluate critically the degree of success and failure of biocontrol programs worldwide but also to provide insights into improving future biocontrol efforts.

Keywords: Biological control, Fungai, Bacteria, Viruses, Predators, Parasitoids, Pathogens.

Introduction: -

Biological control or **biocontrol** is a method of controlling pests such as insects, mites, weeds and plant diseases using other organisms.[1] It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role. It can be an important component of integrated pest management (IPM) programs.

There are three basic strategies for biological pest control: classical (importation), where a natural enemy of a pest is introduced in the hope of achieving control; inductive (augmentation), in which a large population of natural enemies are administered for quick pest control; and inoculative (conservation), in which measures are taken to maintain natural enemies through regular reestablishment.[2]

Natural enemies of insect pests, also known as biological control agents, include predators, parasitoids, pathogens, and competitors. Biological control agents of plant diseases are most often referred to as antagonists. Biological control agents of weeds include seed predators, herbivores and plant pathogens.

Biological control can have side-effects on biodiversity through attacks on non-target species by any of the same mechanisms, especially when a species is introduced without thorough understanding of the possible consequences.

Contents

Types of biological pest control

There are three basic biological pest control strategies: importation (classical biological control), augmentation and conservation.[3]

1. Importation

Rodolia cardinalis, the vedalia beetle, was imported from Australia to California in the 19th century, successfully controlling cottony cushion scale.

Importation or classical biological control involves the introduction of a pest's natural enemies to a new locale where they do not occur naturally. Early instances were often unofficial and not based on research, and some introduced species became serious pests themselves.[4]

To be most effective at controlling a pest, a biological control agent requires a colonizing ability which allows it to keep pace with changes to the habitat in space and time. Control is greatest if the agent has temporal persistence, so that it can maintain its population even in the temporary absence of the target species, and if it is an opportunistic forager, enabling it to rapidly exploit a pest population.[5]

Small commercially reared parasitoidal wasps,[3] *Trichogramma ostriniae*, provide limited and erratic control of the European corn borer (*Ostrinia nubilalis*), a serious pest. Careful formulations of the bacterium *Bacillus thuringiensis* are more effective.[6]

The population of *Levuana iridescens*, the Levuana moth, a serious coconut pest in Fiji, was brought under control by a classical biological control program in the 1920s.[7]

2. Augmentation

Hippodamia convergens, the convergent lady beetle, is commonly sold for biological control of aphids.

Augmentation involves the supplemental release of natural enemies that occur in a particular area, boosting the naturally occurring populations there. In inoculative release, small numbers of the control agents are released at intervals to allow them to reproduce, in the hope of setting up longer-term control, and thus keeping the pest down to a low level, constituting prevention rather than cure.

Augmentation can be effective, but is not guaranteed to work, and depends on the precise details of the interactions between each pest and control agent.[8]

An example of inoculative release occurs in the horticultural production of several crops in greenhouses. Periodic releases of the parasitoidal wasp, *Encarsia formosa*, are used to control greenhouse whitefly,[9] while the predatory mite *Phytoseiulus persimilis* is used for control of the two-spotted spider mite.[10]

3. Conservation

The conservation of existing natural enemies in an environment is the third method of biological pest control.[11] Natural enemies are already adapted to the habitat and to the target pest, and their conservation can be simple and cost-effective, as when nectar-producing crop plants are grown in the borders of rice fields. These provide nectar to support parasitoids and predators of planthopper pests and have been demonstrated to be so effective (reducing pest densities by 10- or even 100-fold) that farmers sprayed 70% less insecticides and enjoyed yields boosted by 5%.[12] Predators of aphids were similarly found to be present in tussock grasses by field boundary hedges in England, but they spread too slowly to reach the centres of fields. Control was improved by planting a metre-wide strip of tussock grasses in field centres, enabling aphid predators to overwinter there.[11]

Biological control agents

1. Predators

Predatory lacewings are available from biocontrol dealers.

Predators are mainly free-living species that directly consume a large number of prey during their whole lifetime. Given that many major crop pests are insects, many of the predators used in biological control are insectivorous species. Lady beetles, and in particular their larvae which are active between May and July in the northern hemisphere, are voracious predators of aphids, and also consume mites, scale insects and small caterpillars. The spotted lady beetle (*Coleomegilla maculata*) is also able to feed on the eggs and larvae of the Colorado potato beetle (*Leptinotarsa decemlineata*).[13]

Predatory *Polistes* wasp searching for bollworms or other caterpillars on a cotton plant

Several species of entomopathogenic nematode are important predators of insect and other invertebrate pests.[14][15] Entomopathogenic nematodes form a stress–resistant stage known as the infective juvenile. These spread in the soil and infect suitable insect hosts. Upon entering the insect they move to the hemolymph where they recover from their stagnated state of development and release their bacterial symbionts. The bacterial symbionts reproduce and release toxins, which then kill the host insect.[15][16]

Species used to control spider mites include the predatory mites *Phytoseiulus persimilis*,[16] *Neoseilus californicus*,[18] and *Amblyseius cucumeris*, the predatory midge *Feltiella acarisuga*,[18] and a ladybird *Stethorus punctillum*.[18] The bug *Orius insidiosus* has been successfully used against the two-spotted spider mite and the western flower thrips (*Frankliniella occidentalis*).[19]

The parasitoid wasp *Aleiodes indiscretus* parasitizing a gypsy moth caterpillar, a serious pest of forestry[20]

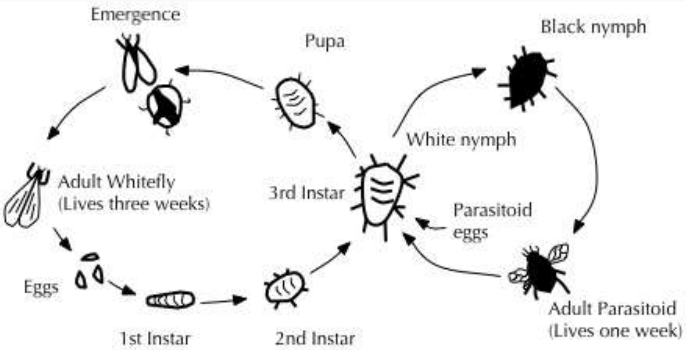
For rodent pests, cats are effective biological control when used in conjunction with reduction of "harborage"/hiding locations.[21][22][23] While cats are effective at preventing rodent "population explosions", they are not effective for eliminating pre-existing severe infestations.[23] Barn owls are also sometimes used as biological rodent control.[24]

In Honduras, where the mosquito *Aedes aegypti* was transmitting dengue fever and other infectious diseases, biological control was attempted by a community action plan; copepods, baby turtles, and juvenile tilapia were added to the wells and tanks where the mosquito breeds, and the mosquito larvae were eliminated.[25]

2. Parasitoids

Parasitoids lay their eggs on or in the body of an insect host, which is then used as a food for developing larvae. The host is ultimately killed. Most insect parasitoids are wasps or flies, and many have a very narrow host range. The most important groups are the ichneumonid wasps, which mainly use caterpillars as hosts; braconid wasps, which attack caterpillars and a wide range of other insects including aphids; chalcid wasps, which parasitize eggs and larvae of many insect species; and tachinid flies, which parasitize a wide range of insects including caterpillars, beetle adults and larvae, and true bugs.[26] Parasitoids are most effective at reducing pest populations when their host organisms have limited refuges to hide from them.[27]

Encarsia formosa, widely used in greenhouse horticulture, was one of the first biological control agents developed.



Life cycles of greenhouse whitefly and its parasitoid wasp *Encarsia formosa*

Parasitoids are among the most widely used biological control agents. Commercially, there are two types of rearing systems: short-term daily output with high production of parasitoids per day, and long-term, low daily output systems.[28] In most instances, production will need to be matched with the appropriate release dates when susceptible host species at a suitable phase of development will be available.[29] Larger production facilities produce on a yearlong basis, whereas some facilities produce only seasonally. Rearing facilities are usually a significant distance from where the agents are to be used in the field, and transporting the parasitoids from the point of production to the point of use can pose problems.[30] Shipping conditions can be too hot, and even vibrations from planes or trucks can adversely affect parasitoids.[28]

The eastern spruce budworm is an example of a destructive insect in fir and spruce forests. Birds are a natural form of biological control, but the *Trichogramma minutum*, a species of parasitic wasp, has been investigated as an alternative to more controversial chemical controls.[31]

3. Pathogens

Pathogenic micro-organisms include bacteria, fungi, and viruses. They kill or debilitate their host and are relatively host-specific. Various microbial insect diseases occur naturally, but may also be used as biological pesticides.[32] When naturally occurring, these outbreaks are density-dependent in that they generally only occur as insect populations become denser.[33]

I. Bacteria

Bacteria used for biological control infect insects via their digestive tracts, so they offer only limited options for controlling insects with sucking mouth parts such as aphids and scale insects.[34] *Bacillus thuringiensis*, a soil-dwelling bacterium, is the most widely applied species of bacteria used for biological control, with at least four sub-species used against Lepidopteran (moth, butterfly), Coleopteran (beetle) and Dipteran (true fly) insect pests. Genes from *B. thuringiensis* have also been incorporated into transgenic crops, making the plants express some of the bacterium's toxins, which are proteins. These confer resistance to insect pests and thus reduce the necessity for pesticide use.[35] *Paenibacillus popilliae* is usually used against Japanese beetle larvae and known to cause the milky spore disease. *Serratia* is use to control beetle larvae. In the case of *Photorhabdus* spp. and *Xenorhabdus* spp., which live in entomopathogenic nematodes symbiotically, here bacteria get entry into the insect host through nematodes. Biopesticides based on heat-killed *Chromobacterium subtsugae* and *Burkholderia rinojensis* are conveyed to have multiple modes of action and target on mites, aphids, whiteflies which are known to be greenhouse pest.

II. Fungi

Entomopathogenic fungi, which cause disease in insects, include at least 14 species that attack aphids.[36] *Beauveria bassiana* is mass-produced and used to manage a wide variety of insect pests including whiteflies, thrips, aphids and weevils.[37] *Lecanicillium* spp. are deployed against white flies, thrips and aphids. *Metarhizium* spp. are used against pests including beetles, locusts and other grasshoppers, Hemiptera, and spider mites. *Paecilomyces fumosoroseus* is effective against white flies, thrips and aphids; *Purpureocillium lilacinus* is used against root-knot nematodes, and 89 *Trichoderma* species against certain plant pathogens. *Trichoderma viride* has been used against Dutch elm disease, and has shown some effect in suppressing silver leaf, a disease of stone fruits caused by the pathogenic fungus *Chondrostereum purpureum*.[38]

The fungi *Cordyceps* and *Metacordyceps* are deployed against a wide spectrum of arthropods. *Entomophaga* is effective against pests such as the green peach aphid.[39] Several members of Chytridiomycota and Blastocladiomycota have been explored as agents of biological control.[40][41]

III. Viruses

Baculoviruses are specific to individual insect host species and have been shown to be useful in biological pest control. For example, the Lymantria dispar multicapsid nuclear polyhedrosis virus has been used to spray large areas of forest in North America where larvae of the gypsy moth are causing serious defoliation. The moth larvae are killed by the virus they have eaten and die, the disintegrating cadavers leaving virus particles on the foliage to infect other larvae.[42]

Most entomopathogens typically take 2-3 days to infect or kill their host apart from viruses and P. locustae which take longer. Related to viruses (highly host specific) and bacteria (moderately host specific), fungi generally have a broader host range and may infect both underground and aboveground pests. due to the soil-dwelling nature, nematodes are more suitable for managing soil pests or people who have soil inhabiting life stages.

A mammalian virus, the rabbit haemorrhagic disease virus was introduced to Australia to attempt to control the European rabbit populations there.[43] It escaped from quarantine and spread across the country, killing large numbers of rabbits. Very young animals survived, passing immunity to their offspring in due course and eventually producing a virus-resistant population.[44]

IV. Oomycota

Lagenidium giganteum is a water-borne mold that parasitizes the larval stage of mosquitoes. When applied to water, the motile spores avoid unsuitable host species and search out suitable mosquito larval hosts. This mold has the advantages of a dormant phase, resistant to desiccation, with slow-release characteristics over several years. Unfortunately, it is susceptible to many chemicals used in mosquito abatement programmes.[45]

4. Competitors

The legume vine *Mucuna pruriens* is used in the countries of Benin and Vietnam as a biological control for problematic *Imperata cylindrica* grass: the vine is extremely vigorous and suppresses neighbouring plants by out-competing them for space and light. *Mucuna pruriens* is said not to be invasive outside its cultivated area.[46] *Desmodium uncinatum* can be used in push-pull farming to stop the parasitic plant, witchweed (*Striga*).[47]

The Australian bush fly, *Musca vetustissima*, is a major nuisance pest in Australia, but native decomposers found in Australia are not adapted to feeding on cow dung, which is where bush flies breed. Therefore, the Australian Dung Beetle Project (1965–1985), led by George Bornemissza of the Commonwealth Scientific and Industrial

Research Organisation, released forty-nine species of dung beetle, to reduce the amount of dung and therefore also the potential breeding sites of the fly.[48]

5. Combined use of parasitoids and pathogens

In cases of massive and severe infection of invasive pests, techniques of pest control are often used in combination. An example is the emerald ash borer, *Agrilus planipennis*, an invasive beetle from China, which has destroyed tens of millions of ash trees in its introduced range in North America. As part of the campaign against it, from 2003 American scientists and the Chinese Academy of Forestry searched for its natural enemies in the wild, leading to the discovery of several parasitoid wasps, namely *Tetrastichus planipennisi*, a gregarious larval endoparasitoid, *Oobius agrili*, a solitary, parthenogenic egg parasitoid, and *Spathius agrili*, a gregarious larval ectoparasitoid. These have been introduced and released into the United States of America as a possible biological control of the emerald ash borer. Initial results for *Tetrastichus planipennisi* have shown promise, and it is now being released along with *Beauveria bassiana*, a fungal pathogen with known insecticidal properties.[49][50][51]

Difficulties

Many of the most important pests are exotic, invasive species that severely impact agriculture, horticulture, forestry and urban environments. They tend to arrive without their co-evolved parasites, pathogens and predators, and by escaping from these, populations may soar. Importing the natural enemies of these pests may seem a logical move but this may have unintended consequences; regulations may be ineffective and there may be unanticipated effects on biodiversity, and the adoption of the techniques may prove challenging because of a lack of knowledge among farmers and growers.[52]

Grower Education

A potential obstacle to the adoption of biological pest control measures is that growers may prefer to stay with the familiar use of pesticides. However, pesticides have undesired effects, including the development of resistance among pests, and the destruction of natural enemies; these may in turn enable outbreaks of pests of other species than the ones originally targeted, and on crops at a distance from those treated with pesticides.[53] One method of increasing grower adoption of biocontrol methods involves letting them learn by doing, for example showing them simple field experiments, enabling them to observe the live predation of pests, or demonstrations of parasitised pests. In the Philippines, early season sprays against leaf folder caterpillars were common practice, but growers were asked to follow a 'rule of thumb' of not spraying against leaf folders for the first 30 days after transplanting; participation in this resulted in a reduction of insecticide use by 1/3 and a change in grower perception of insecticide use.[54]

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