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BACTERIAL, VIRAL, FUNGAL PLANT PATHOGENS

The science, which is concerned with the study of plant diseases and their causes, is known as plant pathology. Therefore, all scientists concerned with this science constantly attempt to treat the diseased plants via various methods. This approach of scientific research is very important owing to the economic and hygienic yield for humans and animals. The phytopathogens are two types: biotic factors, which include all microbes and parasitic plants, and abiotic factors, which include all environmental factors. Essentially, the plant pathology is correlated with other sciences such as entomology, bacteriology, mycology, virology, and weed science due to deleterious effects of insects, bacteria, fungi, viruses/viroids, and weeds on plants, respectively. The first step of plant disease treatment is observation of definite and clear symptoms on the plants.

These symptoms give an initial indication for the type and cause of plant disease, which may end with the death. The modern approach of plant disease control depends on biological control agents such as the production of antimicrobial agents and the production of genetic-improved strains of plants, which are more resistant to plant diseases. This approach is more favorable because it is friendlier with the environment and healthier for humans and animals.

The infected part of the plant gives an indication of the type of plant disease, such as infected root which is usually correlated with root-rot disease. The plant diseases can be classified according to several parameters: disease symptoms, infected organ, infected plant type, and the type of phytopathogen. The latter is considered the more useful criterion used for plant disease classification, because it easily determines the disease cause, potential disease complications, and possible control methods.

According to this criterion, plant diseases are classified into two types: infectious (biotic) diseases, which are caused by eukaryotes, prokaryotes, parasitic higher plants, viruses/viroids, nematodes, and protozoa, and noninfectious (abiotic) diseases, which are caused by different extreme environmental conditions.

Diseases caused by parasitic higher plants

Some plant diseases are developed due to growing certain plants attached on or in other plants, where they take all required nutrients without benefit sharing; these plants are called parasitic higher plants. This abnormal relationship leads to weakness of healthy or host plant. The parasitic higher plants are usually found attached with the surface of the host plant, such as dodder, mistletoe, witchweed, and broomrape.

Diseases caused by nematodes

The nematodes are one of most common phytopathogens which have definite symptoms. These symptoms only appeared in the infected site. The nematode infections in or on plants are widely distributed especially in proper environments such as moderate temperature and high humidity.

Diseases caused by fungi

Interestingly, there are two main types of fungi appearing on plants: pathogenic and saprophytic. The pathogenic fungi live in or on plant tissues and cause serious complications for the vital physiological functions of plants, while saprophytic ones live in or on dead tissues. Accordingly, the diagnosis of plant disease must be exactly carried out. The exact diagnosis and determination of fungi take place by microscopical examination to identify the mycelial morphological characteristics, whatever fruiting structures and spores. After complete identification for the fungus and the symptoms of plant disease, the latter should be compared with that reported

Diseases caused by bacteria and mollicutes

The appearance of bacterial growth in or on plant tissues means that bacterial plant disease may be present, because saprophytes may be present. Therefore, accurate bacterial identification must be carried out by using microscopical examination and physiological parameter determination. The selective media are essentially used in the bacterial identification to determine the bacterial genus and species in some cases. Moreover, the confirmatory test of bacterial pathogenicity may be carried out by inoculation of single pure bacterial colony in the healthy plant, reproducing the same symptoms that appeared on the infected one. Moreover, immunodiagnostic techniques or serodiagnostic assays can be used, such as agglutination and precipitation, fluorescent antibody staining, and enzyme-linked immunosorbent assay (ELISA).

Diseases caused by viruses and viroids

There are distinctive types of plant diseases caused by viruses/viroids. These diseases have definite and clear symptoms, which easily support disease diagnosis and are considered main advantage. Apart from this advantage, some recent techniques are widely used for disease diagnosis and virus identification, such as virus transmission tests to specific host plants by sap inoculation, grafting, certain insect, nematode, fungus, and mite vectors. Moreover, serodiagnostic tests are used for this purpose such as enzyme-linked immunosorbent assays, gel diffusion tests, micro-precipitin tests, and fluorescent antibody staining. The electron microscopy techniques as negative staining of virus particles in leaf dip or purified preparations are also used, as well as immune-specific electron microscopy. On the other hand, there are more accurate techniques used for disease diagnosis and virus/viroid identification, such as electrophoretic tests and hybridization of commercially available radioactive DNA complementary to a certain virus DNA or RNA, or viroid RNA, with the DNA or RNA present in plant.

Diseases caused by more than one pathogen

Sometimes, some plants are exposed to coinfection by two or more pathogens, which lead to the same or different disease symptoms. Therefore, the differentiation and identification of these pathogens are very essential to exactly determine the disease cause.

Parasitism and pathogenicity

Plants cover the most area of the earth's living environment as trees, grasses, flowers, and so on. Plants play different important roles in the environment such as ecosystem balance and food supplement for animals and humans. Moreover, wild or cultivated plants are considered the powerful biofertilizers for the soil, where the plant debris after death and degradation provides the soil with sufficient organic matters. Accordingly, plant care is a great duty and hard mission, which must be constantly improved. The study of plant pathogens belongs to the branch of biology known as plant pathology. The latter is also concerned to overcome the plant diseases arising from the biotic and/or abiotic origin. Biotic (infectious) diseases are developed owing to microbial infection, while abiotic (noninfectious) diseases are developed due to environmental factors. In this chapter, we are concerned with plant pathogens or phytopathogenic microbes such as bacteria, viruses, fungi, mollicutes, and so on.

Basic procedures in the diagnosis of plant diseases

The plant disease diagnosis depends on the exact determination of the disease cause. Generally, there are two plant disease causes: the pathogens and/or environmental factors. The former leads to infectious diseases, while the latter leads to noninfectious diseases.

Infectious diseases

There are wide range of phytopathogens which cause infectious plant diseases such as fungi, bacteria, viruses, viroids, mollicutes, parasitic higher plants, and protozoa. The infectious disease means the ability of phytopathogen to transfer from the infected plant to another healthy one and causes the same disease and the same symptoms. The most phytopathogens can inhabit the internal environment of plants; however, some others can live on the plant surface such as some fungi, bacteria, and parasitic higher plants.

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Diseases caused by more than one pathogen

Sometimes, some plants are exposed to coinfection by two or more pathogens, which lead to the same or different disease symptoms. Therefore, the differentiation and identification of these pathogens are very essential to exactly determine the disease cause.

Noninfectious diseases

Occasionally, some plant diseases have abiotic origin such as environmental factors; these diseases are called noninfectious diseases. Abiotic environmental factors have deleterious effects on plants under extreme conditions, because they can negatively effect on the vital physiological functions and may lead to death, for example, the presence of considerable amounts of toxics in the soil or in the air, deficiency of water, oxygen, or minerals, and extreme conditions for temperature, humidity, oxygen, CO, or light.

Parasitism and pathogenicity

The term parasitism called on the state in which an organism (parasite) lives on or in another one (host) to obtain its required nutrition. Usually, the parasitism is correlated with pathogenicity, which means the ability of an organism to cause a disease. However, the parasitism in some cases leads to a benefit relationship called symbiosis, in which both plant and organism alternate the benefits, such as bacterial nodules in the roots of legume plants and the mycorrhizal infection of feeder roots of most flowering plants. In the case of parasitism-pathogenicity relationship, the plant is diseased with the appearance of different symptoms such as increased respiration, disintegration or collapse of cells, wilting, abscission, abnormal cell division and enlargement, and degeneration of specific components such as chlorophyll.

MORPHOLOGICAL, PHYSIOLOGICAL CHANGES WITH REFERENCE TO DISEASE ESTABLISHMENT IN PLANTS

Thousands of plant diseases have been recorded throughout the world, many of these causing heavy crop losses. Early detection and accurate diagnosis are essential for the effective management of plant disease. Thus, the first step in studying any disease is its timely detection of the diseased plant. Quick initial detection is largely based on the signs and symptoms of disease.

Signs are the visible physical presence of either the pathogen itself or the structures formed by the pathogen. Common examples of easily detected signs are those such as the fungal mycelia and spore masses of downy mildews observed on infected leaves and the bacterial ooze of *Xanthomonas* leaf streak disease on rice.

Symptoms are the visible changes that occur in the host plant in response to infection by pathogens. For any disease in a given plant, there is the characteristic expression of symptoms, usually occurring in a sequential series during the course of the disease. This series of symptoms depicting the disease picture is referred to as the disease syndrome.

Morphological symptoms may be exhibited by the entire plant or by any organ of the plant. These have been categorized into different groups for easy of study. Primarily, morphological symptoms of plant diseases can be categorized into 6 different types.

- Necroses
- Growth abnormalities
- Metaplastic symptoms
- Proleptic symptoms
- Color changes
- Wilts

Necroses

Necroses are caused due to necrosis or death of plant cells. The affected plant tissue usually turns brown to black in color. Necrotic symptoms could appear in any part of the plant such as in storage organs, in green tissues, or in woody tissues.

Necrosis in storage organs. Death of cells in storage organs terminates in decomposition or decay referred to as a rot. Two types of rots are identified as Dry rot and Wet rot on storage tissues.

Soft rots are those where the pathogen breaks down the host cell walls, resulting in the exudation of juices from the infected tissue. The organ becomes mushy or pulpy and a foul smell often develops due to colonization by secondary invaders. Many fungi and bacteria cause soft rots on several fruits and vegetables. Species of the fungus, *Rhizopus* and bacterium *Erwinia* are two such commonly found pathogens causing soft rots.

In a dry rot, the storage organ becomes hard and dry, and in some diseases, there is rapid loss of water and the infected organs become shriveled, wrinkled, and leathery. Dry rots showing such symptoms are referred to as mummifications.

Necrosis in green tissues

Necroses on green tissue are termed differently based on the nature of symptoms and the type of green tissue. The term, damping off refers to the sudden wilting and topping over of seedlings as a result of extensive necrosis of tender tissue of the roots and stem near the soil line, due to the attack of soil-borne pathogens such as fungus, *Pythium*. This fungus is known to cause damping off in an assortment of seedlings such as that of brinjal, chilli, mung beans, tobacco, tomato, and *Cucurbita*.

A spot refers to a well-defined area of gray or brown necrotic tissue. Spots are very common on leaves and fruits and are probably the most familiar necrotic symptom. Sometimes the necrotic tissue within a leaf spot may crack and fall off from the surrounding green tissue leaving an empty space. Such a symptom is known as a shot hole. Minute or very small spots are sometimes referred to as flecks or specks.

When dark mycelia of a fungal pathogen appear on the surface of necrotic spot, blotting the leaves, shoots, an stems as large and irregular spots, the symptom is referred to as a blotch.

Both streaks and stripes occur in grasses and are elongated areas having dead cells. Streaks occur along the stem and veins, while stripes are in the laminar tissues between veins. Net necrosis is a symptom resulting from an irregular pattern of anastomoses between streaks or stripes.

Blights are characterized by the rapid death of entire leaves including the veins or parts of the leaves. Blights also could occur on flowers and stems. Scorches resemble blights, but there necrosis occurs in irregular patterns between veins and along leaf margins. Firing is sudden drying, collapse and death of entire leaves. Firing occurs in response to the activity of root rot and vascular wilt pathogens.

Scald is the blanching of epidermal and adjacent tissues of fruits and occasionally of leaves. The sudden death of unopened buds or inflorescence is referred to as blast. Extensive necrosis of fruits that resemble in premature dropping is called shelling.

Necrosis in woody tissues

Necrosis of woody tissue often brings about various types of die-back symptoms. Dieback is the extensive necrosis of a shoot from its tip downwards. Restricted necrosis of the bark and cortical tissue of stems and roots is termed as a canker. In cankers, necrotic tissue in the sunken lesions is sharply limited, usually by a callus from adjacent healthy tissue. When woody tissues are diseased, they may exude different kinds of substances. When the exudate is gummy, the symptom is called gummosis, while it is resinosis when it is resinous. If the exudate is neither gummy nor resinous, it is described as bleeding.

Abnormalities in growth

Many disease symptoms are associated with growth changes in diseased plants. These could be caused by either reduced growth due to hypoplasia and atrophy or excessive growth due to hyperplasia and hypertrophy.

Hypoplasia and atrophy

Hypoplasia is the failure of plants or plant organs to develop fully due to a decreased production of the number of cells. Hypoplasia results in plants or plant parts of sub-normal size. Atrophy is the reduction in the size of plant cells produced. This also results in stunted plants or plant parts. Dwarfing is the failure of a plant or a plant part to attain its full size. Rosetting is a condition where the internode of a plant do not elongate, and hence, the leaves appear close together in a cluster.

Hyperlasia and hypertrophy

Hyperplasia is the enlargement of a plant tissue due to excessive increase in the number of plant cells produced. Hyperplasia results in overdevelopment in size of plants or plant organs.

Hypertrophy is excessive growth due to the enlargement of individual cells. This condition also results in the overdevelopment in size of plants or plant organs.

Hyperplasia and hypertrophy could result in the enlargement of leaves and fruits, and the enlargement of stems and roots.

Enlargement of leaves and fruits

Several symptoms expressing enlargement of leaves and fruits are commonly observed among diseased plants.

Curling which is the bending of the shoot or the rolling of the leaf, is a result of over-growth on one side of an organ. Often viral diseases cause such leaf distortions due to irregular growth of the lamina. Leaf curl of papaya is caused by papaya leaf curl virus (a begomovirus). Extreme reduction of the leaf lamina brings about the symptom known as the Shoe-string effect. The puckering or crinkling of leaves due to different growth rates in adjacent tissue is known as savoying.

Overgrowth of epidermal and underlying tissues of leaves, stems, fruits and tubers may result scab formation. Scab consists of raised, rough, and discrete lesions. These are often sunken and cracked, giving a typical scabby appearance.

Localized swellings or enlargement of epidermal cells due to excessive accumulation of water or fungal structures is termed intermuscence and the diagnostic symptom is the appearance of a blister.

Enlargement of stems and roots

Symptoms causing enlargement of stems and roots are termed differently based on their nature. Excessive accumulation of food material in stems, above a constricted area produces a swelling termed sarcody. Localized swellings that involve entire organs are termed tumefaction. Commonly exhibited tumefactions are galls, clubs, and knots.

Excessive development of adventitious organs results in fasciculation, that is the clustering of organs around a focal point. Such examples include witch's broom and hairy root. Witch's broom is a broom-like mass proliferation due to the dense clustering of branches of woody plants while hairy root results due to excessive development of roots.

Fasciation is the broadening or flattening of cylindrical organs such as stems. The continued development of any organ after it has reached a stage beyond which it normally does not grow is known as proliferation. The outgrowth of tissue in response to wounding is known as a callus. Callus formation is found to form around most cankers.

Metaplastic symptoms

Metaplastic symptoms are those which form when tissues change from one form to another. Such symptoms include phyllody, the development of floral organs into leaf-like structures, juvenillody, the development of juvenile seedlings on mature plants and russeting, a superficial browning of surfaces of fruits and tubers due to suberization.

Proleptic symptoms

Proleptic symptoms result from the development of tissues earlier than usual. Examples include prolepsis, the premature development of a shoot from a bud, proleptic abscission, the premature formation of abscission layers and restoration, the unexpected development of organs that are normally rudimentary.

Color changes

Changes in the color of plant tissue are a common symptom of plant disease. Often these color changes are brought about by the yellowing of normal green tissue due to the destruction of chlorophyll or a failure to form chlorophyll. Such repression of leaf color may be complete or partial. When color repression is complete, it is known as albication. However, the more common, partial repression is referred to as chlorosis.

Patches of green tissue alternating with chlorotic areas are described as a mosaic. Mosaic is a symptom caused by many viruses. Based on the intensity and the pattern of discoloration, mosaics are termed differently. Irregular patches of distinct light and dark areas are known as mottling. Streaking and ring spots are still other distinct types of discolorations. Ring spots are circular masses of chlorosis with a green center. Vein clearing and vein banding are yet other common color changes on leaves.

Chlorophyll may also develop in tissues normally devoid of it. Thus usually white or colored tissue becomes green in color. This is called as virescence. Anthocyanescence is due to the overdevelopment of anthocyanin and result in the development of a purplish coloration. Color changes can also take place in flowers. Such an example is the color break virus-affected tulips.

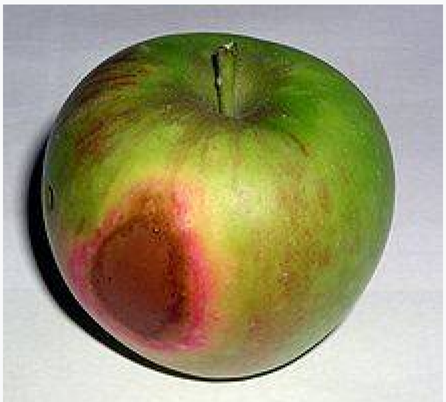
Wilts

Wilting is due to loss of turgor in plant tissue resulting in the dropping of plant parts. They are common symptom in diseases where the pathogen or the toxic metabolites it produces affects the vascular tissue of the host plant. Interference in water transport brought about by the infection of these vascular pathogens leads to wilting. Unlike wilting due to low soil moisture, wilting due to the activity of these pathogens cannot be overcome by watering the plants. Infected plants eventually die.

Physiological plant disorders

Abiotic disorders can be caused by natural processes such as drought, frost, snow and hail; flooding and poor drainage; nutrient deficiency; deposition of mineral salts such as sodium chloride and gypsum; windburn and breakage by storms; and wildfires. Similar disorders (usually classed as abiotic) can be caused by human intervention, resulting in soil compaction, pollution of air and soil, salinisation caused by irrigation and road salting, over-application of herbicides, clumsy handling (e.g. lawnmower damage to trees), and vandalism. Diagnosis of the cause of a physiological disorder (or disease) can be difficult, but there are many web-based guides that may assist with this. Examples are: *Abiotic plant disorders: Symptoms, signs and solutions*; *Georgia Corn Diagnostic Guide*; *Diagnosing Plant Problems* (Kentucky);[3] and *Diagnosing Plant Problems* (Virginia).

Sunburn at apple.

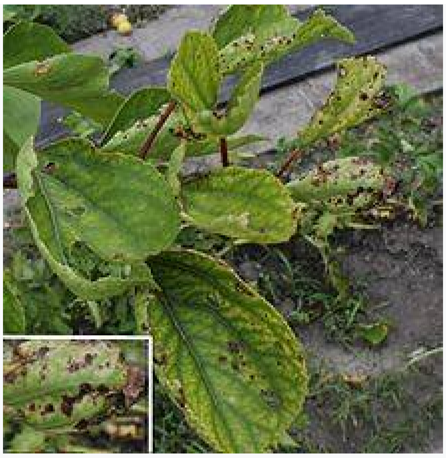


Some general tips to diagnosing plant disorders

- Examine where symptoms first appear on a plant—on new leaves, old leaves or all over?

- Note the pattern of any discolouration or yellowing—is it all over, between the veins or around the edges? If only the veins are yellow deficiency is probably not involved.
- Note general patterns rather than looking at individual plants—are the symptoms distributed throughout a group of plants of the same type growing together. In the case of a deficiency all of the plants should be similarly effected, although distribution will depend on past treatments applied to the soil.
- Soil analysis, such as determining pH, can help to confirm the presence of physiological disorders.
- Consider recent conditions, such as heavy rains, dry spells, frosts, etc., may also help to determine the cause of plant disorders.

Nutrient deficiencies



Iron deficiency

Poor growth and a variety of disorders such as leaf discolouration can be caused by a shortage of one or more plant nutrients. Poor plant uptake of a nutrient from the soil may be due to an absolute shortage of that element in the growing medium, or because that element is present in a form that is not available to the plant. The latter can be caused by incorrect pH, shortage of water, poor root growth or an excess of another nutrient. Plant nutrient deficiencies can be avoided or corrected using a variety of approaches including the consultation of experts on-site, the use of soil and plant-tissue testing services, the application of prescription-blend fertilizers, the application of fresh or well-decomposed organic matter, and the use of biological systems such as cover crops, intercropping, improved fallows, ley cropping, permaculture, or crop rotation.

Nutrient (or mineral) deficiencies include:

- Boron deficiency

- Calcium deficiency
- Iron deficiency
- Magnesium deficiency
- Manganese deficiency
- Molybdenum deficiency
- Nitrogen deficiency
- Phosphorus deficiency
- Potassium deficiency
- Zinc deficiency

PLANT PROTECTION

Plant pests are often regarded as an external, introduced factor in crop production. That is a misperception, as in most cases pest species occur naturally within the agro-ecosystem. Pests and accompanying species – such as predators, parasites, pollinators, competitors and decomposers – are components of crop-associated agro-biodiversity that perform a wide range of ecosystem functions. Pest upsurges or outbreaks usually occur following the breakdown of natural processes of pest regulation.

Because intensification of agricultural production will lead to an increase in the supply of food available to crop pests, pest management strategies must be an integral part of SCPI. However, they will also need to respond to concerns about the risks posed by pesticides to health and the environment. It is important, therefore, that potential pest problems associated with the implementation of SCPI are addressed through an ecosystem approach.

Although populations of potential pests are present in every crop field, every day, regular practices, such as crop monitoring and spot control measures, usually keep them in check. In fact, the total eradication of an insect pest would reduce the food supply of the pest's natural enemies, undermining a key element in system resilience. The aim, therefore, should be to manage insect pest populations to the point where natural predation operates in a balanced way and crop losses to pests are kept to an acceptable minimum.

When that approach does not seem sufficient, farmers often respond by seeking additional protection for their crops against perceived threats. The pest management decisions taken by each farmer are based on his or her individual objectives and experiences. While some may apply labour-intensive control measures, the majority turn to pesticides. In 2010, worldwide sales of pesticides were expected to exceed US$40 billion. Herbicides represent the largest market segment, while the share of insecticides has shrunk and that of fungicides has grown over the past ten years[1].

As a control tactic, over-reliance on pesticides impairs the natural crop ecosystem balance. It disrupts parasitoid and predator populations, thereby causing outbreaks of secondary pests. It also contributes to a vicious cycle of resistance in pests, which leads to further investment in pesticide development but little change in crop losses to pests, which are estimated today at 30 to 40 percent, similar to those of 50 years ago[2]. As a result, induced pest outbreaks, caused by inappropriate pesticide use, have increased[3].

Excessive use of pesticide also exposes farmers to serious health risks and has negative consequences for the environment, and sometimes for crop yields. Often less than one percent of pesticides applied actually reaches a target pest organism; the rest contaminates the air, soil and water.

Consumers have grown increasingly concerned about pesticide residues in food. Rapid urbanization has resulted in the expansion of urban and peri-urban horticulture, where pesticide use is more evident and its overuse even less acceptable to the public. The serious consequences of pesticide-related occupational exposure have been amply documented among farming communities, heightening social sensitivity towards agricultural workers' rights and welfare.

Public concerns are being translated into more rigorous standards both domestically and in international trade. Major retailers and supermarket chains have endorsed stricter worker welfare, food safety, traceability and environmental requirements. However, weak regulation and management of pesticides continue to undermine efforts to broaden and sustain ecologically-based pest management strategies. That is because pesticides are aggressively marketed and, therefore, often seen as the cheapest and quickest option for pest control.

Farmers would benefit from a better understanding of the functioning and dynamics of ecosystems, and the role of pests as an integral part of agro-biodiversity. Policymakers, who are often targets of complex information regarding crop pests, would also benefit from a better understanding of the real impact of pests and diseases in cropping ecosystems.

INTEGRATED PEST MANAGEMENT

Over the past 50 years, integrated pest management (IPM) has become and remains the world's leading holistic strategy for plant protection. From its first appearance in the 1960s, IPM has been based on ecology, the concept of ecosystems and the goal of sustaining ecosystem functions[5-7].

IPM is founded on the idea that the first and most fundamental line of defence against pests and diseases in agriculture is a healthy agro-ecosystem, in which the biological processes that underpin production are protected, encouraged and enhanced. Enhancing those processes can increase yields and sustainability, while reducing input costs. In intensified systems, environmental factors of production affect the prospects for the effective management of pests:

- *Soil management* that applies an ecosystem approach, such as mulching, can provide refuges for natural enemies of pests. Building soil organic matter provides alternate food sources for generalist natural enemies and antagonists of plant disease and increases pest-regulating populations early in the cropping cycle. Addressing particular soil problems, such as salt water incursion, can render crops less susceptible to pests such as the rice stem borer.
- *Water stress* can increase the susceptibility of crops to disease. Some pests, notably weeds in rice, can be controlled by better management of water in the production system.
- *Crop varietal resistance* is essential for managing plant diseases and many insect pests. Vulnerability can arise if the genetic base of host plant resistance is too narrow.
- *Timing and spatial arrangement of crops* influence the dynamics of pest and natural enemy populations, as well as levels of pollination services for pollinator-dependent horticultural crops. As with other beneficial insects, reducing pesticide applications and increasing diversity within farms can increase the level of pollination service.

AS AN ECOSYSTEM-BASED STRATEGY, IPM has achieved some notable successes in world agriculture. Today, large-scale government IPM programmes are operational in more than 60 countries, including Brazil, China, India and most developed countries. There is general scientific consensus – underscored by the recent International Assessment of Agricultural Science and Technology for Development – that IPM works and provides the basis for protecting SCPI. The following are general principles for using integrated pest management in the design of programmes for sustainable intensification.

- *Use an ecosystem approach* to anticipate potential pest problems associated with intensified crop production. The production system should use, for example, a diverse range of pest-resistant crop varieties, crop rotations, intercropping, optimized planting time and weed management. To reduce losses, control strategies should take advantage of beneficial species of pest predators, parasites and competitors, along with biopesticides and selective, low risk synthetic pesticides. Investment will be needed in strengthening farmers’ knowledge and skills.

- *Undertake contingency planning* for when credible evidence of a significant pest threat emerges. That will require investment in seed systems to support deployment of resistant varieties, and crop-free periods to prevent the carryover of pest populations to the following season. Selective pesticides with adequate regulatory supervision will need to be identified, and specific communication campaigns prepared.
- *Analyse the nature of the cause of pest outbreaks* when problems occur, and develop strategies accordingly. Problems may be caused by a combination of factors. Where the origin lies in intensification practices – for example, inappropriate plant density or ploughing that disperses weed seeds – the practices will need to be modified. In the case of invasions by pests such as locusts, methods of biological control or disease suppression used in the place of origin can be useful.
- *Determine how much production is at risk*, in order to establish the appropriate scale of pest control campaigns or activities. Infestation (not loss) of more than 10 percent of a crop area is an outbreak that demands a rapid policy response. However, risks from pests are often over-estimated, and crops can to some extent compensate physiologically for pest damage. The response should not be disproportionate.

Undertake surveillance to track pest patterns in real time, and adjust response. Georeferenced systems for plant pest surveillance use data from fixed plots, along with roving survey data and mapping and analysis tools.

PESTICIDES

Pesticides are chemical substances that are meant to kill pests. In general, a pesticide is a chemical or a biological agent such as a virus, bacterium, antimicrobial, or disinfectant that deters, incapacitates, kills, pests.

This use of pesticides is so common that the term pesticide is often treated as synonymous with plant protection product. It is commonly used to eliminate or control a variety of agricultural pests that can damage crops and livestock and reduce farm productivity. The most commonly applied pesticides are insecticides to kill insects, herbicides to kill weeds, rodenticides to kill rodents, and fungicides to control fungi, mold, and mildew.

History

Pesticides are not recent inventions! Many ancient civilizations used pesticides to protect their crops from insects and pests. Ancient Sumerians used elemental sulfur to protect their crops from insects. Whereas, Medieval farmers experimented with chemicals using arsenic, lead on common crops.

The Chinese used arsenic and mercury compounds to control body lice and other pests. While, the Greeks and Romans used oil, ash, sulfur, and other materials to protect themselves, their livestock, and their crops from various pests.

Meanwhile, in the nineteenth century, researchers focused more on natural techniques involving compounds made with the roots of tropical vegetables and chrysanthemums. In 1939, Dichloro-Diphenyl-Trichloroethane (DDT) was discovered, which has become extremely effective and rapidly used as the insecticide in the world. However, twenty years later, due to biological effects and human safety, DDT has been banned in almost 86 countries.

The Food and Agriculture Organization (FAO) has defined pesticide as: *any substance or mixture of substances intended for preventing, destroying, or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals, causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances that may be administered to animals for the control of insects, arachnids, or other pests in or on their bodies.*

Types of Pesticides

These are grouped according to the types of pests which they kill:

Grouped by Types of Pests They Kill

1. Insecticides – insects
2. Herbicides – plants
3. Rodenticides – rodents (rats & mice)
4. Bactericides – bacteria
5. Fungicides – fungi

6. Larvicides – larvae

Based on how biodegradable they are:

Pesticides can also be considered as:

- **Biodegradable:**
- The biodegradable kind is those which can be broken down by microbes and other living beings into harmless compounds.
- **Persistent:**
- While the persistent ones are those which may take months or years to break down.

Another way to classify these is to consider those that are chemical forms or are derived from a common source or production method.

Chemically-related pesticides:

- Organophosphate:

  Most organophosphates are insecticides, they affect the nervous system by disrupting the enzyme that regulates a neurotransmitter.

- Carbamate:

  Similar to the organophosphorus pesticides, the carbamate pesticides also affect the nervous system by disrupting an enzyme that regulates the neurotransmitter. However, the enzyme effects are usually reversible.

- Organochlorine insecticides:

  They were commonly used earlier, but now many countries have been removed Organochlorine insecticides from their market due to their health and environmental effects and their persistence (e.g., DDT, chlordane, and toxaphene).

- Pyrethroid:

  These are a synthetic version of pyrethrin, a naturally occurring pesticide, found in chrysanthemums(Flower). They were developed in such a way as to maximise their stability in the environment.

- Sulfonylurea herbicides:

The sulfonylureas herbicides have been commercialized for weed control such as pyrithiobac-sodium, cyclosulfamuron, bispyribac-sodium, terbacil, sulfometuron-methyl Sulfosulfuron, rimsulfuron, pyrazosulfuron-ethyl, imazosulfuron, nicosulfuron, oxasulfuron, nicosulfuron, flazasulfuron, primisulfuron-methyl, halosulfuron-methyl, flupyrsulfuron-methyl-sodium, ethoxysulfuron, chlorimuron-ethyl, bensulfuron-methyl, azimsulfuron, and amidosulfuron.

- Biopesticides:

  The biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals.

Examples of pesticides

Examples of pesticides are fungicides, herbicides, and insecticides. Examples of specific synthetic chemical pesticides are glyphosate, Acephate, Deet, Propoxur, Metaldehyde, Boric Acid, Diazinon, Dursban, DDT, Malathion, etc.

Benefits of Pesticides

The major advantage of pesticides is that they can save farmers. By protecting crops from insects and other pests. However, below are some other primary benefits of it.

- Controlling pests and plant disease vectors.
- Controlling human/livestock disease vectors and nuisance organisms.
- Controlling organisms that harm other human activities and structures.

Effects of Pesticides

- The toxic chemicals in these are designed to deliberately released into the environment. Though each pesticide is meant to kill a certain pest, a very large percentage of pesticides reach a destination other than their target. Instead, they enter the air, water, sediments, and even end up in our food.
- Pesticides have been linked with human health hazards, from short-term impacts such as headaches and nausea to chronic impacts like cancer, reproductive harm.
- The use of these also decreases the general biodiversity in the soil. If there are no chemicals in the soil there is a higher soil quality, and this allows for higher water retention, which is necessary for plants to grow.

PHENOLICS & PHYTOALEXIN COMPOUNDS

The natural phenolic compounds have received increasing interest in the last years, since a great amount of them can be found in plants and consumption of vegetables and beverages with a high level of such compounds may reduce the risk of development of several diseases due to their antioxidant power, among other factors.

It is known that the metabolism of plants is divided in primary and secondary. The substances that are common to living things and essential to cells are originated from the primary metabolism. On the other hand, substances originated from several biosynthetic pathways and that are restricted to determined groups of organisms are results of the secondary metabolism. Phenolic compounds are constituted in one of the biggest and widely distributed groups of secondary metabolites in plants.

Biogenetically, phenolic compounds proceed of two metabolic pathways: the shikimic acid pathway where, mainly, phenylpropanoids are formed and the acetic acid pathway, in which the main products are the simple phenol. Most plants phenolic compounds are synthesized through the phenylpropanoid pathway. The combination of both pathways leads to the formation of flavonoids, the most plentiful group of phenolic compounds in nature.

Additionally, through the biosynthetic pathways to the flavonoids synthesis, among the not well elucidated condensation and polymerization phases, the condensed tannins or non-hydrolysable tannins are formed. Hydrolysable tannins are derivatives of gallic acid or hexahydroxydiphenic acid

Flavonoids

According to the degree of hydroxylation and the presence of a C_2-C_3 double bond in the heterocycling pyrone ring, flavonoids can be divided into 13 classes, the most important being represented by the flavonols, flavanols, flavones, isoflavones, anthocyanidins or anthocyanins and flavanones. Within these classes there are many structural variations according to the degree of hydrogenation and hydroxylation of the three ring systems of these compounds.

Tannins

Tannins are phenolic compounds of molecular weight from intermediate to high (500-3000 D) and can be classified into two major groups: hydrolysable tannins and non-hydrolysable or condensed tannins. There is a third group of tannins, phlorotannins, which are only found in brown seaweeds and are not commonly consumed by humans.

The hydrolysable tannins have a center of glucose or a polyhydric alcohol partially or completely esterified with gallic acid or hexahydroxydiphenic acid, forming gallotannin and ellagitannins, respectively. These metabolites are readily hydrolyzed with acids, bases or enzymes. However, they may also be oxidatively condensed to other galoil and hexahydroxydiphenic molecules and form polymers of high molecular weight. The best known hydrolysable tannin is the tannic acid, which is a gallotannin consisting of a pentagalloyl glucose molecule that can additionally be esterified with another five units of gallic acid

PHYTOALEXIN

Phytoalexins are antimicrobial and often antioxidative substances synthesized *de novo* by plants that accumulate rapidly at areas of pathogen infection. They are broad spectrum inhibitors and are chemically diverse with different types characteristic of particular plant species. Phytoalexins tend to fall into several classes including terpenoids, glycosteroids and alkaloids; however, researchers often find it convenient to extend the definition to include all phytochemicals that are part of the plant's defensive arsenal.

Function

Phytoalexin s produced in plants act as toxins to the attacking organism. They may puncture the cell wall, delay maturation, disrupt metabolism or prevent reproduction of the pathogen in question. Their importance in plant defense is indicated by an increase in susceptibility of plant tissue to infection when phytoalexin biosynthesis is inhibited. Mutants incapable of phytoalexin production exhibit more extensive pathogen colonization as compared to wild type. As such, host-specific pathogens capable of degrading phytoalexins are more virulent than those unable to do so.

When a plant cell recognizes particles from damaged cells or particles from the pathogen, the plant launches a two-pronged resistance: a general short-term response and a delayed long-term specific response.

As part of the induced resistance, the short-term response, the plant deploys reactive oxygen species such as superoxide and hydrogen peroxide to kill invading cells. In pathogen interactions, the common short-term response is the hypersensitive response, in which cells surrounding the site of infection are signaled to undergo apoptosis, or programmed cell death, in order to prevent the spread of the pathogen to the rest of the plant.

Long-term resistance, or systemic acquired resistance (SAR), involves communication of the damaged tissue with the rest of the plant using plant hormones such as jasmonic acid, ethylene, abscisic acid or salicylic acid. The reception of the signal leads to global changes within the plant, which induce genes that protect from further pathogen intrusion, including enzymes involved in the production of phytoalexins. Often, if jasmonates or ethylene is released from the wounded tissue, neighboring plants also manufacture phytoalexins in response.

Role of natural phenols in the plant defense against fungal pathogens

Polyphenols, especially isoflavonoids and related substances, play a role in the plant defense against fungal and other microbial pathogens.

In *Vitis vinifera* grape, *trans*-resveratrol is a phytoalexin produced against the growth of fungal pathogens such as *Botrytis cinerea* and delta-viniferin is another grapevine phytoalexin produced following fungal infection by *Plasmopara viticola*. Pinosylvin is a pre-infectious stilbenoid toxin contrary to phytoalexins which are synthesized during infection. It is present in the heartwood of *Pinaceae*. It is a fungitoxin protecting the wood from fungal infection.

Sakuranetin is a flavanone, a type of flavonoid. It can be found in *Polymnia fruticosa* and rice, where it acts as a phytoalexin against spore germination of *Pyricularia oryzae*. In *Sorghum*, the *SbF3'H2* gene, encoding a flavonoid 3'-hydroxylase, seems to be expressed in pathogen-specific 3-deoxyanthocyanidin phytoalexins synthesis,[11] for example in *Sorghum*-*Colletotrichum* interactions.

6-Methoxymellein is a dihydroisocoumarin and a phytoalexin induced in carrot slices by UV-C,[13] that allows resistance to *Botrytis cinerea* and other microorganisms.

Danielone is a phytoalexin found in the papaya fruit. This compound showed high antifungal activity against *Colletotrichum gloesporioides*, a pathogenic fungus of papaya.

Stilbenes are produced in *Eucalyptus sideroxylon* in case of pathogens attacks. Such compounds can be implied in the hypersensitive response of plants. High levels of polyphenols in some woods can explain their natural preservation against rot.