AGC 3342 CROP PROTECTION – PLANT PATHOLOGY COMPONENT
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PATHOGEN MONITORING, PATHOGEN MANAGEMENT METHODS, INTEGRATED DISEASE MANAGEMENT

PATHOGEN MONITORING

Once you decide that you will take precautions to prevent or minimise pest infestations or disease damage, it is important you watch regularly for the appearance of insects, weeds, diseases, and other pests. This is called monitoring. Monitoring helps you to be able to locate, identify, and rank the severity of pest infestations so you can make a decision concerning the control of such pests early enough. These data may also be used to project future populations through pest management models. In addition to giving solid data for making a management decision, regular monitoring works well for checking the success or failure of a control strategy. Pest populations vary from field to field from year to year. Pest monitoring is site-, crop-, and pest-specific. Each situation will require specialized knowledge and tools. Pest monitoring involves three major things: 1) Estimation of changes in pest and pathogen distribution and abundance, 2) Collecting and evaluating information about the pest and pathogen's life history, and 3) understanding the influence of biotic and abiotic factors on pest population.

1) Estimation of changes in pest and pathogen distribution and abundance

This is achieved through a combination of visual observations, laboratory diagnosis and use of traps. When conducting visual observations in the field, it is important that you know the morphological features of the pest or pathogen as well as the symptoms of damage or disease they cause on the plant. Where pathogens are concerned, you will not be able to see them with your naked eye, but you might see some structures such as whitish, brown or red threadlike structures, depending on the species of the fungus in question. The colors mentioned above may also differ depending on the species of fungus you are monitoring. If you are a beginner, you may want to go into the field a manual with color illustrations of some of the common pests. As you will remember, pathogens cause disease and the symptoms of the disease will vary from one pathogen to another. These symptoms are what you actually look for when you are conducting monitoring.

2) **Collecting and evaluating information about the pest and pathogen's life history**

Knowing the life history of the pest or pathogen will help you to know what stages of the pest to look out for.

3) **Understanding the influence of biotic and abiotic factors on pest population.**

Understanding the how the biotic (aspects of the environment connected to living things) and abiotic (non living things) factors in the environment and how they affect pest population dynamics is very important. For example, many fungal diseases occur when abiotic factors such as temperature and humidity are favourable. More specifically, high temperatures (25-33 degress celsius) and high humidity tend to promote fungal diseases. This means that as these abiotic factors become favourable, your monitoring of pests and diseases should heighten. In a similar manner, presence of biotic factors such as vectors of diseases may result in an increase in that disease. It therefore means that the abundance of the vector must also be carefully factored in during pest and disease monitoring.

4.5 Economic Threshold Level

From the insect pest point of view, the economic threshold level (ETL) is the pest density at which management action should be taken to prevent an increasing pest population from reaching the economic injury level. From a plant disease point of view the economic threshold level is the disease prevalence level (incidence and severity) at which management action should be taken to prevent increasing disease prevalence from reaching the economic injury level. As a farmer, you do not have to immediately take action each time you see a single insect or a single diseased leaf in a huge farm. You must only begin to worry once you notice that the pest or disease is increasing. Even then, you will only act if you notice the disease or pest is threatening to increase to a point where you will not make any profit from what will remain undamaged, also called the economic injury/damage level.

4.6 Economic Damage

As you may have guessed from the word “economic”, this is the amount of pest damage or disease level that will prevent you from making profits if you were growing a crop for business. If you monitor pest or disease levels carefully, you will be able to take action before the economic threshold level is reached, and therefore able to prevent economic damage from occurring. This would make sure you remain profitable, or ensure you donot go hungry if you grow your own food.

4.7 Economic Injury Level

Economic injury level is the lowest insect population density that will cause economic damage, or the lowest injury level or level of disease prevalence that will cause you as a farmer to incur economic losses. Although economic injury level is the actual damage done to the plants, it can also be estimated by estimating insect pest density.

PATHOGEN MANAGEMENT METHODS

Cultural Control

In pathogen management, cultural control refers to measures you primarilly use for other reasons, but nevertheless reduce pathogen establishment, reproduction, dispersal and survival. For example, crop rotation was initially meant to address soil fertility issues, but it so happens that crop rotation also helps to reduce pests. Other such examples include the use of clean seed, proper plant spacing (avoid very close spacing), water management (avoid reckless water splashes); use of pest repellants or attractantants of natural enemies of pests, and the use of cover crops. If you use cultural control measures the advantages you will get include increased plant vigour, increased yield, no harmful effects on environment or farmer, and no pesticide residues remain on the crop to be consumed by people. The downside of relying on cultural control measures to manage pests is that it is labour intensive, time-consuming, and cultural measures are only effective when deployed before disease outbreak.

Cultural Control of Pathogens

Below are some cultural practices that can be used to control pathogens and reduce plant diseases.

a. Proper selection and preparation of planting materials and care during planting

As you may know by now, you seed to plant a crop such as maize or groundnut, and vines to plant crops such as sweet potato. However, these planting materials may also be home to insect pests and disease-causing microbes. It is therefore important that you obtain your planting materials (seeds, vines and otherwise) from reputable sources or from disease-free and insect-free farms or companies. All of the major plant pathogens can be transmitted by seed or propagating material. Materials which have been certified free from disease following field inspection or laboratory testing provide a useful safeguard to growers. The value of certified seed is further enhanced if the parent crops have been grown in areas where particular parasites are unknown. Alternatively, rigorous chemical control programs for selected organisms may be instituted during the growing and storage of a seed crop to reduce or eliminate pathogens from planting materials. If these procedures are not followed, you as a grower may have to treat seed or other propagating structures prior to planting. Efficient seed-cleaning procedures also contribute to the control of some diseases such as earcockle of wheat caused by the nematode *Anguina tritici* by removing infected seeds and leaving only uninfected material.

Pathogens can be transmitted to healthy material by contaminated knives during the preparation of vegetatively propagated material for planting. For example, you might be using a knife to cut sweet potato vines for planting in another field. If there are disease-causing microorganisms in one of the vines, the subsequent vines you cut with this knofe may also become contaminated. When you are planting vegetatively propagated crops you need to practise proper hygiene procedures to prevent transmission of pathogens. For some vegetatively propagated crops such as cassava, tissue culture techniques may be necessary to obtain disease-free planting stocks. For example, viruses and vascular wilt fungi do not reach the apical meristems of their hosts until late in the development of the disease. Pathogen-free meristems can be tissue-cultured and used as the basis of a vegetative propagation program. Even if planting materials are apparently free from parasites, infection may occur if they are damaged during planting operations. Common causes of damage include incorrect adjustment of mechanical planting devices and seedling injury during transplanting. Seedling tobacco plants can also be infected with tobacco mosaic virus via workers' hands during transplanting operations. In such situations, growers need to practise proper hygiene procedures to prevent transmission of pathogens.

b. Destruction of crop residues after harvest

Every time you finish harvesting your crop, there is always crop residues that remain behind. Crop residues provide suitable substrates for many pathogens. Burying, burning and removal of postharvest crop residues are important cultural control practices performed during intercrop periods. The effect of destroying crop residues on particular pathogens depends on the type of crop (annual, perennial or harvested product), the extent of the cropping area and the survival mechanisms and host ranges ofthe target pathogens. If you **burry** crop residues, some potential pathogens may be either killed or inhibited in their development. Deeply inverted surface trash assists in the control of groundnut (peanut) blight because the causal fungus *Sclerotium rolfsii* requires a food source near the surface of the soil. Plants with shallow root systems may also escape infection if debris from the previous crop is ploughed in deeply. This practice has been relatively successful in controlling verticillium wilt disease in some crops. Fungal pathogens such as Sclerotinia and Claviceps which produce sclerotia can be controlled to some extent by burying surface soil. While burying crop residues can effectively reduce inoculum, if the form of tillage redistributes pathogens horizontally rather than vertically in the soil, it may promote, rather than reduce, future crop damage. Crop residues and other organic matter can also be composted before reuse. Heat generated during the composting process kills pathogens, provided the material is turned regularly during composting so that all of the organic matter has a turn at being in the hottest part of the compost pile. **Burning** the stubble of harvested cereal crops has been a common practice throughout the world. Rice stubble is burned in many areas to reduce the inoculum of *Sclerotium oryzae* (causal organism for stem rot disease in rice) and other pathogens. Burning potato leaves after harvest reduces inoculum of *Alternaria solani* (causal organism for early blight disease in potato) for the next season. In the slash and burn method of agriculture practised in some tropical countries such as Zambia, burning a l0 cm layer of litter on the soil surface destroys nematodes to a depth of 9 cm. In many areas of the world, sugar cane crops are routinely burned to facilitate harvesting operations. However, many pathogens are also eliminated by the intense heat produced in the process. Where this practice does not occur, postharvest burning of trash may be employed as a disease control practice. The success of burning in destroying inoculum is determined by the intensity of the burn which is, in turn, influenced by the amount, moisture content and quality of the plant debris, the wind velocity and the duration and temperature of the burn. However, any advantage in disease control has to be weighed against the adverse effects of burning. These include loss of nutrients, contamination of the environment with smoke, addition of carbon dioxide to the atmosphere contributing to warming of the earth and increased soil erosion following the removal of protective vegetation. Experience with yellow spot (*Pyrenophora tritici-repentis*) of wheat has shown that stubble burning can be used to reduce the level of inoculum of a fungus without contributing to soil erosion. Inoculum of *P. trittci-repentis* survives between crops in wheat and triticale stubble and while stubble burning soon after harvest was practised, the disease was of minor importance. Unfortunately, stubble burning left the soils exposed to loss of water through evaporation and severe erosion by run-off following high intensity summer storms. Farmers stopped burning their stubble and yellow spot increased in importance, reducing yields. To prevent erosion and improve water infiltration, stubble now is left on the soil after harvest and ploughed in, burnt or grazed shortly before sowing the next season's. This practice has resulted in considerable yield increases under conditions suited to the development of severe yellow spot in some countries. Because burning can totally destroy a source of inoculum, it is widely used in eradication campaigns to remove inoculum of newly introduced pathogens and prevent an epidemic developing. A notable example is the removal and burning of citrus trees infected with citrus canker (*Xanthomonas citri*) in many countries.

c. Elimination of living plants or plant parts that carry pathogens

Do you remember what we said about crop debris remaining in the field after you harvest? Well, sometimes live plants from the previous season might pop-up in your field the following season. Crop plants remaining from previous seasons and volunteer host plants that establish in fallowed land or around cropping areas when climatic conditions are suitable during the time when you crop is not in the field may provide sources of inoculum for succeeding crops. Unwanted crop plants should be destroyed by either cultivation or the application of herbicides. Weeds or wild plants may act as alternative hosts of plant parasites allowing the pathogen to survive between seasons and providing a source of inoculum in the new growing season. For example, grasses such as *Hordeum leportnum* are hosts of the wheat take-all disease causal fungus *Gaeumannomyces graminis*, many dicotyledonous weeds contain *Meloidogyne spp*. and other nematodes and certain leguminous green manure crops maintain the halo blight organism, *Pseudomonas sgringe* pv. *phaseolicola*. Removing the overseasoning host eliminates or reduces inoculum for the following season. However, the relationships between weeds and crop parasites are often obscure and many weeds are symptomless carriers of various viruses. In other situations, it may not be practicable to eliminate alternative hosts because they can be commercially valuable crops. Only cooperative action by growers to delete crops, rearrange crop rotation sequences or undertake concerted efforts to destroy virus vectors can overcome these problems. Other important inoculum sources are the alternate hosts of many destructive rust fungi. Some rusts cannot complete their life cycles in the absence of alternate hosts, which also provide the opportunity for the rust fungus to undergo sexual recombination, possibly producing new races of the fungus. However, the influence of an alternate host on a rust disease can be highly variable and the effectiveness of campaigns to eradicate alternate hosts can be unpredictable. Two important macrocyclic cereal rusts, *Puccinia graminis* and *P. coronata* require alternate hosts (Berberis spp. and Rhamnus spp., respectively) to complete their life cycles. In the absence of their alternate hosts, both rusts survive on susceptible hosts (mainly volunteer plants) via urediniospore infections. This is the way wheat stem rust oversummers in countries like Australia. In colder climates, such as North America, where urediniospores cannot survive the severe winters, the alternate host may play a greater role in providing primary inoculum in a growing season. In our country Zambia, urediniospores are most likely the major inoculum for the disease. There has been a concerted effort to eradicate Berberi.s spp. in the United States. However, infections in wheat crops still arise from urediniospores carried by air currents from the warmer southern states or from Mexico. For these rusts, removal of the alternate host tends to postpone a disease outbreak by eliminating a primary source of inoculum. It also prevents sexual reproduction reducing the probability of producing recombinant genotypes. In contrast, *Gymnosporangium sabinae* (the causal agent of cluster cup rust of pears in North America) always requires the presence of its alternate host, Juniper, to complete its life cycle. Removal of juniper plants in the vicinity of a pear orchard prevents establishment of the disease. Removing diseased plants or plant parts to eliminate sources of inoculum is carried out routinely in many nurseries, greenhouses and high-value crops. Strawberry leaves infected by various leaf-spotting fungi are removed early in the season. Diseased parts of larger plants such as tree crops are often removed by pruning. Infected branches are removed in cases of fireblight of pome fruit (*Erwinia amylovora*), apple canker (*Nectria galligena*), powdery mildew of apples (*Podosphaera leucotricha)* and silver leaf of plums (*Chondrostereum purpureum*). Mummified fruit as well as diseased twigs should be removed from pome and stone fruits to reduce the inoculum of *Sclerotinia spp*. Subsequent sanitation measures usually involve burning pruned material and treating cut surfaces with suitable fungicides. Pruning inevitably influences the microclimate within the tree canopy indirectly affecting any subsequent disease development. In mixed farming enterprises, livestock can be used to graze off crop residues.

d. Crop rotation

As you have noticed by now, some cultural control practices such as crop rotation, are repeated for the management of different pests and diseases. Crop rotation, the successive planting of different crops in the same area, is one of the oldest and most widespread cultural practices. It may also include a fallow period in which land is 'rested' from cultivation. Crop rotation improves soil fertility, moisture and texture and assists in weed and pathogen control. The most successful rotations employ intervals between susceptible crops which are longer than the known survival period of pathogens. Rotations are most likely to be effective in controlling pathogens such as *Gaeumannomyces graminis, Pyrenophora tritici-repentis*, various *Colletotrichum* and *Phoma spp*. and some pathogenic bacteria that only survive in the presence of a specific host (or its residues) or as resistant propagules. They are less likely to be effective in controlling damping-off and root-rot fungi such as Pythium and Aphanomces, Fusarium spp. including the vascular wilt pathogens, Sclerotinia spp, *Macrophomina phaseoli* and *Plasmodiophora brassicae* which can survive for long periods in the soil as saprophytes.

Probably the most widely used rotations are for the control of soil-borne pathogens of cereals. These often include either a non-host leguminous crop which can improve soil fertility as well as reducing inoculum or a fallow period during which alternative weed hosts and volunteer plants are removed or destroyed. Take-all (*G. graminis*), *Ascochyta sp*. and some other pathogens of wheat have been controlled in some regions by removing grass hosts, especially during fallow periods. Long term (long course) rotations are required to control pathogens such as *Streptomyces scabies*, *Phymatotrichopsis omnivora* and *Rhizoctonia solani*- which survive in the soil as resistant spores or as sclerotia. In some European countries, yields from sugar beet crops may become un-economic due to infection by the nematode *Heterodera schachtii*. When non-host crops are grown or the land is fallowed, populations of the nematode fall to about half their initial level. This trend must continue until a 'safe' population level is attained before another sugar beet crop can be grown. Regular cultivation of fallow land during dry seasons can destroy pathogens such as the bacterium Ralstonia solanacearum because crop debris is repeatedly brought to the surface of the soil and exposed to the drying effects of the atmosphere. However, extended fallow periods are of dubious value because the land is unproductive. Some rotations may include a crop which inhibits the development of a specific pathogen. High levels of root knot nematodes (*Meloidogyne spp.*) occur in soils following crops such as maize, sweet corn and capsicum. However, other crops such as forage sorghum, pinto peanut, watermelon, Rhodes grass, green panic and cowpea host few nematodes. Crops of susceptible plants following these crops show little sign of nematode damage. Some legumes have also been used to reduce populations of the nematode *Pratytenchus spp*. in soils. Similarly, *Tagetes spp*. (marigolds) inhibit the development of a range of nematode species. Many brassica crops produce glucosinolates that break down to produce isothiocyanates which are active against several soil-borne pathogens.

e. Tillage

Do you remember what we said would be the role of tillage in weed and insect management in sections above? Tillage is also important in the cultural management of pathogens and plant diseases. Tillage incorporates various types of organic matter including crop residues, manure, green manure, volunteer crop plants and weeds into the soil. Tillage practices tend to have indirect effects on the spread of plant pathogens. Some forms of inoculum can be widely dispersed by implements. Tillage reduces populations of weeds and volunteer crop plants that harbour pathogens between crops. It also buries plant pathogens from the top soil into deeper layers of the soil where they cause less or no disease. Practices involved in the preparation of seed beds can greatly modify physical properties of soils such as moisture characteristics, bulk density, aeration and temperature profiles which in turn influence the incidence of disease. Forming the soil into hills, ridges or raised beds provides better drainage and irrigation. Tillage may also influence nutrient release mechanisms and the total effect is often expressed as increased crop vigour. Healthy plants may be more resistant to some pathogens but the more humid microclimate within the crop can be conducive to the spread of other pathogens. Successive tillage operations can reduce inoculum levels of some pathogens through exposure of the inoculum to desiccation by the sun. Modern agriculture has moved away from regular cultivation of soil between crops towards a system of minimum tillage, or even no-tillage. Minimum tillage is a method of planting crops that involves no seedbed preparation other than opening the soil to place the seed at the intended depth. Usually the soil is not cultivated during crop production and chemicals are used for weed control. Minimum tillage reduces injury to the roots of crop plants caused by mechanical tillage or hand weeding, reducing the opportunities for opportunistic pathogens to infect. It also reduces the spread of pathogens by tillage practices. However, it may favour the development of some diseases such as those that can be controlled by burying inoculum too deep for infection of plant roots to occur. In no-tillage systems, crop residues are left on the surface of the soil. The residues may become a food source for pathogens or alter the physical environment occupied by both the host and its pathogens. The effect of tillage practices on the soil microflora is often overlooked. Many of these organisms are competitors or antagonists of soil-borne pathogens. Minimum tillage practices are thought to promote greater microbial antagonism in the vicinity of cereal roots than normal cultivation practices. However, little is known about the influence of cultivation on these activities although incorporation of organic matter (e.g. green manure crops) is known to reduce the incidence of some diseases.

Plant residues intensify the microbial activity of the soil which may result in the formation of fungitoxic or even phytotoxic compounds.

f. Sowing and harvesting practices

As you all know by now, sowing and harvesting are cultural practices. However, how you conduct these activities can also be designed in such a manner that you also manage diseases in your crop. Many crop plants tend to be more susceptible to attacks by various parasites at certain stages of their development. Changing the usual **sowing time** (either planting early or planting late, depending on the crop your are dealing with) of a crop can exploit weather conditions which are unfavourable for the spread of pathogens or their vectors and reduce crop losses. These practices often necessitate introductions of new cultivars that are adapted to the selected growing period. However, the introduction of a 'new' cultivar with different growth characteristics may also create other disease problems. Other strategies may be applied in tropical climates so that a susceptible growth phase occurs in relatively dry periods. For example, planting tomato in the rain season will lead to a lot of fungal diseases such as late blight on your tomato crop. But if the tomato is planted as the rain season is coming towards the end, you are less likely to have this and many other fungal diseases on your crop. Greatest variation in sowing times is possible in greenhouses where considerable manipulation of crop microclimates is practicable.

Methods of sowing vary considerably between crops and even with the same crop in different regions. It is therefore difficult to generalise about the effect of sowing methods on the spread of diseases. Farmers aim to optimise germination and early growth at densities which give maximum yields in the particular environment. **Depth of sowing** is usually determined by seed size and the moisture status of the soil. Deeper sowing may promote germination but it also lengthens the (usually) susceptible pre-emergence seedling phase. Smuts and seedling diseases caused by *Fusarium spp.* and *Rhizoctonia spp.* are more serious if seeds are planted deeply. Similarly potato seed pieces are more readily attacked by *Rhizoctonia spp.* if planted too deeply.

Crop density can influence disease development. Generally as the density of a crop increases, the incidence of disease also increases. Crowding of the seedlings in a seedbed can lead to serious epidemics of damping-off caused by fungi such as *Pythium spp., Fusarium spp.* and *Rhizoctonia spp*. Very close proximity of plants are associated with the ease of transferring inoculum from one plant to another when the plants are close together. For example, the distance pathogens or their vectors have to travel from one host to the next is reduced, splash dispersal of inoculum is easier and there is also increased contact between the leaves or roots of neighbouring plants. In addition, with denser plantings, more plants may be wounded during cultivation creating more opportunities for weak pathogens to infect. Finally, the micro-environment within the crop is altered, resulting in temperatures being more uniform, the relative humidity increasing and leaves staying wet longer after rain or dew. All these conditions favour the development of disease. Sometimes, dense stands may reduce disease incidence and increase yields. In Africa, the aphid vector of the groundnut rosette virus is attracted to broken ground cover rather than continuous ground cover so dense planting inhibits the landing response of the vector. In this case, weeding actually increases disease incidence because it leaves breaks in the ground cover. Farmers can manipulate plant densities by varying sowing or planting rates and may use increased rates to compensate for expected crop losses from pathogens. Crop density can also be manipulated by pruning, thinning, trellising, fertilisation, water management, staking and harvesting plants or plant parts, depending on the types of crop. All these practices are designed to prevent foliage or root contact.

The **direction of sowing** in some row crops may influence disease incidence. Some plant disease increase in severity if rows are aligned in an east-west direction because plants are less exposed to the drying effects of sunlight than in rows oriented north-south. Germination and early seedling growth can be promoted by modifying the soil environment around the seed. Practices such as lime pelleting may either directly inhibit some infection processes or indirectly reduce disease via greater seedling vigour. Soil-borne pathogens such as *Phytophthora spp.*, and *Pythium spp.* are favoured by high soil moisture so improving soil drainage or sowing or transplanting into raised beds, ridges, mounds or hills reduces the incidence of disease.

g. Intercropping

Do you know what intercropping is? Intercropping, the growing of a crop or crops between the rows of another crop, is more common on smaller farms. Labour requirements increase as the number of crops increases, but total production is generally higher where intercropping is practised. Where cassava is grown with maize, melons or other crops, there is increase in ground cover and as such water splash of soil is reduced and the incidence of soil-borne diseases such as bacterial blight (*Xanthomonas campestris* pv. *manihotis*) decrease. You will tend to notice that the incidence of disease is often less in mixed plantings than in monocultures because the distance between similar plants is greater than in more intensive growing systems so it is less likely that propagules or vectors of pathogens will successfully move from one host to another. The intervening plants pose physical barriers to the dissemination of aerial pathogens or their vectors.

h. Mulching

We have discussed mulching before in connection with cultural control of weeds. Mulching, the application of a covering layer of material to the soil surface, is a commonly used cultural practice, especially in horticulture. Natural materials used for mulching include cereal straw and stalks, crop debris, sawdust, leaves, grass, manure, dry weeds e.t.c. In fact, almost any readily available, preferably cheap, organic material is used. In addition, manufactured products such as plastic materials, aluminium foil, asphalt paper, glass wool and paper can be used. Mulches conserve soil moisture and organic matter and reduce soil erosion. When crop residues are used as mulch they may provide many pathogens with a food source as well as an environment in which to live and reproduce and can, therefore, influence disease incidence. It is therefore important to consider how mulching is used. Crop residues may also affect disease incidence by altering the physical environment of the host and the pathogen. Organic mulches reduce loss of water from the soil, increase infiltration and absorption of water, smother weeds, lower soil temperature, enrich soil by supplying nutrients and organic matter and protect seedlings against the impact of rain, hail and wind (important in the tropics where rain is heavy). All these factors may influence disease development. Spread of soil-borne diseases is reduced because a layer of mulch on the soil surface reduces water splash dissemination of bacterial and fungal propagules and prevents leaves, flowers or fruits from directly contacting the soil and disease propagules in the soil. Crop residues generally enhance competition among soil micro-organisms for nitrogen, carbon or both resulting in fewer problems with soil-borne pathogens.

i. Organic soil ammendments

Organic amendments incorporated into the soil may suppress pathogens by increasing the level of activity of organisms that reduce their growth or survival. Phytophthora cinnamomi causes severe root rot of avocados. The addition of large amounts of chicken manure to the soil around the base of avocado plants almost completely eliminates the problem. Similarly, the addition of chitin from eggshells to soil stimulates the parasitism of nematode eggs by fungi and reduces the level of inoculum for nematodes that would otherwise attach the avocado plant. Unfortunately, the addition of amendments to soil does not always achieve the desired effect. Disease incidence or severity may increase because the pathogen thrives on the amendment. In addition, some organic soil amendments form phytotoxic substances as they decompose. Therefore the addition of organic soil amendments or mulch should be considered on a case-by-case basis.

j. Flooding

A good example of where you will find flooding as cultural practice is in the growing of rice, in what is called paddy field (flooded field) system. The paddy system of growing rice is perhaps the oldest example of using flooding for plant disease management. The primary purpose of flooding is to control weeds. However, it also reduces the number of fungal propagules, insects and nematodes in the soil probably by subjecting them to attack by soil-borne bacteria. By reducing the number of weeds which may harbour rice pathogens and insects, it also indirecfly affects disease development. The destruction of crop debris carrying inoculum can also be hastened by flooding. Rice blast disease (caused by *Pyricularia oryzae*) is less severe on flooded paddy rice than on upland or non-irrigated rice because fewer hours of dew occur in paddy than in upland rice and because populations of fungi, bacteria, nematodes and actinomycetes are lower in flooded soils. On the other hand, flooding can predispose some plants to disease, floodwaters can carry propagules of pathogens such as *Phytophthora* and algae growing in flood waters produce oxygen which encourages the growth of some fungi. Therefore, in places where water molds are common, flooding may not be a good way to control diseases.

Like tillage practices, flooding may influence both the level of initial inoculum and the rate of spread of diseases. Flooding diseased cotton 'trash' for up to six weeks reduced the incidence of bacterial leaf blight (*Xanthomonas campestris* pv. *malvacearum*). In contrast, flooding seems to have little effect on verticillium wilt fungi. Banana wilt diseases (caused by *Fusarium oxgsporum* f .sp. *cubense*) can be partially controlled by flooding infected soils for up to six months. Such practices are expensive, require large amounts of water and keep land out of production for considerable periods of time. However, these disadvantages may be overcome if wetland rice can be incorporated into a rotation. This strategy has been used in rice-producing areas of the world where satisfactory results have been obtained in the control of black shank disease of tobacco (caused by *Phytophthora parasitica*) and diseases caused by *Sclerotinia spp.* on vegetable crops. Flooding has also been used to control nematodes. Hydrogen sulphide produced by anaerobic organisms under flooded conditions kills nematodes but the cost of such treatment is prohibitive. Some soil-borne pathogens may be controlled by manipulating soil water potentials in relation to their growth requirements because they vary considerably in the minimum water potentials required for spore germination and for hyphal growth.

k. Irrigation

As you may now by now, you will need irrigation if you are to grow a crop outside the rain season in Zambia, or during times when there are prolonged dry spells in the middle of the rain season. You will notice that commercial farmers rely heavily on irrigation, and several government programs have been promoting irrigation as a way to improve food security. Irrigation can have a major influence on the spread of some pathogens and on disease development. Irrigation applied during dry seasons means the propagules of pathogens are not exposed to desiccation during periods of drought. Consequently, the level of inoculum increases. The seriousness of this situation is compounded in areas where, because of irrigation, it is possible to grow two susceptible crops in the same field in one year. In addition, irrigation water may contain propagules of pathogens which it carries from one place to another unless the water is from a clean source or is carefully treated before use. Overhead watering may promote disease by increasing the period of time a layer of free moisture remains on leaf surfaces (leaf wetness period). The longer leaf wetness periods increase the likelihood that sufficient time will be available for fungal spores to germinate, form infection structures and penetrate the plant surface to the relatively constant and favourable environment within the leaf. Irrigated crops may become a green island in an otherwise dry environment and attract insect vectors of virus diseases. In such cases, it is often better to delay sowing an irrigated crop for some time after other vegetation has dried up and the vector population has been reduced by desiccation.

Depending on how you use it, irrigation, on the other hand, can be used as a tool to reduce the level of inoculum and to retard disease development. Alternately drying and rewetting soil encourages the activity of micro-organisms that destroy sclerotia. Overhead irrigation can reduce or inactivate airborne inoculum by washing it out of the atmosphere. Short daily waterings encourage the germination of powdery mildew spores but the plants do not stay wet enough for long enough for the fungus to penetrate. Overhead sprinkling of dormant fruit trees reduces the incidence of apple scab because the short-lived ascospores are released in response to temperature changes whilst the tree is dormant and can not survive until leaves are present.

Flood, furrow and overhead (spray, sprinkler) irrigation can facilitate the spread of pathogens. Flood irrigation can spread soil-borne inoculum all over an area while furrow irrigation disperses inoculum along rows. The action of overhead irrigation systems washes inoculum out of the air and facilitates the spread of pathogens that rely on water splash for dispersal. Many important foliage and fruit pathogens such as *Phytophthora infestans* and *Alternaria solani* form their spores at night and release them during the day. Overhead irrigation in the early part of the day washes these spores from the air and splashes them about. If overhead irrigation is delayed until the evening or early night, spores of *P. infestans* dry out on the plant and cannot infect. However, spores of *A. solani* are resistant to drying out and can survive until a dew forms at night so the timing of overhead watering has little influence on disease development. Overhead irrigation plays a role in the distribution of inoculum within a crop as it washes inoculum from higher to lower parts of the plant.

Trickle or drip irrigation, developed in response to the need to conserve water, supplies water directly to the root zones of individual plants and the rate of application is insufficient to disperse pathogens. Moreover drip irrigation produces a mosaic of soil moisture conditions, rather than uniformly moist conditions, which probably inhibits the spread of root pathogens.

l. Roguing

Roguing involves the removal (and destruction) of diseased plants (rogues) to prevent further spread of the pathogen(s). It is practicable in small gardens, where labour is cheap or the cost of labour is not important, when a crop is very valuable or if the level of infection is low. With larger plantings, roguing is only worthwhile if the crop has a relatively high economic value, the disease symptoms are conspicuous and the pathogen has a limited dispersal potential. To minimise disease spread, affected plants need to be removed as soon as possible after symptoms are observed. Roguing may need to be repeated regularly as newly diseased plants appear. To reduce the spread of banana bunchy top virus, both affected plants and adjacent, apparently healthy, plants are removed and destroyed.

m. Fertiliser application and crop nutrition

Am sure you are very aware of the fact that depending on what we as humans may become susceptible to certain diseases. The same is the case with our plants. Soil nutrient status may influence the susceptibility of plants to attack by pathogens. Farmers aim to provide their crops with a well-balanced supply of nutrients. The resultant healthy, vigorous plant should have a greater chance of withstanding attacks by pathogens. However, this is not always the case. The same conditions that favour the growth of the plant may also encourage development of biotrophic pathogens. For example, many viral diseases of crop plants are promoted by fertiliser applications. Deficiencies of nutrients in soils increase the susceptibility of many crops to certain pathogens. In this context, fertiliser applications are sometimes recommended as a control strategy. The influence of the major nutrients nitrogen, phosphorus and potassium, as well as calcium, on disease development will be discussed further. Applications of some of the minor nutrients can also decrease host susceptibility to disease. Applications of zinc reduce the incidence of maize downy mildew disease, while sulphur fertilisation inhibits the occurrence of cercospora leaf spot disease in groundnuts and copper applications reduce take-all disease in wheat. Heavy applications of nitrogenous fertilisers are commonly thought to predispose plants to disease. Nitrogen applications tend to delay crop maturity by prolonging vegetative development. Increased risk of infection may result because plants are susceptible to attack for longer periods. In contrast, the stimulation of vegetative growth may allow plants to 'outgrow' an infection and compensate for any damage. High nitrogen levels are also thought to influence the production of host metabolites which can either inhibit or promote infections by various pathogens. For example, rice blast disease (caused by the fungus *Pyricularia oryzae*) and scald disease (caused by the fungal pathogen *Rhynchosporium oryzae*) generally increase on plants grown in high nitrogen soils whilst maize head smut disease (caused by the fungus *Sphacelotheca reiliana*) tends to decrease in severity. Nitrogenous fertilisers also indirectly affect the spread of disease by modifying crop environments. Reduction in the incidence of *Rhizoctonia solani* following nitrogen fertilisation is thought to result from stimulation of certain soil microorganisms which compete for nutrients. If the density of the crop canopy increases, a microclimate favouring certain foliage pathogens will develop. Rank (overly lush) growth in cereal crops resulting from liberal fertiliser applications can lead to lodging (breaking, bending over or lying flat on the ground of the above ground parts of plants) which is often associated with increased disease incidence (e.g. rice blast disease).

When you apply D-compund fertiliser, one of the nutrients you are supplying to the plant is phosphorous. Fertilising with phosphates can delay the onset and lessen the severity of take-all disease in barley (caused by the fungus *Gaeumannomyces graminis*) and reduce the incidence of potato scab (caused by the bacterium *Streptomyces scabies*) but increase the incidence of cucumber mosaic virus in spinach. The effects of phosphorus fertilisers are attributed to correction of phosphorus deficiency in the soil resulting in healthier plants more able to resist attack by pathogens. In addition, phosphorus hastens the maturity of the crop so young susceptible tissues are not exposed to the inoculum of obligate parasites for long periods of time.

When you apply D-compund fertiliser, one of the nutrients you are supplying to the plant is potassium. Adequate potassium levels inhibit the development of a wide range of parasites including fungi (such as *Fusarium oxysporum* f.sp. *vasinfectum*), bacteria (*Corynebacterium insidiosum* and *Xanthomonas spp.*), various viruses and nematodes. Potassium directly stimulates or reduces penetration of the host by the pathogen as well as its multiplication and survival, aggressiveness and rate of establishment in the host. It also indirectly influences aspects of disease development. For example, potassium promotes wound healing, reducing infection by wound parasites such as *Botrytis spp*. Potassium fertilisation also heightens resistance to frost injury and delays maturity in some crops, postponing the strain of senescence and reducing the risk of infection by facultative saprophytes.

Did you know that your skin acts as a barrier against microbes that would otherwise enter you body and cause you to become ill? The same applies to plants whose outer layer is strengthened by calcium, thereby reducing disease. Calcium is another nutrient which can influence disease incidence. Its principal effect is on the composition of the cell walls of the host. Adequate supplies of calcium make cell walls more resistant to penetration by facultative pathogens such as *Rhizoctonia spp.*, *Sclerotium spp.*, *Botrytis spp.* and *Fusarium spp*. However, soils high in calcium favour the development of diseases such as black shank of tobacco (*Phytophthora parasitica* var. *nitcotianae*). Alternatively, high levels of calcium (lime) in soils can raise their pH to the detriment of pathogens such as *Plasmodiophora brassicae* that are favoured by acid soils.

n. Trap and decoy crops

Trap (or catch) crops are susceptible plants that you grow on land known to contain various pathogens. The pathogens infect the crop that you must destroy before the life cycles of the pathogens are complete. Suitable methods of destroying the crop include ploughing in, applying various biocides or grazing-off with livestock. Trap crops can be grown simultaneously with more valuable crops. The efficiency of trap crops in reducing the spread of pathogens depends on the plant, growth habit differences including height differentials and position relative to the 'protected' crop. Decoy crops stimulate the hatching of nematode eggs or the germination of resting structures or seeds of other pathogens, but the pathogens are unable to establish a compatible relationship with the decoy crop host and eventually die. As a result, the level of inoculum of the pathogen declines. For example, ryegrass reduces the incidence of clubroot disease of crucifers (caused by *Plasmodiophora brassicae*) in infested soil while the poisonous weed thornapple (*Datura stramonium*) reduces the incidence of powdery scab of potatoes (caused by *Spongospora subterranea*). Ideally, a crop you choose to be a decoy crop would be one with economic value and included in a normal crop rotation.

Chemical Control

Chemical control of pesticides refers to the measures in which you go to an agro-dealer shop to buy a pesticide which is then applied to the crop to either prevent pests or to kill pesticides that are already on the crop or in the field. Although chemical pesticides might be hazardous to the environment, animals and people, in some situations they may be the only available control and they may be the most economical option available. Depending on the situation and type of chemical, pesticides can be applied to the soil, seed or foliage. Pesticides should be used judiciously so as to minimise costs, environmental damage, health hazards, and development of resistance.

You need to be very careful about resistance development, whereby the pest stops dying after continous use of a certain pesticides continously year-in-year-out. You must not use the same pesticide in the same field against any given weed, insect or pathogen, you must keep changing them, otherwise the pest will develop resistance against that pest. Consistent use of the same chemical might speed-up build-up of resistance against the chemical in pest populations. To minimise the chances of this happening, it is advisable to rotate/combine chemicals from different chemical groups. These groups are based on mode of action (chemicals with the same mode of action are placed into one group). An example is the FRAC Code (Fungicide Resistance Action Committee-FRAC Code) which places different fungicides into different groups. Avoid using a fungicide from one group continously. You need to keep note of the group to which the fungicide you used last year belongs, so that in the current year you use one from a diffeent group.

Chemical Control of Pathogens

When choosing a chemical to apply against pathogens, please ensure that you pick the correct chemical for the pathogen you have in your field. Do you remember the different categories of pathogens we discussed? For each of those pathogen groups, a different category of chemical will be needed. For example nematicides are what you apply against nematodes, fungicides against fungi and bactericides against bacterial pathogens. Just as is the case with humans and animals, there are no proven viricides for use when you maize crop has a viral disease. Even within these categories additional sub-categories exist. For example, not all the fungicides you find on the market will work against all fungal diseases. Do you remember the groups of fungi we discussed in unit 3? A fungicide effective against fungal diseases caused by Oomycetes will not automatically work against those caused my ascomycetes. For example, if you want to deal with late blight disease in tomato or downy mildew in onion (bot caused by oomycetes), the best fungicide would be that containing metalxyl and/or mancozed and yet these will not work against early blight disease (caused by ascomycetes). When you go to purchase a fungicide ensure that you correctly identify the fungal disease on your crop and also make sure that the fungicide you pick matches the specific fungal disease in your field. This principle applies for the other categories of microbes as well, that is, nematodes and bacteria.

Host Resistance

A critical decision you will make in crop production is the choice of variety to plant. For example there are many different varieties of maize with varying attributes such as drought tolerance, high vitamin A, and so on. The other difference in these varieties might be reistance or tolerance towards a given disease or insect pest. Some cultivars are resistant to particular pathogens and are inherently less damaged than other genetically related plants growing in the same location. Resistant cultivars have provided one of the most successful approaches to the control of pathogens and insect pests of many crops, especially those which cannot be controlled by other means. However, continuous plant breeding programs are often necessary to overcome the effects of the development of new races of pathogens and insects and 'breakdown' of host resistance. As a grower, you therefore need to be aware of the availability of new varieties and be able to evaluate their potential in relation to other agronomic characteristics. In our country Zambia, there are many seed companies that produce crop varieties with resistance or tolerance to certain insect and disease-causing microbes. However, you need to be aware that not all diseases or insect pests will have a resistant variety for use. For example at the moment (2022) there are no known maize varieties with resistance to fall armyworm or viral disease in our country Zambia.

Biological Control

Biological control of pests refers to the use of living organisms to suppress populations of pest and pathogens and thus reduce disease. In general what you do is culture the biological control organism in the lab and release it in huge quantities into the field before the pest and pathogens or diseases spread. It is important that the biocontrol organism you choose is well adapted to the environmental conditions in target locations where you intend to control the pest. The advantages you will get from using this technique include the fact that once established, control spills into subsequent seasons (with little or no additional treatment), no harmful effects on environment or farmer are expected, and no pesticide residues will be on the crop that we harvest and feed on. The downside of using this approach is that the initial investment is high (research & development).

Biological Control of Pathogens

Biological control of pathogens is the total or partial destruction of pathogen populations by other organisms, and this occurs routinely in nature. There are, for example, several diseases in which the pathogen cannot develop in certain areas either because the soil, called suppressive soils, contains microorganisms antagonistic to the pathogen or because the plant that is attacked by a pathogen has also been inoculated naturally with antagonistic microorganisms before or after the pathogen attack. Sometimes, the antagonistic microorganisms may consist of avirulent strains of the same pathogen that destroy or inhibit the development of the pathogen, as happens in hypovirulence and cross protection. In some cases, even higher plants reduce the amount of inoculum either by trapping available pathogens (**trap plants**) or by releasing into the soil substances toxic to the pathogen (**antagonistic plants**). Let us now look at each of the three (antagonistic microbes, trap plants and antagonistic plants) in detail below.

A. Antagonistic microbes in the soil and air

I am sure you know what “antagonisms” means. It simply means active hostility or opposition to something or someone. In the same manner you may have some organisms that antagonize your existence (such as those that cause disease in your body), disease-causing microbes also have antagonists in the soil and in the air. Several soilborne pathogens, such as *Fusarium oxysporum* (the cause of vascular wilts), *Gaeumannomyces graminis* (the cause of take-all of wheat), *Phytophthora cinnamomi* (the cause of root rots of many fruit and forest trees), *Pythium* spp. (a cause of damping-off), and *Heterodera avenae* (the oat cyst nematode), develop well and cause severe diseases in some soils, known as conducive soils, whereas they develop much less and cause much milder diseases in other soils, known as suppressive soils. Suppressive soils operate so partly by the presence in such soils of one or several microorganisms antagonistic to the pathogens. Such antagonists, through the antibiotics they produce, through lytic enzymes, through competition for food, or through direct parasitizing of the pathogen, do not allow the pathogen to reach high enough populations to cause severe disease. Examples of antagonistic fungi include some species from the genera *Trichoderma*, *Penicillium*, and *Sporidesmium*, while antagonistic bacteria include bacteria of the genera *Pseudomonas*, *Bacillus*, and *Streptomyces*. Suppressive soil (that is, soils containing antagonistic microbes) added to conducive soil can reduce the amount of disease by introducing microorganisms antagonistic to the pathogen. For example, soil amended with soil containing a strain of a *Streptomyces* species antagonistic to *Streptomyces scabies*, the cause of potato scab, resulted in potato tubers significantly free from potato scab. Suppressive, virgin soil has been used, for example, to control *Phytophthora* root rot of papaya by planting papaya seedlings in suppressive soil placed in holes in the orchard soil, which was infested with the root rot oomycete *Phytophthora palmivora*. However, in several diseases, continuous cultivation (monoculture) of the same crop in a conducive soil, after some years of severe disease, eventually leads to reduction in disease through increased populations of microorganisms antagonistic to the pathogen. For example, continuous cultivation of wheat or cucumber leads to reduction of take-all disease of wheat and of *Rhizoctonia* damping-off of cucumber, respectively. Similarly, continuous cropping of some watermelon varieties allows the buildup of antagonistic species of *Fusarium* related to that causing *Fusarium* wilt of watermelon with the result that *Fusarium* wilt is reduced rather than increased. Such soils are suppressive to future disease development. A sort of “soil suppressiveness” develops after appropriate crops are plowed under as soil amendments. Such crops, usually in the crucifer family, provide material and the time required for biological destruction of pathogen inoculum by resident antagonists in the soil. For example, significant control of lettuce drop, caused by the fungus *Sclerotinia sclerotiorum*, occurs when broccoli plants have been incorporated in the soil compared to the amount of disease in fields not receiving such treatment.

The mycelium and resting spores (oospores) or sclerotia of several phytopathogenic soil oomycetes and fungi such as *Pythium*, *Phytophthora*, *Rhizoctonia*, *Sclerotinia*, and *Sclerotium* are invaded and parasitized (myco-parasitism) or are lysed (mycolysis) by several fungi, which as a rule are not pathogenic to plants. Several nonplant pathogenic oomycetes and fungi, including some chytridiomycetes and hyphomycetes, and some pseudomonad and actinomycetous bacteria infect the resting spores of several plant pathogenic fungi. Among the most common mycoparasitic fungi are *Trichoderma* sp., mainly *T. harzianum*. The latter fungus has been shown to parasitize mycelia of *Rhizoctonia* and *Sclerotium*, to inhibit the growth of many oomycetes such as *Pythium*, *Phytophthora*, and other fungi, e.g., *Fusarium* and *Heterobasidion* (*Fomes*), and to reduce the diseases caused by most of these pathogens. Other common mycoparasitic fungi are *Laetisaria arvalis* (*Corticium* sp.), a mycoparasite and antagonist of *Rhizoctonia* and *Pythium*; also, *Sporidesmium sclerotivorum*, *Gliocladium virens*, and *Coniothyrium minitants*, all destructive parasites and antagonists of *Sclerotinia sclerotiorum* and all effectively controlling several of the *Sclerotinia* diseases; and *Talaromyces flavus*, which parasitizes *Verticillium* and controls *Verticillium* wilt of eggplant. Also, some *Pythium* species parasitize species of *Phytophthora* and other species of *Pythium*. Several yeasts, e.g., *Pichia gulliermondii*, also parasitize and inhibit the growth of plant pathogenic fungi such as *Botrytis* and *Penicillium*.

In addition to fungi, bacteria of the genera *Bacillus, Enterobacter*, *Pseudomonas*, and *Pantoea* have been shown to parasitize and/or inhibit the pathogenic oomycetes *Phytophthora* sp., *Pythium* sp, and the fungi *Fusarium*, *Sclerotium ceptivorum*, and *Gaeumannomyces tritici*; the mycophagous nematode *Aphelenchus avenae* parasitizes *Rhizoctonia* and *Fusarium*; and the amoeba *Vampyrella* parasitizes the pathogenic fungi *Cochliobolus sativus* and *Gaeumannomyces graminis*.

Remember we discussed that some species of nematodes cause disease on plants. Do you remember some examples of species we discussed? Plant pathogenic nematodes are also parasitized by other microorganisms. For example, *Meloidogyne javanica* and *Pratylenchus* sp. nematodes are parasitized by the bacterium *Pasteuria (Bacillus) penetrans*. Cysts of the soybean cyst nematode *Heterodera glycines* are parasitized by the fungus *Verticillium lecanii*; the root-knot nematode *Meloidogyne* sp. is parasitized by fungi *Dactylella*, *Arthrobotry*, *Paecilomyces*, and *Hirsutella* sp.; whereas the dagger nematode *Xiphenema* and the cyst nematodes *Heterodera* and *Globodera* are parasitized by nematophagous fungi *Catenaria auxiliaris*, *Nematophthora gynophila*, *Verticillium chlamydosporium*, and *Hirsutella* sp.

As you have noticed, most of the antagonisms we have discussed above concern soil-borne plant pathogens. Many other fungi have been shown to antagonize and inhibit numerous fungal pathogens of aerial plant parts. For example, *Chaetomium* sp. and *Athelia bombacina* suppress *Venturia inaequalis* ascospore and conidia production in fallen and growing leaves, respectively. *Tuberculina maxima* parasitizes the white pine blister rust fungus *Cronartium ribicola*; *Darluca filum* and *Verticillium lecanii* parasitize several rusts; *Ampelomyces quisqualis* parasitizes several powdery mildews; *Tilletiopsis* sp. parasitizes the cucumber powdery mildew fungus *Spaerotheca fuligena*; and *Nectria inventa* and *Gonatobotrys simplex* parasitize two pathogenic species of *Alternaria*.

B. TRAP PLANTS

Do you remember when we introduced biological control of pathogens we said it could either be done by microbial antagonists or plants? Higher plants reduce the amount of inoculum either by trapping available pathogens (trap plants) or by releasing into the soil substances toxic to the pathogen. If a few rows of rye, corn, or other tall plants are planted around a field of beans, peppers, or squash, many of the incoming aphids carrying viruses that attack the beans, peppers, and squash will first stop and feed on the peripheral taller rows of rye or corn. Because most of the aphid-borne viruses are nonpersistent in the aphid, many of the aphids lose the bean-, pepper-, or squash- infecting viruses by the time they move onto these crops. In this way, trap crops reduce the amount of inoculum that reaches a crop.

Trap plants are also used against nematodes, although in a different way. Some plants that are not actually susceptible to certain sedentary plant-parasitic nematodes produce exudates that stimulate eggs of these nematodes to hatch. The juveniles enter these plants but are unable to develop into adults and eventually they die. Such plants are also called trap crops. By using trap crops in a crop rotation program, growers can reduce the nematode population in the soil. For example, *Crotalaria* plants trap the juveniles of the root-knot nematode *Meloidogyne* sp. and black nightshade plants (*Solanum nigrum*) reduce the populations of the golden nematode *Heterodera rostochiensis*. Similar results can be obtained by planting highly susceptible plants, which after infection by the nematodes are destroyed (plowed under) before the nematodes reach maturity and begin to reproduce. Unfortunately, trap plants have not given a sufficient degree of disease control to offset the expense and risk involved with their use. Therefore, they have been little used in the practical control of nematode diseases of plants.

C. ANTAGONISTIC PLANTS

Do you remember how we defined antagonistic microbes in the section above? A few kinds of plants, e.g., asparagus and marigolds, are antagonistic to nematodes because they release substances in the soil that are toxic to several plant-parasitic nematodes. When you interplant such plants with with nematode- susceptible crops, antagonistic plants decrease the number of nematodes in the soil and in the roots of the susceptible crops. Antagonistic plants, however, are not used on a large scale for the practical control of nematode diseases of plants for the same reasons that trap plants are not used, as we discussed above.

Mechanical Control

Mechanical/Physical pest control measures are those that kill the pest and the pathogens directly or prevent it from reaching the crop. Examples of such measures include roguing (removal of diseased or pest-infested plants or plant parts), hot water treatment of plant parts or planting materials, disinfection of machinery or tools, and soil sterilisation. Such measures also include the manual picking and crushing of pests. Advantages of mechanical/physical pest control measures include no harm to the environment, no development of resistance among pests, one measure can control several diseases and pests, and no pesticide residues remain on the crop making it healthier for us to consume. Disadvantages are that the measures are typically labour intensive, time-consuming, work well when there is coordination among neighbouring farms, and it is not always practical to rogue.

Mechanical Control of Pathogens

Do you recall what we discussed as control options for pathogens under the section on cultural control of pathogens (5.5.3)? Well some of the techniques discussed under that section also qualify as mechanical control options. More specifically these are "destruction of crop residues (5.5.3 sub-section b)", "elimination of living parts or plant parts that carry pathogens (5.5.3 sub-section c), "flooding (5.5.3 sub-section j)" and "roguing (5.5.3 sub-section j). Please go back to these sections to review those parts.

5.10 Preventative Control of Pathogens

5.10.2 Preventive Control of insects and pathogens

Preventative control methods fallowing (explained above), use of clean/certified seed, use of clean machinery/equipment on the farm, quarantine, controlled livestock movement, proper manure composting, control of vectors of disease, use of resistant or tolerant varieties and early or late planting depending on the pest you are trying to avoid.

INTEGRATED DISEASE MANAGEMENT

Definition of IPM

Integrated Disease Management (IDM, similar to IPM) is the control of diseases using a combination of two or more disease management approaches with the aim of effectively and economically controlling the pest while minimizing harm to the environment. Integrated Disease (Pest) Management (IDM or IPM) is an effective and environmentally sensitive approach to disease (or pest) management that relies on a combination of common-sense practices. IDM or IPM programs use current, comprehensive information on the life cycles of plant pathogens and pests and their interaction with the environment. This information, in combination with available disease and pest control methods, is used to manage diseases and pests by the most economical means, and with the least possible hazard to people, property, and the environment and minimising the use of synthetic pesticides and their hazardous effects on the environment.

History of IPM

What we have come to call IPM was not in place until the symposium of 1965. In 1965 the United Nations (UN) and FAO convened a symposium that was attended by leading plant protection specialists from all over the world to deliberate on strategies for pest management in agriculture. By this time different types of pest management strategies were known, and some farmers and scientists were beginning to notice that combining two or more methods seemed to work better. The scientists attending this symposium agreed that there was need to establish the FAO Panel of Experts in plant protection. This panel of expert deliberated on pest control strategies in general and agreed that proper management of pests requires an understanding of the diverse context in which living things exist. For example, when you go into any forest, you will find a rich combination of living things that feed off each other, and yet the forest is not getting depleted and not many species go into extinction under natural conditions in the absence of human interference. If we are to put it another way, we would say that it is important to learn how living things in the ecology co-exist without causing too much damage one on the other. Against this ecological background evolved the concept of pest management emerged. In 1972, the words “integrated pest management” and its acronym IPM was incorporated into the English literature and accepted by the scientific community. In 1972 there was substantial agreement that 1. “integration” meant the harmonious use of multiple methods to control single pests as well as the impacts of multiple pests; 2. “pests” were any organism detrimental to humans, including invertebrate and vertebrate animals, pathogens, and weeds; 3. IPM was a multidisciplinary endeavor; 4. “management” referred to a set of decision rules based on ecological principles and economic and social considerations. The backbone for the management of pests in an agricultural system was the concept of economic injury level we have already discussed in unit 4.

Principles of IPM or IDM

Each time you develop or use IPM in managing pests, remember that it is built around the following principles:

1. Prevention

I am sure you have head the adage “prevention is better than cure” several times. It is so with pest management. It is better to deploy tactics or management practices that you know will prevent pests or disease outbreaks on your farm, instead of being careless with your agronomic practices simply because you know there is a pesticide you will use when a given pest breaks out.

2. Monitoring of pests, disease-causing agents and their natural enemies

Monitoring insect pests and their natural enemies and disease-causing agents and levels of disease is the field is an important part of IPM. This is because monitoring of these entities helps you to understand how their populations change and also gives you useful information on when and how to manage them. Pest surveillance and forecasting are essential tools in IPM which help in making management decision.

3. Concepts of Economic Injury (EI), Economic Injury Level (EIL) and Economic Threshold Levels (ETL)

These concepts are emphasized in IPM as they help in the minimization of the use of synthetic insecticide and their impact on environment. Do you remember what we said about these concepts in unit 4? Please review that unit 4, and think about how they might be important in IPM.

4. Intervention through integration of pest control tactics

Under IPM, you deploy intervention only when there is need to after careful monitoring and assessment EI EIL and ETL. When action is justified, your aim should be to Integrate the most environmentally friendly approaches first, and only use chemical control as a last resort. Integration simply means proper choice of compatible tactics and blending them so that each component complements the other. The strategy of applying pest management tactics is similar to that of human medicine i.e. Preventive practice then Curative practice.

Steps in IPM or IDM

Step 1 – Deploy preventative control practices on your farm

Establish preventative control practices on your farm. Several cultural practices can be done in such a manner that you minimise or prevent pests and diseases from being introduced into your farm, or from increasing rapidly if accidentally introduced. Do you remember some of these practices? We covered them under unit 5. Please review unit 5. Before continuing with this unit.

Step 2 – Develop or understand the EI EIL and ETL for the common diseases you encountered the previous season, or those known to affect your area

The thresholds we discussed in unit 4 will vary from pest to pest and from disease to disease. For example, when you see a viral disease on your crop, each time you see an insect likely to transmit that various it means you need to take action to kill that vector. However, for some diseases that spread slowly, you may not need to take action of only one plant is diseased in a one hector piece of land.

Step 3 – Pest or disease monitoring

This step could either come here, or before step 2 above. In this step, your interest is to check on whether the preventative cultural prctices you deployed in step 1 are working and also to ensure you take action when need arises without further delay.

Step 4 – Mechanical Control

Once you monitoring has revealed that you need to take action, the first set of control practices you should consider is Mechanical control practices

Step 5 – Biological control

The next set of control practices you should consider is biological control practices. Two or more biological control practices may be deployed in combination with one or more mechanical control practices. Please ensure that the cultural practices you use do not injure the biological control agent used.

Step 6 – Chemical control

Chemical control should only be used as a last resort as well as in cases where a sudden unanticipated pest emerges in your country or field. Even when synthetic pesticides are finally used, you begin with the least toxic pesticide and try to lower the usage of the pesticide. To lower the amount of pesticide you use, you may decide to combine this tactic with one biological control or mechanical control tactics. But if you are going to attempt this please ensure that the chemical being applied does to kill the biological control agent you have applied.

Integrated Management of Pathogens

Do you remember the various disease management strategies we discussed in unit 5? How would you combine these in an IPM? When combining fungicide/bactericide/nematicide use with biological control, ensure that the chemical used does not negatively affect the biological control agent used.