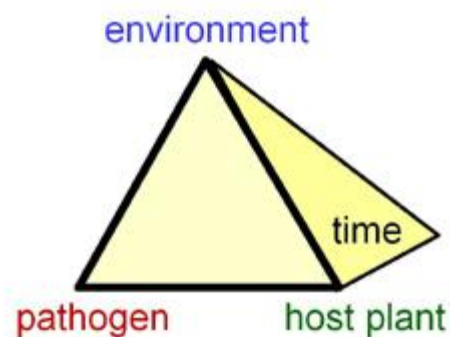


DISEASE MANAGEMENT

All plant diseases result from a three-way interaction between **the host, the pathogen and the environment**. An epidemic develops if all the three factors are favourable to disease development and time is needed for disease to develop. Therefore, disease can be controlled by manipulating one or more of these factors so that conditions are unsuitable for replication, survival or infection by the pathogen.



The pathogen can be manipulated by excluding or reducing inoculum available to infect plants.

- If a particular pathogen is not present in an area then attempts can be made to prevent its introduction. Quarantine regulations govern the introduction of plant material from high-risk areas. Seed certification schemes also reduce the risk of introducing a new pathogen, and propagating material can be treated to kill any inoculum that is present, before it is introduced to a new area.
- If a pathogen is already present in an area, efforts to eliminate or reduce the amount of inoculum present are the only option. Elimination of an existing pathogen is usually not successful, but there are a variety of methods, such as crop rotation, chemical and physical

treatment and trapping, that can effectively reduce the amount of inoculum present.

- The nature of the pathogen (seed borne, soil borne, vector transmit, etc) can have a significant impact on the management of its disease.

The host can be manipulated by increasing its resistance to disease. This can involve:

- Breeding or selecting plants for genetic resistance to a specific disease,
- Applying chemicals, such as fungicides, that prevent or halt infections in the plant.

The environment can be modified so that it is suitable for plant growth but not for disease development. This can involve:-

- improving soil drainage
- changing the time of sowing
- reducing the density of plants in a crop
- Changing the irrigation practices

Altering these conditions can produce conditions unfavourable to particular diseases, while maintaining conditions suitable for the growth of the plant.

Any decrease in the amount of initial inoculum or the rate of disease increase or the time available for development, will cause a decrease in the amount of disease.

Management strategies therefore, look at altering/or reducing one or more of these factors (Pathogen, host and environment) in order to reduce the amount of disease.

- 1.) The **initial amount of inoculum** can be controlled by quarantine practices and preventative treatments.

- 2.) The **time available for disease development** can be reduced in some kinds of crops by harvesting before the disease has developed to epidemic proportions.
- 3.) The **rate of disease increase** can be reduced by
 - a.) Mixing plants that are not all susceptible to the same strain of pathogen
 - b.) Applying preventative chemical treatments
 - c.) Changing the environments the host and pathogen are exposed to, for example, by changing planting dates, crop density or irrigation practices.

When all the strategies are put together it is referred to as integrated disease management (IDM).

Integrated Disease Management uses all suitable techniques that complement each other with the aim of keeping pathogen populations below the threshold at which economic damage occurs. This approach also aims to avoid the problem of pathogens developing resistance to widely used fungicides. In integrated disease management, resistant crop varieties might be used in conjunction with chemical treatment, crop rotation and manipulation of the planting dates and environment in green house crops and in small fields.

Multiple approaches to disease management are particularly useful when the disease cycle is not fully understood.

There are different strategies which can be employed in the management of plant diseases. These include:

- 1.) Cultural management
- 2.) Biological management

3.) Legislative (Quarantine)

4.) Chemical

1.) CULTURAL MANAGEMENT

Cultural disease management practices are the measures undertaken to prevent and control diseases by manipulating plants.

In case of low-return crops, these might be the only forms of disease management that are economically viable. Cultural management practices include:

- Reducing the amount of initial inoculum
- Reducing the rate of spread of an established disease
- Planting a crop at a site that is not favourable to pathogens because of the sites altitude, temperature, or water requirement.

A.) REDUCING THE LEVELS OF INITIAL INOCULUM

This practice is employed where there was/is the presence of disease causing pathogens and other abiotic factors that affect crop growth. It aims to reduce the initial levels of inoculum using several strategies such as;

i.) Selection of appropriate planting material

This can involve

- planting resistant cultivars- this will help manage diseases such as maize streak virus disease, grey leaf spot
- Planting a number of mixed cultivars- useful for selecting for next planting season.
- Using certified seed and ensuring that disease is not spread on vegetative propagating materials (Corms, suckers, tubers, etc) or on planting equipment (planters).

Many agricultural systems are characterised by dense populations with genetic homogeneity (monocultures). Once a disease becomes established in

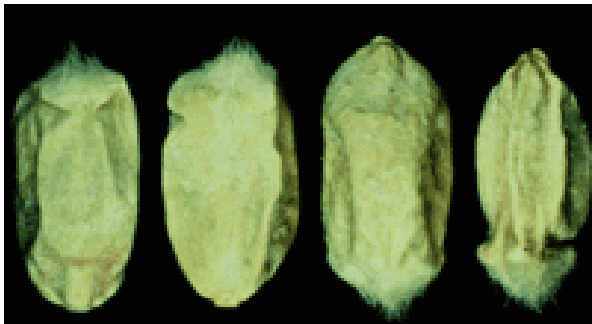
such a plant community, it can rapidly spread to epidemic proportions, hence the value of planting mixed cultivars, which incorporate a range of resistances.



Fusarium head blight infection on durum wheat. Note the bleached spikelets within the infected heads



Symptoms of *Fusarium* head blight in the field. Note the bleached spikelets within the green head



Symptoms of *Fusarium* head blight caused by *Fusarium graminearum* on seed. Note the shrunken, chalky kernels.



Healthy certified wheat seed

ii.) **Destruction of crop residues,**

Crop residues can harbour many pathogens which in turn over winter in the crop residue and become a source of inoculum when a susceptible crop is grown for example rice blast caused by *Magnaporthe oryzae* (*Pyricularia oryzae*).

Destruction of the crop residue is an important practice performed between cropping seasons. This can be done depending on the type of crop, the type of pathogen and the size of the crop.

This can be achieved by, Burying, burning and removal of living plant parts that carry pathogens.

Burying crop residues can destroy some pathogens if ploughed in deep enough, for example plant debris infected by northern leaf blight caused by *Helminthosporium turcicum* (*Setosphaeria turcica*) but some pathogens can survive, and even benefit from this process if it serves to spread them throughout the field.



Large cigar-shaped lesion symptomatic of northern corn leaf blight

Burning crop debris is a common practice, especially for cereal crops, and it is a successful method of destroying many pathogens. Its success depends on the intensity of the fire. For example Head smut of maize caused by *Sphacelotheca reiliana* which survives as teliospores and later forming basidiospore on dry soil can be managed by burning.



Head smut of maize caused by *Sphacelotheca reiliana*

Burning has disadvantages such as loss of nutrients, smoke pollutions, increased soil erosion and contributing to the greenhouse effect. Because burning can completely destroy a source of inoculum, it is commonly used in eradication campaigns against newly introduced pathogens.

Elimination of living plants that carry pathogens can be done for remnant or diseased crop plants as well as wild plants or weeds that can act as alternative hosts between seasons. For example black stem rust of wheat caused by *Puccinia graminis* cannot complete their life cycle in the absence

of an alternate host common Barberry weed/plant, where it undergoes sexual recombination it is then able to infect the next crop of wheat that is grown in the field.

In maize, common rust caused by *Puccinia sorghi* has an alternate host which is *Oxallis latifolia*. The weed needs to be destroyed in order to prevent subsequent infections.

Removing alternate hosts can delay an outbreak, but often inoculum finds its way to crop plants via wind or another vector.



Black stem rust Uredinia of *Puccinia graminis* f. sp. *Tritici* on wheat



Common barberry (*Berberis vulgaris*), an alternate host of *Puccinia graminis*



Maize leaf with symptoms of maize leaf rust caused by *Puccinia sorghi*



Oxalis latifolia the alternate host of common rust of Maize caused *Puccinia sorghi*

iii.) **Crop rotation**

Crop rotation refers to the successive planting of different crops in the same area, sometimes with a fallow, or resting, period in between crops.

The most successful practice rotates crops over periods that are longer than the survival period of the pathogen, thus reducing or eliminating inoculum during the rotation interval before a susceptible crop is planted in the field again. It tends not to be very effective against pathogens that survive for a long time in the soil such as Bacterial wilt pathogen *Ralstonia spp* which may require rotations of up to 5 years.

B.) REDUCING THE RATE OF SPREAD OF DISEASE

The movement of disease from one plant to another may result in epidemics if this is not checked. The rate of disease spreading can be reduced by controlling several factors such as spacing of plants, humidity, moisture levels and amount of sunlight.

These factors are more easily controlled in a greenhouse environment, but some can be manipulated in the field also.

In general, wider spacing of plants reduces the speed with which disease moves between plants while reducing moisture levels can inhibit infection by pathogens.

Other practices that can reduce the spread of pathogens include;

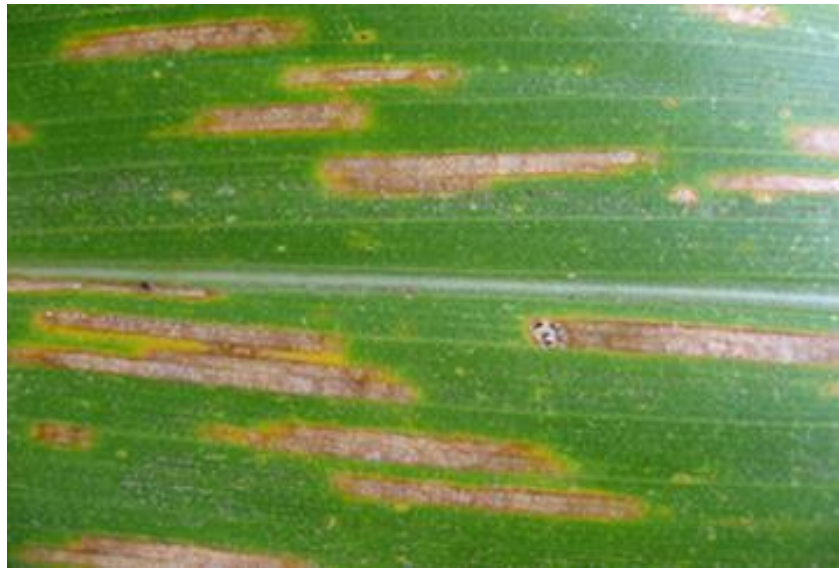
- Tillage practices. They can either burry the pathogens deep into the soil where they are less likely to cause disease although some forms of inoculum can be spread extensively during tillage.
- **Sowing practices**, such as changing time, depth and direction of sowing, and changing the density of the crop can protect plants from pathogens to which they are susceptible only at certain stages of their development. Changing the time of sowing can exploit weather conditions that are unfavourable to the pathogen, thus reducing crop losses. The depth of sowing can have a bearing on the chance of infection, as the seedling's pre-emergence stage, which is usually more susceptible to attack, is longer when seeds are planted deeper. However, deeper planting can stimulate germination.
- **INTERCROPPING** can reduce disease by increasing the distance between plants of the same species, and creating a physical barrier between plants of the same species. How successful intercropping is depends partly on the combination of crop plants chosen, since some combinations can actually make disease worse by providing an alternate host or a stimulus that encourages germination of inoculum on the neighbouring species.

- **Mulching and soil amendments** help to reduce the spread of soil-borne diseases that rely on splash-dispersal, but other diseases, for which the altered environment is favourable, can be enhanced. The addition of organic amendments to the soil can also reduce disease influence by increasing the activity of competing or predatory micro-organisms in the soil, although it can also increase the incidence or severity of diseases caused by pathogens that thrive on the amendment.

- **Rouging-** This is the removal and destruction of diseased plants, or rogues. It can prevent further spread of disease although it is labour intensive. For that reason, it is practicable only in small plantings, or where labour is cheap or if the crop is very valuable. Effective rouging requires the removal of diseased plants as soon as possible after symptoms are observed. In some cases, the diseased plants as well as those immediately surrounding them, are destroyed in an attempt to halt spread of the disease such as vector borne diseases e.g. Viruses.

- **Fertilisers and crop nutrition-** A well-balanced supply of soil nutrients will result in healthy, vigorous plants, which should have a greater chance of withstanding attack by pathogens that unhealthy plants would not. However, many pathogens also thrive under ideal growth conditions, particularly biotrophic pathogens, such as viruses. The major nutrients that influence plant and pathogen success are nitrogen, phosphorous, potassium and calcium.

The application of **nitrogenous fertilisers** delays crop maturity by prolonging vegetative development. This can increase the risk of infection, since plants are more susceptible to disease at that stage of development. For example excessive N in a field favours the development of Grey leaf spot disease in maize caused by *Cercospora zea maydis*



Rectangular lesions of gray leaf spot on maize caused by *Cercospora zea maydis*

The addition of **phosphorous fertilisers** affects different crops and diseases in different ways, sometimes encouraging and sometimes inhibiting disease.

Potassium generally inhibits disease development, counteracts some of the disadvantages of nitrogen fertilisers, and promotes the healing of wounds in plants, all of which reduce disease. However, potassium's effects can be variable, directly stimulating or inhibiting the penetration, multiplication, survival and establishment of a pathogen.

Calcium is a necessary nutrient for the composition of plant cell walls. An adequate supply of calcium produces cell walls more resistant to penetration by facultative pathogens. High levels of calcium can also raise the pH of the soil, disadvantaging any pathogens that favour acidic soils. However, soils

high in calcium can also promote the development of some diseases. Essentially, the use of fertilisers has mixed effects on plant disease. The type of fertiliser that can be used without promoting disease will depend on the starting soil conditions and, importantly, the pathogens that are present.

Trap and decoy crops

Trap crops of susceptible plants are grown on land known to contain pathogens. They become infected and are then destroyed before the pathogens' life cycles are complete, thus reducing the amount of inoculum in the area. Decoy crops stimulate the hatching or germination of pathogen eggs or propagules, but the pathogens are unable to establish and infection of the decoy host and die, again reducing the amount of available inoculum. The ideal decoy crop is one that has economic value and can be used in a routine crop rotation.

BIOLOGICAL CONTROL

Biological control of disease employs natural enemies of pests or pathogens to eradicate or control their population. This can involve the introduction of exotic species, or it can be a matter of harnessing whatever form of biological control exists naturally in the ecosystem in question.

NATURAL CONTROL

All biological communities are complex ecosystems in which the abundance of any organism is dependent on its food supply, its environment and other organisms. If a pathogen is kept in check by the microbial community around it, then biological control has been achieved. Biological control appears to take place on the plant surface by the activity of epiphytic

microflora. This is then an important consideration when applying chemicals to plants, since there is a risk of killing natural antagonists of pathogens other than the one being treated.

There are several mechanisms for microbial antagonism of plant pathogens which include **parasitism, predation, competition, induced resistance** and the **production of antimicrobial substances**.

Competition exists between organisms that require the same resource for growth and survival. Use of the resource by one organism reduces its availability for the other organism. Competition for space or nutrients usually takes place between closely related species. Therefore, it can be effective to treat plants or seeds with a non-pathogenic strain of a related species that can out-compete the pathogenic organism. In some cases, the treating species need not be closely related to the pathogen, as long as it uses the same resources. For example, bacteria and yeasts can reduce fungal spore germination by competing with the spores for nutrients on the surface of leaves.

Parasitism of one fungus by another (*hyperparasitism* or *mycoparasitism*) is affected by environmental factors, including nutrient availability. Formulations of some parasitic species of fungi are available commercially for the control of fungal plant pathogens in the soil and on the plant surface such as *Trichoderma spp.*

Bacteria on the plant surface and in the soil are also known to parasitise plant pathogens, such as other bacteria and fungal spores for example *Bacillus subtilis*.

Predation of plant pathogens by invertebrates can also contribute to general biological control. Bacterial feeding nematodes consume large numbers of bacteria in the soil.

Induced resistance and cross-protection are two mechanisms of plant 'immunity' against a pathogen. In the case of **cross-protection**, an organism present on the plant can protect it from a pathogen that comes into contact with the plant later. For example, symptomless strains of tobacco mosaic virus can protect tomatoes from virulent strains of the same virus, rather like immunisation in animals. **Induced resistance** is a form of cross-protection, where the plant is inoculated with inactive pathogens, low doses of pathogens, pathogen-derived chemicals or with non-pathogen species to stimulate an immune response. This prepares the plant for an attack by pathogens, and its defence mechanisms are already activated when infection occurs. It provides protection against a wide range of pathogens across many plant species.

LEGISLATIVE QUARANTINE

Exclusion, eradication and elimination of disease

The prevention of pathogens entering new regions is known as **exclusion**, and is achieved by quarantine or by treating propagating material (**elimination**) before its introduction. If an outbreak of a disease occurs in a new area, efforts are made to **eradicate** the pathogen from that area.

CHEMICAL CONTROL

Chemical disease control employs the use of chemicals that are either generally toxic and used as disinfectants or fumigants or chemicals that

target specific kinds of pathogens, as in the case of fungicides, bactericides (or antibiotics) and nematicides. No substances have yet been found that effectively control plant viruses.

Ideally, a chemical control agent should be effective at concentrations that will not harm the plant, have low risk to humans and animals, and have minimal effect on the normal microflora on the plants and in the soil. Also, there should be little chance of the pathogen quickly developing resistance to it, and it should be suitable for long periods of storage in ambient conditions.

Chemical interventions of plant disease management will include: Foliar application of plant protection products; Seed dressing, drenching.

These interventions will either be Fungicides, antibiotics or Nematicides

Fungicides are chemicals used in the control of fungal diseases and they are classified as either protectant or systemic.

Protectant fungicides are usually effective against a broad range of fungi and protect the plant against infection on the surfaces of the plant/seed to which they are applied. Often, they require multiple applications during the growing season to maintain coverage as new growth emerges and weathering removes past coverage. An example of the fungicides used for seed treatment is **MAXIM XL** has two active ingredients (Fludioxonil)- On a broad range of disease, including *Fusarium spp*, *Rhizoctonia spp*, *Helminthosporium spp*. and (**Mefenoxam**) is active on fungi of the Oomycetes class to control *Pythium spp* on maize as a seed dress.

Systemic fungicides can be absorbed by the plant without harming it, and transported to other tissues where they are toxic to fungi. These compounds can control and eradicate established infections, but they are also vulnerable

to fungi developing resistance, as they generally only target one step in a biosynthetic pathway to kill the fungus. To minimise the development of resistance by chemical overuse, fungicides are classified into groups based on their chemical activity and should be used alternately between the different classes of fungicides.

Antibiotics are chemicals produced by micro-organisms, which destroy or injure living organisms, in particular, bacteria. Streptomycin is effective against a few fruit pathogens, such as blights and cankers, and cyclohexamine can be used to control some fungal pathogens of crops, particularly powdery mildews and rusts.

Nematicides are used for management of nematodes. Their use is confined largely to high-return horticultural crops, because they are expensive. Additionally, they are all highly toxic, and alternative measures for controlling nematodes are being investigated.



Non treated maize seed



Chemical treated maize seed Maize seed