



Disease Management

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Healthy plants look good, grow well, and are productive. Plants remain healthy as long as conditions favor normal plant growth and development. Sometimes plants are unhealthy, and this occurs when something irritates the plant. The irritation may be somewhat continuous, acting over an extended period, or it may occur nearly instantaneously. Continuous irritation causes disease; instantaneous irritation causes injury.

Disease frequently is expressed by production of symptoms. Some common types of symptoms on specific parts of plants include rotting, stunting or swelling of roots; cankering, rotting, discoloration, distortion, elongation, or stunting of stems; wilting, spotting, blighting, rusting, mottling, discoloration, distortion, or stunting of leaves; and spotting, blighting, stunting, discoloration, distortion, or mottling of fruit.

Common agents that cause plant disease and injury both include nonliving (abiotic) and living (biotic) agents. Nonliving factors that cause disease include harmful levels of temperature, moisture, light, nutrient, pH, air pollutants, and pesticides. Living pathogens that cause disease include fungi, bacteria, viruses, viroids, mycoplasmas, and nematodes; most pathogens are microscopic and derive their food by growing in or on the host plant.

Diagnosis of Major Disease-causing Pathogens

Many plant diseases are recognized by characteristic symptoms on host plants. More specific identification of disease may require observations of characteristics of the causative pathogen. Fungi are identified by their spores and fructifications (fruiting bodies), also called spore-bearing structures. These are examined under the compound microscope directly after removal from the specimen. The specimen should be kept moist for a few days to promote fructification development, or the fungus may be isolated and grown on artificial nutrient media, and identification made on the basis of fructification produced on the media. The shape, size, color, and manner of arrangement of spores on the fruiting bodies, as well as the shape, color, orientation, etc. of the fruiting bodies, are sufficient characteristics to suggest, to one somewhat experienced in taxonomy of fungi, the identity of the particular fungus pathogen. Bacteria can be isolated from leaf spots and blights by surface sterilizing the area to be cut with sodium hypochlorox (Clorox), removing a small part of the infected tissue with a sterile scalpel, and placing it in a sterile plate containing a nutrient medium.

Another common method for isolating bacteria from infected leaves as well as other plant parts is to cut several small sections, five to 10 millimeter squares, from the margin of an infected lesion so as to contain both diseased and healthy-looking tissue. These are placed in a surface sterilant solution, making sure that the surface is wet, and after about 15 to 30 seconds the sections are taken out aseptically one by one at regular 10 to 15 second intervals, so that each of them has been sterilized for different times. The sections are then blotted dry on clean, sterile paper towels or are washed in three changes of sterile water, and finally placed on the nutrient medium, usually three to five per dish. Those sections surface-sterilized the shortest time usually contain contaminants along with the pathogen, while those surface-sterilized the longest produce no growth at all because all organisms have been killed by the surface sterilant. Some of the sections left in the surface sterilant for intermediate periods of time, however, will allow only the pathogen to grow in culture in pure colonies. These colonies of bacteria are then subcultured aseptically for further study.

The serial dilution method is often used to isolate pathogenic bacteria from diseased tissues contaminated with other bacteria. After surface sterilization of sections of diseased tissues from the margin of the infection, the sections are ground aseptically, but quite thoroughly, in a small volume of sterile water, and then part of this homogenate is diluted serially in equal volumes or ten times the volume of the initial water. Finally, plates containing nutrient agar are streaked with a sterilized needle or loop-dipped in each of the different serial dilutions and single colonies of the pathogenic bacterium are obtained from the higher dilutions that still contain bacteria.

An excellent method for isolation and identification of bacteria obtained from plant tissues or soil would be through the use of selective nutrient media. Selective media contain nutrients that promote the growth of a particular type of bacterium while at the same time contain substances that inhibit the growth of other types of bacteria.

Once a characteristic colony of a bacterium is established, the next step is to diagnose the bacterium. The shape, arrangement of cells, and size of bacteria of a given species in a pure culture are quite apparent, and are important and reliable characteristics for diagnosis. The presence, number, and arrangement of flagella on the bacterial cell are also determined, usually after the flagella have been stained with specific stains. The chemical substances in bacterial cells can be detected with specific staining techniques. Information about the presence or absence of such

substances is used for identification of bacteria. For instance, Gram's staining reaction differentiates bacteria into gram positive and gram negative. In this reaction bacteria are treated with a crystal violet solution for 30 seconds, rinsed gently, treated with iodine solution, and rinsed again with water and then alcohol. Gram-positive bacteria retain the violet-iodine stain combination because it forms a complex with certain components of their cell wall and cytoplasm. Gram-negative bacteria have no affinity for the stain combination, which is therefore removed by the alcohol rinse, and the bacteria remain as nearly invisible as before.

Serological methods have been used for quick and fairly accurate identification of bacteria and have gained popularity in recent years. However, serological methods are not of widespread use because of limited availability of antisera. Viruses are identified by a series of tests. The host range of the virus, i.e., the hosts on which the virus induces symptoms and the kinds of symptoms produced, may help to differentiate this virus from several others. Transmission studies can indicate whether the virus is transmitted mechanically and to what hosts, or by insects and which insects, and so on. Each new property discovered helps to further characterize the virus. If the virus is transmitted mechanically, certain properties of the virus, such as its thermal inactivation point, i.e., the temperature required for complete inactivation of the virus in untreated crude juice during a 10-minute exposure, the longevity in vitro, its dilution end point, i.e., the highest dilution of the juice at which the virus can still cause infection, may be used to narrow the possibilities to just a few viruses. If, at this stage, the identity of the virus is suspected, serological tests (such as enzyme-linked immunosorbent assay) may be used, and if they are positive, a tentative identification can be made. Examination of the virus in the electron microscope and inoculation of certain plant species is also usually sufficient for a tentative identification of the virus. The size of the protein and nucleic acid is also helpful for the tentative identification of the virus. Nematodes are generally isolated from the roots of plants they infect or from soil surrounding the roots on which they feed. A few kinds of nematodes, however, attack above-ground plant parts, and these can be isolated primarily from the plant parts they infect by crushing the tissue in water: the nematodes migrate out and are observed in the water. Using a freshly collected soil sample of about 100 to 300 cc, the nematodes can be isolated by sieving and washing the soil and collecting the nematodes into shallow dishes for direct examination under a microscope. Nematodes can be removed from soil by centrifugation in a dense sugar solution. The soil sinks and the nematodes float and can be washed into a dish of water for observation. Soil placed over filter paper on a screen in water allows the nematodes to wiggle through the bottom of the container free of soil and debris for easy observation. Keys are available to aid in identification to genus or species.

General Principles of Managing a Disease

General management considerations: the practical reason for studying crop diseases is to develop economical measures for control. Controls must be based on knowledge of the specific disease, pathogen life cycles, the time and the method of infection, the plant parts affected, the method of causal agent dissemination, and certain other agronomic and economic considerations.

Certain guiding principles must be kept in mind; these include:

1. The cost of the measure must be less than the expected return.
2. The measure must not be too complicated and dangerous to use.
3. The measure must not aggravate other pest problems in the operation, and when possible, should complement other production practices.
4. If the control measure opposes other good farming practices, a compromise may be necessary.

In managing plant diseases, total plant populations are more important than individual plants; since damage or loss of a few scattered plants is insignificant, controls are directed at saving most of the population. The success of a management tactic may be judged in several ways, including extent of reduction in number of diseased plants and by an increase in size and vigor of a crop; ultimately, control must be reflected in an increase in yield, quality, and income.

Management of a plant disease means reduction in the amount of damage caused. It is estimated that the U.S. loses four billion dollars annually due to plant diseases. Complete control is rare, but profitable control, when the increased yield more than covers the cost of disease management, is quite possible. Commercial growers now average a return of four dollars for each dollar invested. The six fundamental principles of disease management are exclusion, eradication, protection, resistance, therapy, and avoidance of insect vectors and weed hosts.

1. Exclusion means preventing the entrance and establishment of pathogens in uninfested crops in a particular area. It means using certified seed or plants, sorting bulbs before planting, discarding any that are doubtful, possibly treating seeds, tubers or corms before they are planted, and most especially, refusing obviously diseased specimens from dealers. For example, tare soil returned to trucks at sugarbeet dump stations should never be returned to production fields because of contamination by nematode and rhizomania diseases from other infested fields.

In order to prevent the import and spread of plant pathogens into the country or individual states, certain federal and state laws regulate the conditions under which certain crops may be grown and distributed between states and countries. Such regulatory control is applied by means of

quarantines, inspections of plants in the field or warehouse, and occasionally by voluntary or compulsory eradication of certain host plants. Plant quarantines are carried out by experienced inspectors, stationed in all points of entry into the country, to stop persons or produce likely to introduce new pathogens. Similar quarantine regulations govern the interstate, and even the intrastate, sale of nursery stock, tubers, bulbs, seeds, and other propagative organs, especially of certain crops, such as potatoes and fruit trees. For example, a Michigan quarantine prohibits the entry of seed potatoes produced in regions infested with rhizomania disease of sugar beet unless accompanied by a certificate indicating the production field has tested free of the disease.

2. Eradication involves the elimination of a pathogen once it has become established on a plant or in a field. It can be accomplished by removal of diseased plants, or parts, as in roguing to control virus diseases or cutting off a cankered tree limb; by cultivating to keep down weed hosts and deep ploughing or spading to bury diseased plant debris; by rotation of susceptible with nonsusceptible crops to starve out the pathogen; and by disinfection, usually by chemicals, sometimes by heat treatment. Spraying or dusting foliage with sulfur after mildew mycelium is present is eradication, and so is treating the soil with chloropicrin to kill nematodes and fungi. Soil treatment with various nematicides (Telone II, Temik 15G, Counter 15 and 20G) is useful to control sugar beet nematodes.

Tan spot, caused by the fungus *Pyrenophora tritici-repentis*, is a major leaf spot disease of winter wheat in the Great Plains of North America. It has become an increasing problem in wheat cropping systems using conservation tillage. This disease can be managed by applying a three-year conservation tillage rotation system called ecofallow. Ecofallow is defined as crop rotation system of controlling weeds and conserving soil moisture with minimum disturbance of crop residue. In this system, corn or sorghum is seeded directly into winter wheat stubble in a winter wheat-grain sorghum/corn-fallow rotation. The uniqueness of this system is that one crop is planted directly into the residue of a different crop rather than into the residue of the same crop. This crop rotation-fallow system effectively breaks disease cycles, such as tan spot, which involve pathogens that survive in crop residue.

3. Protection is the use of some protective barrier between the susceptible part of the suspect or host and the pathogen. In most cases this is a protective spray or dust applied to the plant in advance of the arrival of the fungus spores; sometimes it means killing insects or other inoculating agents; sometimes it means the erection of a windbreak or other mechanical barrier.

Fungicidal sprays that act as protectants are used to control *Cercospora* leaf spot of sugar beet, especially in those fields where inoculum has carried over from the previous year. The principle of protective fungicides is to disrupt the natural sequence of infection. These fungicides act on the leaf surface to kill the newly germinated spores. Flowable sulfur is used as a protectant fungicide to control powdery mildew of sugar beet.

There is a long list of chemicals available in the literature that can be used in present-day protective spraying and dusting, along with eradicant chemicals. The commercially sold chemicals are provided with instructions or notes on compatibility and possibilities of injury. A commercial grower can do his plants irreparable harm instead of the good he intends if he doesn't follow the instructions supplied. Spraying is never to be undertaken lightly or thoughtlessly. Read all of the fine print on the label; be sure of the dosage and the safety of that particular chemical on the plant species to be protected.

4. Disease-resistant and tolerant varieties are the cheapest, easiest, and most efficient way to reduce disease losses. Varieties should be selected that possess resistance or tolerance to one or more disease organisms. For some diseases, such as the soilborne vascular wilts and the viruses, the use of resistant varieties is the only means of ensuring control. Certified seed of resistant varieties is available and sold commercially. The use of varieties of plants resistant to particular diseases has proved to be very effective, i.e., stem rust of wheat, rust of dry bean, and *Rhizoctonia* root rot of sugar beet. Most plant breeding is done for the development of varieties that produce greater yields of better quality. When such varieties become available, they are then tested for resistance against some of the most important pathogens present in the area where the variety is developed and where it is expected to be cultivated. If the variety is resistant to these pathogens for that area, it may be released to the growers for immediate production. If, however, it is susceptible to one or more of these pathogens, the variety is usually discarded, or sometimes it is released for production if the pathogen can be controlled by other means, e.g., chemical, but more often it is subjected to further breeding in an attempt to incorporate into the variety genes that would make it resistant to pathogens without changing any of its desirable characteristics.

There are degrees of resistance to certain diseases, some varieties being completely immune, others partially susceptible. Resistant varieties may become susceptible to new races of a pathogen, i.e., dry bean varieties Beryl and Olathe were resistant to rust races present at the time of their release, but are now susceptible to new rust races.

5. Therapy is used on individual plants and can't be used on a large scale. It is achieved by inoculating or treating the plant with something that will inactivate the pathogen. Chemotherapy is the use of chemicals to inactivate the pathogen, whereas heat is sometimes used to inactivate or inhibit virus development in infected plant tissues so that newly developing tissue may be obtained which is free of pathogen. Thermotherapy involves the exposure of diseased plants or parts of them to hot water or high air temperatures for different periods of time. Loose smut of wheat is controlled by treating the seeds with hot water, but modern resistant varieties are a simpler method of control. Hot water treatment has been used to kill nematodes in bulbs, corms, tubers, and fleshy roots while they are in a dormant condition. Dormant chrysanthemum stools can be rid of foliar nematodes by submerging in water at 112°F (44°C) for 30 minutes.

6. Control of insect vectors and weed hosts: certain insects, especially aphids, beetles and leafhoppers, are known to transmit viruses and mycoplasmas from infected plants to healthy plants. Perennial weeds, including pokeweed, milkweed, Johnson grass, and horse nettle, serve as

overwintering reservoirs of some viruses. Curly top in sugarbeet is a leafhopper-transmissible viral disease, and weeds play a significant role in its spread. Some of the important weeds involved in the spread of curly top disease are certain species of *Chenopodium*, Russian thistle, *Amaranthus*, deadly nightshade, shepherd's pursed, and knotweed.

In some cases, aphids feed on some of the early-appearing weeds and then move to new crop plantings, thus introducing viruses which are then spread in secondary cycles within the planting. Sugarcane mosaic virus (SCMV), an aphid-transmitted virus in maize in the U.S. corn belt, is thought to spread from local weed reservoirs. Spread of SCMV depends upon three conditions: the coincident presence of large numbers of aphids and moderate numbers of infected source plants; when moderate numbers of aphids coincide with large numbers of source plants; or when large numbers of both vectors and source plants coincide. Johnson grass is found to be an important source of primary inoculum for SCMV in several areas. Bean yellow mosaic virus (BYMV) is a common problem in bean growing areas. Forage legumes (red clover) are found to be the source of primary inoculum for aphids to carry BYMV into bean fields.

For lettuce mosaic virus, only 10 to 15 seconds of feeding are needed for an aphid to acquire the virus; then another 10 to 20 seconds on another plant suffices for the aphid to transmit the virus. Diseases in which the aphid-virus relationship is important include lettuce mosaic, celery mosaic, spinach blight, cucurbit mosaic, pea mosaic, sugar beet mosaic, and tomato mosaic. Several grassy weed species host the wheat curl mite vector of wheat streak mosaic virus and build up inoculum for transmission into adjacent fields of wheat. Many broadleaf weed species build up inoculum of nematodes, root rot fungi, and leaf spot fungi that attack sugar beets, dry beans, and corn. All growers should practice good control of insects and weeds.

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