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6. Biological Control of Insect Pests

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Abstract:

Sustainable agriculture is certainly one of the most important challenges at present, considering both human population demography and evidence showing that crop productivity based on chemical control is plateauing. While the environmental and health threats of conventional agriculture are increasing, ecological research is offering promising solutions for crop protection against herbivore pests. Growers and green industry professionals are searching for alternative pest management tactics to satisfy consumer demands and the desire for sustainability and operational flexibility. Many are considering biological control. Biological control is the use of non-chemical and environment friendly methods of controlling insect pests and diseases by the action of natural control agents. The benefits of biological control include reduced reliance on pesticides, decreased potential for development of pesticide resistance, flexibility in usage of personal protective equipment, shorter (or no) restricted entry intervals. Government and manufacturing organizations are developing regulations to assure the safe and appropriate use of biocontrol. Protection of biodiversity and high benefit to cost ratio are obvious reasons to promote the use of biocontrol platforms.

Keywords:

Biocontrol, biocontrol agents, chemical control, environment friendly, biodiversity.

6.1 Introduction:

Indian agriculture sector contributes tremendously towards national GDP their by nation's economy. India produces almost all the crops starting from food grains, horticulture crops and commercial crops (Vanitha *et al*., 2013; APEDA 2020). Even though, there are a number of methods available to control the damage, usage of chemical pesticides is being followed in a large scale especially during post green revolution years. But the unscientific and indiscriminate use of chemical pesticides brought into various problems like residues in products, harmful effects on human and animals along with environmental pollution. On the other hand, various reports from different researchers that, most of the insect pests developed resistance against major insecticides.Resurgence of the pests also being notices in many parts of the country. This has raised a serious concern among researchers and growers to look into alternative/corrective measures of pest control to achieve sustainable crop protection, production and environmental safety. One such option is the biological control which eventually attained global preference over synthetic pesticides for effective and eco-friendly management of insect pests. Here living organisms and their products are used to maintain pest populations below economic threshold levels (ETL) which also protect natural enemies (Altieri *et al*., 2005; Mahr *et al*., 2008). Significant research and development has taken up during past few decades for biological control of insect pests. Over the past 50 years, biological control remains as one of the component of IPM and showing a steady but promising growth in IPM (Orr, 2009).

Biological control is an environmentally sound and effective means of reducing or mitigating pests and pest effects through the use of natural enemies. It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role (Brodeur *et al*., 2013). According to S. H. Dreistadt, 2007, Biological control is the beneficial action of predators, parasites, pathogens, and competitors in controlling pests and their damage. Biocontrol provided by these living organisms (collectively called natural enemies) is especially important for reducing the numbers of pest insects and mites. Biological control has been actively practiced for many years and the history of biocontrol, its failures and successes, has been extensively reviewed. Interest in biological control has increased over recent decades for many reasons (Bailey *et al*., 2009). First, a greater appreciation for environmental stewardship among regulators, growers, and the public has promoted development of more sustainable farming practices. Second, a number of arthropod pests have developed resistance to one or more pesticides leaving growers to search for alternative management strategies (Mc Caffery, 1998). Finally, consumers increasingly demand products that are grown in a sustainable manner and are free of insecticide residue (Dabbert *et al.*, 2004). Despite this, growers have been slow to adopt biological control as part of their pest management program. The primary factors affecting adoption of biological control are efficacy, predictability, and cost (Van Driesche and Heinz, 2004).

Basically there are three types of biological control strategies applied in pests control programs. These are Importation (sometimes called classical biological control), Augmentation and Conservation. Classical biocontrol is defined as the intentional introduction of an exotic (non-native), usually co-evolved biological control agent for permanent establishment and long-term pest control (Van Driesche, 2008). On the other hand, augmentation involves the supplemental release of natural enemies, boosting the naturally occurring population. Relatively few natural enemies may be released at a critical time of the season (inoculative release) or millions may be released (inundative release). An example of inoculative release occurs in greenhouse production of several crops. The conservation of existing natural enemies in an environment is the third method of biological pest control. Natural enemies are already adapted to the habitat and to the target pest, and their conservation can be simple and cost-effective, through vegetation manipulation, Natural enemies of insect pests, (biological control agents) include the following; predators, parasitoids, and pathogens. Predators are mainly free-living species that directly consume a large number of preys during their whole lifetime. A parasite is an organism that lives and feeds in or on a larger host.

Insect parasites (more precisely called parasitoids) are smaller than their host and develop inside, or attach to the outside, of the host's body (S. H. Dreistadt, 2007). Pathogenic micro-organisms include bacteria, fungi, and viruses. They kill or debilitate their host and are relatively host-specific.

6.2 Need for Biological Pest Control in India:

There is very much essential to meet the growing population of the country and their food demands. Beyond good production and productivity of agriculture and horticulture produce, the farmers often facing number of problems including high application of inputs especially chemical fertilizers or pesticides and nutrients to get good yield and control of various insect pest and diseases. This has lead to the high cost of cultivation and investment which will reflect yield and monitory returns. On the other hand, the chemical pesticides and fertilizers have created environmental pollution and also affect human and animal life. This has led to considerable changes in attitude of farmers towards use of pesticides and switching over to alternate and eco-friendly approach. One such option is biological control where number of agents integrated into IPM practice for successful management of pests. Here no microorganism or beneficial insects will deliberately introduced or manipulated for biological control. The potential agents will be tested repeatedly under controlled conditions against a target pest followed by mass production and release for commercial purpose (Hodek *et al*., 2012).

There are three general approaches to biological control:

As mentioned above in introduction, there are 3 basics strategies in biological control of pests, these are;

6.2.1 Classical Biological Control (Importation):

Classical biological control is the importation of pest natural enemies from other countries, to a new locale where they do not occur naturally. It is the international introduction of an exotic, usually co-evolved, biological control agent for permanent establishment and long term pest control (Pickrell, 2004). The goal of classical biological control is to find useful natural enemies, introduce them into the area of the target pest, and permanently establish them so that they will provide continuing pest control with little or no additional human intervention. The search for natural enemies in other countries is often referred to as foreign exploration. The process of importation involves; determining the origin of the introduced pest, collecting appropriate natural enemies associated with the pest or closely related species. Then selected natural enemies are passed, through a rigorous assessment, testing and quarantine process, to ensure that they will work and that no unwanted organisms are introduced. Mass production and release of selected natural enemies.

Follow-up studies are conducted to determine if the natural enemy becomes successfully established at the site of release, and to assess the long-term benefit of its presence. The cottony cushion scale (*Icerya purchasi* Maskell) program in California over the period 1877- 1879 was the first scientifically and institutionally backed biological control program. The importation and release of two natural enemies, the vedalia beetle (*Rodolia cardinalis*

[Mulsant]) and a parasitic fly (*Cryptochaetum iceryae* [Williston]) from Australia for cottony cushion scale control in California (M.S. Hoddle, 2003). In recent years, classical biological control has come under increasing scrutiny for its non target effects (Cory and Myers, 2000; Hawkins and Marino, 1997; Howarth, 1991). However, there are many examples of successful biological control (Bellows, 2001), and the need for biological control is increasing (Cory and Myers, 2000). Lastly, Classical biological control is a powerful tool for suppression of invasive plants and insects in natural ecosystems. It will play an increasingly important part in ecological restoration because; it provides a means to permanently suppress invaders over large landscapes without long-term resource commitments and hence is sustainable. As such, it merits use against many invasive plants and insects that are environmental pests in sensitive landscapes (Morin *et al*., 2009).

6.2.2 Augmentation Biological Control:

Augmentation is the periodic release of a natural enemy that does not occur naturally in sufficient numbers to keep a pest below damaging levels. It's also defined as the release of additional numbers of a natural enemy when too few are present to control a pest effectively (van Lenteren, 2000). The practice of augmentation is based on the knowledge or assumption that in some situations there are not adequate numbers or species of natural enemies to provide optimal biological control, but that the numbers can be increased by releases. This relies on an ability to mass-produce large numbers of the natural enemy in a laboratory or by companies to produce and sell them. There are two general approaches of augmentation: inundative releases and inoculative releases.

A. Inundative Releases:

Inundation involves releasing large numbers of natural enemies for immediate reduction of a damaging or near damaging pest population. It is a corrective measure; the expected outcome is immediate pest control. The inundative approach is achieved by flooding the crop with multiple releases of insectary-reared natural enemies. The released insects control pests present at the time, but there is little expectation that later generations will persist at sufficient levels to provide control. In practice, releases are often repeated if pest populations were not all present in a susceptible stage during the previous application, if new pests disperse into the crop, or if the crop is long lived, increasing the length of time it could become infested (Eilenberg *et al*., 2001). Moreover, Inundative release of natural enemies is undertaken; causing effects similar to the use of conventional insecticides, as there is a knockdown effect of the target host population. Therefore, it may be used in the field and in greenhouse as seasonal release (Cohen 2004, Schneider 2009). However, because of the nature of natural enemy activity, and the cost of purchasing them, this approach using predaceous and parasitic insects is recommended only in certain situations, such as the mass release of the egg parasite *Trichogramma* for controlling the eggs of various types of moths.

B. Inoculative Releases:

Inoculation on the other hand; involves releasing small numbers of natural enemies at prescribed intervals throughout the pest period, starting when the pest population is very low. The natural enemies are expected to reproduce themselves to provide more long-term control. However, the expected outcome of inoculative releases is to keep the pest at low numbers, never allowing it to approach an economic injury level; therefore, it is more of a preventive measure. The separation of inoculation from inundation is clear. A release with the expectation that the released organism will control the target after multiplication is inoculation. Examples of this are the releases of *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) and other natural enemies, now commonly practiced in glasshouses (Eilenberg *et al*., 2000; van Lenteren, 2000). The number of insects released is insufficient to control the pest insects, and success depends on the ability of the released organisms to multiply and reduce the target population.

6.2.3 Conservation Biological Control:

Conservation biological control is defined as modification of the environment or existing practices to protect and enhance specific natural enemies of other organisms to reduce the effect of pests. Habitat manipulation often involves increasing the species diversity and structural complexity of agro ecosystems. Habitat manipulation approaches provide natural enemies with resources such as nectar, pollen, physical refugia, alternative prey and alternative hosts and operate to reduce pest densities via an enhancement of natural enemies. However, although conservation biological control often increases natural enemy abundance, reduced pest abundance or increased yield has rarely been demonstrated (Johnson *et al*., 2008). For example, flowering strips and other shelter habitats, as conservation biological control tactics, increase predation, parasitism, or yield in some cases but not others (Pfiffner and Wyss, 2004 and Griffiths *et al*., 2008).

In addition to natural enemies, conservation biological control tactics, such as habitat manipulation, attract and sustain a diverse suite of herbivores, detritivores, and plant provided foods (Landis *et al*., 2000; Frank and Shrewsbury, 2004). Research has been done on myriad arthropod pests, including species with high levels of insecticide resistance such as *Chilo suppressalis* (Lepidoptera: Crambidae) and *Helicoverpa armigera* -Lepidoptera: Noctuidae (Cory S. Straub *et al.*, 2007). As an example of conservation biological control, alternative habitats for natural enemies are provided, in the form of 'beetlebanks' in Britain or 'sown seed strips' in Switzerland in cereal crops. These practices are highly successful and are among the few documented uptakes of a biological control option in temperate open-field arable agriculture (Landis *et al*., 2000).

A. Biological Control Agents:

Most of the plant protection measures in India are depends exclusively on chemical pesticides. The farmers are using pesticides making it a calendar based application. This has become a common practice over the years by growers. Unknowingly they are destroying natural flora and fauna along with killing beneficial insects like predators, parasitoids and bees. Therefore it is absolutely necessary for the farmers to use biological control agents to conserve these beneficial insects along with safeguarding environment (Altieri *et al*., 2005; Mahr *et al.*, 2008; Halder *et al*., 2011). During past few decades, a steady progress has been made in India towards biological control of insect pests. But, this needs to be aggravated in terms of searching more and more natural enemies, and microbial bio control agents for efficient management of insect pests.

- **Predators:** Predator insects are the beneficial insects which directly kill and feed on pests. Common predatory insects include lacewings, ladybird beetles, carabid beetles, staphylinid (rover) beetle, syrphid (hover) flies, minute pirate bugs, nabid bugs, big-eyed bugs, spiders and preying mantids. Ladybird beetles are recognized for their predatory behavior on many pests. Adult and larvae of ladybird beetle feed on a number of small, soft-bodied insects, their eggs and larvae. Most of the predators are not host specific. They can feed on a number of pests including plant pests and insects eating on organic matter also. Predators are generally have chewing and sucking type of mouth parts and some types they have both the types (Sampaio *et al*., 2010). Some of the insect orders have exclusively predatory insects. Example: The order Odonata has dragon flies, where aquatic nymphs are predatory, and breath through gills. Whereas adults are excellent fliers captures their prey during flight from crop fields. Another order is Mantodea which have praying mantids. They are the excellent hunters of their prey by hiding on leaves and plant surface to confuse their prey. They have strong modified front legs to capture their prey. Similarly order Neuroptera have lacewings and ant-lions where, all the larvae are predators and adults feed on pollen and nectar (Sampaio *et al*., 2010). Order Diptera have rover flies which have similar mechanism of dragon flies to catch their prey. Other orders is Coleoptera (Coccinellids) having lady bird beetles which are the excellent predators. Many of the mite species belong to phytoseidae also reported to have predatory action. They are the important natural enemies of other mites
- **Parasitoids:** Parasitoids are the organisms which live and feed inside or on the host. The parasites can develop inside or outside of an insect's body. Only immature stage of the parasites feed on insect host. Adult females of certain parasites feed on and their hosts providing an easily available source of biological control (Sanda and Sunusi, 2014). Based on the stage of prey that a parasite attacks, they are categorized into egg parasitoids which have whole development within the egg of other insect. Egg-larval parasitoid is the one that has oviposition within egg of the host, but its development completed in the insects larvae. Other parasitoids are larval, pupal and larvae-pupae. In some cases, adult stage of the insects also used as host by the parasitoid (Sampaio *et al*., 2010). When the parasitoid develops on the host, it is called ectoparasitoid and when it develops inside it is called endoparasitoid. Most of the parasitic insects belong to order Diptera (flies) or Hymenoptera (Wasps). Parasitic wasps occur in three dozen Hymenoptera families. Example: Aphidiinae (subfamily of Braconidae) attack aphids that are pests in most of the crops. Other family is Trichogrammatidae, here pasitization is observed on eggs. Aphilinidae, Encyrtidae, Eulophidae and Ichneumonidae are the other families' parasites on insect pests (Flint and Dreistadt, 1998).
- **Microbial Biocontrol Agents:** Just like plant pathogens, these are microbial agents belongs to fungi, bacteria, protozoa, virus, actinomycetes and nematodes which attack insect pests and kill them. Innudative application can be followed by formulating insect-pathogenic fungi (*Metarhizium*, *Beauveria*, *Paecilomyces*), insect-pathogenic bacteria (*Bacillus thuringiensis*), entamopathogenic nematodes (*Heterorhabditis* and *Steinernema*) and viruses (nuclear polyhedrosis virus-NPV and granulosis viruses (GV) (Flint and Dreistadt, 1998). The fungal biocontrol agents belong to 12 classes within six phyla of the major groups like Laboulbeniales, Pyrenomycetes, Hyphomycetes and Zygomycetes. Many of the promising biocontrol agents have been ommercialized globally. They have been proven their efficacy on insect species belonging to Lepidoptera, Homoptera, Coleoptera, Orthoptera and Mites. Majority of the bacterial biological control agents are *Bacillus thuringiensis* based *Bt* formulations. For example

in cabbage they are being used in two formulations like Btkurstaki and Btaizawai as control of diamond back both (DBM) and other defoliating lepidopteran insects (Shelton *et al*., 2007). These formulations are highly specific and very effective against target pests without any impact on natural enemies. Most of the formulations are spore-crystal mixtures having toxins (Btk-Cry1Aa, Cry 1Ab, Cry 1Ac. Cry 2a2A and Cry 2B; Bta;Cry 1Aa, Cry 1Ab, CryIC, Cry ID and Cry 2B toxins) (Heckel *et al*., 2004; Grzywacz *et al*., 2010). Among the fungal biocontrol agenst, *Beauveria bassiana*, *Metarhizium anisopliae*, *Nomuraea rileyi*, *Lecanicillium* spp., gained much more attention during the past 30-50 years. There are more than 300 commercial products available in world market (Faria and Write, 2007).

6.3 Conclusion:

Biological control of pests is the use of pathogens, predators and parasitoids to kill pests by reducing their populations or eliminating them completely. Biological control is generally regarded as most effective and sustainable way of pest management. Conservation of natural enemies, predators, parasitoids and microbial biocontrol agents can sustain the pest management alternative to chemical pesticides. Though biological control will not control all the insects at a time, it should be an integrative component of integrated pest management.

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