Integrated Pest Management (IPM) Principles

1. What is IPM?

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

2. How do IPM programs work?

IPM is not a single pest control method but, rather, a series of pest management evaluations, decisions and controls. In practicing IPM, growers who are aware of the potential for pest infestation follow a four-tiered approach. The four steps include:

- **Set Action Thresholds**

Before taking any pest control action, IPM first sets an action threshold, a point at which pest populations or environmental conditions indicate that pest control action must be taken. Sighting a single pest does not always mean control is needed. The level at which pests will either become an economic threat is critical to guide future pest control decisions.

- **Monitor and Identify Pests**

Not all insects, weeds, and other living organisms require control. Many organisms are innocuous, and some are even beneficial. IPM programs work to monitor for pests and identify them accurately, so that appropriate control decisions can be made in conjunction with action thresholds. This monitoring and identification removes the possibility that pesticides will be used when they are not really needed or that the wrong kind of pesticide will be used.

- **Prevention**

As a first line of pest control, IPM programs work to manage the crop, lawn, or indoor space to prevent pests from becoming a threat. In an agricultural crop, this may mean using cultural methods, such as rotating between different crops, selecting pest-resistant varieties, and planting pest-free rootstock. These control methods can be very effective and cost-efficient and present little to no risk to people or the environment.

- **Control**

Once monitoring, identification, and action thresholds indicate that pest control is required, and preventive methods are no longer effective or available, IPM programs then evaluate the proper control method both for effectiveness and risk. Effective, less *risky* pest controls are chosen first, including highly targeted chemicals, such as pheromones to disrupt pest mating, or mechanical control, such as trapping or weeding. If further monitoring, identifications and action thresholds indicate that less risky controls are not working, then additional pest control methods would be employed, such as targeted spraying of pesticides. Broadcast spraying of non-specific pesticides is a last resort.

3. Do most growers use IPM?

With these steps, IPM is best described as a continuum. Many, if not most, agricultural growers identify their pests before spraying. A smaller subset of growers use less risky pesticides such as pheromones. All of these growers are on the IPM continuum. The goal is to move growers further along the continuum to using all appropriate IPM techniques.

4. How do you know if the food you buy is grown using IPM?

In most cases, food grown using IPM practices is not identified in the marketplace like *organic* food. There is no national certification for growers using IPM, as the United States Department of Agriculture has developed for organic foods. Since IPM is a complex pest control process, not merely a series of practices, it is impossible to use one IPM definition for all foods and all areas of the country. Many individual commodity growers, for such crop as potatoes and strawberries, are working to define what IPM means for their crop and region, and IPM-labeled foods are available in limited areas. With definitions, growers could begin to market more of their products as *IPM-Grown*, giving consumers another choice in their food purchases.

5. If I grow my own fruits and vegetables, can I practice IPM in my garden?

Yes, the same principles used by large farms can be applied to your own garden by following the four-tiered approach outlined above. For more specific information on practicing IPM in your garden, you can contact your state Extension Services for the services of a Master Gardener.

Pesticides and Food: What "Integrated Pest Management" Means

Age-old, common-sense practices are what many people associate with IPM. Today many growers no longer apply pesticides to food on a regular basis regardless of whether or not there are insects, weeds, or other pest problems. In some parts of the country, food is being marketed as IPM food. Some practices for preventing pest damage may include: inspecting crops and monitoring crops for damage, and using mechanical trapping devices, natural predators (e.g., insects that eat other insects), insect growth regulators, mating disruption substances (pheromones), and if necessary, chemical pesticides. The use of biological pesticides is an important component of IPM.

In technical terms, Integrated Pest Management (IPM) is the coordinated use of pest and environmental information with available pest control methods to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property, and the environment.

NEEM

Biopesticides are pesticides with living organism which intervene in life cycle of the insect pest and will kill it by causing diseases. Biopesticides are important in ecofriendly pest management. Many synthetic insecticides used during the last 40 years in Agriculture, forestry & household do not fulfill the requirement for IPM. Application of synthetic pesticides in crop protection has not only contributed effective management of insect pests but also lead to development of resistance against that insecticides & contamination of ground water and food stuffs. Neem, the versatile tree having many good and useful qualities is indigenous to India from where it has spread too many Asian & African countries. Neem and its allelo chemicals have variety of effect on pests.140 active components have been identified to date that occur in different parts of tree. The most important component identified has been the tetratripernoids the azadiractin It has low risk of pest resistance due to different mode of action, specific effect on pests. It specifically acts on Lepidopterons.

Advantages

· Insect die due to starvation

· Deterrence of growth

· Egg sterility

·Interference in the process of Oviposition

Uses

· Ideal for IPM

· Neem oil can be used for seed treatment

· Neem cake can be used to control soil borne pest.

Simple domestic preparation

1.Collect Neem seeds

2.Dry them in shadow

3.Grind it

4.Then prepare aqueous extract by 5.dissolving 50g of grounded seed in 1 liter of water

6.Soak it overnight

7.Use that water for spraying to control pests

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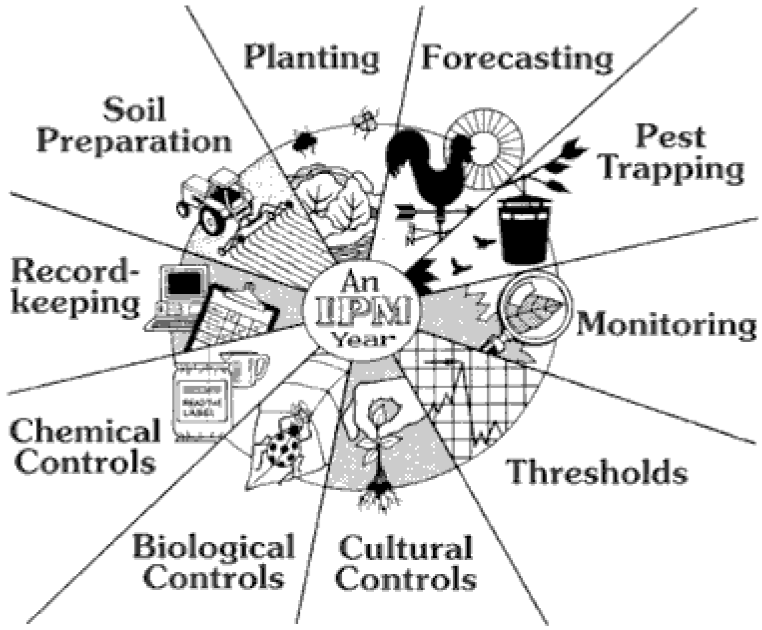
Figure 1 Six components of the Hawaii Area-Wide Integrated Pest Management Program.

What is Integrated Pest Management (IPM)?

IPM is an approach to solving pest problems by applying our knowledge about pests to prevent them from damaging crops, harming animals, infesting buildings or otherwise interfering with our livelihood or enjoyment of life. IPM means responding to pest problems with the most effective, least-risk option. Under IPM, actions are taken to control pests only when their numbers are likely to exceed acceptable levels. Any action taken is designed to target the troublesome pest, and limit the impact on other organisms and the environment. Applying pesticides to crops, animals, buildings or landscapes on a routine basis, regardless of need, is not IPM. Applications of pesticides are always the last resort in an IPM program.



"IPM Year" graphic and text courtesy of Cornell University.

Soil Preparation: Growers give their plants a head start on pest problems by choosing the proper site, testing the soil, rotating crops, creating raised beds where necessary, and providing sufficient organic matter.

Planting: Growers plant crops that tolerate common problems, altering planting time and spacing to discourage certain diseases and insects.

Forecasting: Weather data are consulted to predict if and when pest outbreaks will occur. Treatments can then be properly timed, preventing crop damage and saving sprays.

Pest Trapping: Traps that are attractive to insects are used so that growers can pinpoint when the pest has arrived and decide whether control is justified.

Monitoring: Growers inspect representative areas of the fields regularly to determine whether pests are approaching a damaging level.

Thresholds: Before treating, growers wait until pest populations reach a scientifically determined level that could cause economic damage. Until that threshold is reached, the cost of yield and quality loss will be less than the cost for control.

Cultural Controls: The pest's environment it then disrupted by turning under crop residues, sterilizing greenhouse tools, and harvesting early.

Biological Controls: It is necessary for growers to conserve the many beneficial natural enemies already at work. They import and use additional biologicals where effective.

Chemical Controls: Growers select the most effective and appropriate pesticide and properly calibrate sprayers. They then verify that weather conditions will permit good coverage without undue drift.

Recordkeeping: Records of pest traps, weather and treatment are kept for use in pest management decisions.

Who can use IPM?

Anyone who deals with pest problems can use IPM. Farmers, buildings and grounds maintenance personnel, professional pest control operators, and home dwellers can learn how to apply least-risk solutions to prevent pest trouble or respond to problems when they arise.

What are pesticide hazards?

Pesticide hazards include acute, immediate toxicity to humans and other non-target organisms; chronic or long-term toxicity such as cancer; and potential to contaminate air, or ground and surface water. Information on many of these potential hazards for specific pesticides can be found on pesticide labels, Material Safety Data Sheets (MSDS) and resources such as www.pesticideinfo.org.

Recent studies documenting the need for continued reductions in hazardous pesticide use and practices include the Heinz Center evaluation of our nation's ecosystems in 2002, reporting that seventy-five percent of streams tested had more than five pesticide contaminants. A 2006 US Geological Survey review of 51 studies over ten years reported that 96% of fish, 100% of surface water, and 33% of major aquifers sampled from 1992 to 2001 contained one or more pesticides. Nearly 10% of stream sites and 1.2% of ground water sites in agricultural areas, and 6.7% of stream and 4.8% of ground water site in urban areas contained pesticides at concentrations exceeding benchmarks for human health derived from US EPA standards and guidelines for drinking water.

The adult human body is similarly contaminated with pesticides, pesticide-related compounds and other synthetic chemicals. A 2002 study led by Mount Sinai School of Medicine researchers found an average of 91 industrial compounds, pollutants and other chemicals in the blood and urine of nine volunteers. A total of 167 chemicals were found in these individuals, none of whom worked with chemicals occupationally or lived near industrial facilities. Of the 167 chemicals found, 17 were pesticides or pesticide breakdown products. Seventy-six were carcinogens, 94 neurotoxins, and 79 developmental or reproductive toxins.

Pests can also become resistant to pesticides, increasing control costs, crop losses or other pest damage. Many natural enemies of pests are killed by pesticides, freeing pests from these natural controls.

According to a US General Accountability Office report in 1999, information is currently not collected to fully document the extent of pest problems and pesticide use. Data on impacts of pest infestation and pesticide use on children as well as the general public are lacking. Data of short-term illnesses due to pesticide exposure are limited. Documentation would be difficult to obtain even if concerted efforts were made due to the multiple potential causes for short and long-term symptoms and illnesses associated with exposure to pests and pesticides. These unknown or poorly understood potential hazards argue for additional levels of protection including exposures to multiple pesticides, at home, at school and in the diet; exposure to chemicals in combination with pesticides such as pharmaceuticals, industrial compounds and personal care products; and the general difficulty in attributing chronic illnesses to any one particular cause.

Pesticides are powerful tools for responding to persistent pest problems. It's not smart, effective or affordable to use these tools when they are not necessary. Using IPM to prevent pest problems and minimize reliance on pesticides is the best solution for a healthy en

Are all pesticides bad?

Most pesticide problems are caused by a small number of the pesticides available today. Many low hazard pesticides are available, and more are being developed each year from both naturally occurring and synthetic materials. However, pesticide use without regard to need or potential hazard is always a poor choice, and rarely solves pest problems.

Improvements in pest management are needed, and pesticides will likely always be a part of the solution. According to the World Health Organization (WHO), malaria continues to kill more than 1 million annually.

Asthma incidence and asthma-associated morbidity is increasing in inner city children in the U.S. Asthma is associated with cockroach allergen sensitivity and exposure as well as exposure to pesticides. (Download a review of pest and pesticide associations with asthma in PDF format.)

Other persistent and emerging pest problems include vectored human and animal diseases such as West Nile virus, Eastern equine encephalitis and Lyme disease; plant pests and diseases such as emerald ash borer and soybean rust; and more than 170 noxious aquatic, terrestrial or parasitic weeds continue to challenge pest managers in the U.S. and elsewhere, and demand effective pest management measures.

Since 2003, the majority of new pesticide registrations have met criteria set by EPA for "reduced risk" including lower hazards to human health and non-target organisms, and reduce potential for contamination of groundwater, surface water, and other environmental resources. These EPA "reduced risk" pesticides include biopesticides, which are naturally occurring substances, microorganisms, or pesticidal substances produced by plants containing genetic material introduced specifically to control pests.

How does IPM reduce hazards?

IPM reduces hazards by reducing overall pesticide use, using least hazardous pesticides when there is a demonstrated need, and taking special protective measures to reduce pesticide exposure living organisms and the environment.

How does IPM differ from Organic?

IPM allows the use of pesticides, fertilizers and other materials made from synthetic materials when necessary. Organic programs largely restrict allowable pesticides to those made from natural materials. Pesticides used in organic programs can also have harmful effects on humans, animals and the environment, and must be used carefully and only when needed. IPM strategies can also help organic programs reduce hazards.

What is "IPM Certification"?

Certification implies that a professional, product or service meets a well-defined standard. Certification can be a powerful tool to demonstrate to customers, neighbors and peers in your profession that your pest management practices meet the highest standards for reduced hazard and effectiveness.

Many programs include IPM as a standard that must be met prior to certification. Not all programs require IPM performance to the same degree - some programs have minimal IPM requirements and other truly seek to identify top IPM performers. For an independent rating of many certification programs addressing pest management, visit www.ecolabels.org.

The IPM Institute has worked with public agencies, non-governmental organizations and industry to develop and implement meaningful programs incorporating IPM standards. Clients have included Food Alliance, Protected Harvest, SYSCO Corporation and the Universities of Wisconsin, Florida, Cornell and Rutgers.

The concept and components of integrated pest management

INTRODUCTION

The goal of development is to maximize the use of energy, natural resources, capital and scientific information for the welfare of mankind. However, the process of developing agricultural production, water resource management, improvement of health and other activities of mankind, create an environment favorable to the development of organisms competing with man. This organism is designated as a pest but such a designation is not static, since a pest may be damaging and edible at the same time. For example, crickets and grasshoppers are acceptable as food by some people, but can be a curse to rice farmers.

A pest problem exists when an organism interferes with human activities or desire, or otherwise competes with man. To rationally minimize or control pest depredations, an holistic approach to suppression is emphasized. The control strategy that has subsequently evolved is called Integrated Pest Management (IPM).

PHILOSOPHY OF INTEGRATED PEST MANAGEMENT

IPM brings together into a workable combination the best strategies of all control methods that apply to a given problem created by the activities of pests. IPM has been defined in various ways but a more scientific definition describes it as, "the practical manipulation of pest populations using sound ecological principles to keep pest populations below a level causing economic injury". The emphasis here is "practical" and "ecological". There are many ways of controlling insect pests but only a few are practical, and fewer are ecologically sound, such that an undesirable citation is created.

Another term we frequently encounter is "intergrated pest control". It is offer used interchangeably with IPM, though in the strictest sense these terms are not identical. Originally, integrated control simply meant modifying chemical control in such a way as to protect the beneficial insects and mites, or integrating chemical and biological control methods. Subsequently the concept was broadened to include all suitable methods that could be used in complementary ways to reduce pest populations and keep them at levels which did not cause economic damage. This essentially is IPM It includes a variety of options, any one of which may not significantly reduce the Pest population, but the sum total of which will give adequate reduction to prevent economic losses. A modern definition of IPM may be-the use of all available tactics in the design of a program to manage, but not eradicate pest population so that economic damage and harmful environmental side effects are minimized.

IPM is not a static, unyielding system. It is dynamic, ever-changing, as we develop a better understanding of all factors that affect the system. These factors include climate, alternate host plants, beneficial insects and man's activities. In a narrow sense, IPM means the management of the few important pests generally found on our crops, but consciously or not it must include all insect pests, not only the "key" ones but also the secondary pests, which seldom do any harm. If this were not so, we might suddenly find some of these minor insect pests or even non-pests elevated to the status of serious insect pests because of our failure to consider them in the total scheme.

IPM as a concept is not new, but one that is receiving new emphasis as man looks for better methods to grow and store food for an expanding population, and at the same time preserve his environment. The rationale for using IPM is threefold. First, it can cut production costs mainly by reducing energy inputs. Secondly, IPM can reduce environmental contamination through the judicious use or reduced use of pesticides. And finally, an IPM program allows for maximum utilization of cultural practices and natural enemies (for plant pests) and physical methods (for storage pests). IPM can be designed to take advantage of the ecological principles governing pest population abundance. This requires a thorough understanding of the role of all the factors responsible for a pest population reaching certain levels at a particular time of the year, or duration of storage.

ELEMENTS OF IPM

There are four basic elements of IPM: natural control, sampling economic levels, and insect biology and ecology.

The first element of IPM relates to the fullest utilization of naturally occurring suppressive factors, including any practice by man which will make the total ecosystem less favourable for growth of the insect pest population. Obviously, this requires a thorough understanding of the ecosystem.

The naturally occurring suppressive factors may act directly or indirectly on pest populations. Indirectly, the ecosystem may be managed or altered in such ways as to make the environment more harmful to the pest and thus limit population growth. More directly, protection and the use of beneficial insects may help keep potentially damaging insect pest populations at subeconomic levels In storage, parameters that can be manipulated to control the buildup of a pest population are temperature, relative humidity, moisture content and composition of gases within the storage atmosphere.

The second element is that of using sound economic threshold (ETL) levels as the basis for applying control measures, especially chemical measures. Establishing and using dynamic ETL's provide a basis for delaying the use of insecticides. This permits the maximum utilization of other control methods, such as the use of beneficial insects.

The use of economic threshold levels implies adequate sampling of all harmful and beneficial insects in the agroecosystem and particularly in any one crop at a given time. The levels found through sampling must then be measured against the economic level established for the crop, the beneficial insects, and the probable population trend of the pest species. The sampler thus becomes a key person in an IPM system.

The fourth element, insect biology and ecology, is essential to the fullest utilization of the other three elements. Little concerning natural control can be understood without detailed knowledge of the biology and ecology of all the species present. This knowledge is also essential in establishing the role of each species in the system and in deermining the amount of damage inflicted by each pest species. Adequate sampling is directly dependent a thorough familiarity of the species involved.

Knowledge of the biology of a certain problem pest will serve as a basis for planning the control strategies and provide operational guidelines for these strategies. In this context, it is important to know the relationship between the pest and the crop (crop life tables) and the mortality factors (pest life tables), both biotic and abiotic (parasites, predators, temperature, relative humidity) which play a major role in the determination of pest population dynamics.

An understanding of the sequential dominance of pests in relation to growth stages could provide the immediate impetus for developing a simple integrated control program based on minimum pesticide application (Rejesus, 1976). By delineating the succession of major pests at different stages of plant growth (or storage time for stored products), the frequency, timing and dosage of insecticide application could be synchronized, hence avoiding pesticide use on a time-wise basis, or the "calender" method. The control program could then be based on expected pest population at any given growth stage of storage duration.

COMPONENTS OF IPM

Five general types of single component control methods may be used in IPM programs in stored ecosystems. These are: chemical control, physical and mechanical methods, biological control, host plant resistance and regulatory control.

Chemical Control:

A variety of insecticides and acaricides have been and are continuously being developed for control of insect pests. However, these chemicals are but one tool and should be used in combination with other tactics in an IPM program. The total reliance on chemicals has led to a crisis situation (including pest resurgence, insect resistance, secondary pest outbreaks, environmental contamination, and hazards to human health). However, IPM does not advocate the complete withdrawal of pesticides. That would be impractical. IPM simply demands use of pesticide only when necessary and at rates compatible with other strategies.

Physical and Mechanical Methods:

Physical and mechanical methods are direct or indirect (non-chemical) measures that completely eliminate pests, or make the environment unsuitable for their entry, dispersal, survival and reproduction. Physical-mechanical control measures may include environmental manipulation (temperature, relative humidity, control atmosphere), mechanical barriers, light taps, irradiation, thermal disinfestation, sanitation, etc. Many times, mechanical and physical methods require considerable extra equipment, materials and labor, hence, they may only be economical in certain situations. For field pests, these methods are rather inefficient but in a storage ecosystem, many of the physical techniques are effective and have great potential for use in an IPM system.

Biological Control:

Biological control may be defined in a narrow sense as "the manipulation of predators or patho. yens to manage the density of an insect population". This definition does not include the naturally occurring control agents, but only parasitoids, predators and pathogens that are purposely manipulated by man. In a broader sense, it includes "the manipulation of other biological facets of the pest life system, such as its reproductive processes (i.e. sterile male technique), its behavior (pheromanes), the quality of its food and so forth."

There are some constraints to the potential use and success of natural enemies. Predators, parasites and pathogens found amongst the grain will be regarded as contaminants by consumers and grain exporters. Thus, it makes it very difficult to maintain a pest population level that will enable the biological control agents to establish themselves. The use of pheromones is one of the potentially useful biological agents that could be utilized in IPM for monitoring and partially suppressing pest population not only in agricultural fields but in storage ecosystems.

Host-Plant Resistance:

The manipulation of the genetic make up of the host so that it is resistant to pest attack is called host plant resistance. Over the years there have been numerous successes in breeding for resistance to a variety of pests and currently many crops are being selected for this purpose.

This approach has not been attempted to any great extent in stored products protection systems Investigations in this field have been few. However, research (mainly of rice, maize, wheat) has provided evidence of the utility of varietal resistance in grain storage. Unless research on varietal resistance to storage pests is integrated with breeding of plants that are resistant to field insect pests and deceases the potential of this tactic in storage IPM is limited.

Regulatory Control:

Fundamental regulatory control principles involve preventing the entry and establishment of foreign plants and animal pests in a country or-area, and eradicating, containing or suppressing pests already established in limited areas. Under the auspices of various quarantine acts, numerous control measures are implemented in an attempt to exclude potential pests, to prevent spread and to supplement eradication programs. Ports of entry are the first line of defense against the introduction of new pests. Pests which break through the port of entry are eradicated or contained within limited areas. Quarantine action is used only against insects of economic importance, although it is sometimes necessary to contain insects which are of no economic importance in another country until their behavior in a new environment can be studied

Trogoderma granarium is a most serious pest of stored commodities and every effort is extended to prevent its spread in international trade. In many countries, imported consignments found to contain J. granarium are segregated and immediately fumigated with methyl bromide (at a dosage of 80 9/cu^3 m for 48 hours). Lately, Prostephanus truncates originating from Central America has become a pest of international quarantine importance.

Component Integration:

Each of the many methods in insect control has its place in IPM. There are many situations where two or more can be used in an integrated program. Not all methods, however, are suitable for use in every situation.

In a storage ecosystem, hygiene and good warehouse management are essential. It provides the framework for other supplementary infestation control methods. An IPM system would therefore supplement sanitation and good warehouse keeping with one or more combination of the following practices:

1. improved harvesting and threshing techniques
2. judicious use of residual insecticides
3. use of fumigants (MeBr; PH_3)
4. use of ambient aeration, and refrigerated aeration
5. atmospheric gas modification (hermetic; CO_2; N_2)
6. thermal disinfestation
7. irradiation techniques
8. insect resistant packaging
9. insect growth regulators: (IGRs: methoprene, hydroprene)
10. biological control (parasites, predators and entomopathogens, pheromones)
11. Use of resistant varieties if possible
12. Storage management (FIFO)
13. Adequate grain cleaning prior to storage storage.
14. Storage design (for pest exclusion, principally for rodont and bird pests)
15. Adequate grain cleaning prior to storoge
16. Monitoring, evaluation and inspection of stored commodities, storage structures and their immediate surroundings.

Biopesticide

Biopesticides include "naturally occurring substances that control pests (biochemical pesticides), microorganisms that control pests (microbial pesticides), and pesticidal substances produced by plants containing added genetic material (plant-incorporated protectants) or PIPs

Biopesticides are biochemical pesticides that are naturally occurring substances that control pests by nontoxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pests. For example, a plant in the presence of chitosan will naturally induce systemic resistance (ISR) to allow the plant to defend itself against disease, pathogens and pests Biopesticides are considered eco-friendly and easy to use. In the USA, the EPA regulates the registration and use of earth friendly biopesticides.

Biopesticides are key components of integrated pest management (IPM) programmes, and are receiving much practical attention as a means to reduce the load of synthetic chemical products being used to control plant diseases.

Overview

Biopesticides fall into three major classes:

- Microbial pesticides which consist of bacteria, entomopathogenic fungi or viruses (and sometimes includes the metabolites that bacteria or fungi produce). Entomopathogenic nematodes are also often classed as microbial pesticides, even though they are multi-cellular.
- Plant-incorporated protectants (PIPs) have genetic material from other species incorporated into their genetic material (*i.e.* GM crops).
- Biochemical pesticides are naturally occurring substances that control pests by nontoxic mechanisms.

Biopesticides have usually no known function in photosynthesis, growth or other basic aspects of plant physiology; however, their biological activity against insect pests, nematodes, fungi and other organisms is well documented. Every plant species has developed a built-in unique chemical complex structure that protects it from pests. The plant kingdom offers a diverse array of complex chemical structures and almost every imaginable biological activity. These biodegradable, economical and renewable alternatives are used especially under organic farming systems.

Biopesticides, key components of integrated pest management (IPM) programmes, are receiving much practical attention as a means to reduce the load of synthetic chemical products being used to control plant diseases. In most cropping systems, biological pesticides should not necessarily be viewed as wholesale replacements for chemical control of plant pests and diseases, but rather as a growing category of efficacious supplements that can be used as rotation agents to retard the onset of resistance to chemical pesticides and improve sustainability. In organic cropping systems, biopesticides can represent valuable tools that further supplement the rich collection of cultural practices that ensure against crop loss to diseases.

Examples

Biopesticides are natural plant products belonging to the so-called secondary metabolites, which include thousands of alkaloids, terpenoids, phenolics and minor secondary chemicals. Biopesticides are derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides. At the end of 2001, there were approximately 195 registered biopesticide active ingredients and 780 products. Commonly these are bacterial, but there are also examples of control agents based on fungi, viruses and nematodes. Weeds and rodents have also been controlled with microbial agents. An example from India is Bt cotton.[5]

Various naturally-occurring materials, including fungal or plant extracts, have been described as biopesticides.[6] Products in this category include:

- Chitin
- Chitosan
- Spinosad
- Insect pheromones and other semiochemicals

Bacillus thuringiensis, a bacterial disease of Lepidoptera, Coleoptera and Diptera, is a well-known insecticide example. Because it has little effect on other organisms, it is considered more environmentally friendly than synthetic pesticides. The toxin from *Bacillus thuringiensis* (Bt toxin) has been incorporated directly into plants through the use of genetic engineering.

Other microbial control agents include products based on:

- entomopathogenic fungi (*e.g.Beauveria bassiana, Lecanicillium* spp., *Metarhizium* spp.),
- plant disease control agents: include *Trichoderma* spp. and *Ampelomyces quisqualis* (a hyper-parasite of grape powdery mildew); *Bacillus subtilis* is also used to control plant pathogens.

- beneficial nematodes attacking insect (*e.g. Steinernema feltiae*) or slug (*e.g. Phasmarhabditis hermaphrodita*) pests
- entomopathogenic viruses (*e.g.*. *Cydia pomonella* granulovirus).

Applications

Biopesticides are typically microbial biological pest control agents that are applied in a manner similar to chemical pesticides. In order to implement these environmentally-friendly pest control agents effectively, it can be important to pay attention to the way they are formulated[8] and applied.[9]

Biopesticides for use against crop diseases have already established themselves on a variety of crops. For example, biopesticides already play an important role in controlling downy mildew diseases. Their benefits include: a 0-Day Pre-Harvest Interval (see: maximum residue limit), the ability to use under moderate to severe disease pressure, and the ability to use as a tank mix or in a rotational program with other registered fungicides. Because some market studies estimate that as much as 20% of global fungicide sales are directed at downy mildew diseases, the integration of biofungicides into grape production has substantial benefits in terms of extending the useful life of other fungicides, especially those in the reduced-risk category.

A major growth area for biopesticides is in the area of seed treatments and soil amendments. Fungicidal and biofungicidal seed treatments are used to control soil borne fungal pathogens that cause seed rots, damping-off, root rot and seedling blights. They can also be used to control internal seed–borne fungal pathogens as well as fungal pathogens that are on the surface of the seed. Many biofungicidal products also show capacities to stimulate plant host defenses and other physiological processes that can make treated crops more resistant to a variety of biotic and abiotic stresses.

Advantages

- Do not leave harmful residues
- Substantially reduced impact on non-target species
- Can be cheaper than chemical pesticides when locally produced.
- Can be more effective than chemical pesticides in the long-term
  Disadvantages
- High specificity, which will require an exact identification of the pest/pathogen and may require multiple pesticides to be used
- Often slow speed of action (thus making them unsuitable if a pest outbreak is an immediate threat to a crop)
- Often variable efficacy due to the influences of various biotic and abiotic factors (since biopesticides are usually living organisms, which bring about pest/pathogen control by multiplying within the target insect pest/pathogen)
- Living organisms evolve and increase their resistance to biological, chemical, physical or any other form of control. If the target population is not exterminated or rendered incapable of reproduction, the surviving population can acquire a tolerance of whatever pressures are brought to bear, resulting in an evolutionary arms race.