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Introduction

Dependence of man on plants for food dates back to more than 12000 years. Other animals and plants existed on this planet before the arrival of man and these later became the security against starvation of man. The animals domesticated by man almost wholly depend on plants. In addition to food, plants and animals are the primary sources of materials for other necessities of life such as clothing, house building materials, furniture, drugs and fuel etc. Coal and petroleum products are also derived from the remains of plants buried deep in soil. The congenial climate, the rains, etc are made and modified by the plants.

The availability of food to human population in reasonable quantity is governed by the population density needing food, cultivated land area available for food production and production of food per unit land area. Among these determinants availability of land is almost fixed. Production per unit land area does not rise fast enough while the human populations is a fast rising phenomenon. If the increase in food production can be matched with increase in the number of mouths to be fed, probably the problem will not be acute. However, the rise in human population is much faster than the rise in food production. Although total foodgrain production in the world has been rising and about 1400 million hectares of land surface (12% of the total) is being cultivated for some food crop, the rise in production has not matched with the rise in consumer numbers. For instance, the total food production in India has shown an overall increase of about 65% since 1950 while the population during the same period showed an increase of about 175%.

In the year 1940 the human population on this planet was around 2140 million which rose to 3280 million in 1965, to 3950 million in 1975 and to 4900 million in 1985. In the year 2000 it stood at around 6800 million. Overall rise in world population during the 60 years was about 218%. During the 25 years since 1940 the average rise per year was around 2%. It has shown only slight increase in the average percentage but the picture is different when these figures are considered on regional basis. Two third or more of the total world population is in the countries of Asia, Africa and Latin America. In India alone the population expanded from 360 million in 1940s to 550 million in 1971, to 920 million in 1996 and to about 8.5 million more than

a billion by mid-2000. A report of the FAO in 1994 had estimated that the population of India in the year 2005 will be around 1600 million.

In the rising total food production, some selected crops have shown better increase than others. For example the productivity of wheat has gone up from 1.2 tonnes per hectare (in 1965) to 2.4 tonnes per hectare (in 1989). In India the total foodgrain production has gone up from about 130 million tonnes in 1950-51 to 208.6 million tonnes in 1999-2000. The total wheat production rose from 6.46 million tonnes in 1950-51 to 54.52 million tonnes in 1990-91. The corresponding figures for Punjab, the main wheat producing state, are 1.06 and 12.16. In 1999-2000, wheat production in India was 75.5 million tonnes, nearly 11-fold increase since 1950. One adverse effect associated with rise in production of specific grains has been the fall in production of other crops such as oilseeds and pulses. Area from such coarse grains as millets has been withdrawn in favour of cereals. Diversity has been narrowed and it has its own adverse effects on all crops. Probably the type of change in food production in India has not occurred in other food deficient countries. The spectre of famine, that has scourged humanity from the beginning of the time, and the shortage of food remains as great as ever, or even more than in the past in many regions of the world. The number suffering from hunger or malnutrition runs into billions. It is in this context that the need for fighting the competing microorganisms and other agencies that cause loss of productivity of plants has been felt. Plant diseases have been considered as stubborn barriers to the rapid progress in food production.

The plants that sustain us on this earth evolved much earlier than the first man. However, before the origin of plants, microbes had already developed in the organic evolution. Thus, the association of microbes with plants is much older than association of man with plants. This has significance in the light of adjustment or disadjustment between plants and microbes during their coevolution. In the beginning of this relationship, the microbes started living on dead organic substrates left by plants since they had no faculty to synthesize their own food. With further evolution, these microorganisms gave rise to parasitic forms which are even to-day attacking our crops and disturbing our crop production programmes.

In the pre-agriculture days when there was no systematic cultivation of specific plant types by man diversity of plant populations was great, the microorganisms had less opportunity to thrive and cause damage because of less chances of easy contact with the desired host plant. The introduction of selective culture of plant types by man gave the microorganisms better opportunity for survival, multiplication and consequent destruction. The development of scientific agriculture by man and development of plant diseases by pathogens have been on parallel lines since the very beginning of crop evolution. The attack on plants by these microorganisms changed the appearance and productivity of the crop and this observed change was called a disease.

Protection of plants against their enemies is one of the many approaches for increasing food production. In persuing their justifiable efforts the specialists in crop production emphasize the use of new cultivated plants, better high yielding crop varieties, more quick acting mineral fertilizers, ample irrigation and maximum use of land by not permitting any fallow period. Judged from plant pathological viewpoint these recommendations need careful consideration. Maximization of yields can be achieved only if along with ensured fertilizers, irrigation and seed of high yielding varieties there is also provision for protection of the crop against its enemies. It may involve modified cultural practices, encouragement of biocontrol agencies, induction of resistance and, if necessary, use of toxicants (fungicides, antibiotics, nematicides, etc.).

Introduction of new cultivated plants may involve phytopathological risks. It may cause introduction of potentially dangerous pathogens through seed and planting materials or a pre-existing pathogen may became dangerous because of the introduction of the new plant type. High yielding varieties are not necessarily disease resistant. Even if they are, the resistance is against one or two diseases while the crop is liable to attack by many more diseases. Often, when one or two diseases are checked, some minor diseases become major diseases in the crap. The uniformity of genetic material in the field, heavy plant population and presence of dense crop canopy almost throughout the year favour survival, reproducion and spread of pathogens. Thus, the measures being adopted for increasing productivity are favouring the pathogens also. Danger from diseases will continue to increase in proportion to the developments in technology of production without protection.

However, the modern technology had come to stay and atleast in India it has proved its worth by making the country almost self-sufficient in food production in 40–45 years. In other countries facing deficit modern technology is unavoidable if food is to be produced for the rising population. The compromise between the two situations lies in the recognition of the importance of plant protection so that whatever is sown in the field grows into a crop, whatever is grown is enabled to achieve its maximum production potential and whatever is produced is safely stored and finally reaches the consumer. There are diseases in which the loss caused to the crop is more than the deficit of that particular crop produce and if the diseases are checked the deficit can be reduced to a minimum.

Before the advent of high yielding crop varieties in India the varieties that were grown had not very high yield potential and plant protection was not paid much attention because the expenditure on plant protection measures was more than the income. The situation changed with the introduction and acceptance of high yielding varieties of wheat, rice, maize, many pulses and oilseeds. Attempts are made to take more than two crops in a year from the same field. From commercial point of view the value of the crop is much higher than in the past. Therefore, the loss of even a quintal of foodgrain is felt by the

farmer and he has a genuine desire to stop this loss. He has realised that enemies of crops cause losses and these losses must be prevented by fighting these enemies.

In developed countries (mostly cold climate regions including North America, Europe, Japan, New Zealand, Australia, Israel) only about 11.5% of the population is engaged in agriculture while in the Asian and African countries agriculture engages 57.5% of the population. Ironically, it is the areas that engage the maximum population in agriculture, the population density is highest, crop productivity is low, and hunger most prevalent. Crop losses are much less in developed countries where the population is low then in the developing countries where crop losses are high and more food is required. Estimates differ but on a global basis, about 34% of crops is lost annually due to diseases, insect pests and weeds. Of this annual crop loss, 12% is due to diseases other than nematodes, 11% due to nematodes, 7% due to insect pests and 3% due to weeds. In cereals the annual loss is estimated to be about 18% in the developed countries compared to 46% in Asian and African countries. Corresponding figures for sugarcane are 34 and 56%. Percentages of all produce lost to diseases, insects and weeds are 25 in Europe, 29 in North and Central America, 30 in the Russian Federation of States and China, 33 in South America and 42-43 in Africa and South and South-East Asia.

In 1963, it was estimated that India loses 10% of foodgrains every year due to plant diseases. In some of the essential food crops this loss was more than the actual deficit in the supply of the produce to the consumer. In an estimate published in 1975, the total loss due to pests, diseases and weeds was approximately 18% of our total production. Of this loss the share of different agencies was estimated as follows: weeds 33%, diseases 26%, insect pests 20%, rats 6%, storage losses 7%.

The effect of these losses is not only economic. Many political and social problems originate from food shortage. Therefore, plant protection occupies a very important position in the strategy for making the countries self-sufficient in food and allied materials.

WHAT IS A PLANT DISEASE?

When the plant is under some sort of stress and is not developing and functioning in a manner expected from it, we call it diseased. This does not define the term "disease". Often the symptoms appearing as a result of a disease, the cause of the disease and the injuries caused to the plant have been considered synonymous. However, they signify only the condition of the plant due to disease or the cause of the disease.

In 1858, Julius Kuhn, in Germany, had defined plant disease as abnormal changes in the physiological processes which disturb the normal activity of plant organs. A similar definition was given by H.M. Ward in 1896 who defined disease as a condition in which the functions of the organism are

improperly discharged or, in other words, it is a state which is physiologically abnormal and threatens the life of the being or the organ. In 1918, E.J. Butler had defined disease as variation from normal physiological activity which is sufficiently permanent or extensive to check the performance of natural functions by the plant or completion of its development. Similarly, according to the American Phytopathological Society (*Phytopathology* 30 : 361-368, 1940) disease is a deviation from normal functioning of physiological processes of sufficient duration or intensity to cause disturbance or cessation of vital activities. The British Mycological Society (*Trans. Brit. Mycol. Soc.* 33 : 154-160, 1950) also defined disease as a harmful deviation from the normal functioning of process. Wheeler (1975) broadly considered plant disease as all the malfunctions which result in unsatisfactory performance of the plant or which reduce ability of the plant to survive and maintain its ecological niche. Thus, the major thrust in defining a disease since the time of Julius Kuhn was on the deviation from the "normal", a condition which may be variable.

An analytical approach to definition of the term "disease" was made by Horsfall and Dimond (1959) who clarified many misconceptions. According to them disease (i) is not a pathogen, it is caused by a pathogen, (ii) is not the symptoms or effects seen on the plant, symptoms result from disease, (iii) is not a condition as the condition results from the disease, (iv) is not any injury which results from disease as well as from any traumatic cause and (v) cannot be catching or infectious, it is actually the pathogen which is catching or trasmitted. They defined disease as a malfunctioning process in the plant body due to cotinuous irritation which results in some suffering. It is a pathological process in plants and animals (including man).

Singh *et al* (1989) put up a definition of disease based on views expressed by the above and other scientists. In their opinion disease is "a sum total of the altered and induced biochemical reactions in a system of the plant or plant part brought about by any biotic or abiotic factor(s) or by a virus leading to malfunctioning of its physiological processes and ultimately manifesting gradually at cellular and/or morphological level. All these alterations should be of such magnitude that they become a threat to the normal growth and reproduction of the plant".

The pathogens bring about the irritating processes resulting in a diseased conditions of the plant through different but interrelated pathways:

1) By utilizing the host cell contents.
2) By causing death of cells or by interfering with their metabolic activities through enzymes, toxins and growth regulators.
3) By weakening of tissues due to continuous loss of nutrients.
4) By interfering with translocation of food, minerals and water.

SOCIO-ECONOMIC SIGNIFICANCE OF PLANT DISEASES

Agrios (1988, p. 20) had listed 26 diseases that have caused severe losses

in the past. These include cereal rusts, potato blight, grape mildew, rice leaf spot, coffee rust, banana leaf spot, citrus tristeza, citrus canker, fire blight of pome fruits, sugarbeet cyst nematode and root knot nematodes. In the history of mankind the plant diseases have been connected with a number of important events. Some of these events are mentioned below:

The late blight of potato (*Phytophthora infestans*) is a famous example of what a plant disease can do to change the course of history. The disease coexisted with potato in the highlands of Central America. So long as the transportation across the equator was by slow moving boats, the fungus in potato tubers brought from there to Europe and North America was destroyed by the equatorial heat. With the introduction of steam boats and use of ice for storage on the boats the time taken for crossing the heat zone was shortened and the fungus could survive in the cold stores. This enabled introduction of the viable inoculum into Europe and North America. In 1845 the disease destroyed the potato crop of Ireland where potato was the staple diet of the population in the villages. The disease had started in Ireland, England and parts of the continental Europe as early as 1830 and was every year causing some damage resulting in food shortage. In England, which ruled Ireland at that time, free trade and import of foodgrains was not permitted. When the late blight epidemic destroyed the potato crop in 1845 there was famine in Ireland. The demographic data are highly variable (*cf.* Hampson, 1992) but it was reported that in 1840 the population of Ireland was 8 million which was reduced to 4 million after the famine. Hundreds of thousand perished from hunger and disease. There was large scale migration of the population to other countries including the north American continent where 1.6 million are reported to have migrated between 1847 and 1854. There are opinions contradicting the belief that the entire catastrophe in Ireland was due to potato late blight. Socio-political conditions including failure of the government to manage the situation were also equally, if not more, responsible. But the fact remains that this single disease forced man to realize the importance of plant diseases. As a result, scientific investigations were taken up, the cause of the disease was identified, concept of fungus as a cause of plant disease was finally established and extensive use of chemicals for plant disease control came into existence. The late blight epidemic not only brought the science of plant pathology to limelight, it caused many social and political changes in the affected countries. Free trade in England was permitted and import of foodgrains and other foodstuff was allowed. In order to protect shipping the country had to strengthen its navy which remained the strongest navy in the world for a long time. People who had migrated settled in other continents and helped in the development of new nations.

The history of devastation caused by cereal rusts is much older than that of late blight. The rust had been feared by farmers even thousands of years ago. In absence of scientific knowledge, the disease was considered curse of

gods and rituals propitiating the rust god Robigus became routine among farmers. The annual festival of Robigalia was started in 700 BC and continued in some form even into the Christian era. The black or stem rust (*Puccinia graminis tritici*) had been appearing in epidemic form in many countries and in some areas such as the central Europe the farmers abandoned wheat cultivation and resorted to cultivation of rye as a cereal because it was less damaged by the rust. Similarly in Mexico and neighbouring areas wheat rust prompted the farmets to grow more corn (maize). These changes in cropping systems resulted in change in food habits of the population.

In the last year of the Second World War (1943) Bengal state in India had to face a serious famine. One of the reasons to which this famine has been attributed was the loss in yield of the rice crop (major diet of the population) due to attack of Helminthosporium leaf spot which had been damaging the crop for the last several years. The situation was similar to the Irish potate famine but not so catastrophic. In this case also many reasons other than loss of the rice crop are listed. The important reason was the rise in the price of rice due to short supply resulting from low production and demand by army engaged in the battle front near Bengal. The population, mostly poor villagers, could not, thus, pay for the food.

In the middle of the nineteenth century coffee and tea were equally consumed in England because these were available in plenty from such occupied countries as India, Sri Lanka and Malaysia. Sri Lanka (Ceylon) used to produce maximum coffee in the world. In 1867 coffee rust attacked the plantations in Sri Lanka and by 1893 the export of coffee from Sri Lanka had declined by 93 per cent. The economic crisis forced the planters to cut down coffee plants and take to tea planting. Export of tea revived the economy to some extent and at the same time consumption of tea increased in England. When coffee rust was spreading in Sri Lanka the science of plant pathology was just developing and control measures for the disease were not known. Tea was also attacked by a blight but by that time chemical control measures were known and the situation did not deteriorate. The system of monoculture in coffee plantations of Sri Lanka was considered a contributory factor in devastations caused by the coffee rust which was not prevalent in coffee growing countries of South America. Coffee rust was first seen in the Western Hemisphere in 1979, in Brazil, where it is now spreading. In Brazil coffee trees are often surrounded by other kinds of trees. The decline of coffee cultivation in Sri Lanka gave a boost to coffee industry in Brazil which became a major coffee exporting country in the world. Nearness of this country to USA could be one reason for popularity of this beverage in USA. These instances of plant disease epidemics are worth mentioning because they left their effect not only in the country concerned but also in other countries.

Nearly half the citrus trees in the world had been destroyed by the citrus trisetza virus up to the year 1959 and millions are annually destroyed every

year. Panama disease or Fusarium wilt of banana is considered one of the six most destructive plant diseases in recorded history (Agrios,1988). In Jamaica alone it had destroyed 4 million plants within 25 years of its appearance there. The epidemic of southern corn leaf blight in the United States had caused a loss of $1 billion. To eradicate citrus canker in Florida (USA) millions of trees had to be destroyed in 1910s and again in 1980s. The fire blight of apple kills numerous tress annually in the United States.

In India, wheat rusts were considered to cause a loss of over Rs. 40 million annually. In the years of epidemics there were losses amounting to Rs. 500 million or more. During the wheat season of 1956-57, average yield of wheat in the state of Bihar was reduced from 900 kg/ha to 50 kg/ha due to rust epidemic. Although introduction of dwarf high yielding varieties has reduced the losses caused by rusts to a great extent even now the farmers lose 8–10% of the expected yield due to rusts. The loose smut of wheat (*Ustilago segatum tritici*) is estimated to cause an average loss of 3% (about Rs. 50 million) every year. This figure is based on only 3% incidence. Individual fields not adopting proper seed treatment may show 23–30% smutted heads. Different smuts of sorghum are responsible for an annual loss of Rs. 100 million. Five to 75% loss in chickpea (gram) due to Ascochyta blight was reported from Rajasthan during 1982. Wilt of pigeonpea causes 5–10 per cent loss every year in U.P. and Bihar. At a time when there is shortage of pulses in the country control of only wilt and sterility mosaic of pigeonpea could increase the production by 15–16%. The first epidemic of apple scab that occurred in Kashmir Valley in 1973 ruined apples worth Rs. 5.4 million in a single season. In the Shimla Hills, 16–34% fruits are rendered worthless annually due to scab. Losses due to this disease in Himachal Pradesh are estimated at Rs. 15 million every year (cf. Singh, 2000).

Worldwide losses due to nematodes are estimated at $1 million (Perry, 1996). Of about 10 per cent crop losses in India due to nematodes, there is a loss of about Rs. 20 million every year in coffee alone due to the attack of *Pratylenchus coffeae*. The 'Molya' disease (cereal Cyst nematodes) of wheat and barley prevalent in most parts of Rajasthan, causes a loss of Rs. 30 million in barley and Rs. 40 million in wheat every year losses varying from 10–26% in different vegetable crops by root knot nematodes are common every year.

Other plant diseases, such as red rot and wilt of sugarcane, potato viruses, rice blast and blight, Karnal bunt of wheat, root knot of tomato, brinjal and cucurbits, apple scab, mango malformation, bunchy top of banana, and sandal spike are responsible for huge losses. Epidemics of these diseases have been frequent.

In addition to direct loss in yields and monetary returns to the farmer, the plant diseases affect the society in many other ways. When foodgrains are attacked by fungi they may contain toxins (such as aflatoxins) which cause

insanity, paralysis, stomach disorders and liver cancer. The money spent on management of plant diseases is also a loss because in absence of diseases this money could be saved. The expenditure on raising the crop before it is attacked by the pathogens is also a waste. When there is less production transport industry may suffer due to lack of goods for transport. Industries that consume raw agricultural materials (cotton, jute, oilseeds, vegetable and fruits for processing) face difficulty in utilizing their installed capacity when there is less production due to plant diseases. In order to make up for the loss of foodgrains and other agricultural products such as oilseeds the governments have to import these commodities which means loss of foreign exchange at the disposal of the government. Plant disease management requires use of toxic chemicals. Excess use of such chemicals may lead to environmental pollution affecting human health.

THE SCIENCE OF PLANT PATHOLOGY

Plant pathology or Phytopathology (*phyton*– plant; *pathos*– ailments; *logus* – knowledge) is that branch of agricultural, botanical or biological science which deals with the cause; *etiology*, resulting losses and management of plant diseases. It is a science similar to that of medicine and veterinary which deal with diseases of man and animals, respectively. The science of plant pathology has four major objectives:

1) to study the living, non-living and environmental causes that induce disease,
2) to study the mechanisms of disease development by pathogens,
3) to study the interactions between the plants and the pathogen,
4) to develop strategies for managing the diseases and reduce the losses caused by them.

A plant pathologist or phytopathologist has to achieve these objectives. For the plant world his place is the same as that of a physician for human beings. He protects the plants from their enemies, enables them to live their full life and express their maximum ability for production. This provides the plant pathologist a special status in the society since the latter has to depend on health of the plants. The plant pathologist is a practical scientist. His aim is not only to destroy the enemies of the food crops or fruits trees but also to increase the productivity of the crop and profits of the growers. Disease management is only a means of achieving these aims.

It appears that in early days plant disease management developed as an art practiced by farmers on the basis of their and their ancestros' experiences. No science was involved. This perhaps continued for centuries until some attempts were made to understand the nature of disease and relationship between the disease and its causal agent. The observations reported by biologists during the latter part of the nineteenth century gave the subject some appearance of

science comparable with other branches of biology. The science of plant pathology is related to most of the old and new branches of science. It was related to physics, chemistry, botany and zoology in the early stages of its development but now it is similarly related to molecular biology and biotechnology, bacteriology, virology, nematology, plant anatomy, physiology, genetics, biochemistry and soil science including soil microbiology. In many of these biological sciences plant pathology has contributed in basic research.

TERMINOLOGY

Disease and Disorder: These two terms carry the same meaning, i.e., malfunctioning in the plant body. However, while the term disease includes all types of harmful physiological changes in the plant, often the non-infectious plant diseases due to abiotic causes such as adverse soil conditions are termed disorders. Components of a disease are the pathogen and the host interacting in a given set of environments.

Pathogen: In a literal sense a pathogen is any agent that causes *pathos* (ailment, suffering) or damage. It should, therefore, include all living organisms associated with the disease, viruses as well as the abiotic agents such as adverse atmospheic or soil conditions. However, the term is generally used to denote specific living organisms (fungi, bacteria, MLO, nematodes) and viruses but not such agents as nutritional deficiencies.

Parasite: Organisms which derive the material they need for growth from living plants (the host or the suscept) are called parasites. Most, but not all, pathogens are parasites, similarly most, but not all, parasites are pathogens.

Biotrophs: Organisms which, regardless of ease with which they can be cultivated on artificial media, always obtain their food in nature from living tissues on which they complete their life-cycle are called biotrophs or **obligate parasites**. Fungi causing rust, smut and powdery mildew are typical examples.

Saprophytes: Organisms that derive their nutrition from dead organic matter.

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 way as a biotroph but will continue to grow and reproduce after the tissue is dead. Such parasites can also be called **facultative saprophytes**. A parasite is **necrotroph** when it kills host tissue in advance of penetration and then lives saprophytically. *Sclerotium rolfsii* is an example. Similar to necrotrophs are **facultative parasites** which live as saprophytes but under favourable conditions attack living plants and become parasites. The necrotrophs are also known as **perthotrophs** or **perthophytes**.

Pathogenicity is the ability of a pathogen to cause disease while **pathogenesis** is the chain of events (steps) that lead to development of disease in the host. **Virulence** is a measure or degree of pathogenicity of an isolate or race of the pathogen. The term **aggressiveness** is often used to describe the capacity of a pathogen to invade and grow in its host plant and to reproduce on or in it.

This term, like virulence, is also used as a measure of pathogenicity.

Infection is establishment of parasitic relationship between two organisms following entry or penetration. In immune or highly resistant plants penetration may occur without infection.

Systemic infection: The pathogen grows from the point of entry to varying extents without showing adverse effect on tissues through which it passes.

Invasion and Colonisation: After infection the pathogen grows through the tissues of the host to varying extent drawing nutrition during its growth.

Immune: Immunity of a plant against a given disease is an absolute quality. It denotes that the pathogen cannot establish parasitic relationship with the host. 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 physically or physiologically damaged by a pathogen is used to measure the **resistance** or **susceptibility** of the plant. High resistance or law susceptibility approaches immunity. **Hypersensitivity** is extreme degree of susceptibility in which the host cells react violently to the invading pathogen and as a result there is rapid death of cells in the vicinity of the invading pathogen (*infection court* or *site of infection*). This may halt the progress of the pathogen although it may or may not die immediately. Thus, hypersensitivity is a sign of incompatibility or very high resistance approaching immunity.

Resistance can be **horizontal** (uniform) when it is evenly spread against all races (strains) or a pathogen, or **vertical** (differential) when it is effective against one or few races but not against others. Since the number of races of the pathogen is indefinite, new races being evolved often, the resistance may be found lacking even in varieties with uniform resistance. Resistance may be **monogenic** (single gene), **polygenic** (determined by many genes) or oligogenic (several genes). **General resistance** is known under a number of synonyms such as partial resistance, race nonspecific resistance, horizontal resistance, field resistance, dilatory resistance, slow rusting, slow mildewing and slow blighting.

Systemic acquired resistance: Resistance triggered in the plant during its life time is acquired resistance. It can be local (LAR) confined to few cells or tissues or systemic (SAR) having been moved throughout the plant.

Tolerance is a type of defence that minimises crop loss without restricting disease development. **Disease escape** is the ability of an otherwise susceptible plant to avoid damaging disease stress because of the way it grows. This is considered a useful system of protection in natural ecosystem.

Elicitors are signals, presumably chemical signals, generated by an organism to bring about metabolic shifts in another organism. It is usually applied in phytoalexin production. **Inducer** is more general term. Elicitation is the first step in cell-cell communication when the infection propagule comes in contact with the host cell surface.

Recognition system: Cell recognition is defined as the event of cell-cell communication which elicits a defined biochemical, physiological or morpho-

logical response. The term is used to explain the earliest events in host-parasite interaction or pathogenesis when molecules of the host cell surface recognise like molecules in pathogen surface and accept it for establishment of parasitic relationship. If the pathogen molecules are unlike, they are rejected and no relationship is established. Similarity at molecular level or genetic matching leads to **compatibility** between host and parasite and dissimilarity leads to **incompatibility**. At the molecular or genetic level the interactions are highly specific giving specificity to the host or the pathogen in the recognition system.

Incubation period: The time lapsing between inoculation and appearance of symptoms (sign of establishment of parasitic relationship) is known as incubation period. It varies with pathogen, host and environmental conditions.

Latent, dormant or **quiescent** parasitic relationship is a condition in which the pathogen spends long periods during host's life in a quiescent stage until, under specific cirumstances, it becomes active. In epidemiology the period from spore landing until the parasitized tissue produces new spores is known as **latent period.**

Queiscence of an organism is the stage when under the influence of some biological, physical or chemical stress the organism or its propagules undergo an inactive state. This is known as dormant, anabiotic or queiscent stage. This is an adaptation for survival under adverse conditions.

Symbiosis: Living together of two unlike organisms is known as symbiosis, the two organisms being called **symbionts**. This includes parasitism also when the attacked plant or organism remains alive. In associations where there is some or high dergee of adjustment between the two organisms whereby each gets some benefit the term **mutualism** is used. In contrast to mutualism is **antagonism** in which one organism is injured by the other either through competition for food or other demands or through secretion of toxic substances (**antibiosis**) or by direct injury (**parasitism** and **predation**).