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Biological pest control: Advantages and challenges

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Plant pest control practices are dated back as old as farming itself. Annual economic losses due to pests are estimated in billions of dollars in the World. There are up to 10'000 insect, 100'000 pathogen, and 30'000 weed species competing human on agriculture. Chemical pesticides are large component of agricultural revolution. In recent years, however, increasing awareness of the impact of chemical pesticides use on the environment and human health has resulted in efforts to reduce reliance on chemical control. Many countries have instituted more strength regulations on pesticides, manufactures, registrations and uses. Therefore, the need for alternative pest control practices to reduce chemical pesticide use is evident. Under natural conditions and seasonal change, there are natural "checks and balances" on population of all living things. Weather is one of the important factors in natural death (too hot, too cold, too dry, or too wet), lack of food often causes death, and many organisms are killed by others organisms (predators, parasites, and pathogens (diseases organisms). When organisms are killed by other organisms with no interference or intervention by human is known as natural biological control. All pests have natural enemies and environmental constraints that limit their population size, providing natural control, that it is why we are not kneedeep in pests all the time [having pests of non economical importance (secondary or of less damage)]. Natural control is usually only noticed when it is lost. Loss of natural biological control results from the miss management practices *i.e.* indiscriminate use of pesticides, changes in agronomic practices, and alteration of habits, or lacking requirements of natural enemies. Biological control on other hand as it will be referring to it from this point involves human activities to enhance the effectiveness of the natural enemies. Biological control simply means the use of living organisms to suppress pest populations, making them less damaging than they would otherwise be. It can be used against all types of pests, including invertebrates, plant pathogens and weeds as well as insects.This definition is referred to what is known as "classical biological control". The new innovations and continuously developed techniques such as microbial and plant pesticides, transgenic crops, genetic engineering for improving natural enemies and utilization of ecological approaches whatever, refine biological pest control. These new innovations though are considered to be under the scope of biological pest control technologies. This article is indented to focus on concept and advantages of biological control technologies, and its practices, challenges and opportunities with emphasis on insect control.

The classical biological control:

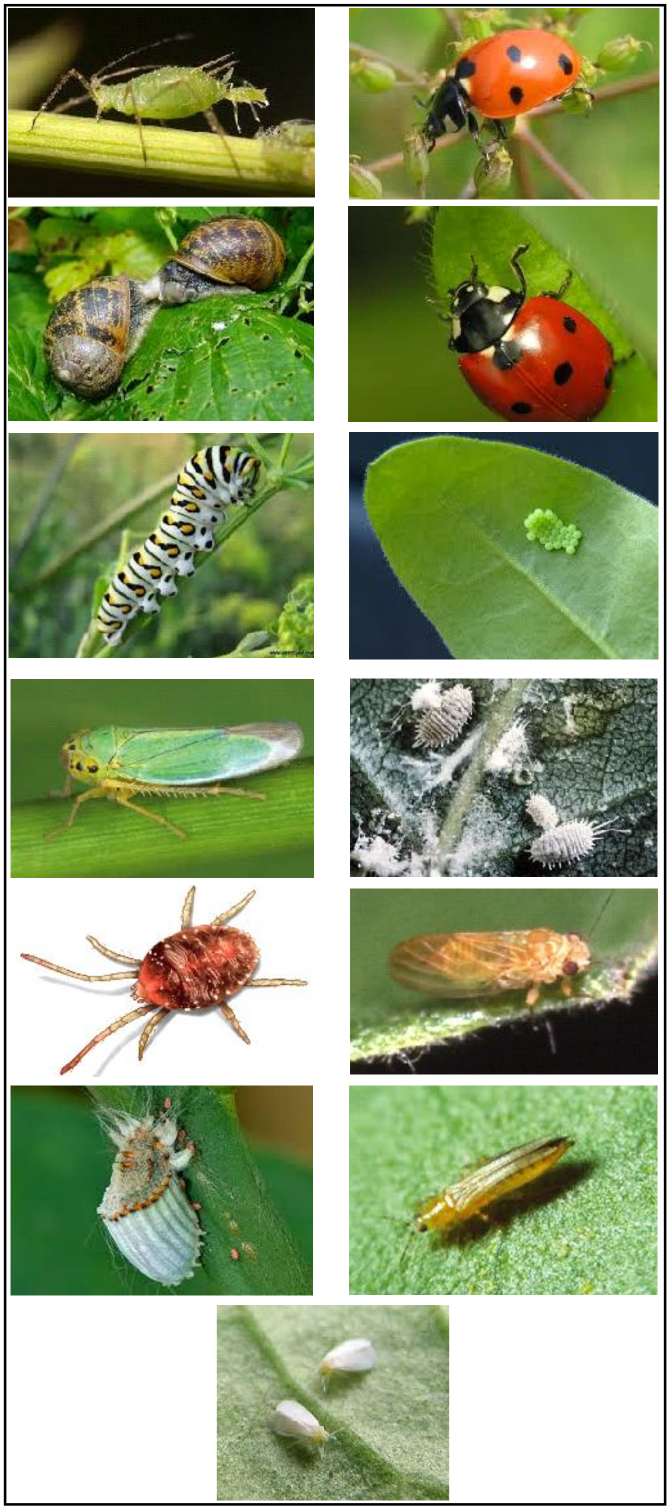
The early historical perspective: Biological control is not a new concept. It is dated back as early as 500 B.C., the Chinese were placing bamboo poles between nests of predaceous ant (*Oncophylla samadina*) and Citrus trees to make it easier for ants to prey on scale insects. In 1750's the British and French transported mynah birds form India to Mauritius to control locusts. Well taught that biological control projects were becoming numerous in the mid to late 1800's. Biological control in the Arab country Yaman was practiced by date palm growers in "Tihama" region long before the discovery of pesticides, the farmers in Yemen are used to transport nests of predatory ants from Africa to the date palm growing areas to control pests of dates. From the First World War until 1960's when pesticides were plentiful and cheap, biological control was somewhat forgotten. However, since 1960's the interest in biological control it has been renewed. The commercialized bio-control agents of insect pests are listed in Table 1.

Table 1 : Number of the natural enemies of the major insect pest groups that a tact most of the economic crops and natural vegetation

Pest	No. of natural enemy
Aphids	13
Beetles	5
Garden Snails	2
Bugs	6
Caterpillars	13
Insect eggs	5
Leaf hoppers	3
Mealy bugs	6
Mites	11
Psyllids	5
Scales	8
Trips	3
Whiteflies	7

Advantages: Biological control of pests offers a number of advantages over other pest control practices, particularly pesticides as follows:

– It is safe to the environment and the farmer and there are no residues.



– It is frequently economical, often we are manipulating something to favor naturally occurring control.

– It is usually permanent element (sustainable).

– Biological control agents are frequently host specific.

Weaknesses:

– It is often slow. If a pest population is already at

Table 2 : Commercialized predators of insect pests

Common name	Scientific name
Assassin bugs	Reduviidae family
Bigeyed bugs	*Geocoris* spp.
Brown lacewings	*Hemerobius* spp.
Convergent lady beetle	*Hippodamia convergens*
Damsel bugs	*Nabis* spp.
Decollate snail	*Rumina decollate*
Dustywings	*Conwentzia barrette*
Euseius tularensis	*Euseius tularensis*
Green lacewings	*Chrysopa* spp. *Chrysoperla* spp.
Mantids	Mantidae family
Mealybug destroyer	*Cryptolaemus montrouzieri*
Minute pirate bugs	*Orius* spp. *Anthocoris* spp.
Multicolored Asian lady beetle	*Harmonia axyridis*
Phytoseiulus persimilis	*Phtoseiulus persimillis*
Praying mantids	Mantidae family
Predaceous ground beetles	Carabidae family
Predaceous midge aphid midge	*Aphidoletes aphidimyzea*
Sevens potted lady beetle	*Coccinella septempunctata*
Six spotted thrips	*Scolothrips sexmaculatus*
Soldier beetles, leather-winged beetles	Cantharidae family
Spider mite destroyer lady beetle	*Stethorus picipes*
Syrphid flies	Syrphidae family
Twice stabbed lady beetle	*Chilocorus orbus*
Vedalia beetle	*Rodolia cardinalis*
Western predatory mite	*Galendromus occidentalis*
Assassin bugs	Reduviidae family
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or above economically damaging level, pesticides are frequently the only suitable answer. Careful advance planning however, is usually necessary for successful biological control.

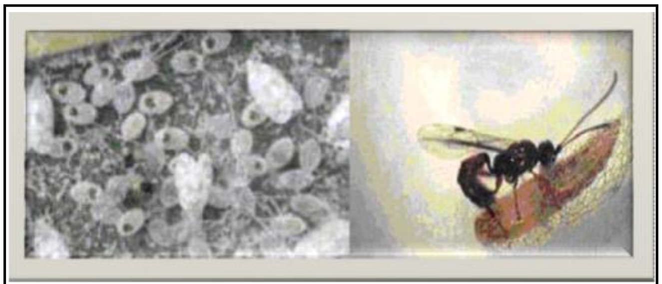

Plate 1 : Common parasitoids of insects

Plate 2 : Common predators of insects

– Biological control agents do not completely eradicate (eliminate) the host, if so, the two would die. Therefore we must get used to the idea of having a few of the pest species around. However biological control may be integrated with other pest - controls strategies to keep pests below economic levels.

– Crossing over may occur with biological control. That is the biological control agent may live on a desired plant or insect also. Careful selection of the control agent will minimize the problem.

– In the biological control of weeds, the biological control agents are frequently effective only in single - weed situations, and not in multi-weed complexes.

Natural enemies of insect pests:

There are three categories of natural enemies of insect pests:

Predators: Insect predation recognized at early stages, insects are an important media for many invertebrates and vertebrates, including birds, fish and mammals and other insects and spiders. These "insectivorous" are called predators. The predators are usually:

– Kill multiple prey and often both adults and immature stages are predaceous.

– Polyphagous (attack many species) or they may be fairly specific in what species or kind of prey they will attack.

– 200 families of insects and other arthropods are predators.

– Common in all habitants.

– Easily recognized predators such as ladybird beetles, wasps, beetles, spiders and lacewings.

– Less easily recognized- predaceous such of mites, syrphids and flies. Commercialized predators for insect control are listed in Table 2.

Parasites (Parasitoids): Insect parasitoids not recognized until the turn of the 17th century. Arthropods with an immature stage that develop on/or in an insect host, and ultimately their adults are free- living and/or predators. The parasites usually:

– Kill one pest insect when it develops from egg to adult.

Table 3 : Commercialized parasitoids of insect pests

Common name	Scientific name
Anaphes species	*Anaphes iole*, *Anaphes nitens* and other *Anaphes* spp.
Aphidius species	*Aphidius* spp.
Aphytis spp., armored scale parasites	*Aphytis* spp.
Bracon cushmani, grape leaffoder parasite	*Bracon cushmani*
Citrus mealybug parasite	*Leptomastix dactulopii*
Cotesia medicaginis, alfalfa butterfly parasite	*Cotesia medicaginis*
Cottony cushion scale parasite	*Crypotchaetum iceryae*
Elm leaf beetle parasite	*Erynniopsis antennata*
Hyposoter exiguae, caterpillar parasite	*Hyposoter exiguae*
Encarsia Formosa, whitelfly parasite	*Encarsia Formosa*
Lysiphlebus testaceipes, aphid parasite	*Lysiphlebus testaceipes*
Tachnid flies	*Tachinidae family*
Trichogramma spp., egg parasites	*Trichogramma* spp
Trioxys pallidus, walnut aphid parasite	*Trioxys pallidus*

– Almost always the immature stages that kill the host (prey).

– Primarily certain kinds of wasps and flies.

– More than one million species (60’000 Ichneumonid and 40’000 Brancondis).

– Have specialized life styles that allow them to find, attack and kill their hosts.

– Attack only one life stage of the host.

– Are less familiar and less easily recognized.

Commercialized parasitoids for insect control are listed in Table 3.

Microbial control:

Pathogens: Insect pests like other animals and plants are infected by pathogens (bacteria, fungi, protozoa, nematodes, mycoplasma and viruses) that cause diseases. Therefore, utilization of entomopathogenic microorganisms has become an integral part of biological control programs, because these agents are more selective and are highly specific to their pest hosts. Although the use of biotic agents are more than 80 years old, their developments have depended largely on the accumulated knowledge of the biology of such pathogens as viruses, bacteria, protozoa, and fungi (more than 100 species). Economically important results have been obtained mainly with viruses and bacteria during the last two decades against larvae of sawflies, Lepidopteran, Dipteran and Coleopteran-insects. Recent trends in microbial control found great similarity of methods of applications between pathogens and chemical insecticides which prompted the name “microbial insecticide”. However, some of the fundamental differences between them are evident in their spread and persistence, vectors, selectivity and safety, host resistance and evaluation of mortality figures.

Spread and persistence: The artificial spread of biotic agents by dusting and spraying is very similar to the application of chemical insecticides. Ground and aircraft equipment producing sprays, fogs, and dusts have been found useful depending on the special situation. The artificial spread of pathogens is recommended where natural spread will be insufficient because the density of the host population is too low to allow satisfactory natural spread. The availability of insect pathogens that can be produced in large masses for use on a commercial scale has shown remarkable progress. *B. thuringiensis* (Bt), *B. popilliae* and *B. lentimorbus*, as well as the fungus *Beauveria bassiana*, and the polyhedral and granular viruses are few examples of the interest to the farmers. Specifications have been developed for safety evaluation as well as for the data required on virulence against the target insect, specificity, processing and purification procedures. Production techniques of microbial pesticides have improved so much that costs are competitive with chemical insecticides. Repeated artificial spread is needed where pathogens do not persist naturally, however, there are diseases that can persist and are self-perpetuating, either unaided by man or after application.

Environmental persistence: The pathogen itself is highly resistant as for instance, viruses in inclusion bodies or bacteria and microsporidia in spores. This type of persistence against the influences of the environment might be compared to the long-lasting effect of insecticides such as chlorinated hydrocarbons, which remain active in the soil for years e.g. the Nuclear Polyhedral Viruses (NPV) of the cabbage looper (*Trichoplusia ni*) remain viable in the soil for several years. Industry has greatly improved several virus and *B. thuringiensis* preparations by specific formulations which utilize buffers or coating substances to increase their environmental persistence.

Biological persistence: Results from vector activity or from transmission of the pathogen from one generation to the next (vertical transmission). Such transmission occurs frequently with viruses and with microsporidia, more rarely with bacteria. The viruses of some sawflies and the microsporidiosis of the spruce budworm (*C. fumiferana*) are wellknown examples. This type of transmission, where it occurs, again demonstrates the great differences between biocontrol agents and chemical insecticides. There are frequently called short-term and long-term biocontrol agents, but transitions occur, *B. thuringiensis* usually obtains short-term control and is generally preferred for use near cities because of its harmlessness to man and animals. The general conclusion seems to be warranted that any search for new natural enemies in other areas should automatically include a search for pathogens from the target host and related species.

Vectors: In the transmission of diseases, predators or parasites may play a role as vectors. Vectors which naturally spread a disease are not easily assessed as to their efficiency. We know that the passage of some pathogens even through the intestinal tracts of such predators as voles, birds, and insects does not inhibit their infectivity. Parasitic Hymenoptera can transmit microorganisms into hosts, either when feeding or during egg deposition. The spread of pathogens from dead carcasses, from excrement, or in several other ways shows how an epizootic may be furthered by vector activity. As a matter of course, we judge the value of biotic agents by the direct mortality they produce. A special case of vector activity is that of the nematode *Neoaplectana carpocapsae*, commonly designated as DD-136. These worms carry insect-pathogenic bacteria. Apparently, the relationship is symbiotic. A wide range of insects is attacked by the nematode and subsequently by the septicemic infection.

Selectivity and safety: Some of the insect pathogens are highly specific and limited to one host species, as are several viruses of sawflies of coniferous trees. Others, like *Bacillus popilliae*, causing the milky disease of Japanese beetle grubs or *B. thuringiensis* infect a group of related species. *B. thuringiensis* primarily attacks open-feeding lepidopterous larvae, dipteran larvae and coleopteran larvae. This broader specificity is advantageous when it allows us to combat several pests with one pathogen. At the same time, beneficial insects are not affected and the natural balance is not disturbed as with long-lasting broad-spectrum insecticides. *Beauveria* fungi proved to be efficient biocontrol agent, too. Furthermore, all microbial preparations so far used against insects are safe to men and domestic animals. This removes the problem of toxic residues and of unintentional poisoning of vertebrates (including man) by careless handling of such preparations which contrasts with most insecticides.

Host resistance: The emergence of pests that are more or less tolerant to microbial pesticides is much more difficult to arise compared to chemical pesticide which encouraged the selection of genetic strains better able to survive their action. This because during the interplay of a chemical compound and a pest insect, the insect alone is capable of genetic change however, in the struggle between pathogen and host (insect), both have the possibility of changing - toward greater pathogenicity or greater tolerance, respectively. In addition, selection by pathogens is probably never as extreme as that by insecticides, because other natural enemies continue to exert pressure. Thus, theoretically, increased tolerance against pathogens should occur more rarely than against insecticides, or not at all. Actually, studies have shown that tolerance against some microorganisms can be increased by continuous laboratory selection, e.g. the large white butterfly *Pieris brassicae* became resistant to a granular virus. In nature, however, where the selection is neither so one-sided nor so enduring, reduced susceptibility of insect populations was never observed to be the permanent effect of high mortality by a pathogen. Although there is reason for an optimistic outlook, care has to be taken when pathogens like *B. thuringiensis* are cultured in an artificial medium for an immense number of generations. The counterbalance between pathogen and host is disrupted, and mutants of different pathogenicity may appear. Permanent supervision of such processes is required, to assess both their effect on insects and their harmlessness to warmblooded animals.

Evaluation of mortality figures: The differences between biological and chemical control methods are abundantly clear following application, when the effect of the treatment is measured. The interval between spraying and mortality is usually longer with pathogens and immediate mortality cannot be used to judge the value of the method. Not only the speed, but also the degree of mortality is sometimes lower after applications of microbial pathogens than after insecticides. In such cases, latently infected individuals are frequently needed to carry over the epizootic from one generation to the next.

General characteristics of the effective natural enemy:

A natural enemy must have a number of characteristics, in order to be successful used in a biological control program. These are:

– With the exception of pathogens, the natural enemy must have a high searching capacity.

– Distribution of the natural enemy must be similar to the distribution of the host.

– It would not perform to import a natural enemy into an area where it could not survive.

– The life cycle of the natural enemy should be in synchrony with that of the host.

– The natural enemy should have a high reproductive rate and short development period.

– The natural enemy must be easy to mass rear or grow under laboratory conditions.

– The natural enemy should be easy to disperse.

Adoption of biological control: There is a sequence of steps in the successful adoption of biological control that should be taken into consideration in any biological pest control project. These steps ensure that the so- called beneficial does not turn out to be a pest in itself. These steps are as follows:

Studying and literatures reviewing: The first step is to study the literatures and looking for other areas where the targeted pest is not of economic importance there (it is not a pest). One usually needs to look no further than the origin of the host plant. In their nature habitant, host and pest have usually reached a natural balance. When an area is found where host and pest live in harmony, research nearly always includes exploration for natural enemies. Finding effective natural enemies in the host plants native habitant concludes the first step.

Importation or introduction: The next step in the biological control process involves importation of the natural enemy (enemies) “introduction of exotic natural enemies to control pests”. This is because:

– Many of our worst pests are exotic - they become a problem because they arrive without their natural enemies.

– Most native natural enemies do not “switch” to the new species, so natural control doesn’t work in this case.

– Exotic natural enemy can establish between a pest and it's - standing natural enemy.

– Ideally is to return to the origin home of the pest and find one or more of the biotic factors that keep the population in check there. Importation involves a quarantine period for all imported organisms. Such question as where it can live and reproduce its spectrum of potential hosts etc. must be answered. This step is necessary so that we do not import "solutions" that become more serious" problems".

Augmentation: It means "adding numbers and/or kinds of natural enemies" (existing natural enemies may be present but not numerous or effective enough). Such a release may be used merely to improve the natural enemy/ pest ratio.

Approaches for augmentation:

Inundation:

– Mass rear and release natural enemy.

– Overwhelm the pest and provide a remedial, knockdown effect.

Inoculation:

– Release small numbers early in pest cycle.

– The natural enemy reproduces through a season and keeps pest numbers low over a longtime - usually over the season.

Conservation: Conservation means keeping or enhancing those natural enemies already present in the area. Through conservation practices, we create conditions that enable the control agent to stay and live in the target area. Knowing the biology and ecology of the natural enemies is important. This will enable us to provide suitable protective sites of survival, especially during the off seasons. Appropriate cultural practices and selective use of pesticides can help conserve natural and introduced biological control agents.

Tactic for conservation:

– Alter management favor practices such as strip cropping or poly culture.

– Alter harvesting or non- crop habitats.

– Alter using and timing of pesticides.

– Help natural enemies by provide food (non- host) like sugar, nectar or pollen sources.

– Landscaping, plant crop varieties that "friendly" to natural enemies.

Modern biotechnology and pest biological control: Biotechnology is the science of modifying genetic composition of plants, animals and microorganisms. Historically, biotechnology has relied on conventional plant and animal breeding practices to modify genetic composition. Modern biotechnology, however, relies on newer technique as genetic engineering to incorporate genetic material from one organism into another. Biotechnology has been applied to enhance pest control in a number of ways, including the following:

Plant-Incorporated Protectants (PIP's): Some plants and other organisms naturally contain protein or other chemicals that serve as a natural defense against pests. Such chemicals and proteins can also be introduced to plants either through the conventional breeding of sexually compatible plants or through techniques of modern biotechnology.

Genetically modified microbial pesticides: Genetically modified microbial pesticides by manipulations are directed to improve the performance of an engineered producer, whose DNA has been modified to express pesticide properties relative different to its "wild type" by:

– Broadening the target spectrum of the product.

– Increasing the speed of action of the product.

– Improving the delivery of the product to the pest.

Herbicide-tolerant crops: Weed control is one of the farmers' biggest challenges in crop production, because poorly controlled weeds drastically reduce crop yield and quality. To control weeds farmers often use broad-spectrum herbicides. Biotechnology has been applied to create crops that are resistant to certain herbicides. Herbicide tolerant crops contain new genes that allow the plant to tolerate these herbicides.

Improving pests natural enemies: This has focused principally on pathogens of insects emphasis has been placed on bacteria and viruses. Research has focused on increasing the host range and virulence of *Bacillus thuringiensis* (BT), and *Xenorhabdus* spp and insect's viruses.

Genetic improvement of biocontrol agents: Genetic improvement or enhancement of biological control agents would include all sorts of natural enemies; *i.e.* microbes, parasites and/or predators.

Natural populations of insects exist in a state of continuous change, dynamic, not only in numbers, sex ratios, age classes and other phenotypic changes, but also the genetic composition is modified by each individual that drops out or is born into the group. Artificial manipulation or selection of better strains of populations of insects has been tried in two directions: (a) to improve them; or (b) to make them less fit for survival. The breeding of predators or parasites varieties better suited to a certain purpose has long been exercised similar to what has been with domestic animals, including silkworms and honeybees. Improving the efficiency of predators or parasites by selection has been done in four steps *i.e.* (1) determination of characters that need improvement (2) provision of adequate genetic variability (3) satisfactory selection procedures and (4) maintenance of the integrity of the new strain in the field.

As mentioned above, the accumulation of as much genetic variability as possible is the modern basis for the importation of beneficial insects. From this pool, natural selection will preserve the strains that are superior under the prevailing environmental conditions. A good start, however, is necessary and the numbers released should be able to compete with the existing population.

Transgenic crops: Production of transgenic or genetically modified crops represents a new trend in biological control. In that respect, genes encode for potential insecticidal proteins are integrated into the plant chromosomes in which plants acquire resistance to pest damages; e.g. Bt genes in cotton. A number of potential benefits and risks are associated with the use of transgenic crops in agricultural production systems. Among the benefits cited are reductions in broad-spectrum insecticide use, improved suppression of target pests, improved yields, reductions in production costs, and increased opportunities for biological control. There are also potential risks, including out crossing through pollen drift, horizontal transfer of transgenes to other organisms, food safety, loss of susceptibility to Bt toxins in target pests, and direct or indirect detrimental effects on non-target organisms. A Three years comprehensive study (1999-2001) was completed to examine non-target effects of Bt cotton in Arizona, USA, with emphasis on the natural enemy complex. Replicated studies evaluated three criteria in paired: (1) Bt and non-Bt cotton plots (2) abundance and diversity of non-target organisms, and (3) effects on natural enemy function. Results failed to demonstrate any consistent or statistically-significant changes in any of these criteria in Bt cotton, emphasizing the economics and safe use of Bt-cotton plants. Analyses of collected data indicated that natural enemy abundance and overall arthropod diversity were not directly affected by transgenic cottons in comparison with non-transgenic cottons, but were affected by the use of additional insecticides for other pests. The study also confirmed that natural enemy function, measured as rates of predation and parasitism on two key pests (*Pectinophora gossypiella* [Saunders] and *Bemisia tabaci* [Gennadius]) of cotton in the western United States, is unaffected in Bt cotton. However, other food producing transgenic plants need more detailed studies to calm consumers and allay their fears. The classical biocontrol methods constituted of the three basic approaches importation, augmentation and conservation of natural enemies. However, the ever changing needs of pest management require continuous development of specific techniques within these approaches to meet new challenges. The use microbial pesticides, and transgenic plants, genetic improvement of natural enemies, utilization of new ecological theories, all will refine the adaptation of most appropriate biological control approaches and applications to be fulfill our needs. This leads us to adapt a comprehensive pest control strategy, namely: Integrated Pest Management Program (IPM).

Integrated pest control methods : Integrated Pest Management (IPM) is a process consisting of the balanced use of cultural, biological and chemical procedures that are environmentally compatible, economically feasible, and socially acceptable to reduce pest populations to tolerable levels. It has been successful in combating several pests under field conditions when applied, for example in the USA. practicing IPM can reduce the quantity of chemical pesticides entering the environment and can save money. IPM is based on taking preventive measures, monitoring the crop, assessing the pest damage and choosing appropriate actions. Many different tactics are used in IPM, including cultural practices, biological control agents, chemical pesticides, pest-resistant varieties and physical barriers.

Why practice IPM? : Here are some reasons for use of IPM than just the use of chemicals.

– *Keep a balanced ecosystem:* Every ecosystem, made up of living things and their non-living environment has a balance the actions of one creature in the ecosystem usually affect other, different organisms. The introduction of chemicals into the ecosystem can change this balance, destroying certain species and allowing other species (sometimes pests themselves) to dominate. Beneficial insects such as the ladybird beetle and lacewing larvae, both of which consume pests, can be killed by pesticides, leaving few natural mechanisms of pest control.

– *Pesticides can be ineffective:* Chemical pesticides are not always effective. Pests can become resistant to pesticides. In fact, more than 600 cases of pests developing pesticide resistance have been documented to date including common house flies, the Colorado potato beetle, the Indian meal moth, Norway rats and the greenhouse whitefly. Furthermore, pests may survive in some situations where the chemical does not reach pests, is washed off, is applied at an improper rate or is applied at an improper life stage of the pest.

– *IPM is not difficult to practice:* The steps used in IPM are similar to other ordinary control methods, farmers can figure out the problem (the pest), determined the extent of the damage and decided on the action to take.

– *Save money:* IPM can save money through avoiding crop loss (due to pests), and avoiding unnecessary pesticide expense.

– *Promote a healthy environment:* We have much to learn about the persistence of chemicals in the environment and their effect on living creatures. However, more cases of contaminated groundwater appear each year, and disposal of containers and unused pesticides still pose challenges for applicators. Even though long term documentation on the effects of all pesticides is still unavailable, it is generally agreed that fewer pesticides means less risk to surface water and groundwater, and less hazard to wildlife and humans.

– *Maintain a good public image:* Recent public outcry about the use of growth regulators and the presence of pesticide residues on produce has heightened pesticide applicator awareness of the level of public concern about chemicals. Growing food under integrated pest management can help calm public concerns.

Challenges to biological pest control: There are many and different constrains on the way of biological control, these can be summarized in:

– Less numbers of laboratories, equipments, tools and facilities required for biological pest studies.

– Lack of professional extension services in biological control.

– Economic constrains.

– Institutional constrains.

– Insufficient supported regulations and legislations.

– Strong influence of pesticide industry and trading.

– Absence of proper incentive.

Opportunities to biological control:

– It is well documented that adoption of biological pest control increases the ecological and economic sustainability of farming systems by reducing both risk of crop losses and human health from pesticide use.

– Most or even all regions have strong and well designed quarantine laws and facilities.

– The India has various geographical environmental and rich biodiversity (flora and fauna).

– Registration number of natural enemies' might reach hundreds with proved capabilities and performance.

– There are successful examples in biological control in the region, despite its limited number.

– Investment in commercial production projects of biological control agents and products are profitable worldwide.

Suggestions for successful biological control: Successful biological pest control is not an easy business without authentic research on pests, crop and other components of the agro-system. Agro- system from one location to another can not be the same reliance on effective biological control is the first step towards successful integrated pest management programs. It is therefore, suggested that the agricultural policy makers, research centers, investors and developers are be prepared to share the successful of biological control through:

– Taking responsibility and accountability concerning the following questions:

– Does the intervention reduce the risk of crop losses to a level that is acceptable to farmers?

– What is the environmental impact?

– Is there an impact on human health?

– Establishing more number of reference center for promotion biological control technologies, such center must be linked to a network of satellite research facilities located allover country.

– Establishing enough laboratories of bio-control agents mass' rearing.

– Adopting strong and efficient capacity building programs, training services and effective extension in order to help transfer and disseminate biological practices to all beneficiaries.

– Encouraging and supporting the investment projects in biological control technologies (production, trading, services commercialization).

– Adopting an intellectual property rights and issuing proper registration and regulation laws.

Conclusion: In conclusion, the classical biocontrol methods constituted of the three basic approaches: importation, augmentation and conservation of natural enemies. However, the ever changing needs of pest management require continuous development of specific techniques within these approaches to meet new challenges. The use of microbial pesticides and transgenic plants, genetic improvement of natural enemies, utilization of new ecological theories, all will refine the adaptation of most appropriate biological control approaches and applications to be fulfill our needs. This leads us to adapt a comprehensive pest control strategy, namely Integrated Pest Management Program (IPM).

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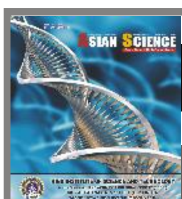
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