Section III

New Mexico Pesticide Applicator Training
Agricultural Pests and Agricultural Weeds

Control of Plant Pathogens

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CONTROL OF PLANT PATHOGENS
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I. INTRODUCTION

This study guide was compiled and written as an aid for those desiring to pass the plant pathology portion of the New Mexico Agriculture Pest and Weed Control examination. Exam material will come from this publication. Emphasis will be placed on basic information in this study guide and the diagnosis and control of diseases discussed in this guide.

II. GENERAL PRINCIPLES

A. PLANT DISEASE DEFINED

Plant disease is basically the abnormal growth and development of a plant. Sometimes it is difficult to determine what is abnormal and what is normal, but if the growth and development of a plant does not live up to normal production expectations, it may then be considered diseased. In its broadest meaning, a diseased plant is one that is incapable of carrying out its normal physiological functions to the best of its genetic potential.

B. CAUSES OF PLANT DISEASE

The causes of plant disease may be grouped under two categories: infectious disease resulting from invasion or infection by parasites or pathogens, e.g., fungi, bacteria, viruses, mycoplasmas, nematodes or parasitic plants; and noninfectious conditions resulting from unfavorable growing situations, e.g., nutrient or water excesses or deficiencies, extremes of air temperature, pH and other soil conditions, air pollution or phytotoxic pesticides.

The development of a plant disease is dependent on three conditions or entities: 1) the host or plant, 2) the environment, and 3) the disease-causing pathogen or condition. These three components make up what is called the disease triangle. In order for a disease to develop, all three of these factors must interact:

1. The host plant must be susceptible, that is, the plant is capable of becoming diseased. Depending on the disease, it may also mean that the plant is in a certain physiological state, such as seedling, mature plant, flowering or fruiting.

2. The environmental conditions (e.g., moisture, temperature and nutrients) must be right for growth and development of the pathogen or nonparasitic agent.

3. The pathogen or nonparasitic condition must be present in a damaging form. With regard to pathogens, this means that the organism is virulent (aggressive and able to cause disease), not in a state of dormancy, and that the pathogen population is sufficient to cause disease.

If any one of the three components in the triangle is absent, disease will not occur. The degree to which these components interact determines the severity of the disease episode. For example, if you have a highly susceptible host, a highly conducive environment, and a highly virulent pathogen, the disease will be severe. Disease can reach epidemic levels in this situation when you have a large number of genetically identical plants in close proximity. All disease control strategies revolve around modification of one or more of these components.

C. INFECTIOUS DISEASE AGENTS

1. FUNGI

Fungi constitute the largest group of plant pathogens. Aside from their importance in plant disease, few people are aware of the prevalence of fungi in daily life. The layperson readily recognizes mushrooms, bread molds and yeast as fungi, but little else. This is because most fungi live a microscopic existence, and special techniques are needed for their study. But fungi play a significant role in the decomposition of organic matter and the cycling of nutrients back into the soil. It is as pathogens--whether of plants, animals or humans--that fungi become deleterious. Most agricultural plants are susceptible to attack by many different fungi. Alfalfa, chile and cotton, for example, are each subject to attack by at least 30 different fungi.

Fungi can be thought of as plants that lack chlorophyll, but they are not true plants. They obtain food from other living organisms or from decaying, nonliving organic material. Fungi, along with other microorganisms, break down organic matter into inorganic nutrients that plants can use. A typical fungus begins life as a microscopic spore, which can be compared to the seed of a higher plant. Under favorable environmental conditions, the spore germinates giving rise to miniature threads (hyphae), which grow and branch into multifilament mycelium and other specialized structures (fruiting bodies).

Hyphae may enter a plant through wounds, natural openings, or by forcing their way through the surface of an intact plant. In due course, the fungus body (mycelium) produces spores, which can spread from the source, so the disease cycle is repeated. Some fungi have complicated life cycles with more than one type of spore and may even require more than one host plant to complete its life cycle (for example, wheat rust).

Just as higher plants have different flowers and seeds, fungi have different fruiting bodies and spores that allow them to be recognized by plant pathologists. Spores may vary in diameter from a few microns to 300 microns (1 micron = 1/1000 millimeter, or .0004 inch); they come in all shapes and sizes, the largest ones just barely visible to the unaided eye. Fungal spores, important in the spread and build-up of disease, may be air-borne, soil-borne, water-borne, seed-borne, or carried by man, animals, insects or equipment. Some can lie dormant for long periods, waiting for a susceptible host and a favorable environment for the disease cycle to begin again.

Fungal pathogens are most commonly grouped in one of two ways: 1) in terms of the types of diseases they cause, such as rusts, smuts, powdery mildews, downy mildews; or 2) within natural classes of fungi, according to their spore types and fruiting bodies: Oomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes (Fungi Imperfecti).

Classification of fungi is based on the size, shape, color and number of cells in the spores; whether they be asexual (conidia) or sexual (oospores, zygospores, ascospores or basidiospores); and also on the characteristics of the fruiting bodies (conidiophores, sporangia, pycnidia, acervuli, sporodochia, perithecia, cleistothecia, apothecia, basidiocarps, aecia, spermagonia, telia or uredia). All these features have to be examined with the aid of a microscope. Mycelial characteristics are of limited value, but the presence of cross walls in the mycelium is important, as are clamp connections, which are hyphal outgrowths at the cell wall connecting two adjacent cells of basidiomycete fungi.

2. BACTERIA

The number of major diseases caused by bacteria is relatively small, in contrast to those caused by fungi. Nevertheless, some are highly destructive and perplexing , such as fireblight, bacterial canker, and crown gall of tree fruits. Furthermore, blackleg and ring rot of potatoes are important bacterial diseases, to say nothing of the postharvest decay of produce caused by soft-rot bacteria.

Bacteria are one-celled organisms that lack chlorophyll and depend on external sources of living (or dead) organic matter for their food. Placed end to end, bacteria of average size would number about 8,000 to the millimeter; hence these minute organisms have to be magnified several hundred times to be seen, even with a microscope. Bacteria multiply by simple division of the cell into two equal parts; these two parts then increase in size until they also divide into two. The rate of increase in a bacterial population can be phenomenal, with division occurring every few minutes under optimal conditions.

Most bacteria enter plants through wounds or natural openings on the plant surface. A few produce enzymes that weaken host cells and allow entry by the bacterium (e.g., soft rot bacteria). Once inside the plant, they rapidly multiply and break down the tissue. Some swim about in plant sap or water by means of small "whips" (flagella) attached to the wall of the bacterial cell. Unlike fungi, which are often seen with a hand lens or even the naked eye, bacteria are only apparent when clumped together into colonies of millions of individual cells (bacterial ooze is a diagnostic aid with some bacterial plant diseases).

Man plays an important role in spreading disease-causing bacteria on tools and equipment, or by moving affected plants and plant parts. Splashing rain, insects, and wind-blown dust also aid spread. Fortunately, most bacteria are readily killed by exposure to dry air, sunlight, heat, chemicals and antibiotics produced by other organisms; but they still constitute one of the more difficult to control groups of plant disease organisms.

Some bacterial diseases can be identified by the symptoms they produce on plants. When more detailed investigation is required, however, classification of bacteria is based on their shape, number and arrangement of flagella, motility, nature of spores (if any) and biochemical activity. In general, these characteristics are determined after the bacterium has been isolated in pure culture, on or in specialized media.

There are relatively few genera of bacteria credited with causing plant disease. Two of these, ***Pseudomonas*** and ***Xanthomonas***, have polar flagella (whip-like appendages at the ends of cells); the other three, ***Agrobacterium, Erwinia,*** and ***Calvibacter,*** have peritrichous flagella (appendages all around the cell).

A few examples of common diseases caused by these genera are as follows:

Pseudomonas - bacterial canker of stone fruits, angular leaf spot of cucurbits, halo blight of bean, olive knot.

Xanthomonas - angular leaf spot of cotton, bacterial spot of pepper, common bacterial blight of bean.

Agrobacterium - crown gall.

Erwinia - fireblight, soft rot, blackleg of potato, bacterial wilt of cucurbits.

Clavibacter - ring rot of potato, bacterial wilt of alfalfa.

The **Actinomycetes** are a distinct group within the bacteria, characterized by mycelium and conidial chains. This group contains few plant pathogens, although species of ***Streptomyces*** cause scab diseases of potato and sweet potato.

3. VIRUSES AND VIROIDS

Individual virus particles are extremely small and cannot be seen with a light microscope. For example, tobacco mosaic virus, one of the best known plant viruses, is only 280 nm long (about 1/3500 millimeter). The electron microscope is used to determine the morphology of viruses. This microscope has a considerably better resolving power than the light microscope and magnifies objects to between 150,000 and 300,000 times their true size.

Virus particles consist of protein substances (coat protein) and nucleic acid. Viruses cannot carry on the complicated processes of respiration, digestion, and other metabolic functions. They cannot grow or multiply outside the host cell. Once inside the plant cell, viruses utilize host components to make new viruses particles. Some viruses spread within the plant creating a "systemic" infection while others remain localized at the site of virus entrance into the plant. Most viruses do not kill their hosts unless the plant is infected as a young seedling, however virus diseases are severe in that infected plants are unproductive. Many plants may be symptomless carriers of viruses and serve as a reservoir for susceptible hosts. Certain cultivated variegated plants (e.g., tulips with color break in petals) are virus infected.

Viruses are generally classified on the basis of the diseases they cause, such as tomato spotted wilt, beet curly top or pepper mottle. However virus diseases are not limited to the host named. For example, beet curly top infects over 300 plant species.

Viruses are dependant on vectors (transmitting agents) for spread from one plant to another. Vectors create wounds that enable the virus to enter the plant. Man often plays a role in this by propagating, pruning and handling plants. Viruses of grapevines, trees and roses can be spread by budding and grafting. Many plant viruses are spread from diseased to healthy plants by insects (primarily aphids, leafhoppers, and thrips) while feeding on the plants. Nematodes, mites and some fungi are also known to vector certain plant viruses. A few are transmitted through seed or pollen.

Viroids, like viruses only smaller, consist only of ribonucleic acid (RNA). The most familiar disease caused by a viroid is potato spindle tuber.

4. MYCOPLASMA-LIKE ORGANISMS

Although mycoplasmas have long been known to infect mammals, including man, it has only been during the last several years that they have been recognized as a cause of plant disease. Some diseases previously attributed to viruses are now thought to be caused by mycoplasma like organisms (MLOs). Use of the electron microscope has aided the study of MLOs, yet they are difficult to classify because their characteristics are hard to establish. However, it is fair to say that they are intermediate in size between bacteria and viruses. They have no cell wall (like bacteria do) but are surrounded by a unit membrane. They vary in shape from spherical to ovoid or irregularly tubular to filamentous. Pear decline, aster yellows, western-X of peach, and buckskin of cherry are all examples of diseases caused by these types of organisms.

Mycoplasma-like organisms are typically virus-like in their symptom expression and systemic movement through the plant, but they are amenable to treatment with certain antibiotics (while viruses are not). Another difference between viruses and MLOs is the ability to culture some MLOs on artificial media outside the living host.

5. PARASITIC HIGHER PLANTS

Parasitic higher plants are flowering plants that live off other plants. True and dwarf mistletoes and dodder are examples of parasitic plants.

Mistletoes have chlorophyll, but no true roots and thus, rely on host plants for water and nutrients. **True (or leafy) mistletoes** parasitize hardwood trees, such as fruit and nut trees and ornamental shade trees. This pathogen is disseminated by birds, which feed on the seedbearing mistletoe berries. **Dwarf mistletoes**, which forcibly discharge their seeds and are disseminated by air currents, attack conifers and are important pathogens in conifer forests.

Dodder has no chlorophyll and no true roots. This pathogen depends on its host for water, nutrients and carbohydrates. Dodder is a soil-borne, vine-like, leafless plant that is yellow, orange, white or purple in color. It twines around host plants and attaches by haustoria, through which it obtains water and nutrients from the host. It is mostly a problem in agricultural fields, but can be troublesome in home gardens and landscapes, particularly in newly developed areas that were once used for agriculture.

6. PLANT DISEASES AND PATHOGENS IN NEW MEXICO

Many disease which commonly occur in humid, high-rainfall areas, such as the Pacific Northwest or the Atlantic Coastal Plains, are rare in semi-arid, irrigated New Mexico crops. Low humidity and lack of surface moisture in the Southwest are generally unfavorable for survival or growth of organisms that cause diseases of foliage, fruit or seed.

Consequently the most common plant diseases, and those that cause economic losses in the Southwest, result from attack by soil-borne organisms. Of course there are exceptions. Ornamentals and deciduous fruits grown at higher elevations, where temperatures are lower and rainfall more abundant, are sometimes severely affected by pathogens that attack the aboveground plant parts. As a general rule, however, the plant pathogens most frequently encountered in New Mexico are those that attack roots.

These organisms survive because they are adapted to a soil environment where moisture and temperature are favorable for them and the organs they attack. Important diseases caused by soil-borne fungi include Phymatotrichum root rot, Verticillium wilt, Fusarium wilt and root rots caused by species of *Phytophthora, Rhizoctonia* and *Pythium.* Losses may also be severe when root knot nematodes are present.

Several bacteria such as those causing crown gall and soft rots are soil-borne, have large host ranges, can cause severe damage, and are widespread in New Mexico.

Virus diseases are also important in some areas. Tomato spotted wilt is an important disease in greenhouse-grown tomatoes, peppers and bedding plants. In some years, beet curly top causes economic losses in field-grown peppers, tomatoes and cucurbits. Likewise, alfalfa mosaic virus can be severe in alfalfa and pepper.

D. NONINFECTIOUS DISEASE CONDITIONS

In New Mexico and many other semi-arid regions, nonparasitic (abiotic) causes are responsible for more than half the plant disease problems. For example, high temperatures and lack of natural moisture are serious deterrents to growing healthy plants.

Desert soils also frequently contain either excesses or deficiencies of certain elemental nutrients or other chemicals, which can adversely affect plant growth.

1. NUTRIENT DEFICIENCIES

Nutrient deficiencies occur when essential elements are not available in the required amounts. The effect on plants is dependant on the host plant and the elements that are deficient. Some general symptoms include stunting, chlorosis, small leaves, malformed leaves, poor root growth, weak plant growth and poor turfgrass stand establishment.

Below is a list of some of the more common nutrient deficiency symptoms associated with certain elements. Not all of these symptoms will occur on all plants, and other less common symptoms are not listed.

- **Nitrogen:** slow growth, stunted plants, chlorosis (particularly of the older leaves).

- **Phosphorus:** slow growth, stunted plants, purplish coloration of foliage on some plants, dark green coloration with tips of leaves drying, delayed maturity, poor fruit or seed development.

- **Potassium:** leaf tips and margins "burn" starting with the older leaves, weak stalks (plants lodge easily), small fruit, slow growth.

- **Iron:** interveinal chlorosis of young leaves (veins remain green except in severe cases), twig dieback.

- **Zinc:** decrease in stem length, rosetteing of terminal leaves, reduced bud formation, interveinal chlorosis, dieback of twigs (if deficiency lasts more than one year).

- **Magnesium:** interveinal chlorosis of older leaves, curling of leaves upward along margins, marginal yellowing with green "Christmas tree" pattern along mid-rib of leaf.

- **Calcium:** death of growing points (terminal buds and root tips), abnormal dark green color, premature shedding of blossoms and buds, weak stems.

- **Sulfur:** light green color of (mostly) young leaves, small and spindly plants, slow growth, delayed maturity.

- **Manganese:** interveinal chlorosis of young leaves (gradation of pale green coloration with darker color next to veins--no sharp distinction between veins and interveinal areas as with iron deficiency).

- **Boron:** death to terminal buds; thickened, curled, wilted and chlorotic leaves; reduced flowering and improper fertilization.

Soil availability of nutrients is influenced by soil characteristics. The pH of the soil has a profound effect on nutrient availability. For example, iron, though typically plentiful in soil, is mostly unavailable to plants when the soil pH is above 7.5 (alkaline soils). Likewise, phosphorus, manganese, copper and zinc are also less available in alkaline soils. Boron, which is needed by plants in very small amounts, is almost completely unavailable between pH 7.5 and 8.5. A soil pH between 6.5 and 7.5 gives a maximum availability of the primary nutrients (nitrogen, phosphorus and potassium) and a relatively high degree of availability of the other essential elements. Unfortunately, much of the soil in the Southwest is alkaline.

Some elements, such as nitrogen, readily leach through the soil and therefore need more frequent applications to provide plants with an adequate amount of the element. Additionally, the relative amounts of different elements affect nutrient availability. Excesses of certain nutrients may result in a plant's inability to take up another essential elements. For example, excess phosphorus, though rare, can interfere with absorption of nitrogen.

A soil test is needed to determine the base nutrient content and other important soil characteristics. The results of the soil test will help to determine the type and amount of fertilizers needed for different plants. Nutrient toxicities can occur with over fertilization or with improper application of fertilizers. In most cases, application of a balanced fertilizer with essential micronutrients is beneficial to plant growth. In some areas, additional foliar applications of some micronutrients, such as iron and zinc, might be needed to keep plants green and growing strong.

2. PESTICIDE INJURY

All pesticides, if used improperly, can be toxic to plants. In most cases, damage results from improper application or from pesticide drift. Failure to thoroughly clean spray equipment can also result in injury to plants.

Common symptoms of pesticide injury include leaf burn, leaf distortion, chlorosis, flattened or enlarged stems and roots and plant death. Symptom type and severity depend on the type of pesticide and the concentration of the chemical applied. In field and turf situations, the damage is often associated with the application of the chemical (for example, a double application if the sprayer back tracks over some areas, or more chemical applied as the sprayer slows down to turn).

When any pesticide is used, it is imperative that the material be applied **carefully and in accordance with the pesticide label**. It is also important to avoid spraying on windy and/or hot days.

3. TEMPERATURE EXTREMES

Plant varieties and species differ considerably in their ability to withstand low or high temperatures. For example, lettuce and barley are very tolerant of low temperatures, but peppers and tomatoes are sensitive.

Low-temperature injury can be subtle or severe depending on the temperature and the host plant. Severe injury results in cracking or splitting of bark; die back of leaves, twigs and branches; and even plant death. On trees, wounds created by low-temperature injury eventually turn into cankers. These cankers become entry sites for secondary pathogens, such as fungi and bacteria. Low-temperature injury, when not completely obvious, is recognized when epidermal cells of leaves and stems separate form underlying tissues, sometimes giving the affected part a silvery appearance. The affected herbaceous (non-woody) tissue may eventually wilt and turn black.

High-temperature injury causes sunscald of bark of trees such as pecans, stone fruits and apples, especially when trees have been severely pruned. High temperatures may scald fruit on plants, such as peppers, which do not have an extensive plant canopy for protection. Young seedlings of many plants may develop heat canker, a zone of sunken, dead tissue on stems at soil line. Heat stress, particularly when coupled with high wind, causes excessive transpiration and damage results in marginal leaf necrosis and twig or branch dieback. An added stress of excessive salt will increases the severity of the damage (see **Salt Injury**).

4. SALT INJURY

Salt injury occurs when excessive soluble salts, either from the soil or the irrigation water, are taken up by the plant. Damage results from a loss of feeder roots. The primary symptoms of salt stress are marginal leaf necrosis and twig and branch dieback. In severe cases, defoliation may occur. Salt injury is more severe in combination with heat stress and high winds.

Unfortunately, much of the soil in New Mexico is high in soluble salts. Additionally, irrigation water may also be high in salt. Therefore, good water management and proper leaching of the soil are essential in order to minimize potential salt injury.

5. WATER EXCESS AND DROUGHT INJURY

Water plays a critical role in overall plant health. Both too much and not enough water can lead to direct and indirect adverse effects on plants.

Excess soil moisture can result from excessive irrigation, heavy rainfall and/or poor soil drainage. The soil in many agricultural areas in New Mexico is predominately clay. These clay soils drain slowly and can create problems associated with water logged conditions. Impervious layers of caliche or hardpan can also restrict drainage. Plants in such situations may appear chlorotic or thin (little foliage) and have numerous dead or dying roots due to lack of oxygen in the soil. Soil in chronically wet situations may be black and odorous. Indirect injury results in the attack of weak roots by microorganisms.

Chronic lack of water (drought) results in different kinds of injury to different kinds of plants. Grasses appear bluish in color and leaves roll. Shrubs and trees may wilt in the afternoon, have new foliage which is small and pale in color, and suffer twig dieback. Shedding of leaves may also be a symptom of severe drought, but this condition also occurs commonly in New Mexico when plants are subjected to high levels of soluble salts, and may also be symptomatic of plants attacked by the fungi causing root rots and wilts.

6. WIND EFFECTS

Wind has both direct and indirect effects on plants. A direct effect results from the consistent, directional force of wind on the physiology and morphology of plants. In some cases, trees may be radically altered in shape by wind. Evapotranspiration rate is related to sunlight, wind speed, temperature and relative humidity. High winds, particularly at high air temperatures, can readily desiccate plants. Additionally, leaves can become tattered either from the force of the wind whipping through the foliage, or from wind-blown sand.

Wind has indirect, but important, effects on plant disease development. Wind is an important means of pathogen spread, and can carry fungus spores and insect vectors for long distances. Wounds created by wind and wind-blown sand are excellent sites for pathogen entry into plants. Lack of wind and formation of inversion layers can cause air pollutants to become concentrated in localized areas, resulting in damage to sensitive plants. Additionally, lack of air circulation around plants can lead to disease problems associated with foliar pathogens, such as powdery mildew.

7. LIGHT EFFECTS

Light provides the energy needed for photosynthesis, and its intensity, wave-length and duration can affect the germination, growth and shape of plants. Lack of light causes etiolation and results in poor color because of insufficient chlorophyll development. Shading may kill out branches on some trees, and seedlings in shaded areas may not mature and become predisposed to other debilitating agents. Too much light on shade- or partial shade-loving plants may lead to problems with chlorosis and sunburn injury.

8. AIR POLLUTION EFFECTS

In many areas of the United States, damage to vegetation by air pollution poses significant economic and environmental problems. In addition to the obvious visible symptoms of air pollution damage, there may be an invisible effect: the plant appears healthy, but growth and production are reduced in some cases by 50 percent or more.

Correct diagnosis of air pollution damage to plants is extremely difficult. Many other influences such as herbicide injury, insect damage, plant pathogens, nutritional imbalances, and weather effects cause similar symptoms. It is advisable to rule out these possibilities before strongly considering air pollution as the causative factor of a particular problem.

Below is a table listing the major air pollutants, their sources and symptoms:

Pollutant	Major Sources	Symptoms
Nitrogen oxides	Any combustion source	Invisible damage
Ozone	Interaction of sunlight and nitrogen oxides	Flecking of upper leaf surface
Hydrocarbons	Incomplete combustion, petroleum evaporation	Unimportant
PAN (peroxyacetyl-nitrate)	Interaction of ozone, nitrogen oxides and hydrocarbons	Bronzing of lower leaf surface
Sulfur dioxide	Coal burning, copper	Interveinal bleaching

9. OTHER ENVIRONMENTAL EFFECTS

Electrical storms and the resultant lightning can often damage plants or even kill trees and small patches of vegetation. Hail and ice can result in plant lesions, which may provide entry points for pathogens or make produce unmarketable. Plants beside roads and highways are often subject to toxicants or debris associated with their location (such as sand and gravel herbicides). Construction damage or changes in soil grade may seriously affect shade trees by compacting the soil or reducing effective root area.

III. SYMPTOMS AND SIGNS OF PLANT DISEASE

Plant diseases are manifested by specific symptoms and/or signs. The terms blight, chlorosis, mildew, canker, rust, rot and wilt all have meaning to the plant pathologist in terms of certain maladies. The purpose of this section is to introduce some of the widely used diagnostic terms in plant disease studies.

Symptoms - the response of a plant to attack by a pathogen or damage by a non-parasitic problem. Leaf spot, wilt, and mosaic are examples of symptoms.

Sign - the visual presence of some structure formed by a pathogen on a host. Examples of signs are the mycelia seen in powdery mildew, the black sclerotia associated with Sclerotinia drop of lettuce and the strands associated with Phymatotrichum root rot.

Hypha (pl. **hyphae**) - a single thread of the fungal body.

Mycelium (pl. **mycelia**) - mass of hyphae or thread-like structures that make up the fungal body.

Sclerotium (pl. **sclerotia**) - a hardened mass of mycelium, more or less spherical. This type of fungal structure is generally less vulnerable to destruction by environmental conditions than other fungal structures. It is a survival structure and can often be seen with the unaided eye.

Spore - a fungal reproductive body, produced on a hypha, that can germinate like a seed and produce new hyphae. Spores are the primary means by which many fungi are spread from one place to another.

Strand (rhizomorph) - a group of hyphae that have come together to produce a rope-like growth. Strands are often visible to the unaided eye and can be found in association with diseases such as Phymatotrichum and Armellaria root rot.

Leaf spots or fruit spots - the most common symptoms of plant disease. Usually definite, spots vary in shape, size and color; leaf and fruit spotting diseases are sometimes called tar spot, or anthracnose. Diseases of this type are favored by splashing water. Fruiting structures of fungi (e.g. pycnidia, acervuli or perithecia) may be present in these spots. Bacterial leaf spots are frequently water soaked before more serious injury of the infected tissue occurs. Numerous spots coalescing may lead to blotches or leaf blight (complete death of a large part or the whole leaf).

Shothole - the term for leaf spots in which the diseased tissue falls out leaving a hole in the leaf which can have either a smooth or ragged margin. This symptom may be caused by fungi, bacteria, viruses, chemical spray injury, insect damage or mechanical injury.

Twig, shoot or blossom blight - indicates greater involvement of the tissue in disease, and often death of large portions of the plant or the current flowering or fruiting structures.

Leaf curl - symptom used to describe curling or twisting of leaves; common with many fungal and virus diseases. Can be used to describe a fungal disease of peach (peach leaf curl) that appears as conspicuous, colored blisters on leaves that become puffy and deformed; spores are produced on surfaces of the blisters. Some insects produce similar symptoms in leaves.

Downy mildew - term used to describe diseases caused by certain fungi in the Oomycetes. Numerous hosts grown under moist, humid, cool conditions may be affected by downy mildews. Leaves of the plant may show pale green or yellowish areas on the upper surface, with a corresponding downy gray or white mildew growth on the under side of the leaf. Other plant parts may be affected, and general wilting, blighting or death of plant parts can ensue.

Powdery mildew - term used to describe diseases caused by certain fungi in the Ascomycetes. Appears on infected plant parts (leaves, shoots, buds, flowers) as a white to gray powdery coating. Powdery mildew is most common on the upper leaf surface, but in some hosts, such as chile, the fungus sporulates predominately on the underside of the leaf. It is common during the late spring or when warm days are followed by cool nights, and in late summer when rains increase the humidity and plant canopies are large, restricting air circulation in field crops.

Rust - describes a symptom in which bright orange, brown, red or black spore pustules appear on infected plant parts. Term used to describe certain types of fungi that produce these symptoms. Many rust fungi have several spore forms and complicated life cycles involving more than one host plant.

White rust - describes that spore pustules that develop on the leaves and stems of infected plants. The fungi causing these symptoms are unrelated to those causing the true rusts.

Smut - describes diseases which produce dark brown to black sooty spore masses inside swollen blisters on infected plant parts. Many smut-producing fungi enter plants at the seedling stage and grow systemically in the plant, to appear during fruiting, usually as smutted heads of cereals and grasses.

Sooty mold - term used to describe dark, brown-to-black, superficial fungal growth caused by several different species of fungi. Growth can occur on any above-ground plant part. The fungi are not parasitic on the plant but grow on "honeydew" excretions of insects or secretions of plants themselves. Indirect damage results from heavy infestations when a large amount of the plant surface area is covered and light reaching the plant is reduced.

Scab - consists of a roughened, crustlike, raised area on fruit surface or other plant parts.

Anthracnose - term used to describe a disease characterized by black, sunken leaf, stem or fruit lesions, which produces asexual spores in an acervulus (particular type of fruiting body).

Wilt - loss of turgidity and drooping of plant parts. If permanent and not from lack of moisture, can be caused by fungi or bacteria growing in the plant's water-conducting tissues, preventing water movement through the plant. Wilt may also be caused by root-infecting nematodes which prevent water movement into the above-ground tissue. Some viruses produce wilt-like symptoms, but they do not cause true wilt.

Rot - usually of fruit, crown (collar), wood or roots of a plant; describes a rapid breakdown and death of the tissues. Caused by fungi or bacteria, root rot can be confusing to the amateur diagnostician because the damage is hidden from view. Plants tend to wilt or decline and show no response to water or nutrients.

Canker - a necrotic, discolored, often sunken lesion on a stem, branch or twig of a plant. Cankers can be produced by adverse environmental conditions, mechanical injury and pathogens (e.g., fungi, bacteria and occasionally viruses). If the canker girdles the limb or trunk, the portion of the plant above the canker will wilt and die.

Damping-off - describes the collapse of seeds and/or seedlings, primarily from attack by soil-borne fungi. In some instances, damping-off may be caused by excess soluble salts in the soil. Pre-emergence damping-off refers to the failure of seeds to germinate or to collapse prior to emergence from the soil. Post-emergence damping off refers to the collapse of newly emerged seedlings.

Gall - is used to characterize a tumor-like outgrowth from the plant that may be hard or spongy; galls may occur on roots, stems, branches, leaves or flowers. Galls are most commonly caused by bacteria, nematodes, or insects.

Mosaic, mottle, streak, calico, crinkle, ringspot, stunt, flower break, infectious variegation and yellows - some of the terms used to describe symptoms of viruses (and some mycoplasma-like organisms). Various degrees of leaf yellowing and malformation may also be produced. The severity of the disease is governed by the strain of the pathogen and/or host plant involved.

Vascular discoloration - a diagnostic symptom for many vascular wilt disease organisms (such as *Verticillium* and *Fusarium*).

IV. DIAGNOSIS OF PLANT DISEASES

Positive and correct diagnosis of the causal agent of a plant disease is almost always essential to the application of effective control measures.

A well-trained and experienced diagnostician should be able to make a systematic visual inspection of a plant disease situation and narrow it down to some of the most likely possibilities. Laboratory and greenhouse techniques may then be used to identify or verify the cause. Since the latter are time consuming and costly, the importance of thorough visual inspection is paramount.

Far more can be learned and appreciated about a disease in the field than from working with dry specimens removed from their origins. Once in the field, one must have a thorough knowledge of the normal growth characteristics of the crop or commodity in question, or the "disease" situation may not be apparent.

There is no substitute for experience; the accurate diagnosis of plant ailments is a skill that requires much time and effort to develop.

In general, a consultant or diagnostician should be aware of the following:

- The diseases that are reported to occur on a particular host (provided by host indexes, experience and other references).
- The distribution of the diseases, particularly those that might occur in the given area and/or under certain conditions.
- The symptoms of common diseases that occur on a particular crop.
- Sources and methods of spread of the spores or inoculum of the pathogen (whether air-, soil-, or water-borne or vector transmitted).
- The effect of weather, soil, and other conditions on the development of the disease.
- Signs that a fungus or other pathogen might produce in the field, such as cleistothecia of powdery mildews, strands of Phymatotrichum root rot and galls of root knot nematodes.

In the field, useful tools to assist in diagnosis are a hand lens, pocket knife, shovel, soil core and insect net, but above all an open mind. It is helpful to talk to the grower: persistent questioning about the problem often uncovers helpful clues leading to correct diagnosis. The following steps (guidelines) are given to help in understanding the type of information needed to make an accurate diagnosis:

1. Identify the plant species affected: genus, species and cultivar (whenever possible). Look around the area and determine if more than one type of plant is affected.

2. Observe the symptoms: determine the part(s) of the plant affected, if the disease is localized or spreading (both on the plant or to other plants) and try to determine when the symptoms first appeared. The pattern of distribution of the disease can provide valuable information as to the cause of the problem. The following outline gives a broad indication of the likely causes of different field patterns.

Field Pattern	Most Likely Causes
Row effects	• Mechanical injury • Poor planting practices or spread of pathogen during transplanting • Excess or deficiency of fertilizer or pesticide applied; possible spray tank contamination • Root pathogens spread by equipment or water • Excess or deficiency of water
Scattered occurrences of abnormal trees or plants in the field	• Mechanical, animal or rodent injury • Genetic mutation • Differences in rootstock • Insect, air- or soil-borne pathogen • Low disease incidence in planting stock

Field Pattern	Most Likely Causes (con't...)
Irregular patterns	• Nutrient deficiencies or excesses • Excess or deficiency of moisture (faulty irrigation practices) • Salinity or alkalinity • Poor drainage (soil compaction, sand spots, caliche or hardpan) • Soil pathogens or insects • Insect- or nematode-borne viruses • Poor field leveling, low spots, cuts or fills) • Mechanical injury due to soil compaction or equipment • Chemical injury (pesticide drift, air pollution, spray injury from equipment turning or temporarily stopping)
Seasonal and/or Locality effects	• Seasonal nutrient deficiencies • Effects of high or low temperature, frost damage, sunscald, lightening, etc. • Air pollution • Hail

3. Determine the environmental conditions prior to and during symptom development: day and night temperatures, air and soil moisture, clouds, wind, hail, dust, blowing sand, etc.

4. Determine the growing conditions:

   a. Soil conditions: type, structure, drainage, etc.
   b. Plant location: lawn, home garden, organic garden, landscape, courtyard, greenhouse, golf course, commercial field, commercial nursery, indoors, etc.
   c. Exposure: sun, shade, wind, etc.
   d. Proximity to structures: other plants, buildings, sidewalks, roads, walls, power lines, etc.
   e. Irrigation history: how applied, how much, how often, time applied, etc.
   f. Fertilizer history: what, how applied, how much, how often, etc.
   g. History of chemical use: what, how, how much, how often, etc.
   h. Other information useful in diagnosis: acreage, crop rotation, past problems with that plant or that location, percent of plants affected, distribution of disease, etc.

The above information (steps 1-4) and observation of the disease situation should help in determining if the cause of the problem is an infectious or non-infectious disease. In some cases, the most likely cause(s) of the problem can be made.

No matter how much field experience one may have, certain problems require further investigation in the laboratory, and it is suggested that specimens be collected for diagnosis. Proper diagnosis of plant problems is dependant on examination of a "*good*" plant specimen. When possible, submit the whole plant for diagnosis. It is difficult, if not impossible, to determine the cause of disease from a single leaf, dried or old specimens or (especially) a dead plant. In addition to diseased material, sending a healthy plant (when possible) is very helpful to the diagnostician. It is also important, especially with stem and branch disorders, that the margin of the disease (that is, where healthy and diseased tissue come together) is included in the sample.

V. COLLECTING SPECIMENS FOR LABORATORY IDENTIFICATION

The following are some guidelines for submitting specimens to the Extension Plant Pathologist for diagnosis.

A. COLLECTING

1. *Provide as much information regarding the specimen as possible.*
   a. Identify the plant material (variety), acreage (when applicable), and indicate the percentage of plants affected.
   b. Indicate when the symptoms first started and whether or not the symptoms are continuing to develop or spread.
   c. List all cultural practices, such as frequency of irrigation, the rate and time of application of chemicals used (herbicides, insecticides, fungicides, etc.), fertilizer regime, and crop rotation over the previous two years (especially note previous crop) when applicable. List any control measures already attempted.
   d. Try to give an estimate of the weather conditions preceding and during symptom development.
   e. For home or urban plantings, indicate the type of environment in which the plant is growing (e.g., lawn, flower bed, pot, house greenhouse, etc.).
   f. A photograph of the plant in its environment, when available, can be extremely helpful to the diagnostician.

2. *Select material showing the symptoms you are concerned about.* If possible, it is best to send several samples showing various stages of the problem; especially important are the early stages of symptom development.

3. *Send samples of all plant parts including roots whenever possible.* Above-ground symptoms are often caused by root or stem diseases, thus examination of all parts can be essential in an accurate diagnosis. Dig out plants (do not pull them out) of the soil. Pulling plants out of the soil will generally leave the roots behind, especially if the roots are rotted. Retain a small amount of soil around the roots. DO NOT WASH ROOTS. Keep the roots and soil separate from the above-ground parts of the plant by placing them in a plastic bag and sealing them off with a rubberband.

4. *When the entire plant cannot be sent, send several affected portions of the plant.* Remember to include the margin of disease on stem and branch samples, as this is where the causal agent is most likely to be isolated. Dead plant tissue is rapidly

invaded by secondary organisms that can mask the true cause of disease by crowding out the primary pathogen.

5. Non-woody specimens travel best if they are kept slightly moist with a damp paper towel. Remember, these specimens will rot with too much moisture so it is best not to tightly seal plastic bags. Providing a few holes in the bag or using "vegetable" bags is a good way to send samples.

6. If you suspect vascular wilt diseases, such as Verticillium wilt, send a sample from dying or wilted branches with yellow leaves. Remember, DO NOT SEND COMPLETELY DEAD WOOD. Place several branch sections 1/4 inch to 1 inch in diameter and approximately 6 inches in length in a plastic bag. This will prevent the sample from drying in transit.

7. Turfgrass samples should be taken from the edge of the affected area and include both dying and healthy plants. Again, DO NOT SEND TOTALLY DEAD GRASS. Send several 3 x 3 inch squares of sod including at least 1 inch of soil. Place the sample (soil down) on a thin layer of damp (not wet) paper toweling, then wrap the entire sample in dry newspaper.

8. Fleshy specimens, such as fruit, mushrooms or other fungal fruiting bodies should be as firm as possible and show both early and intermediate symptoms. Wrap specimens separately in dry paper toweling or dry newspaper. DO NOT PUT IN PLASTIC. Carefully pack specimens so that they are not crushed during shipping.

B. PACKING

1. MAIL SPECIMENS AS SOON AS POSSIBLE AFTER COLLECTION. Mail early in the week to avoid delivery delays over weekends, and be aware of holidays that might delay arrival of the package.

2. Keep plants cool and moist prior to shipping. Take along an ice chest when collecting the sample and place the sample in the refrigerator until the specimen can be sent. Do not leave unprotected samples in automobiles.

3. Pack in a sturdy container to prevent crushing during transit. Use newspaper to firmly pack specimen in the container.

4. Identify package with labels both outside and inside. Be sure to include your name, mailing address, and phone number. **Don't forget to include an explanation of the diseased material.**

In the laboratory, the specimen material should be thoroughly examined with low- and high-power microscopes at the outset. This will enable detection of many fungal or bacterial organisms, sometimes with the aid of staining or sectioning, and will also facilitate determination of the plant tissues involved. With this as a guide, cultural isolation procedures are likely to be much more successful.

The nature of the organism dictates the type of surface disinfection to use and the best cultural medium for isolation. Many specific and selective media have been developed for certain pathogens. Incubation of diseased tissue in a moist chamber helps fruiting bodies to form and can aid diagnosis. Choice of techniques for isolation is wide, and experience is helpful in selecting the best method.

VI. AFTER DIAGNOSIS

After a diagnosis is determined, several decisions need to be made. The diagnostician and/or consultant should consider the following and then make recommendations based on the answers to these questions:

- What can be done now to improve the situation?
- Is the damage significant to warrant action?
- What action should be taken now? Later?
- What management practices can the grower/home owner reasonably do (consider; cost, equipment, labor)?
- Can the problem be avoided in the future? How?

VII. DISEASE MANAGEMENT METHODS

The ultimate objective in plant disease control is to effectively manage diseases at economically acceptable levels.

A well-conceived management program should be based on knowledge of the characteristics of the pathogen and the host, cultural and climatic conditions under which the crop is grown, climatic condition that favor the pathogen, and available control measures, including cultural, genetic and chemical approaches. The basic principles of plant disease control are:

1. **Avoidance** - avoiding disease by planting at times when, or in areas where, the pathogen is ineffective, rare or absent.

2. **Exclusion** - reducing, inactivating, eliminating or destroying the pathogen at the source.

3. **Protection** - preventing infection by use of a toxicant or other barrier between the host and the pathogen.

4. **Disease resistance** - use of genetically resistant or tolerant plant material.

5. **Therapy** - reducing the effect of a disease in an already infected plant.

6. **Trap crop** - the act of establishing plants attractive to insect virus vectors (trap crops) on borders of the desired crop, then destroying the trap crop or treating with an insecticide to destroy the insects before they move into the main crop.

The terms "integrated pest management" and "biological control" are frequently heard these days; plant pathologists are often asked whether these concepts have application in the field of plant disease management. The truth of the matter is that the principles of integrated disease management and biological control have been an integral part of plant pathology for decades. For the most part, *plant diseases are controlled by prevention, not cure*. In essence, this means that appropriate measures are taken before the disease develops, not after an outbreak has occurred. Broadly speaking, these principles of control can be considered under three major headings: cultural and biological control, genetic control and chemical control.

A. CULTURAL AND BIOLOGICAL CONTROL

Many effective cultural techniques of disease avoidance were practiced long before the causes of plant disease were known. For centuries, innovative farmers and experimenters have found ways to reduce plant disease losses. Crop rotation, green manuring, deep plowing, sanitation, rouging--are all time-honored methods of reducing both biotic and abiotic diseases. Time of planting, plant spacing, irrigation method, and choice of location are other examples of sometimes unconscious disease-control methods. Technically, biological control is the act of controlling a pathogen with another living organism. Many cultural control practices alter the microbial environment around plants. In many cases, the population of beneficial microorganisms (biological control agents) is increased and these microbes play a role in the reduction of disease. As such, many cultural control methods can also be considered to be biological control methods.

Other methods of cultural/biological control are as follows:

1. DISEASE-FREE PROPAGATION MATERIAL

Assuming the planting medium and location are free of pathogens, it is particularly important to use clean, uninfected propagating material, whether seeds, bulbs, plants or trees. Numerous fungi, bacteria, viruses, parasitic plants and nematodes can be introduced into a disease-free area on infected plant material.

To obtain disease-free seeds, crops free of disease organisms are often grown in an arid climate under furrow irrigation, well away from commercial areas. This reduces the risk of insect transmission of plant pathogens and also discourages build-up of water-splashed organisms. Certified seed crops of beans, cucurbits, potatoes and other commodities are produced in this manner.

Meristem-tip culturing is an interesting method used for producing virus-free plants of specialized clones. Strawberries, carnations, citrus, grapes and orchids are some examples where this technique has been employed. Viruses move slowly through plant tissues under some conditions. Often the plant growing tips are developing fast enough to be ahead of infection; they can then be removed and cultured free of disease.

Heat treatment involving hot-air, steam-air mixtures, hot water or prolonged growth at high temperatures is particularly effective in eradicating some viruses, fungi and bacteria from planting materials. Microorganisms are often killed at lower temperatures than the host plant. This technique is commonly used for cleaning up virus-infected fruit trees as well as bacterium and fungus-infected seeds, bulbs, corms and rhizomes of vegetables, field crops and ornamentals.

2. SANITATION

Crop sanitation goes hand in hand with the use of clean planting material. Infected residues from previous crops provide carry-over for may pathogens and provide one of the strong arguments for agricultural burning. Some examples of disease control by sanitation techniques include pruning out brown rot "mummies" in peach trees, deep plowing to bury inoculum for vegetables, and rouging infected plants to prevent virus spread.

Man spreads numerous pathogens by pruning and handling plants, especially when they are wet. For this reason, pruning shears are sterilized between trees when removing fire blight-infected tissue and other disease cankers. Additionally, field equipment should be cleaned between fields to prevent transfer of soil pathogens from one field to another.

3. VARIOUS OTHER CULTURAL CONTROLS

A crop-free period (fallowing), such as that used to control beet yellows, prevents carry over of virus inoculum, thus reducing disease. Controlling weed hosts plays an important role in managing many disease agents, notably viruses and nematodes. Similarly, reducing insect-vector build-up on weed hosts may reduce infection by viruses such as beet curly top. Controlling insect vectors also can restrict the spread of bacterial and fungal disease such as cucurbit wilt and Dutch elm disease.

Crop rotation can be an excellent means of managing some diseases. For example, a one-year rotation out of wheat prevents continued build-up of take-all disease caused by *Ophiobolus graminis*. Good rotational crops for this purpose include oats, corn or beans. Many crops require longer crops rotations, perhaps four years or longer, to reduce the severity of particular diseases.

Growing plants on raised beds improves drainage and reduces plant disease in plants of all ages (e.g., Phytophthora root rot of chile). Controlled irrigation methods markedly reduce foliage, flower, fruit and root diseases in many crops. Unquestionably, there is great potential in cultural methods of control that require neither chemicals nor plant breeding.

B. GENETIC CONTROL (PLANT BREEDING)

Disease-resistant varieties usually provide the most effective, simple and economical means of controlling plant diseases. This practice has played an important role in maintaining high productivity with many crops. In the United States, resistant varieties are used in almost 75 percent of the total acreage under agricultural production.

However, true resistance is rare. What we are really talking about is tolerance--the plant is tolerant of the pathogen. The level of tolerance may vary from slight or low tolerance to high tolerance. Tolerance may break down under heavy disease pressure. Likewise, pathogens change genetically to overcome tolerant plant material just as they develop resistance to chemicals. Thus genetic tolerance must be continually monitored and development of new tolerant varieties needs to be on going.

With crops that have a low value per acre, disease tolerance often provides the only feasible approach to control since chemicals are too expensive. Without tolerance, some crops could no longer be grown in certain areas. Successful examples of the use of disease-resistant varieties are rust and smut-resistant cereals; wilt-resistant tomatoes, crucifers, cucurbits, and cotton; curly top-resistant sugar beets; and mosaic-resistant beans.

C. CHEMICAL CONTROL

Chemical control of plant diseases is widely practiced, and the quality and yield of many crops are dependant on proper use of plant disease toxicants. Although better understanding of host-pathogen-environment dynamics will permit the increasing use of other cultural methods of control, for the present there are certain diseases for which chemicals play a vital role.

Chemicals may act either to eliminate, reduce or remove the inoculum at its source (eradication); to prevent plant disease (protection); or to cure disease (therapy). The majority of applications involve the principle of protection, which means preventing the disease organism from entering the plant and starting an infection.

It is imperative that the use of chemicals present no hazard to man--applicator, grower or consumer or other animals. Additionally, chemicals must be less toxic to the crop plant than the organism they are designed to kill.

The greatest number of plant disease chemicals are fungicides, designed to act on fungi. Similarly, there are bactericides and nematicides, but no commercially effective viricides.

Fungicide toxicity usually depends on physical as well as chemical properties. Physical properties affecting toxicity include particle size, polarity, solubility, adhesion and molecular size and shape. Chemical properties involve differential reactivity between the chemical and essential metabolic systems of the parasite and the host, as well as stability under different environmental conditions.

Bordeaux mixture and copper compounds were among the earliest wide-scale plant disease protectants used by man. They are still very effective against certain diseases, although they are being replaced by newer fungicides that are less harmful to plants. The copper ion is the fungicidal agent in these compounds. Since application in the form of copper salt alone is toxic to plants, lime (as an example) is added to copper sulfate in the preparation of bordeaux mixture to reduce its toxicity to plants.

Sulfur products, in the form of wettable powders, flowables and dusts have long been used to control a variety of diseases. Large volumes are annually used to control powdery mildew on crops such as cucurbits and peppers. Lime sulfur is a useful dormant clean-up spray for insects and mites, as well as fungi.

The dithiocarbamates and other organic fungicides have been widely used since World War II. They are generally less toxic to plants than other fungicides and are more specific in their action. Some examples of these materials are: ziram, zineb, thiram, maneb, captan, dichlone and dinocap.

A new era of systemic fungicides has been developed in recent years with oxathiin and some of the benzimidazole compounds (e.g., benomyl and thiabendazole). The latter have a wide spectrum of activity against many important plant pathogens.

Copper materials have been used successfully as bactericides as well as fungicides, although they are gradually being replaced by more specific antibiotics, such as streptomycin.

Soil fumigants are still frequently used for difficult soil-borne disease problems such as Verticilium wilt and root-knot nematode.

The above mentioned chemicals are some of the most common chemicals used in plant disease control. More details on disease control chemicals are given in section IX of this portion of the study guide.

Everyone concerned with the use and application of pesticides should have a clear understanding of their potential and limitations. Users should always **read the label carefully and follow the instructions.** Some of these chemicals are restricted to use and purchase only by certified applicators and those under their direct supervision; this information also appears on the label. To achieve the desired effect of healthy, disease-free plants, the right chemicals must be applied in the right way, at the right time, and in the right concentration.

VIII. MAJOR INFECTIOUS DISEASES OF AGRICULTURAL CROPS IN NEW MEXICO

Pesticide applicators should familiarize themselves with the following major diseases of New Mexico crops. Be aware of the major symptoms of the disease, as well as structures of the pathogen that can easily be seen with a hand lens or the unaided eye. Knowledge should be acquired concerning environmental conditions that influence disease development (particularly weather), how the pathogen is spread, and the cultural and chemical management procedures available for control.

New Mexico State University publications should be consulted for up-to-date information.

The following is a list of crops and their most common diseases, which can occur in New Mexico. Diseases caused by nematodes may also be found in **Section IV, CONTROL OF NEMATODES.**

Crop	Disease	Pathogen or Agent
Alfalfa	Root knot nematode Phytophthora root rot Phymatotrichum root rot - (aka Texas or cotton root rot) Crown rots Stem nematode Downey mildew Alfalfa mosaic	*Meloidogyne* spp. *Phytophthora megaspema* *Phymatrichopsis* (=*Phymatotrichum*) *omnivorum* *Rhizoctonia solani, Fusarium* spp. and other organisms. *Dirthylenchus dipsaci* *Peronospora trifolirum* Virus (aphid vector[1])
Apple and Pear	Verticillium wilt Crown gall Fireblight Phytophthora crown and root rot (apple) Powdery mildew (apple) Phymatotrichum root rot Bitter pit (apple)	*Verticilium albo-atrum* *Agrobacterium tumefaciens* *Erwinia amylovora* *Phytophthora cactorum* *Podosphaera leucotricha* *Phymatotricopsis omnivorum* Calcium deficency in developing fruit
Barley	Smuts Barley yellow dwarf Rusts Barley stripe	*Ustilago* spp. Virus (aphid vector) *Puccinia* spp. *Drechslera graminea* (=*Helminthosporium gramineum*)

Bean	Root knot nematode Curly top Common bacterial blight Halo blight Brown spot Rhizoctonia root rot Rust Bean common mosaic Bean yellows mosaic White mold	*Meloidogyne* spp. Virus (leafhopper vector) *Xanthomonas campestris* pv. *phaseoli* *Pseudomonas syringae* pv. *phaseolicola* *Pseudomonas syringae* pv. *syringae* *Rhizoctonia solani* *Uromyces appendiculatus* Virus (aphid vector) Virus (aphid vector) *Sclerotinia sclerotiorum*
Corn	Maize dwarf mosaic Rusts Common smut Helminthosporium leaf spots and blights	Virus (aphid vector) *Puccinia* spp. *Ustilago maydis* *Bipolaris* spp., *Drechslera* spp. and *Exserohilum* spp.
Cole crops (broccoli, cabbage, cauliflower, etc.)	Downy mildew Sclerotinia rot Bacterial soft rot Fusarium wilt	*Peronospora parasitica* *Sclerotinia* spp. *Erwinia carotovora* *Fusarium oxysporum*
Cotton	Aflatoxin (yellow lint stain) Boll rot Phymatotrichum root rot Seedling diseases Southwestern cotton rust Verticillium wilt Root knot nematode	*Aspergillus niger, Rhizopus* spp. *Aspergillus niger, Rhizopus* spp. and other organisms. *Phymatotricopsis omnivorum* *Rhizoctonia solani, Thielaviopsis basicola* and other fungi *Puccinia cacabata* *Verticillium dahlia* *Meloidogyne* spp.
Cucurbits (cucumbers, cantaloupe, honeydew, pumpkin, squash, watermelon	Curly top Fusarium wilt Verticillium wilt Cucumber mosaic Squash mosaic Watermelon mosaic II Zucchini yellow mosaic Powdery mildew Phytophthora fruit rot of pumpkin and squash Blossom-end rot	Virus (leafhopper vector) *Fusarium oxysporum* *Verticillium dahlia* Virus (aphid vector) Virus (beetle vector) Virus (aphid vector) Virus (aphid vector) *Erysiphe cichoracearum and Sphaerotheca fuliginea* *Phytophthora capsici* Calcium deficency in developing fruit

Grapes	Crown gall Fruit and bunch rots Phymatotrichum root rot Powdery mildew	*Agrobacterium tumefaciens* Several fungi *Phymatotricopsis omnivorum* *Uncinular necator*
Lettuce	Downy mildew Sclerotinia drop (watery brown rot) Bottom rot Powdery mildew	*Bremia lactucae* *Sclerotinia sclerotiorum* *Rhizoctonia solani* *Erysiphe cichoracearum*
Onion (seed, dry and green)	Bacterial soft rot Pink root Botrytis soil-line rot Fusarium basal rot	*Erwina caratovora* *Pyrenochaeta terrestris* *Botrytis* spp. *Fusarium oxysporum*
Nut crops (pecans and pistachio	Phymatotrichum root rot Verticillium wilt (pistachio) Collar or crown rot	*Phymatotricopsis omnivorum* *Verticillium dahlia* *Phytophthora* spp.
Peanuts	Seedling diseases Web blotch Root knot nematode	*Rhizoctonia solani, Aspergillus niger* and other fungi *Phoma arachidicola* *Meloidogyne hapla*
Pepper (chile)	Bacterial spot Curly top Phytophthora root rot Pepper mottle Verticillium wilt Seedling diseases Alfalfa mosaic Blossom-end rot Tomato spotted wilt Root knot nematode Powdery mildew	*Xanthomonas camperstris* Virus (leafhopper vector) *Phytophthora capsici* Virus (aphid vector) *Verticillium dahlia* *Rhizoctonia solani* and other fungi Virus (aphid vector) Calcium deficency in developing fruit Virus (thrips vector) *Meloidogynae incognita* *Oidiopsis taurica*
Potato	Bacterial soft rot Rhizoctonia canker Verticillium wilt Early blight Powdery mildew	*Erwinia carotovora* *Rhizoctonia solani* *Verticillium dahlia* *Alternaria solani* *Erisyphe cichoracearum*
Sorghum	Leaf blight Maize dwarf mosaic Loose kernel smut Rusts	*Bipolaris turcica* Virus (aphid vector) *Sphacelotheca cruenta* *Puccinia* spp.

Stone fruit (apricots, peaches and plums)	Crown gall Phymatotrichum root rot Bacterial canker Crown rot	*Agrobacterium tumefaciens* *Phymatotrichopsis onivorum* *Pseudomonas syringae* *Phytophthora* spp.
Tomatoes (greenhouse and field)	Curly top Fusarium wilt and crown rot Tobacco mosaic Phytophthora root and crown rot Verticillium wilt Early blight Tomato spotted wilt Powdery mildew Root knot nematode	Virus (leafhopper vector) *Fusarium oxysporum* Virus (easily mechanically transmitted) *Phytophthora capsici* *Verticillium dahlia* *Alternania solani* Virus (thrips vector) *Oidiopsis taurica* *Meloidogyne* spp.
Wheat	Smuts Rusts Rhizoctonia root rot Barley yellow dwarf	*Tilletia* spp., *Ustilago* spp. *Puccinia* spp. *Rhizoctonia solani* Virus (aphid vector)

[1] Insects in parentheses are primary vectors for viruses listed.

IX. CHEMICALS USED IN PLANT DISEASE CONTROL

Following is a partial list of chemicals used in New Mexico for plant disease control. Inclusion or exclusion of a fungicide from this list does not constitute a recommendation or condemnation of use of the product by the New Mexico Cooperative Extension Service. **Remember to always consult the product label for current registered uses and rates.**

Common Name	Uses
benamyl	systemic fungicide for fruits and foliage
captan	protectant fungicide for fruits, foliage and seed treatment
carboxin	systemic fungicide used for seed treatment
chlorinated C_3 hydrocarbons	preplant soil fumigant
chlorothalonil	protectant fungicide for fruits and foliage
copper compounds	protectant fungicides for fruits and foliage
fosetyl-Al	systemic fungicide specifically for downy mildews and related diseases
mancozeb and maneb	protectant fungicides for fruits and foliage
metalaxyl	systemic fungicide specific for diseases caused by Oomycetes
metam-sodium	preplant soil fumigant
PCNB	soil fungicide and seed treatment
sulfur	protectant fungicide for fruits and foliage
thiophanate-methyl	protectant fungicide for fruits and foliage
triadimefon	systemic fungicide specific for powdery mildews and rusts
ziram	protectant fungicide for fruits and foliage

GLOSSARY

Each disciplinary field has its own special terminology; some of the words and definitions used in relation to plant pathology are listed. Although some of them do not appear in this section of the manual, PCAs will encounter them and should be familiar with their meaning. In addition, this will serve as a general reference glossary.

activator - a material added to a fungicide to increase toxicity.

adherence - property of a pesticide to adhere or stick to a surface.

adjuvant - an ingredient that improves the properties of a mixture.

adulterate - to reduce the strength or purity of a material below the standard or quality it is represented to have; to abstract or omit any ingredient necessary to the effectiveness of the material or to substitute other materials.

aerosol - a colloidal suspension of solids or liquids in air.

alternate host - one of two hosts (usually referring to the "non-economic" host) required to complete the life cycle of certain rust fungi.

antagonism - decreased activity arising from the effect of one chemical or another (opposite of synergism).

anthracnose - a term used to describe diseases in which a key symptom is the appearance of black, sunken leaf, stem or fruit lesions; fungi that cause anthracnose produce their sexual spores in an acervulus.

antibiotic - substance produced by a microorganism that is injurious to other microorganisms (e.g. streptomycin and cycloheximide).

atomize - to reduce a liquid to fine droplets.

avirulent - without virulence

bacterium (pl. **bacteria**) - microscopic, one-celled organism that reproduces by division.

bactericide - any bacterium-killing substance.

bacteriostatic - a substance or condition that prevents the multiplication of bacteria without killing them.

bentonite - a colloidal native clay (hydrated aluminum silicate) that has the property of forming viscous suspensions (gels) with water; used as a carrier in dusts; has good sticking qualities.

biological control (biocontrol) - management of pathogens by other organisms.

blast (similar to blight) - common name for a number of different diseases on plants, especially when collapse is sudden; e.g., leaf blight, blossom blight, shoot blight.

calico - distinctive yellow leaf pattern associated with certain plants infected with virus.

canker - a necrotic, discolored, often sunken lesion on a stem, branch or twig of a plant.

carrier - an inert material serving as a vehicle for the active ingredient or toxicant in pesticides.

chemotherapy - the treatment of a diseased plant with chemicals to destroy or inactivate a pathogen without seriously affecting the plant.

chimera - a genetic mutation usually involving a small sector of leaf or flower petal tissue in which the section affected is abnormally colored; in lettuce and cotton V-shaped sections of yellow and white tissue may appear on green leaves.

chlorosis - a deficiency of chlorophyll usually resulting in yellowing or pale green color.

coalesce - to merge or grow together.

common name (synonym, coined name) - name given to a chemical by a recognized committee, such as the American Standards Association Sectional Committee on Common Names for Pest Control Chemicals K62, the Interdepartmental Committee of the USDA, and others. Example: the common name of zinc ethylenebisdithiocarbamate is zineb.

compatible - capable of acting together; chemicals are said to be compatible when neither affects the action of the other.

concentration - the relative content of a material in a liquid or solid carrier.

corm - a short, bulb-like fleshy stem with a few thin scale-like leaves, as in gladiolus or crocus.

cormel - a small corm.

coverage - distribution of a pesticide over a discontinuous area, such as leaves.

damping-off - seed decay in soil, or seedling blight.

deflocculating agent - a material added to a spray preparation to prevent aggregation or sedimentation of the soil particles.

deposit - quantity of a pesticide deposited on a unit area.

desiccate - to dry up.

diatomaceous earth - a whitish powder prepared from deposits formed by the skeletons of diatoms; used as diluent in dust formulations.

dieback - gradual death of shoots or roots, usually starting at the tip.

diluent - a component of a spray or dust that serves to reduce the concentration of the active ingredient or toxicant (see carrier).

disease - any abnormal growth or development in plants that results from the irritation by pathogens or abiotic stresses.

disinfectant - an agent that kills or inactivates organisms present on the surface of the plant or plant part, or in the immediate environment.

dose, dosage - quantity of toxicant applied per unit of plant, fungus, soil, animal or special surface (synonym: rate).

epidemic - a widespread and severe outbreak of a disease.

epiphytically - the act of one organism living on another without causing disease.

emulsifier - a substance that increases and stabilizes the dispersion of one liquid in another liquid.

eradicant - a chemical used to eliminate a pathogen from the host or environment (see chemotherapy).

etiolation - yellowing of tissue and elongating of stems caused by reduced light or darkness.

evapotranspiration - a combination of the loss of water from the soil by evaporation and by transpiration from surface of plants.

fixed coppers (insoluble coppers) - compounds containing copper in a combined form. These are usually finely divided, relatively insoluble powders, easier to prepare than bordeaux mixture but not quite as tenacious. They are evaluated on the basis of the percentage of active agent expressed as metallic copper. (Examples: cuprous oxide, basic copper sulfate, copper oxychloride, copper oxychloride sulfate, copper oxalate).

fruiting body - A complex fungal structure containing spores.

full-coverage spray - a spray applied thoroughly over the crop to a point of runoff or drip (see low-volume and ultra-low volume sprays).

fumigant - a substance that forms vapors that destroy pathogens, insects, etc.

fungicide - any fungus-killing substance.

fungistatic - pertaining to the action of a chemical that inhibits the germination of fungus spores or growth of mycelium while in continued contact.

fungus (pl. **fungi**) - an organism with no chlorophyll, usually reproducing by spores; mycelium with well-defined nuclei.

gall - outgrowth or swelling of unorganized plant cells produced as a result of attack by bacteria, fungi or other organisms.

germicide - a substance that kills germs (microorganisms).

graft transmission - the transfer or spread of a virus from an infected plant to a susceptible healthy plant by way of a bud or scion graft.

haustorium (pl. **haustoria**) - a specialized outgrowth of a stem, root or mycelium (in fungi) that penetrates the host plant and absorbs food.

herbaceous plant - a plant that does not develop woody tissue.

host - any plant attacked by a parasite.

host range - the various plants that are susceptible to a given pathogen.

hypha (pl. **hyphae**) - single thread of a fungus mycelium.

indexing - a procedure for determining the presence of virus in a plant; transfer of a bud, scion, sap, etc., from a suspect plant to one or more kinds of plants (indicators) that are known to be sensitive to a specific virus.

infection - process of beginning or producing disease.

infectious disease - a disease caused by a pathogen that is capable of being spread from one plant to another.

infested - refers to soil, tools, equipment, plant surfaces, etc., that possess a large number of pathogens, insects, mites, etc. When pathogens are present on plant surfaces or in soil without causing disease the plant surface or soil is contaminated (or infested).

inflorescence - arrangement of flowers on an axis, such as an umbel or panicle.

inoculum - pathogen or that part of it which infects plants (e.g., spores, mycelium, etc).

insect transmission - the transfer or spread of a virus from an infected plant to a susceptible healthy plant through the feeding activities of insects such as aphids and leafhoppers.

integrated disease management - an approach that attempts to use all available control methods resulting in economic, effective, and environmentally safe disease management.

LD50 (lethal dose 50) - the dose or quantity of toxicant that produces 50 percent mortality in a population; used to express relative mammalian toxicity (acute oral toxicity to rats) as well as fungicidal activity. A low LD50 indicates high toxicity or fungicidal value.

lesion - localized spot of diseased tissue.

low-volume spray (concentrative spray) - a spray applied to uniformly cover the crop being treated, but not as a full coverage treatment to the point of runoff (see ultra-low-volume spray).

mechanical transmission - the transfer or spread of a virus from an infected plant to a susceptible healthy plant through sap transfer.

medium (pl. **media**) - chemical substrate used in a laboratory for growing microorganisms.

mildew - a fungal disease characterized by the growth of mycelium and spores on the surface of infected plants.

mist spraying - method in which concentrated spray is atomized into an air stream.

M.L.D. - median lethal dose (LD50).

mold - a profuse or woolly fungus growth on damp or decaying organic matter or on plant surfaces; may be saprophytic or parasitic depending on the fungus and the host.

mosaic - leaf pattern of yellow and green, or light and dark green, produced by certain virus infections.

mummy - a shriveled or dried fruit which often carries spores or other parts of pathogens.

mycelium (pl. **mycelia**) - mass of fungal hyphae.

necrotic - having dead or dying tissue.

nematicide - any nematode-killing substance.

noninfectious disease - a disease caused by an adverse condition (e.g., environmental conditions, nutrient problems, soil problems, etc.) which is unable to spread from plant to plant.

oral toxicity - the relative toxicity of a chemical when introduced through the mouth. LD50 refers to the number of milligrams of a chemical per kilogram of body weight of laboratory animals (usually rats), administered orally in one dose, that will kill one half the animals. The lower the LD50 value, the higher the toxicity of the chemical.

parasite - an organism that lives on or in a second organism, causing disease in the latter.

pathogen - any disease-producing organism or virus.

pesticide - (legally defined as "economic poison" in Section 1061 of the Agricultural Code) - any substance used for controlling, preventing, destroying, repelling or mitigating any pest; includes fungicides, herbicides, insecticides, nematicides, rodenticides.

pesticide tolerance - the amount of pesticide residue that is permitted by federal regulation to remain on or in a crop;

phloem - the primary food-conducting tissue in a plant.

phyllody - conversion of flowers to leaf-like structures.

phytotoxic - injurious to plants.

protectant - a chemical applied to the plant surface in advance of the pathogen to prevent infection.

pustule - a blister-like swelling or elevation.

rachis - axis of an inflorescence, such as a barley or wheat head.

raw agricultural commodity - any food in its raw and natural state, including fruits, vegetables, nuts, eggs, raw milk and meats.

resistance - host plant ability to exclude or overcome, completely or in some degree, the negative effect of a pathogen or abiotic stress; **resistant** - plant is infected little or not at all.

rhizomorph - a cord-like strand of fungus hyphae.

ring spot - a circular pattern of chlorosis with a green center, usually on leaves, possibly on fruit; generally caused by a virus.

rot - softening, discoloration and disintegration of plant tissue.

russet - brownish, roughened area on surface of fruits or stems resulting from abnormal cork production caused by fungus, insect, chemical spray, or other mechanical injury.

rust - a disease with symptoms that usually include reddish-brown or black pustules; a group of fungi in the basidiomycetes.

safener - a chemical that reduces the phytotoxicity of another chemical (example: lime in bordeaux mixture).

sanitation - an important means of plant control; the removal and destruction of infected plants or plant parts; the decontamination of infested tools, equipment, hands, etc.; weed and insect control; etc.

saprophyte - an organism that feeds on dead organic matter.

scab - crust-like disease lesion.

sclerotium (pl. **sclerotia**) - resting mass of fungal tissue, more or less spherical, normally having no spores on it.

senescence - process of growing old or exhibiting signs of aging.

shothole - a disease symptom in which small, round fragments drop out of leaves.

sign - visual presence of some structure formed by a pathogen on a host.

slurry - a thin, watery mixture such as liquid mud or cement; fungicides are applied to seeds as slurries to minimize dustiness.

smut - a fungus with sooty spore masses; a group of fungi in the Basidiomycetes.

spore - a single- to many-celled reproductive body in fungi.

spot - a localized necrotic area on plant tissue, usually on the leaves.

spreader - material added to a spray preparation to improve contact between the chemical and the plant surface.

sticker - material added to a spray or dust to improve adherence to plant surface.

supplement (synonyms: **adjuvant, auxiliary**) - material added to a fungicide to improve some physical or chemical property; may be a sticker, spreader, wetting agent, emulsifier or safener, but not a diluent.

surfactant - a material that facilitates or accentuates surface modifying properties of a pesticide formulation (dispersing agent, spreader, wetting agent).

suspension - a system consisting of finely divided solid particles dispersed in a liquid, solid or gas (example: a wettable powder in water).

symptom - the expression by the plant of disease development; root rot, mosaic, blight, etc., are types of symptoms.

symptomless carrier - a plant that although diseased, shows no symptoms.

synergism - increased activity arising from the effect of one chemical on another (opposite of antagonism).

systemic - absorbed and distributed throughout a plant; can refer to chemicals or pathogens.

tenacity - the tendency of a deposit to resist removal by weathering.

tolerance - the ability of a plant to withstand the effects of disease without suffering serious injury; degrees of tolerance may be found in plants such that heavy disease pressure can break down the tolerance in the host and the plant may suffer some adverse effect of the pathogen.

toxicant - a poisonous material exhibiting toxicity.

toxicity - the relative ability of a chemical to interfere adversely with the vital processes of an organism.

trade name (synonyms: **trademark, brand name**) - name given a product by the manufacturer or formulator to distinguish it as being produced and sold by them (example: Dithane Z-78 or Parzate C are trade names of zineb).

ultra-low-volume sprays - sprays applied at one half gallon or less per acre or sprays applied in undiluted form (see low-volume and full-coverage sprays).

vector - an agent that transmits disease, such as man, insects, etc.

viricide - a substance that inactivates a virus completely and permanently.

viristatic - able to prevent multiplication of a virus.

viroid - a submicroscopic disease agent consisting only of ribonucleic acid (RNA), which enters plants via vector and replicates inside the host plant.

virulent - able to cause disease; pathogens possess varying degrees of virulence (a highly pathogenic organism is highly virulent); in general the greater the degree of virulence, the more severe the disease.

virus - a submicroscopic disease agent consisting of coat protein and nucleic acid (RNA or DNA), which enters plants via vectors and replicates inside the host plant.

xylem - the primary water-conducting plant tissue; may also serve as supporting tissue for the plant.

wettable powder (W.P) - an inert powder that holds active material, usually insoluble in water, but capable of forming a fairly stable suspension in water.

wetting agent - material added to a spray preparation to reduce surface tension and enable a liquid to spread more readily over a solid surface.

wilt - loss of freshness or drooping of plants because of inadequate water supply or excessive transpiration; a vascular disease interfering with water utilization.

yellows - a chlorotic condition in plants sometimes accompanied by stunting which may be induced by infectious and/or noninfectious agents.

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