



FUNDAMENTAL PRINCIPLES OF PLANT PATHOLOGY FOR AGRICULTURAL PRODUCERS

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All crop plants produced in Kentucky have the potential to become diseased under certain conditions. Diseases of crops can affect yield and/or quality of the harvested commodity. This can impact profitability and increase the risks of farming.

A plant is diseased when it is affected by some agent that interferes with its normal development. Some disorders are caused by noninfectious factors, such as temperature extremes or nutrient deficiencies. However, this publication focuses on diseases caused by infectious microorganisms.

Diseased plants exhibit a variety of *symptoms*. These can include stunting, yellowing, wilting, twisting, reddening, browning, blighting, root rot, fruit rot, or other abnormalities. Accurate *diagnosis* is important in order to effectively control a plant disease. Diagnosis is an art as well as a science, and experience is important. Until a disease is properly diagnosed, a farmer may waste time and money trying to correct a problem with an unknown cause. Once a disease is diagnosed, appropriate control practices can be selected. Your local Extension agent can provide information on identification and management of crop diseases.

Infectious Organisms that Cause Diseases

Plant diseases can be caused by fungi, bacteria, viruses or nematodes.

Fungi

Fungi are the most common infectious organisms causing plant disease. Many are microscopic organisms that feed on living plants and/or on dead organic matter. When they attack living plants, disease often results.

Fungi usually produces *spores* which, when carried to a plant, can begin an infection (Fig. 1). Spores can be spread from plant to plant by wind, water, insects, birds, and equipment. Adequate moisture and the right temperature are required in order for fungal spores to begin new infections. A plant wound is sometimes also needed as an entry for the fungus (Fig. 2). Plant diseases caused by fungi are common during wet, humid seasons. Fungi survive between growing seasons in one or more of the

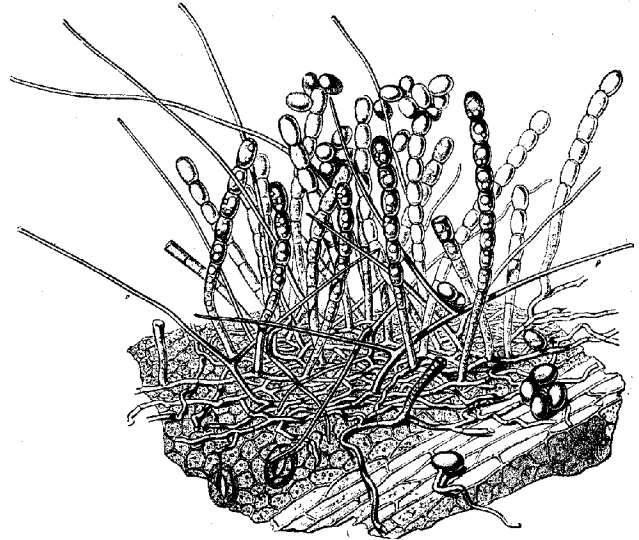


Fig. 1. A microscopic illustration of chains of barrel-shaped spores, which are produced by a powdery mildew fungus growing on a leaf. The spores illustrated here are spread by air currents.

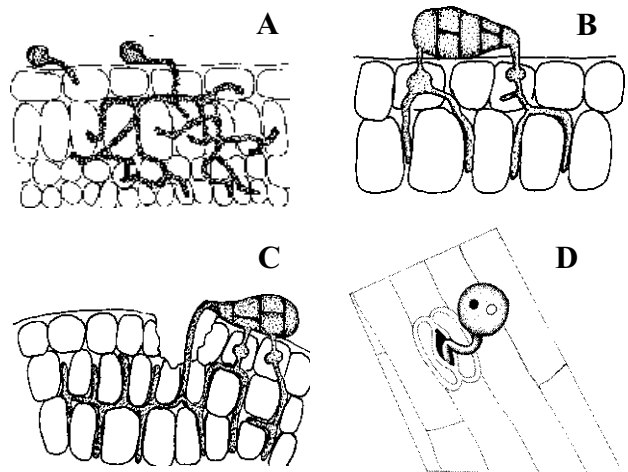


Fig. 2. A microscopic view of plant infection by spores of various fungi. Some fungi can infect plant tissue through unwounded surfaces (A, B). Sometimes, fungi can infect best through wounds (C) or natural microscopic pores in plants (D).

following ways: in crop residues, weeds, soil, seeds, live buds, or in crops or weeds growing south of Kentucky.

Some fungi have the ability to reproduce very quickly under the right environmental conditions. An infection that began from one spore may produce millions of spores in just a few days. Other fungi reproduce slowly and may take one or two years to complete a disease cycle.

Infections of plants by fungi can cause a variety of types of diseases, including leaf diseases, wilts, root rots, crown rots, stem rots, and a variety of other diseases (see Figs. 3 and 4).

Bacteria

Bacteria are single-celled microscopic organisms. Some attack living plants and cause plant diseases. Bacteria can be carried from plant to plant in droplets of water by wind, rainsplash, insects, and equipment (Fig. 5). Bacteria often survive between growing seasons in crop residue, in crop seeds or cuttings, or in weeds.

Under warm, wet conditions, bacteria reproduce extremely quickly. Under conditions ideal for disease development, a single bacterial cell can give rise to *17 million daughter cells in 24 hours*.

Diseases of leaves, growing shoots, and fruit are the most common types of bacterial diseases in Kentucky (Fig. 6).

Viruses

Viruses are the smallest parasites causing plant disease. They are extremely small and can be seen only with an electron microscope. Structurally, viruses are nothing more than a protein shell surrounding a small amount of genetic material (Fig. 7).

Most viruses are spread by certain types of insects. Conditions that favor large numbers of insect *vectors* (agents that spread viruses) often lead to severe virus outbreaks. Most viruses survive between growing seasons in live plant tissues (weeds, crop seeds, cuttings, or trees).

Viral infections of plants cause stunting, color changes in leaves, and growth distortions.

Nematodes

Nematodes are microscopic worms that live in the soil. Parasitic nematodes feed on plant roots (see Figs. 8 and 9). Low numbers of nematodes are not damaging to crops, but feeding by large numbers of nematodes on roots interferes with uptake of water and nutrients.

Plant nematodes often require three or four weeks or more between generations. In contrast to some fungi and most bacteria, destructive levels of nematodes take some time to develop. Once destructive levels are reached, however, even nematodes that reproduce slowly can cause serious crop damage.

Nematodes are spread by anything that moves soil: boots, machinery, running water, etc. Nematodes usually survive between seasons in the soil.

The Disease Triangle

A fundamental concept in plant pathology is the disease triangle. This principle states that disease occurs when three



Fig. 3. Gray leaf spot, a fungal disease of corn leaves, can cause yield loss by killing the upper leaves during grain fill. Individual lesions on leaves are rectangular.

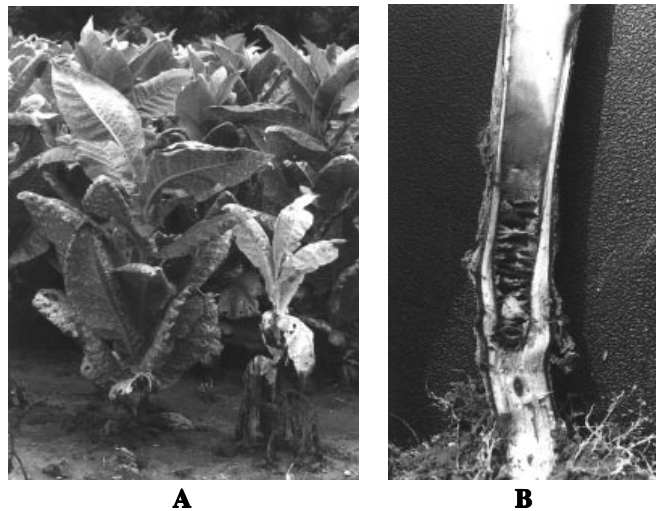


Fig. 4. Black shank of tobacco (A), a rot of roots and lower stems caused by a fungus, is becoming more common and destructive in Kentucky. Plants with rotted roots and stems (B) suffer from lack of water and nutrients, and they may eventually die.

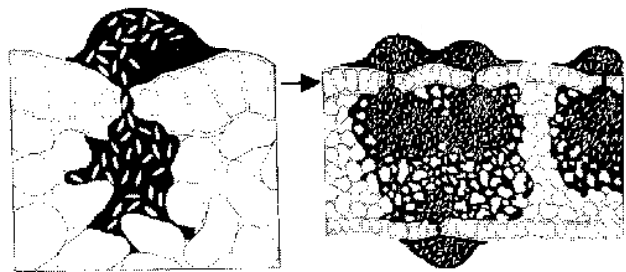


Fig. 5. Two microscopic views of leaf infection by bacteria (illustrated as white rods in black droplets of moisture). Bacteria multiply and spread in moisture droplets.

sides of the triangle occur together: a susceptible host, a *pathogen* (the agent that causes disease), and an environment favorable for disease to develop (Fig. 10).

For example, consider blue mold of tobacco. A farmer may have susceptible tobacco plants and the weather may be



Fig. 6. Symptoms of bacterial spot on pepper leaves and fruits. This disease limits the success of pepper production in Kentucky.

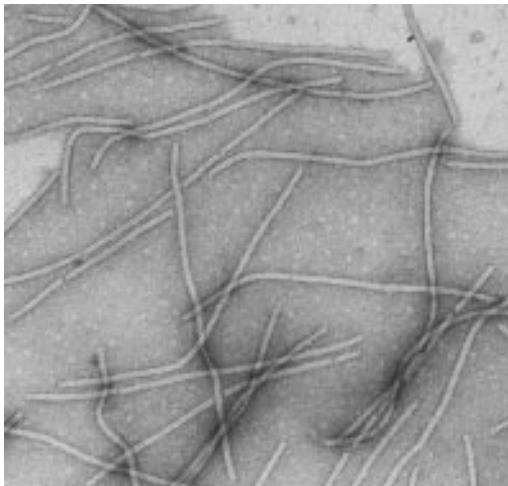


Fig. 7. Tobacco vein mottling virus viewed through an electron microscope, magnified 54,000 times. These virus particles are flexible, rod-shaped crystals of genetic material surrounded by a protein coat.

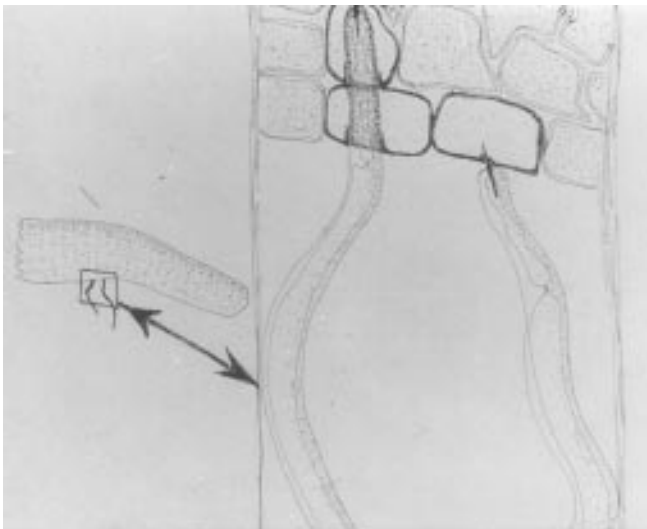


Fig. 8. Microscopic view of worm-shaped nematodes feeding on roots.

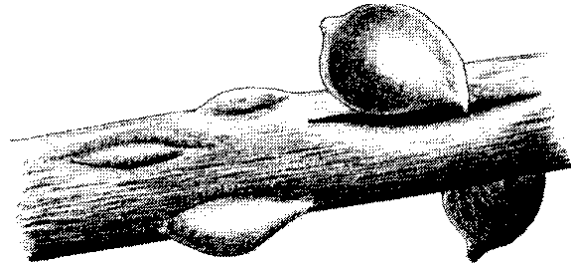


Fig. 9. Microscopic view of pear-shaped soybean cyst nematodes feeding on roots.

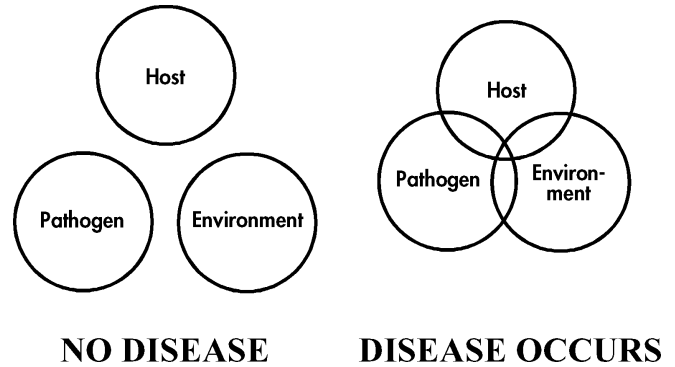


Fig. 10. The disease triangle

cool and damp, but blue mold cannot develop if spores of the blue mold fungus have not been carried by air currents into the crop. In this case, one side of the disease triangle—the pathogen—is missing.

Likewise, spores may land on a field of susceptible plants, but if the weather is hot and dry, infection will not occur and blue mold will not develop. A different side of the disease triangle—a favorable environment—is missing in this case.

One more example: Spores are blown into a crop, and the weather is cool and damp. However, the tobacco has been topped, which increases plant resistance to blue mold. In this case, blue mold may develop, but it will not likely become an epidemic. The third side of the triangle—a susceptible host—is missing.

Disease develops only when all three sides of the disease triangle are complete. Plant diseases are managed by manipulating the disease triangle: the plant, the pathogen, and/or the crop production environment.

Managing Plant Diseases

Plant diseases can be managed through the use of appropriate cultural practices combined with resistant varieties when available. Appropriate use of pesticides in an integrated disease management plan may also be an important part of controlling certain diseases.

Cultural Practices

Several cultural practices involving the use of crop rotation and sanitation, proper planting dates and fertilization, and other

practices can be an important part of a disease management program.

Crop Rotation

Crop rotation is a fundamental disease management practice. Growing the same crop in a field year after year encourages the buildup of pathogens. For example, if the black shank fungus is present, growing tobacco every year leads to dangerously high spore levels in the field. When a farmer rotates to a crop other than tobacco, spores of the black shank fungus begin to starve, since they can only infect tobacco. Fewer spores survive each year, until eventually none remain in the soil.

Sanitation

Many important disease management practices fall under the category of sanitation. For example, removing infected prunings eliminates a source of infectious material, which can help in disease management. Plowing to bury pathogen-infested crop residue is another form of sanitation. Using steam to disinfect greenhouse pots is another example.

Planting Date

Choosing the proper planting date can affect disease development. Some diseases are favored by planting too early, while others are favored by late planting. The best overall approach is to plant when environmental conditions favor growth of the plant but not growth and reproduction of the pathogen.

Improving Soil Structure and Drainage

Poor soil drainage can create an environment favorable to certain root rot diseases. Therefore, improving soil structure and drainage can alleviate some root rot diseases.

Proper Fertility

Proper fertility is another important cultural practice for disease control. Properly fertilized crop plants are generally more resistant to diseases than under-fertilized or over-fertilized plants.

Other Practices

Proper plant density can affect disease development. Overcrowding of plants can lead to excess humidity around leaves, favoring fungal and bacterial diseases. Timely harvest can also be important, as some diseases develop on the harvested commodity only as the crop matures. Selecting disease-free seed is important when the seed is the source of the pathogen. There are numerous cultural practices that can contribute to a disease management plan.

Resistant Varieties

Using crop varieties with disease resistance is one of the best disease control practices. With a highly resistant variety, a crop disease can be controlled with no added cost, and with no health risks to the farmer, farm workers, or the environment. For example, in a field infested with cyst nematode, soybean yields can be improved by as much as 30-40% simply by selecting the proper resistant variety.

Scouting fields and identifying disease outbreaks are important steps in order to select appropriate disease-resistant varieties in future growing seasons.

Pesticides

When used properly, pesticides can be an important tool for disease control. For example, proper use of foliar fungicides in high-yield wheat can enhance farm profits.

However, pesticides cannot substitute for good crop management. In fact, many diseases cannot be controlled economically with pesticides. Pesticides are the last line of defense for controlling crop diseases, not the first line of defense.

Types of Disease-Control Pesticides

Pesticides used to control plant diseases are classified as fungicides, bactericides, and nematicides.

Fungicides are used to control diseases caused by fungi. They may be applied to seed, soil, or foliage (Fig. 11).

Protectant (contact) fungicides remain on plant surfaces and must be applied before infection occurs. Examples of protectant fungicides include products containing mancozeb, maneb, chlorothalonil, ferbam, captan, and thiram.

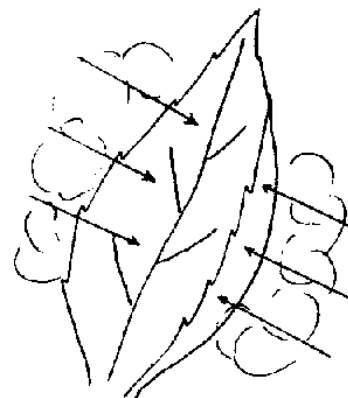


Fig. 11. Uniform coverage of both upper and lower leaf surfaces is necessary for disease control using a fungicide.

Systemic fungicides penetrate and are redistributed within the plant (Fig. 12). Because they penetrate the plant, systemic fungicides sometimes can be applied shortly after infection to eradicate recent infections. This is known as eradicant or “kick-back” activity. Examples of systemic fungicides include benomyl, metalaxyl, triadimefon, and thiophanate methyl. Movement of almost all systemic fungicides within the plant is upward toward plant tops and leaf tips, but not downward from leaves to roots. Some fungicides are locally systemic—that is, they penetrate the plant to a limited extent and move only a limited distance from the point of penetration.

Fungicides may be classified as either *broad-spectrum* or *narrow-spectrum*. Broad-spectrum fungicides are active against a wide variety of fungal pathogens. In contrast, narrow-spectrum fungicides are effective against just one or a few types of fungi. This distinction is important for farmers, who sometimes assume that any commercial fungicide will kill all types of fungi. This is not true. The label is the best

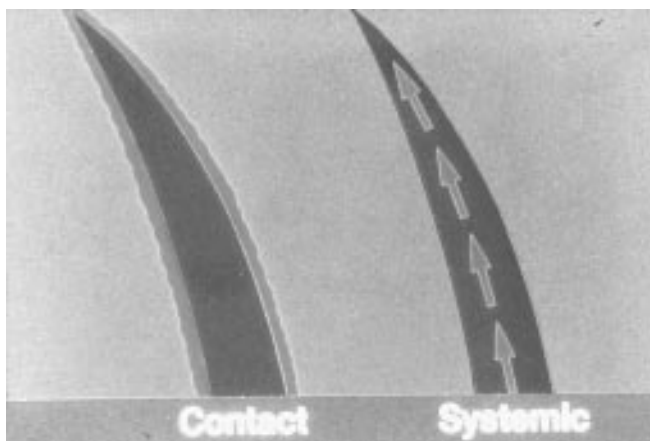


Fig. 12. Contact (=protectant) fungicides remain on plant surfaces. Systemic fungicides penetrate the plant.

guide as to which fungal diseases can be controlled with a commercial product.

Bactericides are pesticides that kill bacteria. Bactericides act as protectants and must be applied before infection occurs. Bactericides cannot eradicate an existing infection. Most copper fungicides are also bactericides. Streptomycin is another bactericide labelled for certain uses.

Nematicides are used to control diseases caused by nematodes. Nematicides are usually toxic to warm-blooded animals and should only be used with extreme caution. Nematicides may be either fumigants or non-fumigants (discussed below).

Types of Application

Pesticides can be applied to seed, to the soil or to foliage, flowers, or fruit.

SEED TREATMENT

Fungicides are sometimes applied onto seeds to protect against disease. Protectant fungicides surround the newly planted seed and young seedling with a zone of fungicide. This zone acts as a toxic barrier to fungal infection and protects against seed rots and seedling disease. Protectant fungicides can also eradicate infectious spores present on the surface of the seedcoat before planting.

Systemic fungicides applied to seed are absorbed by the developing seedling. This protects against infection by fungi causing seed rots and seedling disease. Systemic uptake of a fungicide also can eradicate some internal infections of the seed present before planting.

Common seed treatment fungicides include captan, thiram, and metalaxyl.

SOIL APPLICATION

Pesticides may be applied to the soil to control diseases caused by fungi or nematodes. Soil-applied disease-control chemicals are classified as either fumigants or non-fumigants.

Fumigants are applied to the soil as liquids or granules before planting. After application, they turn into gases. These gases diffuse throughout the soil to form a fumigated zone.

Soil conditions must be suitable if fumigants are to be effective. Generally, a soil that is in “seedbed condition”

(slightly moist and friable) with a temperature between 50°F and 75°F is suitable. If the soil is too wet, the fumigant gas will not diffuse through the soil. On the other hand, if the soil is too dry, the gas will escape from the soil too quickly. Either way, fungal spores and nematodes will not be killed, and poor disease control results.

Fumigating when the soil is too cold or too warm also results in poor disease control. The fumigant may not diffuse properly in cold soils and may escape too quickly in warm soils. See label directions for instructions on proper conditions for applying fumigants.

Examples of fumigants include dichloropropene, methyl bromide, chloropicrin, and dazomet.

Non-fumigants are applied to soil as liquids or granules. These may be applied to the seed furrow, incorporated before planting, or sprayed onto the soil and incorporated during crop growth. Soil-applied pesticides provide roots with a zone of protection against infection. Some soil-applied pesticides are systemic. Systemics applied to the soil are taken up by roots and translocated to leaves, providing roots and leaves with protection against infection.

Fungicides sometimes applied to the soil include metalaxyl, thiophanate methyl, and PCNB. Non-fumigant nematicides include carbofuran, ethoprop, and aldicarb. Some non-fumigant soil pesticides can move with water movement and have the potential to contaminate groundwater or surface water if used improperly.

APPLICATION TO FOLIAGE, FLOWERS, AND FRUITS

Fungicides and bactericides are sometimes applied to foliage (leaves), flowers, and/or fruits to provide protection against infection.

When applying a pesticide to foliage, the farmer should consider whether it is a protectant or systemic. If it is a protectant, it must be applied over *all susceptible tissues before infection occurs*. For example, if you are applying mancozeb to control Septoria leaf and glume blotch of wheat, the application must cover the flag leaf and glumes before infection occurs. If symptoms are showing on the flag leaf, it is too late because infection has already occurred. Even if the fungicide was applied before infection, if coverage is poor, then unprotected spots on the flag leaves and glumes may become infected later (see Fig. 13).



Fig. 13. Protectant fungicides and bactericides must be applied before infection occurs. The fungal infections shown here cannot be eradicated using a protectant fungicide.

Systemic fungicides “translocate,” or move within the plant. Thus, thorough coverage is less important with systemics. In fact, sometimes the best use of a systemic is to *not* spray the target tissue. For example, spraying tobacco *leaves* with the systemic fungicide metalaxyl (Ridomil2E®) for blue mold control results in somewhat poor coverage (it is also an illegal use of the product). On the other hand, spraying the soil at layby allows tobacco roots to absorb and translocate the fungicide. This way, metalaxyl is uniformly distributed throughout the tobacco plant, and best control of blue mold is obtained.

Foliar fungicides sometimes must be applied several times to control a disease. This is because fungicide deposits do not persist indefinitely. Fungicide deposits are subject to *weathering* from rainfall, sunshine, etc. Also, if a protectant was applied, leaves produced since the last application are unprotected.

When should foliar sprays be applied? This depends on the disease triangle. When is your crop susceptible? When are the spores present? When do environmental conditions favor infection? Understanding the biology of the disease is important for knowing the best time to spray. Your local Extension agent can provide information on timing of pesticide applications.

Integrated Disease Management

The old saying “Don’t put all your eggs in one basket” also applies to good disease control. Don’t rely on one method of disease control, especially pesticides. Otherwise, you run the risk of pesticide resistance.

Practice crop rotation. Use resistant varieties when available. Learn how cultural practices can be used to reduce disease pressure. Often pesticide use can be avoided by using good cultural practices.

Sources of Information on Plant Diseases

A great deal of information on plant diseases and their control is available through the University of Kentucky Cooperative Extension Service. Several publications are listed below. Contact your local Extension agent to obtain more information on plant diseases.

Kentucky Plant Disease Management Guide for Corn and Sorghum, PPA-10a
Kentucky Plant Disease Management Guide for Soybeans, PPA-10b
Kentucky Plant Disease Management Guide for Small Grains, PPA-10c
Kentucky Plant Disease Management Guide for Forage Legumes, PPA-10d
Midwest Tree Fruit Handbook, ID-93
Kentucky Commercial Small Fruit & Grape Spray Guide, ID-94
Kentucky Commercial Tree Fruit Spray Guide, ID-92
Tobacco in Kentucky, ID-73
Commercial Vegetable Disease Control Recommendations, ID-36

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