CHAPTER 1

Introduction

The importance of vegetable in human diet needs no over-emphasis. Vegetables constitute a major portion of human diet in western countries. It is unfortunate that in India our food is so much cereal based that vegetables hardly find a place in the diet of the majority of the population. Our national agricultural policy has also put greater emphasis on improvement of cereals, pulses and oilseeds than on vegetables and fruits which could, to a great extent, relieve the pressure on foodgrains. Occasionally, there have been statements emphasising the need for proper storage and processing of vegetables and fruits but little is said about production and protection. According to dietary standards, a man's diet must include 200–350 g of vegetables of which 200 g should be in the form of leafy material. Up-to-date statistics of acreage under vegetables in India and annual production are not available but it has been stated that the production is approximately half of the requirement as per dietary standards. Vegetables being perishable commodity their shortage cannot be met by imports. Available cultivated area under grain production cannot be diverted for vegetable production for justifiable reasons. This emphasises the need for increasing the production and availability from the existing area under these crops and ensuring that the produce remains unspoiled before it reaches the consumer. Diseases in the standing crop from the seedling stage till harvest and spoilage caused by microorganisms during transit, storage and marketing are the major constraints in increased production and availability. In monetary terms, a report published in 1975 states that about 25 per cent of our produce of vegetables and fruits, worth 5 crores, is annually lost before it reaches the consumer.

What is plant disease?

Although everyone is aware of what a disease is through the effects it produces, a precise definition of the term is difficult to give. Since a disease is related to health the definitions mostly are in relative terms of a healthy condition of an organism. Disease has been defined in various ways. Some of the definitions are given below:

1) Disease is a malfunctioning process that is caused by continuous irritation in the living system which results in some suffering for the organism, producing symptoms. This definition was accepted by the American Phytopathological Society and the British Mycological Society.

2) Disease is the sum of the normal chemical reactions that are inhibited, or the abnormal chemical reactions induced inside the cell and in the tissues of the plant as a result of the irritation brought about by the causal agent.

3) Disease is an alteration in one or more of the ordered sequential series of physiological processes culminating in a loss of coordination of energy utilization in a plant as a result of continuous irritation from the presence or some agent of factor.

The Encyclopaedia Americana defines the term as "impairment of the health or normal functioning of an organism. It may primarily affect a single organ or tissue or a group of organs or tissues, or the entire body. It may result from wide variety of causes, including infectious organisms, hereditary factors and environmental hazards". The Encyclopaedia Britannica defines the term as "a departure from the normal physiological states of a living organism sufficient to produce overt signs or "symptoms". Singh, *et al.* (1989) have extensively discussed the definitions of the term disease. All definitions of the term disease given till now since the time of Julius Kuehn in 1858 have focussed the importance of deviation from normal which results in loss of economic value of the plant.

Whatever the definition of disease may be, the common man is concerned about the effect the diseases produce. The effect of plant disease is always adverse. If there is no adverse effect on utility of the plant, the abnormal changes occurring as a result of continuous irritation due to inroad of some irritation producing agent in the system, are not signs of diseased condition from an economic viewpoint. The effects of diseases cause reduction in yield, spoilage of the quality of the produce, and wastage during storage, transit and marketing.

Terminology

Disease and disorder. These two terms are often used interchangeably. Both mean some sort of malfunctioning in the plant system. However, the term disease is normally used for all types of harmful physiological changes in the plant while the term disorder is mainly used for malfuntioning due to non-infectious causes such as nutrient deficiency.

Epidemiology. Science which studies disease in a population. It includes rate of development of a disease in the population and factors determining the rate.

Injury, damage and loss. These three terms, used to define the effect of a disease, have different meanings. Attack of a parasite may cause injury to a cell or mass of cells (tissue) but there may not be damage to the organ which may continue functioning normally. However, when the injury causes extensive malfunctioning by which the organ ceases to function normally it is damaged. Loss is an economic term. When we expect a particular level of quantity of produce from a plant or crop and the expectation is not met due to damage to the plant or its organs, the difference between the expectation and actual yield is a loss.

Pathogen. The agent responsible for inciting pathos (ailment or suffering) or damage is a pathogen. Most, but not all, parasites and all the viruses are pathogens.

Parasite. Organisms which derive nutrition for growth and multiplication from living plants (host or suscept) are called parasites. Most, but not all, pathogens are parasites.

Biotroph. A parasite which, regardless of the ease with which it can be cultivated on artificial media or non-living substrates, obtains its food in nature from living tissues on which it completes the active part of its life cycle is called a biotroph or *obligate parasite.* Fungi causing rusts and downy or powdery mildews are typical examples.

Saprophyte. An organism which derives its nutrition from dead organic matter including animal remains, fallen dead leaves, fruits and twigs, etc., is a saprophyte. Amongst plant pathognens *Pythium* appears to have tendencies of a true saprophyte, but it has developed the faculty to become a parasite even though restricted to attacking only the juvenile and succulent plant tissues.

Parasites and saprophytes may have the faculty to change their mode of nutrition. A parasite may be *hemibiotroph*, i.e., it will attack living tissues in the same manner as biotrophs but will continue to live, grow, and reproduce as a saprophyte after the tissue is dead. Such parasites can also be called *facultative saprophytes*. Under natural conditions, such parasites have an ascending parasitic phase in the living host and a descending saprophytic phase in the dead host remains. Species of *Phytophthora*, some smuts, and *Agrobacterium* sp. are examples of hemibiotrophs. A parasite is *necrotroph, perthotroph* or *perthophyte* when it kills host tissues before entering them and basically lives as a saprophyte in the dead cells of the living plant. *Pythium* is a typical example of necrotrophs. *Rhizoctonia* and *Sclerotium* are also necrotrophs but more hardy than *Pythium* because they can exploit the mature tissues also. Similar to necrotrophs are the *facultative parasites* which mainly live as a saprophyte but under favourable conditions attack living plants and become parasites.

The above-stated categories of parasites are stages in the evolutionary development of parasitism. In the evolution of parasitism there has been a growing tendency in both host as well as the parasite to accommodate each other (Singh and Singh, 1984). Least specialized pathogens, by virtue of their ability to produce hydrolytic enzymes and toxins, cause extensive damage to host tissues which is probably much more than required for balanced nutrition of the parasite. Necrotrophs or facultative parasites represent this category. With increasing specialization of the parasite the tissue damaging effect goes on decreasing and the relationship becomes mainly nutritional. There is growing synchronisation of genetic and subsequent physiological system of the parasite and the host. The damage to tissues (quick killing effect) goes on decreasing and in very highly advanced parasites the latter do not kill the tissues but only withdraw nutrients. Finally, there are parasitic relationships without pathogenic effects and both host and the parasite become mutually beneficial. Lichens and mycorrhizal associations represent this category. In between the necrotrophs and lichens or mycorrhizae are the other categories like hemibiotrophs and biotrophs.

Pathogenicity. This term is used to denote the ability of a pathogen to cause disease under a given set of environmental conditions while *pathogenesis* is the chain of events that lead to development and expression of the disease in the host.

Virulence is a measure or degree of pathogenicity of an isolate of the pathogen. Different isolates of a given pathogen may be pathogenic, i.e., show pathogenicity, on a given host variety but different isolates of the same pathogen exhibit different levels of intensity of injury or damage on the same host variety. The term *aggressiveness* is often used to describe the capacity of a pathogen to invade and grow in the host tissues.

Immunity of a plant against the attack of a given pathogen denotes that the pathogen cannot establish parasitic relationship with the plant due to genetic and physiologic incompatibility between the two. The extent to which a plant prevents the entry or subsequent growth of the pathogen within its tissues or the extent to which a plant is damaged by a pathogen is used to measure the *resistance* or *susceptibility* of the plant. High resistance or low susceptibility approaches immunity. Resistance is *horizontal* or *uniform* when it is evenly spread against all the races of a pathogen. It is *vertical* (*differential*) when effective against some races of the pathogen but not against the others. Depending on multiplicity of host genes involved in resistance to a pathogen, resistance may be *monogenic, polygenic* or *oligogenic.*

Tolerance is a term used to denote capacity to endure parasitism. It is not genetic resistance to a pathogen but capacity of the plant to give normal yield even if infected because of its other characters such as early maturity, ability to replace damaged roots, etc.

Hypersensitivity is extreme degree of susceptibility in which rapid death of cells in the vicinity of the pathogen (*infection court*) occurs. This halts the progress of the pathogen although it may not be immediately killed. Thus, hypersensitivity is a sign of very high degree of resistance approaching immunity.

Infection is establishment of parasitic relationship between the pathogen and the host, following entry or penetration. In immune or highly resistant plants penetration may occur without resulting in infection.

Units of the pathogen which cause infection constitute *inoculum.* The inoculum which first initiates the disease in the plant population is called *primary inoculum* and causes *primary infection.* If and when subsequent crops of inoculum are produced by primary infections and dispersed to cause new infectins in the crop, the inoculum is called *secondary inoculum* and causes *secondary infection.*

Endemic disease. When a disease is more or less constantly present from year to year in a moderate to severe form in a particular area it is classed as endemic for that area.

Epidemics or *Epiphytotics.* An epidemic disease is one which occurs periodically but widely, affecting rather rapidly a high proportion of the plant population over a large area. When it becomes widespread throughout the country it is known as *pandemic.*

Sporadic diseases are those which occur at very irregular intervals and locations and relatively in few instances.

CAUSES OF PLANT DISEASES

A pathogen or inciting factor or agent is always associated with a disease. These agents have been grouped under following categories:

1. *Abiotic,* inanimate or non-living causes such as environmental stresses including nutritional, extremes of temperature and moisture, presence of injurious chemicals in soil or in atmosphere, etc.

2. *Mesobiotic.* Viroids which are naked, infectious strand of nucleic acid (example is spindle tuber disease of potato) and viruses which are infectious agents made up of one type of nucleic acid (RNA or DNA) enclosed in a protein coat. Leaf roll of potato, leaf curl of tomato and mosaic diseases are incited by viruses.

3. *Biotic,* living or animate causes. This group consists of *prokaryotes* including mycoplasma-like organisms (MLO), spiroplasmas, rickettsia-like bacteria (RLB) and true bacteria; *eukaryotes* including fungi, protozoa, algae, nematodes and flowering plant parasites.

Viroids and viruses

These are non-cellular (non-living) infectious agents which behave in many ways like a living organism. The difference between a viroid and a virus is that the nucleic acid strand of which they are made up is naked in viroids and enclosed in a protein coat in viruses. The plant viruses are a group of submicroscopic entities showing obligate relationship with living cells, that is, they are not active (do not multiply) outside the living cell. Their place of activity is at a molecular level inside the cell. Viruses have characters of both living and non-living. They do not reproduce like living organisms by asexual or sexual methods but multiply inside the host cell by self replication of their genome and synthesise their protein coat separately. The genome and the protein coat reassemble to form a virus particle. These particles are tubular or spherical and are composed of nucleic acid which is either RNA (ribonucleic acid) or DNA (deoxyribonucleic acid) but never both. The nucleic acid strand is enclosed in the protein shell. The nucleic acid is the actual infectious component of the virus particle which may cause infection even if the protein coat is removed. The two components can be separated and crystallised by chemical treatment without affecting infectivity of the nucleic acid. Since viruses have no cellular structure and do not produce any resting body, they maintain a continuous disease cycle by remaining active on alternate hosts or through seeds. They are mostly transmitted by insect vectors but many are sap transmissible and highly contagious, being transmitted by contact. Several viruses are transmitted by nematodes, fungi and dodder. In vegetatively propagated crops the propagating material is the main source of their transmission.

Prokaryotes

i) *Mollicutes.* These include mycoplasmas, mycoplasma-like organisms and spiroplasmas. Smaller than true bacteria, unseen with light microscope, these wall-less prokaryotes are the real causal agents of many plant diseases that had earlier been considered of viral origin. The mycoplasmas or the mycoplasma-like organisms (MLO) are very small, unicellular, usually non-motile (*Spiroplasma* has self-motility), pleomorphic organisms lacking a rigid cell wall which is represented by a single triple-layered membrane. They are the smallest known cells capable of growing in artificial media but not all plant pathogenic members of this group have been so grown. Although true *Mycoplasma* species have been cultured, the plant pathogenic forms that could be grown on cell-free media have been found to be *Spiroplasma* having a helical structure with definite evidence of motility. Except for their cellular structure and reproduction by binary fission, presence of RNA and DNA both, and living nature, these plant pathogens behave in the same manner as viruses so far as their survival, dispersal or transmission and infection are concerned. Little leaf of eggplant, witches' broom of bottlegourd, phyllody of cucumber and bottlegourd, purple top roll of potato, and marginal flavescence of potato are examples of disease caused by MLO.

ii) *Bacteria*. The true bacteria are prokaryotes with unicellular, chlorophyll-less bodies having definite cell walls but lacking membrane-bound nucleus and other cell organelles. The cells are usually single or in groups but in some groups they form fungus-like filaments. They can be cultured on artificial media but some fastidious bacteria (the so-called rickettsia-like bacteria or RLB) do not grow on cell-free media routinely used for other bacteria. The fastidious bacteria are very small compared to true bacteria with wall. They have been called rickettsia-like although they may be entirely different taxa. Bacteria reproduce by binary fission of cells. With very few exceptions, the plant pathogenic bacteria do not produce resting spores for survival. The survival is achieved by continued slow or rapid activity in affected parts of perennial hosts, in propagating material including seed, or on dead remains of the host as saprophytes to a limited extent. Bacteria are facultative saprophytes or parasites and hemibiotrophs or necrotrophs. Dispersal of bacteria is passive with water, sometimes by wind in dust particles, by raindrop splashes and by seed material. Many are carried by insects. Examples of bacterial diseases are brown rot and wilt of potato and tomato, leaf spot of tomato and chilli and black rot of cabbage.

The following genera of prokaryotes which contain major or minor plant pathogens are internationally approved:

Agrobacterium, Arthrobacter, Bacillus, Chlamydia, Clavibacter, Clostridium, Curtobacterium, Erwinia, Nocardia, Pectobacterium, Pseudomonas, Rhodococcus, Spiroplasma, Streptomyces, Xanthomonas. Characters of some important genera are given below:

Clavibacter. This genus contains species that were earlier considered under the genus *Corynebacterium*. The cells are Gram-positive, non-acid fast, pleomorphic rods, often arranged at an angle to give V-formation as a result of snapping or bending type of cell division. No spherical cells are formed. They are non-spore forming, non-motile, strict aerobes and nutritionally exacting.

Curtobacterium. This genus also contains species that were earlier included under *Corynebacterium*. Cells are small short rods, spherical (coccoid) cells found in old cultures; weakly Gram-positive, frequently old cells lose Gram-positivity; generally motile by lateral flagella; multiplication by bending type of cell division; pleomorphism only slight.

Erwinia. Cells predominantly single, straight rods, motile (except in *E. stewartii* and *E. dissolvens*) by peritrichous flagella; Gram-negative; aerobic as well as anaerobic. One group of species produces pectolytic enzymes and is often considered under genus *Pectobacterium*.

Pseudomonas. Some of the world's most serious plant diseases are caused by members of this genus. Cells single, straight or curved rods but not helical; motile by polar flagella; non-spore forming; Gram-negative; strict aerobes.

Streptomyces. Slender, coenocytic filaments; aerial mycelium at maturity forms chains of three to many spores; Gram-positive and aerobic.

Rhodococcus. The genus is allied to *Streptomyces*. Cells in young cultures are slightly curved rods arranged singly, at angles or as palisade layer; Gram-positive and non-motile.

Xanthomonas: The genus, close to *Pseudomonas*, has following characters: cells single, straight rods; Gram-negative; motile by single polar flagellum; non-spore forming; strict aerobes.

Eukaryotes

i) *Fungi*. These are microorganisms with chlorophyll-less, nucleated, unicellular or multicellular, filamentous body called thallus (body not differentiated into root and shoot). Plant pathogenic fungi are multicellular and filamentous. The thallus reproduces by division of its vegetative cells or branches (hyhae) or by formation of various kinds of well defined asexual or sexual spores. Mostly the vegetative or asexual units of reproduction are produced in abundance and spread the disease in the plant population after appearance of the disease. The sexual spores mostly serve as structures of survival during off-season of the crop or when environmental conditions are unfavourable for activity of the fungus. Often, the fungi produce asexual resting structures such as sclerotia and chlamydospores during their life cycle and these serve as structures of survival. Plant pathogenic fungi may be biotrophs, hemibiotrophs or necrotrophs. Dispersal of spores occurs by active or passive means. Active dispersal of spores is accomplished by different mechanisms provided in the fungus while passive dispersal is through wind, water or rains, seed, insects, movement of soil, etc. Most plant diseases are caused by fungi. Examples are wart, late and early blight diseases of potato, downy and powdery mildews of pea, cucurbits and crucifers, rusts of beans and peas.

ii) *Nematodes.* Among members of the animal kingdom, nematodes are the most important incitants of plant diseases. Apart from being independently associated with a disease they often act as carriers of other pathogens especially viruses and also as aggravators of disease complexes involving fungi and bacteria. Many root diseases of plants caused by fungi and bacteria become more destructive when the plant is earlier infected by some species of nematodes. In appearance, nematodes resemble roundworms found in human intestine but are very small although some form structures which are visible to naked eye. The body is bilaterally symmetrical with tapering ends, more so, towards the posterior part which forms the tail. The bilateral symmetry is disturbed in females of many species which become swollen when mature and internal organs are almost displaced by the female reproductive organs. The males are usually cylindrical, filiform or spindle-shaped. At the anterior end is the mouth, provided with papillae, leading to a buccal cavity, which in turn, leads to the esophagus or pharynx. A valve is located at the junction of the esophagus and the intestine, the latter opening into the rectum and anus. The buccal cavity of plant pathogenic nematodes is always provided with a spear or stylet. The entire body is covered with a cuticle which is smooth or transversely striated. Below the cuticle there is subcuticular muscular layer. The cells of the muscles are so arranged that the nematode can move only in forward position. The cavity between the cuticle and the body organs is filled with colourless fluid.

The plant parasitic nematodes are obligate parasites (biotrophs) and cannot complete their life cycle without the association with the host plant. Although they are motile the movement is helpful only for local activity in the host or immediate surroundings. The main methods of dispersal of nematodes are through seed or planting material, movement of water and soil. They survive in soil as eggs, eggmasses, cysts, seed galls, and sometimes as immature larvae or juveniles. Larvae hatched from eggs or cysts cause infection of the plant. During the life cycle, the plant parasitic nematodes undergo four moults, thus having five stages. The first moult always occurs within the egg. The hatched larvae are stylet bearing second stage juveniles.

In addition to the above major animate causes of plant diseases there are some protozoan parasites, some algae which attack fruits and leaves, and many phanerogamic plants such as dodder, mistletoes, and striga which also parasitise higher plants.

THE DISEASE TRIANGLE

Although a disease is the result of interaction between two biological entities, the host plant and the pathogen, neither of these is independent of the environment in which it is functioning. The interaction between the host, the pathogen and the environment constitutes the disease triangle. The interactions between the host and the pathogen are profoundly influenced by the external environment during the period when the pathogen comes in contact with the host, sometimes before and after this stage. Major environmental factors are temperature, moisture, pH, presence of nutrients for the host or the pathogen, associated microbiota around the roots and on the foliage, etc. A pathogen may be present in the soil or even on the host surface but unless environments favour germination of the spores, infection will not occur. Even after penetration, environments may enable the host to shake off the pathogen. In understanding developments of a disease and in finding out suitable measure for its control or management, all the three components of the disease triangle are taken into consideration.

DIAGNOSIS OF DISEASE

Although practice is the most sound method of identifying or diagnosing a disease, some basic principles are given here. Any abnormality detected in the appearance and functioning of the plant is indicative of a diseased condition. What is causing this condition needs systematic observation in the field and study in a laboratory. However, most of the important diseases such as rusts, smuts, and downy and powdery mildews are easy to identify by simple visual observation in the field.

A laboratory study is required to identify the botanical genus and species of the causal agent. In those cases where symptoms are such that may be caused by a variety of living or non-living disease incitants, the first step is to find out whether the disease is infectious or non-infectious. This can be done by observing the pattern of development of the disease in the plant population and possible spread of the symptoms on other plants. If the disease is spreading in the population it is infectious. An infectious disease may be caused by fungi, bacteria, viruses, MLOs or nematodes. These can be determined first by visual observation of the affected parts for presence of fungal structures or bacterial exudates and then by laboratory studies. The fungal structures if present on the host and examined under microscope may reveal presence of a particular fungus. If the fungus is not a biotroph and can be cultured, isolation on artificial media and tests for Koch's postulates can pinpoint the actual cause of the disease. Bacteria can also be identified as disease incitants in the same manner. Examination of cut pieces of the affected parts in water under microscope will reveal streaming of bacterial cell masses in water. Nematodes, if present, can be seen on the host or in tissues examined under microscope. By separating them from the host and multiplying them under sterile conditions on a susceptible host, sufficient number of larvae can be obtained for proving the Koch's postulates.

Viruses can neither be seen nor cultured. They generally produce symptoms similar to those of nutritional deficiencies. However, the latter condition is non-infectious and does not spread in the population while viruses are infectious and spread. If in artificial cultures no pathogen is obtained and in tissue examination no fungal structure of a biotroph is seen, but the disease is infectious, it can be expected that the disease is caused by a virus or MLO. The plant pathogenic MLOs are not easy to culture. Transmission tests by grafting, sap inoculation or use of vectors can help in final diagnosis. The differentiation between viruses and MLOs can be made by electron microscopy and by spraying tetracycline antibiotics which mask the symptoms of MLOs but not of viruses.

MAJOR SYMPTOMS OF PLANT DISEASES

Symptoms or signs of disease in plants help in its diagnosis and can also indicate the nature of damage and loss. The symptoms can be broadly grouped in two categories: those caused by physical appearance of the pathogen on the host surface and those resulting from interaction between the host and the pathogen systems within the tissues.

Following symptoms are included in the first category:

Rusts. The rusts appear as relatively small pustules of spores, usually breaking through the host epidermis. The pustules are either dusty or compact and red, brown, yellow or black in colour.

Smuts. This word means a sooty or charcoal-like powder. In smut diseases, the fungus appears on the affected organs as a black powder. These symptoms usually appear on the floral organs, particularly the ovaries which are wholly or partly converted into a black powdery mass. Some smuts appear on stems, leaves, and even roots.

Mildews. In these diseases the fungus is seen as white, grey, brownish or purplish growth on the host surface. In downy mildews the superficial growth appears as a tangled cottony mass or downy growth while in powdery mildews the growth is powdery, flour-like.

White blisters. Often called white rust, these diseases appear as white, dusty blisters on the host surface.

Blotch. This symptom consists of a superficial growth giving the surface of the affected fruit a blotched appearance.

Sclerotia. A sclerotium is a compact, often hard, black or dark brown structure which may develop in or on the affected organ, especially fruits and stems of the plant.

Exudations. In several bacterial diseases, masses of bacterial cells ooze out to the surface of the affected organs where they can be seen as drops or smear. When dry they form a crust on the host surface.

In the second category of symptoms which result from interaction between the host and the pathogen the following are included:

Colour changes. Change of normal colour of the affected organs is the most common symptom of plant diseases. The green colour is replaced by yellow (*chlorosis*) or red, purple or orange (*chromosis*). Sometimes there may be no colour (*albinism*) and the leaf may look white.

Overgrowths and hypertrophy. Many pathogens, through their biochemical activity, induce excessive multiplications of cells (hyperplasia). The overcrowding of cells increase the size of the organ. Often the size of cells is increased (hypertrophy). This also results in overgrowth. The overgrowths and their effects are of various types such as galls, knots, curls, pockets, bladders, hairy roots, phyllody, witches' broom, intumescence, etc.

Atrophy or hypoplasia. These symptoms result from inhibition of normal growth of an organ. The whole plant may be dwarfed or only special organs may be so affected. Sometimes hypertrophy and atrophy may occur in different parts of the same organ.

Necrosis. As a result of enzymatic action or action of toxins during its parasitic activity a parasite may cause death of cells, tissues, or organs. The necrotic symptoms include spots, streaks or stripes, canker, blight, damping off, burn, scald or scorch, and rot.

Wilt. These diseases are characterised by drying of the entire plant. The drying may be preceded by loss of turgidity of leaves and other green or succulent parts which may become flaccid and droop.

Die-back or Wither tip. This is necrosis of stems and branches from the tip backwards.

MANAGEMENT OF PLANT DISEASES

Operations undertaken to reduce losses from plant diseases have been termed as "control measures". The term is now generally replaced by the term "management". Control carries the notion that a disease problem has been finally solved which is not true. Rarely a plant disease has been completely eliminated. Diseases may be checked in a field or locality but continue to occur in another field or locality. They may be checked in one crop season but, unless the operations are repeated in the next season, they may reappear. No pathogen is actually completely eradicated by measures directed against it. Only its population is reduced. If the measures are not repeated the pathogen multiplies and again causes serious incidence of the disease. Thus, the measures applied against a disease or a pathogen are a continuous process. The term "management" conveys the concept of a continuous process. It implies that plant diseases are inherent component of the agroecosystem and should be dealt with on a continuous knowledgeable basis. Disease management is not directed only against the pathogen but also takes into consideration the other two components of the disease triangle, i.e., the host and the environment. The main objective is an integrated approach to maintain the damage or loss below an economic injury level or at least minimise the recurrence of a disease above that level.

Management practices against disease should be planned in such a way that they can be conveniently accommodated in the normal cultural practices for the crop and as far as possible the operations recommended should be such that they are effective against more than one disease. Success of management practices can be ensured only if they are recommended to and followed by majority of growers of the crop in the area. If a neighbouring grower does not follow disease management practices his crop may harbour the pathogen in enough quantity to reinfect the crop in which management practices had been applied. This reduces the efficacy of the recommended practices and increases the cost of plant protection.

Cure of a diseased plant is generally not possible because the disease is visible only after injury to the plant has taken place. Therefore, preventive measures are most important in plant disease management. These preventive measures involve induction of resistance in the host (immunization) and protection of the plant by prophylactic measures.

Immunization consists of development of resistant varieties through breeding and induction of resistance through chemotherapy. In prophylaxis legislative measures (quarantine, etc.) at central and state levels, protection of the crop by chemical and cultural methods, and eradication of the pathogen by chemicals and crop or field management practices are involved. Prevention of entry of diseased plants or planting material through quarantine regulations, seed certification, notification of plant diseases, and prevention of sale of diseased plants or plant materials constitute legislative measures. Cultural and field or crop management practices include crop rotation, sanitation of the field, eradication of alternate or collateral hosts, summer ploughing and fallowing, flooding of the field, alteration in sowing and irrigation time, etc. Chemicals are used both for eradication of the pathogen from the host as well as providing protection against secondary invasion of the crop by the pathogen.

The most appropriate approach for disease management is integration of practices directed against the pathogen (pathogen management), in favour of the host (host management) and for modification of the environment in favour of the host and against the pathogen. Genetic and chemical immunization is host management while the prophylactic measures including cultural practices and use of chemicals for protection and disinfection are interchangeably the practices for the management of the pathogen and environment.

Problems in management of vegetable diseases. Most vegetable grain crops differ from crops in that while in grain crops the produce is harvested only once at the end of the season giving ample time for management with chemicals, in most green vegetable crops like tomato, okra. cucurbits, table peas, beans, etc. harvesting is spread over a long period. This restricts the use of chemicals because of health hazards to the consumer.

Commercial vegetable growing in India is carried out mostly by a section of the farming community who follow intensive cultivation of the land, growing several crops of vegetables simultaneously or one after another. A large number of pathogens, especially viruses and nematodes, have a wide host range among vegetable crops. This enables the pathogen to maintain a continuous disease cycle. Chances of application of cultural practices as means of management of the pathogen and environment are restricted in vegetables. In villages and towns, vegetables are often grown in small kitchen gardens around the house. Many cucurbits are actually raised on roof of thatched huts in the villages not only for home consumption but also for the market. Economic application of management practices in such cases is not possible. These home-grown plants serve as a reservoir of inoculum of many pathogens which can be carried by wind and insects to the field-grown crops.

Cost of cultivation of vegetables is high, hence cost of the produce is also high. There are, therefore, limited buyers. This disturbs the rule of demand and supply affecting remunerative returns for the grower who, therefore, is reluctant to increase the cost through additional inputs.

There has been very little effort at breeding for disease resistance in vegetable crops in India. Considering the above limitations only resistant varieties could be the safest and cheapest method of disease control in vegetables. In absence of such varieties, chemicals and some cultural practices are recommended. However, use of chemicals in vegetables, many of which are eaten raw, is full of dangers for the consumers, especially when the grower is not educated enough to follow some cut off date for application of chemicals to the standing crop.

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