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About this manual

This manual was prepared for use in Missouri's Pesticide Applicator Training Program and is intended to provide the information needed to meet the minimum Environmental Protection Agency (EPA) standards for certification of commercial applicators in Category 7A — General Structural Pest Control — under the Federal Insecticide, Fungicide, and Rodenticide Act and the Missouri Pesticide Use Act. It also prepares trainees for an examination, based on this manual, administered by the Missouri Department of Agriculture.

This manual **does not** provide all of the information you need for safe and effective use of pesticides. Examine the label for each pesticide you use. Labels must list directions, precautions, and health information — all of which are updated regularly when a pesticide is registered for use in Missouri. If information on a current pesticide label conflicts with information in this manual, follow the label.

Manufacturers will supply additional information about products registered for use in Missouri. Information is also available from the Office of the Pesticide Coordinator, 212 Waters Hall, University of Missouri-Columbia, Columbia, MO 65211, or phone (573)882-6361.

Missouri's Pesticide Applicator Training Program is a cooperative effort. The Missouri Department of Agriculture is the state lead agency. MU Extension at the University of Missouri-Columbia is responsible for the content of the training program. The EPA and the Missouri departments of Conservation, Health, Natural Resources, Transportation also contribute to the development of educational materials and participate in the training program.

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Introduction to Pest Management

Missouri has a very diverse agriculture. Soybean is Missouri's largest cash crop. Corn, wheat and grain sorghum, as well as forages for hay and pasture are grown throughout the state. Specialty crops such as tobacco and a number of fruit and vegetable commodities are also produced in various locations. While in southeast Missouri cotton and rice are primarily grown.

With these diverse crops grown under a wide range of environmental conditions come a diverse number of pest problems. Weeds, insects and plant diseases can, and do cause damage to Missouri crops and losses to Missouri producers. A great deal of time, effort and money is spent each year trying to minimize these losses.

For example, the 1992 pesticide use survey for Missouri (Grain Crop Pesticide Use Missouri, 1992 by Integrated Pest Management Unit, University of Missouri) found that herbicides were applied to more than 95 percent of the statewide soybean, corn and grain sorghum acreage. In an effort to provide acceptable control of field crop pests with minimal impact on the environment and maximum economic return, producers and agricultural business personnel are stressing the concept of Integrated Pest Management (IPM).

IPM is the combining of appropriate pest control tactics into a single plan or strategy to reduce pests and their damage to an acceptable level. Using many different tactics to manage a pest problem tends to provide the best long term control with the least disruption to the living organisms and surroundings at the treatment site. The following steps are necessary to successfully implement an IPM program:

1) correctly identify the pest or pests causing the damage
2) determine whether control is warranted for each pest
3) determine what control tactics are available for each pest
4) evaluate the benefits and risks of each tactic or combination of tactics
5) choose an effective, practical, economical and safe strategy
6) observe local, state and federal regulations

The following sections are designed to aid agribusiness personnel in identifying the weed, insect and plant disease problems that are likely to occur in Missouri's major crop commodities. Information on possible control tactics for these pests is also summarized. This section is not a comprehensive guide to all pest problems in Missouri, but it should be a starting point to identifying pest problems and management strategies.

More detailed information on pest identification is available in MU Publications and other sources referenced through the text and in the appendix. Current information on pesticides can be found in MU Publications M160 "*Insect and Disease Management: Field Crops, Forages and Livestock*" and MP575 "*Weed Control Guide for Missouri Field Crops.*"

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- Laura Sweets, Department of Plant Pathology
- Allen Wrather, Department of Plant Pathology, MU Delta Center

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The information in this manual is supplied with the understanding that no endorsement is implied or discrimination intended.

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Fall 1997

Corn, Grain Sorghum and Soybean

Weeds

Principal weeds causing losses in field corn, grain sorghum and soybean are given in Table 1 (p. 6). Although annual grass and broadleaf weeds present a continual problem, most can be adequately controlled with herbicides. However, perennial weeds such as field bindweed, johnsongrass, hemp dogbane, common milkweed and yellow nutsedge can emerge as problematic weeds in no-till production systems.

Shattercane and johnsongrass are forage-type sorghums that are probably the most troublesome weeds in grain sorghum. They are so closely related to grain sorghum that they share the same genus name. Since they are so closely related herbicides that are safe to grain sorghum are also safe to johnsongrass and shattercane.

They can grow 3 to 10 feet tall and produce more than 1000 seeds per panicle. The seed can remain viable for up to 13 years and frequently drop before harvest. Crop rotation into soybeans and corn is the most effective method for controlling these weeds. In a severe shattercane or johnsongrass infestation, it is highly recommended to grow soybeans or corn with soybeans being the more desirable choice. Cocklebur and common waterhemp are two problem weeds in soybeans grown in northern Missouri. Many fields now have populations of cocklebur and common waterhemp that are not controlled by herbicides inhibiting the ALS enzyme.

In southeastern Missouri, sicklepod is one of the most serious weeds for this warm and humid climate. These grain crops can be grown with or without tillage. Once the seedbed is prepared, the main reason to cultivate is weed control. Where herbicides adequately control weeds, there is little reason to cultivate. Reduced-tillage systems are gaining favor in some areas, particularly as a means to reduce soil erosion. With no-tillage systems, however, herbicides are essential for weed control. The critical weed-free period for these crops is during the first 4 to 6 weeks following crop emergence because weed competition during this period will reduce yields.

Soybeans planted in narrow rows, 20 inches apart, require 45 days for the foliar canopy to develop and provide full soil shading. Soybeans planted in rows spaced 30 inches apart require 60 days for full soil shading. When the soil is fully shaded, sunlight is not available for weeds to establish and compete.

However, cultivation becomes very difficult when row widths are less than 20 inches because large tractor tires don't fit between the rows. Herbicides are the only practical means of controlling weeds in narrow-row soybeans.

The typical weed management strategy for conventional-till production is to prepare the seedbed and apply a residual herbicide to control annual grasses and small-seeded broadleaves. This application can be made either before or shortly after planting, although herbicides applied before planting can be incorporated to ensure activation. Incorporation is required for optimal performance with some herbicides due to their chemical properties (be sure to read the label). Herbicide applications made after planting should be made as close to the planting date as possible to maximize herbicide activity in the crop.

A typical weed management strategy for no-till corn and grain sorghum production is to apply a mixture of a **burndown** (herbicide to control existing vegetation) plus a residual herbicide approximately two weeks prior to planting. Early preplant applications of residual herbicides have increased in recent years because of flexibility.

With favorable weather, there is little harm in planting a week early. After one week, the grower should know if his burndown herbicide is going to be successful. If the weather is unfavorable, there is little harm in delaying planting a week or two. Although preplant timings of 4 to 8 weeks before planting are sometimes used, the residual activity of **preemergence** herbicides may break down too soon. In fact, most 30-day early preplant labels require an additional preemergence application at planting, so chemical costs are actually increased.

Also, the early preplant applications have an even greater failure risk if weather delays planting. These treatments also limit the soil protection that would otherwise be provided by the winter vegetation, thus defeating one of the main advantages of no-till-erosion control. Research and grower experience indicates the optimum timing is approximately 2 weeks before the anticipated planting date.

The typical weed management strategy for double-crop soybean production in northern Missouri is to apply burndown herbicides to control existing vegetation and use **postemergence** herbicides to control weeds in the crop.

In the Missouri Bootheel, many producers burn the wheat stubble, disk twice and use postemergence herbicides to control weeds in the crop. MU research suggests that soil-applied, residual herbicides in double-crop soybeans production are often ineffective.

The postemergence weed control approach is more successful in the double-crop system because of lower rainfall amounts in June and July when double-crop soybean is planted. Lack of rainfall will result in poor activation of soil-applied herbicides. In addition, if rainfall is low, weeds may not germinate which will eliminate the need for postemergence herbicides at all. Be aware that crop rotation intervals are extended for many herbicides if they are applied in late summer.

Planting soybeans in narrow rows has advantages in double-crop soybeans. The most important of which is faster canopy closure which enhances weed control by shading the soil and preventing late weed **germination**.

Reduced-tillage systems favor perennial weeds, however, with true 100 percent absolute no-till the weeds spread slowly. In reduced tillage, field cultivators and similar implements tend to drag root s and rhizomes around the field where they can establish new colonies. With more intensive conventional tillage, root s and rhizomes are cut into smaller segments, thus producing smaller, weaker plants. Weaker plants combined with cultivation create s an unfavorable environment and perennials decline.

In either conventional-till or no-till production, weeds emerging after the initial herbicide application can be controlled with cultivation (conventional till), rotary hoe and/or additional herbicides.

Annual grass control in grain sorghum can be particularly troublesome as there are only a few herbicides labeled for post- directed applications. Postemergence herbicides for grass and broadleaf control in soybeans are numerous.

Consult MU Publication MP575 "*Weed Control Guide for Missouri Field Crops*" for more specific information on pre-e merge and post- emerge herbicides. Consult MU Publication G4907 "*Herbicide Resistance in Weeds*" and MU Publication G4851 "*Waterhemp Management in Missouri*" for more information on herbicide-resistant weeds and managing ALS-herbicide resistant cocklebur and common waterhemp mentioned earlier.

Perennial broadleaf weeds are controlled with fall, spring or in the crop herbicide applications.

There must be at least 8 to 12 inches of actively growing weed shoot to obtain goo d herbicide contact. In addition, herbicide applications must be made at least 2 weeks before a killing frost or weed dormancy to ensure adequate up take and movement of the herbicide into the plant. Fall applications in soybeans will not be possible du e to the fact that soy- beans mature just before or after a killing frost.

Consult MU Publication G4875 "*Control of Perennial Broadleaf Weeds in Missouri Field Crops*" for more information on perennial weed control in row crops.

Table 1. Common weeds and life cycles found in corn, grain sorghum and soybeans grown in Missouri.

Weed	Life cycle
Fall panicum	Annual grass
Giant foxtail	Annual grass
Volunteer corn	Annual grass
Shattercane	Annual grass
Barnyardgrass	Annual grass
Common cocklebur	Annual broadleaf
Common lambsquarter	Annual broadleaf
Common sunflower	Annual broadleaf
Common waterhemp	Annual broadleaf
Common ragweed	Annual broadleaf
Velvetleaf	Annual broadleaf
Giant ragweed	Annual broadleaf
Hemp sesbania	Annual broadleaf
Jimsonweed	Annual broadleaf
Pitted and Ivyleaf morningglories	Annual broadleaf
Pennsylvania smartweed	Annual broadleaf
Sicklepod	Annual broadleaf
Redroot pigweed	Annual broadleaf
Common milkweed	Perennial broadleaf
Field bindweed	Perennial broadleaf
Hemp dogbane	Perennial broadleaf
Johnsongrass	Perennial grass
Yellow nutsedge	Perennial sedge

Corn Insects

Field corn Insect pests range from annual pests to those that infrequently da mage corn. The more severe pests include the northern and western rootworms, European corn borer, black cutworm, southwestern corn borer, fall armyworm, and corn ear worm.

Other species that cause problems on a less frequent basis are shown on page 7. Although the increased use of no-till systems have not increased insect problems, the problems which occur are often from insect species that can use increased crop residue in order to overwinter in no-till fields. The following is a discussion of major corn insect pest species.

European corn borer
Ostrinin nubilalis

The European corn borer overwinters in Missouri in the pup al stage and can become a severe pest of corn in late r years.

Adults emerge in the spring, mate and lay eggs in masses of about 30 eggs each. Eggs are generally laid on the underside of leaves and have an appearance similar to a small mass of white fish scales. The first generation feed on leaves causing small holes referred to as "buckshot" da mage. Larger larvae tunnel into leaf midribs and leaf sheaths and may feed in the plant whorl. Third instars (1/2 inch larvae) will tunnel into plant stalks at nodes located on the lower portion of the plant. White frass (fecal or waste material) is generally present at tunnel entrances.

Second generation adults emerge in July and August and lay eggs on corn plants. Larvae from this generation feed on leaf sheaths, collars and midribs when small and eventually tunnel into stalks. In Missouri, early planted corn is a preferred host of first generation and late planted corn is the preferred host of second generation.

Most corn varieties contain a chemical called DIMBOA which provides some resistance from first generation European corn borer when plants are less than 20-inches tall. For all infestations, scouting for first and second generations is a critical step to good management. If insecticides are used, proper timing is extremely important.

Treatment of first generation infestations is justified when 50 percent of corn plants show leaf feeding and live larvae are present. For second generation, treatment is justified when 50 percent of plants have larvae on the first leaf above and below the ear. Genetically altered corn varieties that produce the BT (*Bacillus thuringiensis*) toxin offer some control of this insect pest.

Occasional corn insect pests:

- wireworms
- white grubs
- grasshoppers
- grape colaspis
- dingy cutworm
- true armyworm
- flea beetles
- maize billbug
- chinch bugs

Fall armyworm
Spodoptera frugiperda

Fall armyworms feed deep inside the whorl on developing leaves causing ragged-edge holes and leaving moist, brown frass. Occasionally, they will kill the tassel before it emerges. If the tassel is not killed, the plant will outgrow the feeding injury.

Armyworms that attack later in the season will enter the ear and cause damage similar to that of corn ear worms. Problems are usually most severe on late-planted corn.

The larvae are variable in color, ranging from nearly black to green to light tan. They have three narrow yellowish-white lines running down the back from the head to the tail. Darker stripes extend down the side of the body. Black tubercles (bumps) with spines are scattered along the body.

The moths migrate into Missouri from Gulf Coast states and there two or three generations per year. In mid-Missouri, the pest usually appears in mid-July.

Generally, fall armyworm is not an economic pest unless the crop was planted late. A crude threshold is to treat when 75 percent of plants show leaf feeding and larvae are less than an inch in length.

Black cutworm
***Agrotis ipsilon* (Hufnagel)**

The black cutworm is the most important species of several cutworms that attack corn. It has a wide host range including the field crops of corn, alfalfa, soybeans, sorghum and cotton.

A majority of black cutworm moths found in Missouri in early spring migrate into the state from the south, although some may overwinter in Missouri. Female moths lay eggs on soil, grasses, broadleaf weeds and plant debris in crop fields prior to spring tillage and planting.

Infestations are often more severe in fields that have a broadleaf weed problem prior to planting and are planted late in the season. Chickweed, a winter annual weed, is especially preferred as an ovipositional site by black cutworm moths. Other preferred sites include river bottom fields and areas which support early spring weed growth.

If management allows increased spring weed growth in fields prior to planting, black cutworms may be a problem. The larvae may feed on corn leaves or cut plants above or below ground.

Fields should be checked at least once a week beginning with corn emergence and continuing until plants reach 24 inches in height. Scouts should check fields for leaf-feeding, wilted, cut or missing plants.

If damage is found check for larvae on plants, in the plant residue, on the soil surface and in the soil around the base of corn plants. Cracks in the ground the planter furrow and soil clods may harbor cutworm larvae.

Cutting of corn plants by larvae may occur below or above ground. Rescue treatments based on scouting are preferable in fields where infestations are sporadic. Rescue applications are justified when 3 to 5 percent of the corn seedlings are cut below the growing point and ½ inch or smaller larvae are present.

Several insecticides are effective in the control of this pest, especially pyrethroids. Soil-applied granular or liquid insecticides (broadcast or soil incorporated) are useful where infestations are chronic or the site is predisposed.

Although black cutworm infestations can be found in the state each year, most Missouri corn fields are at risk of developing an economic infestation approximately once every four years.

Corn earworm
***Helicoverpa zea* (Boddie)**

Corn earworm moths migrate into Missouri each spring and lay eggs on corn seedlings. First generation larvae feed on plant whorls producing “shot-hole” damage, shredded leaves and possible injury to the growing points and developing tassels of infected plants. Moths from this generation emerge and lay eggs on green corn silks.

Larvae initially feed on silks before moving to the developing ear tips. Kernels are damaged and the feeding area is filled with fecal pellets. Generally only one larva will be found per ear as larger larvae are cannibalistic. Control of corn ear worm is rarely attempted as ear damage is minimal and reaching the insect inside the ear with an insecticide is difficult.

Southwestern corn borer
***Diatraea grandiosella* (Dyar)**

The southwestern corn borer is a serious pest of corn grown in the southern most counties of Missouri. The second of two generations produced each year may cause substantial loss of field corn through lodging.

The first generation feeds on leaves and may tunnel into the stalk. The second generation tunnels into the stalk and prepares to overwinter in the stalk by chewing a thin ring just above ground level on the inside of infested corn plants. This results in weakening and eventual lodging of the corn plant.

Insecticide applications should be applied at peak second generation oviposition or when 25 percent of the plants have eggs and live larvae. Several insecticides are labeled for control of this pest.

Grain Sorghum Insects

Brief descriptions of Missouri's common grain sorghum insect pests, damage they cause and treatment thresholds are discussed in the following section. For more detailed information on insect pests of grain sorghum, refer to MU Publication M160, "*Insect and Disease Management: of Field Crops, Forages and Livestock*."

Fall armyworm
Spodoptera frugiperda

Late plantings of grain sorghum can be severely damaged by fall armyworm infestations. Larvae feed on the leaves, whorl and head causing defoliation and the plant to take on a tattered appearance. Treatment for fall armyworm is justified when an average of 2 or more larvae are present per sorghum head or when 75 percent of the plants are infested and live larvae are present.

Chinch bugs
***Blissus leucopterus* (Say)**

Chinch bugs suck the juices from plants with their piercing-sucking mouthparts. They vary in color depending on age.

The nymphs are red and white in color when young and become darker with age. Adults are black with white wing covers crossed with black lines.

Sporadic problems usually occur in May and June when chinch bugs migrate into sorghum fields growing adjacent to ripening or recently harvested small grain fields or into wheat fields that have been destroyed and replanted to sorghum because of poor winter survival of wheat.

Chinch bug problems are more common in hot, dry years. Most damage occurs on small seedlings up to 18-inch tall plants. Infested plants often exhibit leaf reddening, wilting and may become severely stunted or die when chinch bug feeding is heavy.

Control is frequently necessary along field borders to prevent migration to adjacent sorghum fields. Infested sorghum may also require treatment if chinch bug numbers are high.

An insecticide application is recommended if an average of 2 or more adult chinch bugs are found on 20 percent of the seedling sorghum plants that are 6-inches or less in height. Treatment is warranted on plants taller than 6-inches when chinch bugs are found on 75 percent of plants.

If control is attempted, use a minimum of 20 gallons of spray per acre and drop nozzles to direct spray toward the base of sorghum plants.

Corn earworm
Helicoverpa zea

Improperly filled corn heads is a typical symptom of ear worm infestations on grain sorghum. Larvae feed on developing kernels and contaminate grain heads allowing molds and some head rots to grow.

Sorghum is most susceptible to corn earworm attack during the two week period following pollination. Therefore, scouting should begin about one week after pollination. It will be necessary to scout sorghum weekly until grain is nearly mature. Tight headed sorghum varieties are more susceptible to attack than loose headed varieties. Late-planted and double-cropped plantings are also favored for infestation by this pest.

Treatment should be considered when an average of 2 or more corn earworm larvae are found per sorghum head.

Greenbug ***Schizaphis graminum***
Bird cherry-oat aphid ***Rhopalosiphum padi***
English grain aphid ***Sitobion avenae***
Corn leaf aphid ***Rhopalosiphum maidis***
Yellow sugarcane aphid ***Sipha flava***

A complex of aphid species can be found infesting sorghum plants.

The greenbug is the most serious pest as it injects a toxin when feeding that may kill seedling plants. It also transmits maize dwarf mosaic virus which severely stunts plants and causes leaves to yellow. Heavy greenbug infestations on sorghum plants during late whorl to milk stages may reduce grain yields.

Greenbug-resistant varieties can help reduce problems, and insecticides will effectively control greenbugs applied as spot treatments along field edges. Several insect predators and parasites also help reduce greenbug numbers in grain sorghum.

The bird cherry-oat aphid and English grain aphid can be found on grain sorghum, but they rarely cause economic loss. The corn leaf aphid is an occasional pest of sorghum and may cause some damage to seedling plants when numbers of aphids are extremely high. This aphid serves as an important host for the development of beneficial insects which help control the more damaging greenbug.

The yellow sugarcane aphid is found frequently on grain sorghum growing in southern and central counties of Missouri. Seedling sorghum plants may be killed if infestations are high.

This aphid injects a toxin during feeding which causes seedlings to develop a purple coloring on leaves and possible death of the plants. Larger plants are often stunted and more mature leaves turn yellow; probably caused by maize dwarf mosaic, a virus vectored by this aphid.

The economic thresholds for yellow sugarcane aphid on sorghum vary depending on size of the sorghum plants being infested. Thresholds range from two or more aphids on seedling plants to several colonies being present on plants in the reproductive stage of development for justification of insecticidal treatment.

Sorghum midge
***Contarinia sorghicola* (Coquillett)**

The sorghum midge is a problem of late - planted or double-cropped sorghum in Missouri, especially in the southern half of the state.

Damage is caused by small maggots which emerge from eggs laid on spikelets of flowering sorghum heads. They feed on the developing ovaries preventing kernel development.

Effective control is difficult to achieve, but is best attempted with an integrated approach to pest management.

A sorghum variety with uniform maturity should be planted early in the season. This action allows most of the sorghum heads to have flowered prior to a buildup of adult sorghum midges. Some sorghum varieties resistant to sorghum midge are available, but scouting and possible treatment may still be required.

At present, treatment is justified if an average of one or more adult sorghum midge is present per sorghum head prior to 50 percent bloom. Several insecticides are labeled for control of sorghum midge in grain sorghum.

Sorghum webworm
Nola sorghiella

Sorghum webworm is often a problem in late summer and early fall during cool, wet years. Larvae emerge from eggs laid on sorghum plants and are especially damaging to late-planted or double-cropped grain sorghum.

They feed on developing grain in the milk or soft dough stage by hollowing out the kernel. Varieties with compact grain heads are at greater risk of developing a sorghum webworm infestation.

Heavy infestations of webworms are indicated by the presence of white fecal pellets on grain heads, leaves and the ground. Insecticidal treatment is justified when an average of 5 or more webworms are pre- sent per sorghum head.

Soybean Insects

Insect problems on soybean are not a major consideration for most producers in this state.

The bean leaf beetle is our most serious soybean pest in normal years and the two spotted spider mite the most damaging in times of extended drought.

Many potential insect pests of soybean are controlled by natural agents, predators, parasites and diseases.

A good example is the green cloverworm. In states both north and south of Missouri, this insect can cause extensive damage to soybean. In Missouri, the green cloverworm rarely becomes a serious pest because of a complex of biological control agents (fungus, predators, parasites) which normally keep green cloverworm populations below the economic threshold.

Bean leaf beetle
Ceratoma trifurcata

This insect is an occasional pest of soybean in Missouri. Adults overwinter in plant debris within fields or wooded areas surrounding bean fields. Then they move to alfalfa fields in early spring and into soybean fields at the time of soybean germination.

In soybean fields, germinating soybeans are damaged by adults feeding on cotyledons and later by cutting small, circular holes in the surfaces of developing bean leaves. Some plant mortality may occur, but is generally not a problem unless the soybean seedlings are under drought stress.

Eggs are laid in the soil, larvae develop and emerge in July and early August followed by production of a second generation in late September and early October.

Larval damage is generally non-economic, however significant pod damage may result from feeding by the second (overwintering) generation of adults.

Insecticidal control of bean leaf beetles in seedling soybean is warranted when five or more beetles are present per row foot or 1 plant per row foot is destroyed in the seedling stage.

In the pre- bloom stage of growth, control is warranted if ten or more beetles are present per row foot and defoliation exceeds 30 percent.

Between bloom and seed maturity, bean leaf beetle control is warranted if ten or more beetles per row foot are present and defoliation reaches 20 percent or when fifteen or more beetles are present per row foot and pod damage reaches 10 percent.

Two-spotted spider mite
Tetranychus urticae

Damage from this pest generally occurs on soybean in years of severe or extended drought.

Mites overwinter on grasses along field borders and move into crop fields with the prevailing winds or by the movement of animals and equipment.

Scouting for this pest is difficult, although the first indication of an infestation is generally the development of large brown circles of dying and dead plants.

Spider mite populations increase rapidly under dry, dusty conditions and collapse rapidly when rainfall occurs.

Mites can be found on the underside of soybean leaves where they lay eggs, produce young and feed on plant sap. Feeding causes plant leaves to become speckled, turn yellow, dry and fall from the plant.

Occasional soybean insect pests:

- Green cloverworm
- Corn earworm
- Grasshoppers
- Seedcorn maggot
- Soybean thrips

Because of their small size, scouts must use a minimum of a 10x magnification lens to observe this pest. Several insecticides are labeled and effective for control of this pest. Insecticidal treatment may be justified, especially under hot and dry conditions.

Corn Diseases

Although a number of different diseases can occur on corn grown in Missouri, the most common only found corn diseases can be divided into several broad categories depending on the portion of the plant that is affected and the symptoms which develop.

Brief descriptions of these common corn diseases, the factors which favor disease development and disease management strategies are discussed.

More detailed information on diseases of corn in Missouri and corn disease management strategies may be found in MU Publication M160, "*Insect and Disease Management: Field Crops, Forages and Livestock*."

Seed rots and seedling blights of corn

Seed rots occur prior to germination. The seeds are soft and brown and may be overgrown with fungi. They may be difficult to find because they decompose rapidly and soil adheres fairly tightly to decomposing seed.

Seedling blights may be either pre-emergence - the seed germinates but the seedling is killed before it emerges from the soil, or post- emergence - the seedling emerges through the soil surface before developing symptoms.

With pre-emergence seedling blight, the **coleoptile** and developing root system tend to turn brown and have a wet, rotted appearance.

With post- emergence seedling blight, the young tissue becomes soft and watersoaked. The seedlings tend to yellow, wilt and die, and brown sunken lesions may be evident on the young tissue.

The root system is usually poorly developed - the roots are brown, watersoaked and sloughed off.

Seed rots and seedling blights are caused by a number of different fungal species. Many of these early season corn pathogens are common soil fungi found wherever corn is grown. However, a few of them can be seed borne.

Rots and blights are more severe in wet soils, in low lying areas, in soils that have been compacted or remain wet for an extended period of time and have low soil temperatures (50-55°F).

Disease severity is also affected by planting depth, soil type, seed quality, mechanical injury to seed, crusting, herbicide injury or other mechanical factors which delay germination and emergence of corn.

Management of corn rot and blight should include the following:

- Planting good quality seed under good seedbed conditions, especially at soil temperatures above 50-55° F
- Using fungicide treated seed

Foliage diseases of corn

There are a number of fungi and a few bacteria which cause foliage corn diseases. These various foliar pathogens cause leaf spots, leaf blights and similar symptoms on corn.

Symptoms may range from small oval to elliptical water-soaked lesions with Holcus leaf spot to the long elliptical grayish-green or tan lesion of the northern corn leaf blight.

Gray leaf spot tends to produce pale brown to tan, long narrow rectangular lesions restricted by leaf veins.

Rust pustules are circular to oval, light-brown to reddish-brown pustules or blister-like lesions. Lesion size, shape and color may vary with hybrid and with environmental conditions.

The fungi which cause most of these corn foliage diseases survive in infested corn residues left on the soil surface. The following growing season spores are produced during moist periods and are carried by wind currents to susceptible corn leaves where infection begins.

Eventually, spores that are produced in initial lesions are windblown to other leaves or plants causing secondary infection.

Common rust and southern rust of corn are two exceptions to this simplified explanation of disease development. The rust fungi do not survive in infested residues, in fact, they do not survive the winter months in this area. Rather the rust fungi are reintroduced into this area each season when spores are carried up air currents from the southern states.

Most of these foliage diseases of corn are favored by warm, wet or humid weather. They tend to start on the lower leaves and, if weather conditions are favorable, move up through the plant.

Generally, if foliage diseases are not established 6 weeks after silking; yield losses are minimal. If a foliage disease becomes established within 4-5 weeks after silking, yields may be reduced by up to 25 percent. If disease is established before silking or becomes severe within 2-3 weeks after silking, losses in yield of up to 50 percent may occur.

Management of corn foliage diseases should include the following:

- Planting disease resistant corn hybrids
- Rotating crops with at least one year out of corn
- Managing corn residues
- Applying foliar fungicides if warranted

Stalk rots of corn

Stalk rots are important worldwide and are among the most destructive corn diseases. A number of different fungi and bacteria cause corn stalk rots. Although many of these pathogens cause distinctive symptoms, there are also general symptoms which are common to all stalk rot diseases.

Early symptoms, which occur a few weeks after pollination, usually start with premature dying of bottom leaves. Eventually, the entire plant may die and appear light green to gray.

Diseased stalks usually begin losing firmness during August due to the cells in the interior of the stalk dissolving. Stalks may then lodge, particularly if harvest is delayed or wind storms occur.

Stalk rots are caused by several different fungi and bacteria which are part of the complex of microorganisms that decompose dead plant material in the soil. They survive from one growing season to the next in soil, infected corn residues or seed.

Pathogens enter the corn plant in a variety of ways: (1) The spores may be blown into the base of the leaf sheath where they may geminate and grow into the stalk. (2) Spores may enter directly into a plant through wounds made by corn borers, hail or mechanical injury. And when fungi are present in soil or infested residue as either spores or mycelium, (3) they may infect the root system causing root rot early in the growing season and later grow up into the stalk.

This disease becomes a problem when plants are stressed during the grain filling stage of development. Water shortage, extended periods of cloudy weather, hail damage, corn borer infestation, low potassium in relation to nitrogen, leaf diseases and other stresses that occur in August and September may be associated with an increase in stalk rot.

Losses vary from season to season and from region to region. Yield losses of 10 to 20 percent may occur on susceptible hybrids. Tolls greater than 50 percent have been reported in localized areas.

Losses may be directly due to poor filling of the ears or lightweight and poorly finished ears or indirectly through harvest losses because of stalk break- age or lodging.

Management of stalk rots of corn should include the following:

- Selecting hybrids with good stalk strength and lodging characteristics
- Planting at recommended plant populations for that hybrid
- Following proper fertility practices
- Avoiding or minimizing stress to corn (especially during pollination and grain fill)
- Harvesting in a timely manner

Ear and kernel rots of corn

There are a number of fungi which can invade and cause damage to corn ears or kernels. In general, we can divide these fungi into two groups- field fungi and storage fungi.

Field fungi invade the kernels before harvest while the corn is still in the field and can affect the appearance and quality of the kernels. Usually dam age caused by field fungi occurs before harvest and can be detected by routine inspection of corn fields. It does not continue to develop in storage if the grain is stored at proper moisture content and temperature.

Some of the field fungi on corn in Missouri include species of *Alternaria*, *Cladosporium*, *Aspergillus*, *Penicillium*, *Diplodia*, *Fusarium* and *Gibberella*. Most of these fungi are more prevalent when rainfall is above normal from silking to harvest. One exception is *Aspergillus flavus* which is favored by drought stress to corn during pollination and warm temperatures as kernels mature.

For all of the field fungi, damage tends to be more severe on ears with insect, bird or hail damage. Ears well covered by husks and maturing in a downward position usually have less rot than ears with open husks or ears maturing in an upright position.

Storage fungi invade grain or seeds during storage and they may not be present to any serious extent before harvest. A small amount of **inoculum** may be present as dormant spores on the outside of the kernels or as dormant **mycelium** under the **pericarp** of a few kernels.

Under improper storage conditions this small amount of inoculum can increase rapidly leading to significant problems. The development of storage fungi in stored grain is influenced by the moisture content and temperature of the grain, the length of time the grain is stored and the amount of insect or mite activity in the grain.

The most common storage fungi are about half dozen species of *Aspergillus* and several species of *Penicillium*.

An additional concern with ear and kernel rots is the possibility of **mycotoxin** production. Mycotoxins are naturally produced chemicals which, in small amounts may be deleterious to animal or human health. Three genera of fungi - *Aspergillus*, *Penicillium* and *Fusarium (Gibberella)* are most frequently involved in cases of mycotoxin contamination. The presence of molds or their spores on or in corn does not necessarily mean that mycotoxins will always be produced.

Circumstances that favor mold growth may allow production of mycotoxins in some situations, but frequently mold growth occurs with little or no mycotoxin production.

Once formed, mycotoxins are stable and may remain in grain long after the fungus has died. In general, swine and poultry are more susceptible than ruminants to mycotoxin-induced health problems at an equivalent dosage. In cases where mycotoxin problems are suspected, a sample should be submitted to a qualified laboratory for mycotoxin analysis.

Little can be done to prevent or reduce the invasion of field fungi. However, the following recommendations should help prevent storage mold problems or minimize damage from field and storage fungi on stored corn:

- Adjust the harvesting equipment for minimum kernel damage and maximum cleaning
- Clean the grain and bins thoroughly before storage to remove dirt, dust and other foreign matter, crop debris, chaff and cracked or broken kernels
- Store grain in watertight structures that are free from insects and rodents
- Store grain at proper moisture content and temperature
- Monitor grain on a regular basis throughout storage life to insure moisture content and temperature are maintained at correct levels

Miscellaneous corn diseases

There are several corn diseases which do not fit into the previous categories. These diseases include those which occur in low levels in most years such as common corn smut; or diseases that may be widespread and severe when they occur, but they occur only sporadically such as maize dwarf mosaic virus. These "miscellaneous" corn diseases are listed in Table 2.

Table 2. Miscellaneous corn diseases.

Disease common name	Pathogen type
Crazy top	Fungus
Corn smut	Fungus
Maize dwarf mosaic	Virus
Stewart's wilt	Bacteria

Nematode diseases

There are several species of **nematodes** or microscopic round worms which can cause damage to corn. Some corn nematode species spend most of their lives in the soil, while others live mostly in the roots. During feeding, nematodes may directly harm plants or they may cause wounds through which fungi and bacteria can enter plants and cause secondary rots.

The presence of nematodes in a field depends on the soil type and its properties, other soil microorganisms, cropping history, climatic factors such as temperature and rainfall, tillage and the use of pesticides.

The extent of nematode damage is often related to the growing conditions of the plant. Corn that is stressed by poor fertility or lack of moisture cannot withstand the additional stress of nematode feeding and will show more pronounced symptoms.

It is difficult to generalize about the symptoms caused by nematode damage because they vary with the species and number of nematodes present and the soil environmental factors.

Above ground symptoms are due to nematode injury to the roots. Early season symptoms may include stunting and/or off-color leaves. Later in the season, a ragged or uneven appearance to the field, lodging, general unthriftiness and reduced yields occur. Common evidence of nematode feeding on roots includes pruning, especially of feeder roots, proliferation of fibrous roots, thickening or swelling of the smaller roots and slight to severe discoloration of roots.

Since nematodes cannot be seen with the naked eye and since injury symptoms are easily confused with other types of corn production problems, nematode problems should be diagnosed by sub mitting soil and root samples to a laboratory qualified to run a nematode analysis on the samples.

Management options for corn nematodes should include the following:

- Fertilizing according to soil test recommendations because corn suffering from improper fertility is more susceptible to injury from nematodes
- Maintaining good weed control
- Rotating to a crop other than corn in fields with nematode problems

Grain Sorghum Diseases

The principle diseases of sorghum in Missouri can be divided into seed and seedling, foliage, root and stalk, head blights and molds and a few miscellaneous diseases. Brief descriptions and management strategies for each of these categories of sorghum dis- eases are given below.

For more detailed information see M160, "*Insect and Disease Management: Field Crops, Forages and Livestock*" or MU Publication G4356, "*Management of Grain Sorghum Diseases in Missouri*."

Seed and seedling diseases

There are a number of soil-borne and seed- borne fungi which can cause seed and seedling dis- eases of sorghum. Seed may be discolored and deteriorated. While seedlings may show a general rotting, discolored embryos, leaves and roots may die and stands may be thin and uneven.

Seed and seedling diseases tend to be more severe in poorly drained soils. They may occur more often if prolonged periods of wet, cool weather follow planting or if hot weather occurs when seedlings are emerging and secondary roots are developing.

Management of sorghum seed and seedling diseases should include the following:

- Planting high quality seed that is free of undersized, cracked or discolored kernels
- Planting in good seed bed conditions, especially planting in warm, well drained soils
- Using fungicide seed treatments

Foliage diseases

Sorghum is susceptible to a large number of both fungal and bacterial foliage diseases. Symptoms range from small, insignificant spots and stripes on leaves to extensive damage of large areas of leaf tissue that may result in premature death of leaves and plants.

Diagnosing specific leaf diseases on sorghum can be difficult because hybrids respond differently to the same pathogen, symptoms may vary with environ mental conditions and several foliage diseases may occur on the same leaf at the same time.

Severity of these foliage diseases depends on the specific disease, the susceptibility of the hybrid and the weather conditions during the growing season. Foliage diseases are usually favored by warm temperatures, wet weather or high humidity.

Fungal foliage diseases of sorghum in Missouri include anthracnose, leaf blight, gray leaf spot, zonate leaf spot, rough spot and sooty stripe.

Symptoms range from small, circular to elliptical spots to large elongated spots which may extend several inches in length. These usually develop on lower, older leaves first.

Bacterial foliage diseases of sorghum include bacterial spot, bacterial streak and bacterial stripe.

Bacterial spot tends to produce water soaked elliptical spots on leaves. While bacterial streak and bacterial stripe both result in long, narrow stripes on the leaves. Lesions from all three bacterial foliage dis- eases tend to have a reddish color or reddish margin.

Management of foliage diseases of sorghum should include the following:

- Planting locally adapted, resistant hybrids
- Planting disease free seed
- Rotating crops
- Managing crop residues
- Eliminating alternate or weed hosts

Root and stalk diseases

Several root and stalk diseases occur on sorghum. These diseases are usually most evident late in the season as plants are maturing.

These rots include charcoal rot, Fusarium stalk rot, Anthracnose or Colletotrichum stalk rot and Rhizoctonia stalk rot.

Stalks tend to be soft, discolored and deteriorated. Plants may die prematurely. Lodging may be a problem in fields with high levels of stalk rot. Stress to plants at flowering and grain filling stages may increase the incidence and severity of stalk rots.

Management of root and stalk rots of sorghum should include the following:

- Selecting hybrids with good stalk strength and tolerance to stalk rots

- Planting at proper plant populations
- Providing adequate moisture at planting and adequate irrigation through season
- Maintaining balanced soil fertility
- Controlling weeds
- Harvesting in timely fashion to minimize lodging and harvest losses

Head blights and molds

Several fungi cause head blights and molds on sorghum. Pink, gray, white or black mold growth on the heads or grain surface is the most obvious sign of problem.

The development of these head blights and molds is favored by wet weather and high relative humidity during flowering and grain fill. There is some variation in susceptibility among sorghum hybrids to head molds.

Management of head blights and molds on sorghum should include the following:

- Planting adapted, tolerant hybrids
- Rotating crops
- Managing residues
- Harvesting in a timely manner

Miscellaneous diseases of sorghum

Under certain specialized conditions, there are several miscellaneous diseases which may appear in grain sorghum. These diseases and their pathogen type are listed in Table 3.

Table 3. Miscellaneous grain sorghum diseases.

Disease common name	Pathogen type
Maize dwarf mosaic virus	Virus
Crazy top	Fungus
Root knot, lesion and stunt	Nematode

Soybean Diseases

The soybean diseases most likely to occur in Missouri can be divided into several broad categories based on the type of symptoms they cause and the time of year they develop.

For more detailed information on soybean diseases and their management see M160 "*Insect and Disease Management: Field Crops Forages and Livestock*."

Early season soybean diseases

The early season soybean diseases include those that cause seed decay, seedling blights and root rots. Most of these early season soybean diseases are caused by soil-borne fungi which are found wherever soybean are grown.

Pythium, Phytophthora, Rhizoctonia and Fusarium are the most common, although Phomopsis and Macrophomina (charcoal rot fungus) may also cause early season seedling problems.

General symptoms range from seed decay to pre-emergence or post-emergence damping off to wilt and death of established seedlings.

Pythium is more likely to cause seed decay, pre- or post- emergence damping off. Affected tissues are discolored and have a wet, rotted appearance. This disease is favored by cool (50-60^{o}F), wet soil conditions.

Phytophthora may also cause seed decay and pre- or post- emergence damping off, but a more typical symptom is the seedling blight phase. At this stage, young seedlings that appear to be established turn off-color to yellow, wilt and die. The brown dead leaves remain attached to the plant, and the dead seedlings remain evident in the field until the rows close.

Phytophthora may also develop on older plants later in the season. Infected older plants are killed more gradually or show reduced vigor throughout the growing season.

Lower leaves may show a yellowing between the veins and along the margins. Upper leaves may yellow. The stems show a characteristic brown discoloration that extends upward from below the soil line. Eventually the entire plant may wilt and die. Withered leaves remain attached even after the plant dies.

Phytophthora is more severe in low, poorly drained clay soils, but may appear in lighter soils or higher ground if the soil remains wet after planting. Significant rain after planting favors the development of Phytophthora in all sites.

Rhizoctonia can cause a pre-emergence damping off of soybean seedlings in which the seedlings turn yellow, wilt and die. Reddish brown lesions may be evident on the **hypocotyl** just below the soil line, and the hypocotyl and roots may be dry, stringy or shredded.

More typical Rhizoctonia symptoms are found on seedlings, young plants and even older plants and consist of localized reddish brown lesions on the hypocotyl near the soil line and the decay of lateral roots.

The reddish- brown color of lesions on the hypocotyls is a good symptom to use in diagnosing Rhizoctonia, but it is best observed immediately after plants are removed from the soil as the color fades as plants are exposed to air. Lesions are usually confined to the outer layer of the main root and hypocotyl.

If the lesions remain localized, the stem usually remains firm and dry and plants will survive although they may be stunted. If they girdle the entire stem, plants may be extremely stunted and die, especially during periods of moisture stress later in the season. Fusarium may cause a discoloration and deterioration of the main tap root. Affected plants may have a proliferation of secondary roots above the damaged main tap root and the tap root may actually be completely rotted. Rhizoctonia and Fusarium root rots can occur at any time during the growing season, but are most common on seedlings and young plants.

Crusting, herbicide injury, deep planting, poor seed quality, hail damage, mechanical injuries, poor fertility or other factors that prevent vigorous plant growth favor the development of these diseases.

Management options for the early season soybean diseases should include the following:

- Planting varieties with either resistance or tolerance to Phytophthora in fields with a history of that disease
- Planting good quality seed
- Planting in good seedbed conditions
- Using an appropriate fungicide seed treatment

Soybean foliage diseases

Foliage diseases such as Septoria brown spot, bacterial blight, downy mildew and powdery mildew can occur on Missouri soybeans.

Generally, these diseases occur in low levels and do not cause significant losses. However, under favorable conditions for disease development, losses can be serious.

Septoria brown spot causes small brown spots on the unifoliate and lower trifoliate leaves. The individual spots may run together forming irregularly shaped brown blotches on the leaves. Infected leaves may yellow and drop prematurely.

Brown spot usually starts on the lower portion of the plant and under favorable weather conditions (warm, wet weather), the disease may move up through the plant. The fungus which causes this disease survives in infested residues left on the soil surface. Continuous soybean are more likely to show damage.

Bacterial blight also causes small brown lesions on the leaves. The lesions usually begin as small, angular, translucent, water soaked, yellow to light brown lesions that turn reddish brown as the lesions dry out.

In cool, rainy weather the small, angular lesions may enlarge and merge producing large, irregular dead areas in the leaf. With wind and rain these large dead areas may drop out or tear away, giving the leaf a ragged appearance.

Favored by cool, rainy weather during the early to midseason, this disease usually occurs five to seven days after windy rainstorms.

Initial symptoms of downy mildew are pale green to light yellow spots or blotches on the upper surface of young leaves. These areas may enlarge into pale to bright yellow lesions of indefinite size and shape. Eventually the lesions turn grayish brown to dark brown with a yellowish green margin. During periods of heavy dew or wet weather, a gray to purple fuzz of mold develops on the lower leaf surface in the diseased areas.

Powdery mildew may begin as small areas of white mold growth on the upper leaf surface. These lesions may expand to cover larger areas of the leaf surface. They may also form on the lower leaf surfaces, stems, petioles and pods. Heavily infected leaves may yellow and drop prematurely. It is favored by cooler than normal temperatures.

Management of soybean foliage diseases should include the following:

- Planting good quality seed of resistant varieties
- Planting disease free seed
- Maintaining good plant vigor
- Applying foliar fungicides if warranted

Soybean virus diseases

There are several viral diseases in Missouri soybean that include bean pod mottle, soybean mosaic and tobacco ringspot or budblight.

These viruses tend to cause green to yellow mottling of leaf tissue, stunting of plant growth and deformation of plant tissues.

Bean pod mottle causes a green to yellow mottling of young leaves in the upper canopy. Symptoms are not obvious during periods of high temperatures or after pod set. This virus is sap-transmissible and may be vectored by beetle species such as the cereal leaf beetle.

Soybean mosaic virus may also cause a green to yellow mottling or mosaic pattern in leaf tissue as well as puckering and distortion of the leaf shape. Symptoms vary with the susceptibility of the host, strain of the virus, age at which the plant becomes infected and environmental conditions. Soybean mosaic virus is sap-transmissible and may be vectored by many aphid species.

Tobacco ringspot virus or budblight usually causes the terminal bud to curve forming a crook. The pith of stems and branches may show a brown discoloration starting at the nodes and extending into the **internodal** areas. Petioles and larger leaf veins may show a brown discoloration.

Plants may be stunted with a bushy appearance, leaves may be wrinkled and rolled and pods may be underdeveloped or aborted. Tobacco ringspot virus is readily sap-transmissible, but no efficient insect vector has yet been discovered.

Management of soybean virus diseases should include the following:

- Planting virus free seed
- Maintaining good weed control

Mid to late season diseases of soybean

There are several other important diseases of

Missouri soybean that tend to be evident after stands are established, i.e. mid to late season.

Symptoms of soybean cyst nematode may range from subtle differences in plant height and vigor to severe stunting and discoloration of plants.

Foliage symptoms include a yellowing of leaves which resembles potassium deficiency symptoms in that the yellowing starts at the edge of the leaves. The root system is poorly developed with stunted roots.

If plants are carefully dug up, cysts may be evident on the roots. The cysts appear as tiny, whitish, yellowish to brownish, lemon-shaped structures.

Symptom expression may be more severe if plants are subjected to other stresses such as moisture stress, nutrient deficiencies, herbicide injury, etc.

Confirm presence of soybean cyst nematode; take samples!

Contact the Extension Plant Nematology Laboratory:

108 Waters Hall
University of Missouri
Columbia, MO 65211
(573) 882-2716
FAX (573) 882-0588

Management of soybean cyst nematode should include the following:

- Employing a program of soil sampling to identify problem fields and to determine the extent and severity of the problem in the field
- Planting resistant varieties
- Rotating crops
- Maintaining good plant vigor

Charcoal rot may cause a seedling infection, but is more common later in the season. Infected plants are less vigorous and may have smaller leaves. Leaves may turn yellow and wilt. The taproot and lower stem may develop a silvery gray to light gray discoloration of the **epidermis**.

Fine black specks or **microsclerotia** may be evident in tissues below the epidermis and eventually in epidermal tissues. If the lower stem and tap- root are split open, a reddish brown to blackish dis- coloration may be seen in **vascular tissues** of the taproot and stem.

The fungus which causes charcoal rot is a common soil fungus in Missouri. Corn and grain sorghum may also be hosts of this fungus. Charcoal rot is favored by hot, dry weather, so symptoms usually appear at temperatures between 82-95° F.

Management of charcoal rot of soybean should include the following:

- Rotating to cereals, cotton or other non-hosts
- Maintaining good crop vigor may also help reduce losses from charcoal rot

Symptoms of sudden death syndrome may appear several weeks before flowering, but are more pronounced after flowering.

Foliage symptoms begin as scattered yellow blotches in the **interveinal** leaf tissue. These yellow blotches may increase in size and merge to affect larger areas. Yellow areas may turn brown. And severely affected leaflets may drop off the plant leaving the petiole attached or curl upward and attached to the plant.

Root systems may show deterioration and discoloration of the lateral roots and taproot. When split open, internal tissues of the taproot and stem may show discoloration.

Management of sudden death syndrome should include the following:

- Planting disease resistant or tolerant varieties
- Rotating crops
- Maintaining good crop vigor

Pod and stem blight, anthracnose and stem canker are three late season stem diseases of soybean. With pod and stem blight, infected plants may be stunted.

Black **pycnidia** or fruiting bodies of the fungus develop on the lower portion of the main stem, branches and pods as plants reach maturity. It may be limited to small patches usually near the nodes or it may cover dead stems and pods.

On stems, the pycnidia are usually arranged in linear rows while on pods they are randomly scattered. Prolonged periods of warm, wet weather during flowering and pod fill favor the development of pod and stem blight.

Anthracnose causes symptoms which are somewhat similar to those of pod and stem blight. During flowering, irregularly-shaped brown areas may develop on stems, petioles and pods. The anthracnose fungus also produces small black fruiting bodies in infected tissue.

With stem canker, small reddish-brown lesions develop on stems near a leaf node. Symptoms usually begin during flowering, and over time, the lesions expand to form larger, sunken cankers which are brown to black in color.

Interveinal yellowing or browning of leaf tissue may also develop. Stem canker is also favored by warm, wet conditions.

Management of pod and stem blight, anthracnose and stem canker should include the following:

- Rotating crops
- Using disease free seed
- Using fungicide seed treatments
- Using a foliar fungicide during the growing season if warranted

Cotton

Weeds

Most cotton weed control practices are eventually customized for individual farms and fields. Cotton requires intensive herbicide applications, intensive cultivation and often needs hand hoeing. Because weed control is difficult, cotton should not be planted into extremely weedy fields.

Cotton is a slow-growing plant and only a limited selection of herbicides are registered for weed control. These two factors sometimes make cotton weed control difficult.

It is a semi-tropical, perennial plant, although it is grown as an annual crop. Its growth is especially slow in the northern Cotton Belt where it is often planted early into cool soils. Unfortunately, cool weather does not stop the growth of most weeds.

Over-the-top, broadleaf weed control is particularly difficult as there are only several selective herbicides available for cotton. Because of the availability and good performance of postemergence grass herbicides, weed control programs should emphasize broadleaf weed control.

Traditionally, postemergence broadleaf control was accomplished with herbicides that injured the cotton, but are applied in a directed spray that does not contact most of the cotton plant.

These herbicides are still integral to cotton weed control and still provide some of the broadest spectrum, longest residual and most economical weed control.

A solid program of pre- plant incorporated and preemergence herbicides followed by postemergence directed herbicides is needed for successful cotton weed control. Scouting for weeds the season *before* can help in planning a weed control program for optimal performance and minimal cost.

With favorable environmental conditions, the soil-applied herbicide program will give cotton a 2 to 4-week head start on weeds, after which the herbicides decompose and weeds begin to emerge.

Postemergence- directed herbicide applications are made to control the emerging weeds. Post- directed sprayers are often mounted on cultivators so that the applicator bands the herbicide on the row and cultivates the row middles at the same time. If post-directed sprays are not applied in a timely manner, weeds can quickly grow too tall and the cotton-weed height differential will be lost. Plan to apply directed sprays approximately two weeks after planting, but scout for weeds before spraying.

Cotton is typically treated with postemergence-directed herbicides at a 3- to 8-inch height and at an 8- to 14-inch height. Sometimes a third, lay-by application is applied when the row middles are covered by the cotton foliage and no further cultivation is possible.

When 8-inches and taller, directed sprays can be applied as high as two to three inches up the cotton stalk. When cotton is 3 to 6 inches tall it is best to keep the spray off of the foliage.

Consult MU Publication MP575 "*Weed Control Guide for Missouri Field Crops*" or an equivalent publication to compare herbicides for their control of particular weeds.

The MP575 guide is updated annually and contains a large amount of detailed information regarding herbicide mixtures, effectiveness on individual weeds, effects on rotational crops, adjuvants and rainfast intervals for herbicides.

Insects

During most seasons, cotton insect pests get ahead of beneficial organisms in sufficient numbers to make insecticidal controls necessary and economical.

Pest insect populations often recover faster than do populations of beneficial insects. This results in even more damage to production. Therefore, it is important that an economic insect threat is present prior to the application of insecticides.

Recommended insecticides for cotton pest insect control and scouting procedures are available in MU Guide G4252, "*Cotton Insect Control.*"

Thrips
Frankliniella fusca

Thrips are tiny insects, about 1⁄25 inch long. They overwinter as adults and nymphs in plant debris. They rasp the plant's surface and suck the sap.

Controlling thrips may result in earlier maturity and increased cotton yields. Cotton plantings usually are in the four-leaf stage or younger at small grain harvest, and often they are subject to heavy thrips populations migrating from the drying field.

Thrips injury causes leaf edges to brown, curl and pucker. On heavily infested plants, the undersides of leaves, especially the first cotyledonary leaves, have a silvery appearance.

Fleahoppers and plant bugs
Miridae spp.

Cotton fleahoppers and tarnished plant bugs sometimes injure plants by sucking juices from small squares that cause them to blast. Most severe injury occurs in the first four weeks of the fruiting season. This square blasting causes plants to remain in the vegetative state, delaying fruiting and fiber maturity.

Chemical control measures are usually justified when there is an average of 6 to 8 clouded plant bugs per 100 row feet during the first week of squaring; 8 to 10 bugs during the second week; 10 to 12 during the third week; and 15 or more during the fourth week of squaring.

Aphids
Aphididae spp.

Aphids are tiny green, yellow or black soft-bodied insects that feed on the underside of cotton leaves. They suck plant juices and excrete a sweetish, sticky fluid (honeydew) that sometimes blackens the upper surfaces of leaves. Damaged leaves curl down at the edges.

Aphids are more common after insecticide applications have been made. Insecticidal control of aphids is rarely needed in Missouri because beneficial insects normally control them. Aphid buildup may result in some leaf curling and honeydew deposition. Control may be required under these conditions.

Spider mites
Tetranychus spp.

Spider mites are tiny greenish, tan or red mites that may be found on the underside of leaves. They attack cotton at any stage of growth, but they generally cause more damage in mid to late season following hot, dry weather.

As the mites remove leaf juices, injured leaves take on a reddish-bronze appearance and develop a slight downward curl. When damage is severe, leaf drop occurs. Such defoliation results in a decrease in the quality and quantity of lint.

Spider mites usually first occur around field margins next to vegetation, stumps or ditch banks, etc., where they have overwintered. A good cultural control method is to leave a vegetation-free zone 10 to 20 feet wide between any border vegetation and the cotton field point rows.

Remember any equipment, people or animals moving through a cotton field can spread mites. And usually, mite infestations often occur immediately after mowing border vegetation. Spot treating border areas can stop an infestation before it spreads throughout the entire field.

Control efforts should begin as soon as mites are evident, or as soon as leaves in an infested area begin to discolor. For effective control with all miticides, it is essential to get good coverage of all foliage, especially the underside of leaves.

Note that spider mite populations may decline suddenly in early August. Therefore, observe fields carefully in August to determine whether mites are present in damaging numbers before applying control measures.

Bollworm
Helicoverpa zea

Cotton bollworm is the same insect as corn earworm. However, many cotton fields escape damage from bollworms because beneficial insects and spiders keep them under control.

Bollworm eggs are pearly white and about the size of a period mark in print. The eggs are laid singly on terminal buds, terminal leaves, or blooms and squares. Although at certain times, moths seem to prefer the lower portions of a plant for egg laying. Newly hatched bollworms can be found feeding on terminals or in small squares.

As bollworms increase in size, they tend to feed downward, attacking larger squares, blooms, small bolls, and finally nearly full-grown bolls.

While natural outbreaks sometimes occur, severe outbreaks usually follow insecticide applications meant to control other pests. In cases where no insecticides have been applied to a field, natural control usually is excellent and little damage results. However, if bollworms are damaging more than 5 percent of the squares, insecticide treatment may be justified.

The greatest danger of a bollworm outbreak is in midseason after most corn has stopped silking.

The bollworm moths then become attracted to cotton in bloom. From this time until the end of the fruiting season, fields should be checked weekly.

Depending on the number of beneficial insects present in each field, control measures should begin when 10 bollworms or eggs per 100 plants and some damage to the fruiting forms are found.

Because bollworm insecticides also kill beneficial insects and spiders, it is often difficult to decide when insecticide applications should begin. In fields

Cotton: beware of the phenoxy herbicides!

Cotton is extremely sensitive to phenoxy (2,4-D and 2,4-DB) herbicides. Application equipment that has been used to apply these herbicides should be thoroughly flushed, soaked overnight with a 1 percent solution of household ammonia (1 gallon ammonia in 100 gallons water) and flushed again before treating cotton.

It is interesting to note that in Arkansas, where cotton acreage is significantly higher than corn acreage, it is illegal to apply 2,4-D within 1/4 mile of a cotton field with ground equipment and illegal to make an aerial application within 4 miles. This is not a Missouri law because corn acreage is many times greater than cotton acreage.

that have never been treated, spraying may be delayed a few days to give beneficial insects an opportunity to bring infestation under control.

However, as larvae become larger, they become increasingly difficult to control. Recommended insecticides will not give effective control of ¾-grown to fully grown bollworms.

Boll weevil
Anthonomus grandis

Boll weevils are unable to survive Missouri winters in great numbers due to low temperatures and the lack of suitable hibernation quarters.

Localized damage may occur fairly early in some years, while late-season injury by migrating weevils may occur nearly every year in some fields along the floodway ditches, the St. Francis and Mississippi Rivers.

Under normal conditions, control measures should be taken when 20 percent of the squares are punctured. If infestations occur early (mid-July), treatment should begin when 15 to 20 percent shows feeding punctures. Pheromone traps are recommended in spring to monitor weevil populations.

In fields where boll damage is evident or where a high percentage of remaining squares are being punctured, control should continue until the bolls are at least 16 days old.

Stalk destruction immediately after harvest will reduce local boll weevil infestations significantly.

European corn borer
Ostrinin nubilalis

Cotton damage by this insect has been noted since 1956. Infestation levels are related to the corn acreage planted near cotton fields, as well as the maturity of adjacent cotton.

Properly timed insecticide applications, as well as excellent coverage, are necessary to control this borer. Scouting usually does not provide accurate population estimates.

Eggs are laid in masses of three to 50 with 15 eggs / mass being average. They are deposited on the underside of leaves and hatch in three to five days. Larvae bore into bolls or stalks within 48 hours of hatching.

Diseases

The principle diseases of cotton in Missouri can be divided into seedling diseases, foliage diseases, wilt diseases, nematode diseases and boll rots. Brief descriptions and management strategies for each of these categories of cotton diseases are given below.

For more detailed information see Mu Publications M160, "*Insect and Disease Management: Field Crops, Forages and Livestock*," and G4254, "*Cotton Seedling Diseases*" and G4261, "*Cotton Disease and Nematode Management*."

Seedling diseases

Several soil-borne and seed-borne fungi can cause seedling diseases in cotton. These fungi may cause seed decay, pre- and post-emergence damping-off before developing root rot.

Plants may emerge slowly. Seed decay, pre- and post-emergence damping-off or sore shin can cause stand loss which may range from minor damage in specific problem areas to extensive stand loss through the entire field.

Seedling root rot may be less obvious, affecting general vigor and thriftiness of plants.

Management of cotton seedling diseases should include the following:

- Planting good quality, disease free seed
- Using an appropriate fungicide seed treatment
- Planting in warm, well drained soils
- Using in-furrow fungicides at planting
- Maintaining good crop vigor by proper fertilization, watering and weed control

Foliage diseases

Bacterial blight and several fungal leaf spot diseases are the most common cotton foliage diseases in Missouri.

On the foliage, bacterial blight develops as angular shaped, water-soaked lesions. As these lesions age their color darkens to brown. This disease may also affect cotyledons, hypocotyls, stems ("black arm") and bolls. And it can result from seed-borne bacteria or bacteria splashed onto plants from diseased cotton debris left in a field.

Further infection of the plant occurs as bacteria moves up the plant by splashing or windblown water. The fungal leaf spot diseases on cotton are generally considered minor problems because they generally occur late in the season and have little effect on yield. They are more likely to occur on plants showing stress or late-season decline.

These fungal leaf spots begin as small, reddish-brown to brown or black spots on the leaves, and they increase in size.

As the lesions age the centers may turn lighter in color, crack and eventually drop out. In some cases lesions may also occur on cotyledons, stems and bolls.

Management of cotton foliage diseases should include the following:

- Planting high quality, disease free seed of resistant varieties, especially for bacterial blight
- Rotating crops

- Maintaining good plant growth through proper fertility and watering

Wilt diseases

There are two principle wilt diseases of cotton - Fusarium wilt and Verticillium wilt. Symptoms of these two diseases are somewhat similar and laboratory identification may be necessary.

Fusarium wilt symptoms can develop at any stage of plant growth. In young plants, the cotyledons and leaves wilt, turn yellow and then brown and drop. In older plants, symptoms usually develop on the lower leaves as plants first begin to flower. Portions of the leaf wilt and turn yellow or brown.

These symptoms may occur at the leaf margins first, but eventually the entire leaf is affect d. Symptoms then develop on other leaves in the plant.

As affected leaves drop, plants become stun ted and die and the vascular systems show a dark brown to black discoloration. Fusarium wilt tends to be more severe in soils that are also infested with root knot nematode.

Symptoms of Verticillium wilt usually app ear 35-40 days after plants emerge. Irregular yellow areas develop along leaf margins or between main leaf veins on lower leaves. This mottling of leaf tissue may move up the plants. Premature defoliation m ay occur. Plants may be stunted. Terminals may show a downward curling, and fruiting branches and bolls may drop prematurely. Vascular tissues of infected plants may show a light to dark brown discoloration.

Management of vascular wilt diseases of cotton should include the following:

- Planting locally adapted, resistant or tolerant varieties
- Avoiding cotton in previously known heavily infested fields
- Avoiding fields with high levels of root knot nematode
- Managing for good crop vigor with adequate but not excessive nitrogen, proper potassium and proper soil pH

Nematode diseases

Several nematode species including root knot and reniform nematode may cause injury to Missouri's cotton crop.

Nematodes feed on or in roots causing systems to be restricted in size and have poor feeder root development. Roots may be discolored and deteriorated.

With root knot nematode, distinctive spindle shaped galls or knots occur on the root s. Above ground symptoms include stunting, yellowing or general unthrifty appearance.

Since nematode s cannot be seen with the naked eye and symptoms of nematode injury are easily confused with nutrient deficiency or other cotton problems, it is important to confirm nematode problems with laboratory assays.

When nematode da mage is suspected, root and soil samples should be submitted to a nematology laboratory for analysis and identification of nematode species causing da mage.

Management of cotton nematodes should include the following:

- Planting locally adapted varieties (although there are no root knot resist ant varieties adapted for Missouri, varieties with resistance to Fusarium wilt do better in the presence of root knot nematode than Fusarium wilt susceptible varieties)
- Rotating crops
- Maintaining goo d crop vigor, especially with proper fertility
- Using a nematicide either as a soil fumigant prior to planting or as a soil treatment at planting, if warranted

Boll rots

A number of different fungi can cause boll rots of cotton. A few of these fungi are true parasites and can penetrate the outer layers of the boll directly without the aid of natural openings or wounds.

But most of these are **saprophytes** and must use natural openings or wound s to reach the interior of the boll.

Most boll rots begin as small brown to reddish brown to black spots on capsules or bracts of the boll. Under ideal conditions the spots expand rapidly, affecting part or all of the boll. High humidity is essential for boll infection.

Tall, rank plant growth leads to shading, reduced airflow and increased humidity within the canopy of cotton plants which may favor development of boll rots.

Management of boll rots should include the following:

- Planting high quality, disease free, fungicide treated seed of resistant varieties
- Managing the crop to avoid rank plant growth. This includes proper nitrogen fertilization and plant populations, use of a growth regulator and control of insects.

Rice

Weeds

Rice weed control is significantly different from weed control in conventional, dryland crops. Herbicide application timing is extremely critical. Additionally, label directions must be followed strictly as significant problems can arise from subtle changes in the use pattern of a herbicide. The same herbicide may be used in distinctly different ways in the delayed flood versus continuous flood cultures.

In drill-seeded, delayed-flood rice, some rice herbicides work best with extremely wet conditions and require flushing; others will falter if flushed too many times. Because the agronomic and weed control aspects of rice are greatly different from dryland crops, inexperienced growers are encouraged to try rice on small acreages for two to three years before planting significant acreages.

Rice is generally grown in a flooded culture. However the rice plant does not require flooding for optimum growth, but instead it is used for weed control.

Specifically, the flood provides 50 to 80 percent of the weed control in a typical field. However, herbicides are essential for the remaining 50 to 20 percent of uncontrolled weeds. There are methods to grow rice without a flood; however, in economic terms, a properly-managed flood is by far the best method.

There are two important issues regarding the flood that should be remembered: (1) The flood stops weed seeds from germinating *but does not necessarily kill existing weeds*. (2) Pumping capacity and field design are critical.

The grower should be able to establish a flood in at least four days on drill-seeded delayed-flood fields and completely drain and reflood a field in four days with the permanent-flood water-seeded method.

Permanent-flood water-seeded fields should be smaller, or need larger pump capacities than delayed flood, dry seeded fields (Consult University of Arkansas Guide MP192, "*Rice Production Handbook*" for information on pumping capacities).

Flushing (flooding a field for one to three days) is another important aspect of flood management. Flushing is recommended under dry conditions to both stimulate the emergence of newly planted rice or to provide irrigation water for stressed rice. It is also essential to assure proper activity of several (but not all) herbicides.

There are two main cultural methods to grow rice: (1) delayed-flood dry-seeded system and, (2) continuous (or nearly continuous flood), water-seeded system. In either system, the soil must be relatively impermeable to minimize water pumping costs.

In the delayed-flood dry-seeded system, a firm, level seedbed is prepared and rice is usually planted with a grain drill. The flood is applied four to six weeks later when the rice is 6 to 8 inches tall.

Weed control is essential during the four to six dry weeks. If weeds are controlled when the flood is applied further herbicide application is generally not necessary.

There are several ways to control rice weeds during the dry period. Although, it is essential that grass weeds be controlled before they have four leaves (or are larger than 1.5 inches). This is because postemergence rice herbicides tend to be contact- type herbicides. If there is any significant size or protection of the weed growing point it may survive herbicide treatment.

The permanent-flood water-seeded system is used for two primary reasons: (1) It is the best way to

Red rice: A special management problem

Red rice is a special weed problem in that it is taxonomically the same as commercial rice cultivars. Therefore, herbicides cannot control red rice without controlling the commercial rice.

The best red rice control is rotation to soybeans. Rotation to corn and cotton are also good choices; however, soybean herbicides provide the most powerful red rice control options.

Chloroacetamide herbicides generally provide excellent control of red rice. Even though these herbicides provide only excellent preemergence control, they do not provide season-long control and enough red rice typically germinates to reinfest the entire field.

Some of the same postemergence grass herbicides labeled for use in soybeans and cotton are viable options for red rice control. Be sure to consult labels under the "Weeds Controlled" section for proper rates and other notes.

In rice, red rice is controlled by the use of the water-seeded continuous flood method. Rice (red or a commercial cultivar) will emerge through the soil or through floodwater, but will not emerge through both.

Consequently, with continuous flood systems, red rice cannot germinate; while at the same time, the commercial rice is pre-sprouted and left on the soil surface where it can germinate through a flood.

Continuous floods provide good suppression of light to moderate red rice infestations; however, control is not complete. There are always a few red rice seed present on the soil top that can germinate along with the commercial cultivar.

manage red rice besides planting another crop and, (2) because seedbed preparation and planting can be difficult on clay soils. The permanent-flood water-seeded system allows one to plant rice with minimal tillage.

This system is usually used on precision-graded fields. In fact, fields are normally "flat-graded, zero slope" and have only a single, permanent, outer levee around the perimeter. An essentially flat field makes pinpoint floods more accurate and saves essentially all of the work of annually building, flattening and then rebuilding levees.

A drawback is that once a field is put to zero slope, drainage may become a problem when the field is rotated to dryland crops.

Registered herbicides are commonly applied after the rice has established a root system. These herbicides are used to control grasses which escape control from the flood and aquatic, broadleaf weeds which thrive in this system.

The same aquatic weeds can infest drill seeded rice, but the competition from a well-established rice crop suppresses most aquatic broadleaves.

Common Weed Problems

In rice, barnyardgrass is one of the most prevalent and yield-robbing weed problems. Broadleaf signalgrass is another common weed, however, it is less competitive. They are generally controlled by standard weed control practices.

Amazon and bearded sprangletop are also common but may be more difficult to control as they are more tolerant to several common rice herbicides.

It should be noted that in many areas of Arkansas, barnyardgrass has become resistant to products containing the active ingredient, propanil. Resistant barnyardgrass occurs almost exclusively in fields that were repeatedly planted to rice and treated with propanil. Crop, as well as, herbicide rotation are effective in preventing a buildup of propanil-resistant barnyardgrass.

Common broadleaf weed problems include hemp sesbannia, morningglory, smartweed and jointvetch. These weeds often go undetected in rice until they have attained sizes much larger than what they would have in normal dryland crops. Smartweed and jointvetch are especially difficult to control when large.

Aquatic weeds include purple ammannia (red-stem), duck salad, round leaf mudplantain and arrowhead species. Several nutsedge species also favor the flooded environment of a rice field.

In drill-seeded rice, these problems typically occur only in areas where rice stands were not established. In the water-seeded culture, there is little competition during the first weeks of establishment, but these weeds will take advantage of the flooded environment.

Specific herbicide recommendations for rice weed control are available in MU Publication MP575, "*Weed Control Guide for Missouri Field Crops*."

Insects

Insect populations can damage rice crops if they are allowed to go unchecked. Several insect species are commonly found in rice, but only a few species in isolated situations require insecticide treatment.

The most common insect pests in Missouri rice fields are the rice water weevil, the rice stink bug and grasshoppers. Several other insects occasionally may cause severe damage in individual fields (see text box). For additional information on rice pests, damage symptoms, scouting methods and recommended treatments, consult MU Publication G4362, "*Controlling Insects in Rice*."

Occasional rice insect pests:

- grape colaspis larvae
- maize billbugs
- grasshoppers
- armyworms
- rice stalk borers
- chinch bugs

Rice water weevil
Lissorhoptrus oryzophilus

Adult rice water weevils are snout beetles about 1/8-inch long. They lay eggs in seedling rice immediately after rice fields have been flooded. Standing water is necessary for high larval production.

The white, legless larvae feed on roots and may cause loss by severe root pruning. They feed for about 3 weeks, then pupate. Adults emerge after 5 weeks.

Most emerging adults feed for a short time and then fly to overwintering sites, but some may lay eggs in late planted rice.

Adult feeding produces tan, longitudinal scars on leaves, but usually does not damage the crop.

Draining a flooded field provides an effective control alternative to insecticides. The field must be allowed to dry thoroughly before reflooding to ensure adequate control. Insecticidal control measures are a viable option if draining is not feasible.

Rice stink bug
Oebalus pugnax

The rice stink bug is a tan-colored, shieldshaped insect about 3⁄8-inch long that feeds in developing heads of rice plants. Heavy infestations may result in improperly filled grain.

This insect feeds on the seeds of many grass species; however, it prefers barnyardgrass. Populations generally develop in grassy areas before moving into rice.

Masses of green, barrel-shaped eggs are laid on rice blades. The eggs hatch in five days and nymphs mature in about 18 days. Adults overwinter in leaf debris.

Diseases

Missouri rice may be affected by seedling diseases, leaf and sheath diseases and kernel smut diseases. Brief descriptions and management strategies for these categories of rice diseases are given below.

For more detailed information on rice diseases see MU Publications M160 "*Insect and Disease Management: Field Crops, Forages and Livestock*," MP645 "*Rice Blast Control*" and MP646 "*Rice Sheath Blast Control*."

Seedling diseases

Several soil-borne fungi may cause seedling diseases of rice. These diseases may rot seed, weaken or kill seedlings, discolor roots and reduce stands.

Blighted seedlings which survive are likely to be weak and yellowish. Stands may be spotty, irregular or thin. Environ mental conditions that delay rice seedlings' emergence from the soil often favor the development of seedling diseases.

Management of rice seedling diseases should include the following:

- Planting high quality fungicide treated seed
- Planting in a well prepared seed bed

Leaf and Sheath Diseases

Most of these diseases are caused by fungi which attack leaf and stem tissues. Symptoms range from discrete lesions on leaves to a general rotting of stems.

Brown spot disease produces small, oval to circular, brown spots on the leaves of infected plants. Sheath spot produces gray-green lesions with red-brown borders which are confined to the sheath. Sheath blight produces similar gray-green lesions with red-brown borders that eventually extend up the stem.

Stem rot begins as small black lesions on the leaf sheath near the water line but may develop into a more extensive rotting of the stems.

Rice blast is one of the most severe foliar diseases. The fungus that causes this disease may affect all parts of the sheath, but rarely affects the leaf sheath. Symptoms vary with environment, host resistance and hostage.

Initially, lesions are diamond-shaped and white to gray-green with a darker green border. Older lesions may be more white to gray with brown borders. Losses from rice blast tend to be associated with intensive, high-input rice cultivation.

It is more likely to occur on irrigated rice grown in temperate regions and is favored by nitrogen fertilization, long periods of leaf wetness and temperatures in the range of 62-73^{o}F.

Management of leaf and sheath diseases of rice should include the following:

- Avoiding susceptible varieties especially in fields with histories of leaf or sheath disease problems
- Planting good quality, disease free seed
- Rotating crops
- Planting at proper plant populations
- Applying nitrogen at recommended rates and times
- Using foliar fungicides, if warranted

Kernel Smut

Kernel smut is a disease in which the grain on the plant is replaced with masses of black, powdery spores. Initially, these spores are within the hull and not readily visible. But eventually, the hull breaks open revealing the mass of black spores.

It is worse when warm, rainy weather occurs du ring bloom. Losses are seldom severe so, controls are seldom warranted.

Winter Wheat

Weeds

Principal weeds causing losses in wheat are given in Table 4. Winter annual grass and broadleaf weeds have a growing season similar to wheat. They germinate and emerge from the soil along with the wheat seedlings, withstand adverse weather conditions and put on new growth in the spring.

Winter wheat is a competitive crop, and it tends to suppress dense stands of many weeds. However, if the wheat stand becomes thin due to winter kill, dis- ease or other reasons, weeds emerge wherever there are bare areas.

Small weeds are commonly present under the winter foliar canopy and they develop rapidly when harvesting removes the canopy.

The presence of tall, green vegetation at harvest time (such as common lambsquarters, common and giant ragweed and Pennsylvania smartweed) may disrupt harvesting.

Wild garlic and wild onion are not competitive with wheat; but, the presence of their aerial bulblets in harvested grain causes dockage at market time.

Wheat is graded “garlicky” when two or more green aerial bulblets of either species or an equivalent of dry or partially dry bulblets are present in 1000 g of seed.

These bulblets impart an odor and flavor in the wheat and wheat products that persist even after they are removed. When crushed in wheat milling, the bulblets contaminate the milling equipment, forcing the mill to shutdown for cleaning.

A typical weed management strategy for conventional-till or no-till winter wheat production is to prepare the seedbed (in conventional-till) and sow or drill the wheat in the fall.

Wheat is typically grown in rotation with corn and soybean on farms where grains are the principle product. On farms that raise cattle, hay crops such as alfalfa and clover may be included in the rotations to provide for forage needs.

If weeds have been adequately controlled in soybean or corn grown for silage, wheat can be seeded directly into the field.

Winter wheat grows rapidly and is a highly competitive crop and most Midwest farmers do not plan a weed control program in anticipation of serious weed infestations.

Herbicide applications are not usually made in the fall unless cheat or downy brome are present. Most herbicide applications are made in the spring.

Reduced-tillage systems favor perennial weeds; however, with true no-till the weeds spread slowly.

In reduced tillage, field cultivators and similar implements tend to drag roots and rhizomes around the field where they can establish new colonies.

With more intensive conventional tillage, roots and rhizomes are cut into smaller segments. These small pieces produce smaller, weaker plants.

In either conventional-till or no-till wheat production, broadleaf weeds emerging in the spring can be controlled with additional herbicides. The stage at which winter wheat is treated with growth regulator type herbicides is critical if crop damage is to be avoided.

This growth stage has been described for many years as “after fully tillered but before jointing.” But the criterion of “fully tillered” has proven to be an inadequate guide with respect to gaging the safest growth stage of wheat.

This is a stage of growth when the wheat plant is most tolerant to herbicides. A more suitable criterion is based on the longest leaf sheath length on the main shoot, measured from the soil surface to the upper-most ligule. When the length of this leaf sheath exceeds 2 inches, measured from the soil surface, but is less than 4 inches, wheat has reached the stage in

Table 4. Common weeds and life cycles found in wheat grown in Missouri.

Weed	Life cycle
Italian ryegrass	Annual grass
Wild oat	Annual grass
Yellow foxtail	Annual grass
Downy brome	Annual grass
Cheat	Annual grass
Carolina geranium	Annual broadleaf
Chickweed	Annual broadleaf
Common ragweed	Annual broadleaf
Common waterhemp	Annual broadleaf
Common lambsquarters	Annual broadleaf
Cornflower	Annual broadleaf
Field pennycress	Annual broadleaf
Wild buckwheat	Annual broadleaf
Wild mustard	Annual broadleaf
Giant ragweed	Annual broadleaf
Henbit	Annual broadleaf
Kochia	Annual broadleaf
Pennsylvania smartweed	Annual broadleaf
Redroot pigweed	Annual broadleaf
Vetch	Annual broadleaf
Curly dock	Perennial broadleaf
Field bindweed	Perennial broadleaf
Canada thistle	Perennial broadleaf
Johnsongrass	Perennial grass
Wild garlic	Perennial monocot
Wild onion	Perennial monocot

its development that is most tolerant to growth regulator herbicides.

This stage is often reached when the wheat plant has six leaves unfolded on the main shoot. However, it is more accurate to measure the longest leaf sheath length than to count the number of leaves.

An objective determination of "jointing" can be made by counting the nodes that can be seen or felt aboveground within the leaf sheath surrounding the main stem.

The first node (beginning of jointing) can usually be found by gently squeezing the leaf sheath of the main shoot above its base between thumb and finger when the leaf sheath measures 4 to 4.5 inches from the soil surface to the uppermost ligule.

Herbicides applied before the leaf sheath of the main shoot is 2 inches long or after the first node is detectable can disrupt the formation of the normal seedhead, resulting in deformed heads and unfilled grain at harvest.

The time span in which these herbicides can be safely applied to the spring or winter wheat is relatively short - about 2 weeks.

Table 5 outlines wheat growth stages and susceptibility to injury caused by growth regulator herbicides. Consult MU Publication MP575 "*Weed Control Guide for Missouri Field Crops*" for more specific information on herbicide selection.

Perennial broadleaf weeds are controlled with herbicide applications in the crop or at harvest. Several herbicides are labeled for preharvest application at hard dough (30 percent grain moisture) as harvest aid treatments. There must be at least 8 to 12 inches of actively growing weed shoot to obtain good herbicide contact.

Consult MU Publication G4875 "*Control of Perennial Broadleaf Weeds in Missouri Field Crops*" for more information on perennial weed control in row crops.

Table 5. Wheat response to growth regulator herbicides.

Growth stage	Wheat response
Seedling plants	Killed
Fully tillered	No injury
Jointing	Injury
Heading	Injury
Flowering	Injury
Soft dough	Injury
Hard dough	No injury

Insects

Armyworm (true)
Pseudaletia unipuncta

Dense fields of small grains or grasses are common infestation sites for this pest. Adults lay eggs in early spring, and larvae emerge and feed on available vegetation. Tall fescue seed fields are generally first attacked, followed by wheat fields when armyworm populations reach outbreak levels.

Larvae feed on plant foliage, but can feed on or cut off developing grain heads. They often move in mass from field to field as the food supply is depleted. Years of cool, wet weather favor armyworm development. Several insecticides are effective controls.

Cereal leaf beetle
Oulema melanopus

First found in the St. Louis area in the early 70's, this pest has steadily moved westward and can now be found in most Missouri counties.

Adult beetles overwinter in protected areas around and in crop fields. In early spring, they move to small grain fields to mate and lay eggs. Oats are the preferred host if available; but, wheat also serves as the primary host.

Damage is caused by slug-like larvae which crawl and feed the length of the flag leaf of small grain plants. Larval feeding removes the green tissue and leaves a plant surface that is skeletonized and appears frosted or silver in color. However, in wet years, larval mortality may occur when larvae are washed from plants by heavy rainfall.

Economic levels of larvae can be managed with insecticide applications. The use of biological agents for control of this pest are being investigated.

Chinch bug
Blissus leucopterus l

Chinch bugs occasionally require control in small grains. Although most years, a fungal pathogen keeps their numbers low. Occasionally, numbers will build to levels where wheat and other small grain plants will show signs of wilting. When this occurs, treatment may be warranted.

Greenbug *Schizaphis graminum*
Bird cherry-oat aphid *Rhopalosiphum padi*
English grain aphid *Sitobion avenae*

Greenbugs are the most common and damaging species of aphid found on Missouri wheat, although all three species are often present on the same plant.

The greenbug is the most serious pest because its saliva contains a toxin which stunts plant growth and reduces yields. The other species of aphids are minor pests which cause damage when plants are drought stressed.

The bird cherry-oat aphid may transmit barley yellow dwarf virus to wheat if they have fed on infected alternative plant hosts.

The thirteen-spotted lady bird beetle is responsible for control of most aphid infestations in wheat. This beneficial insect readily feeds on aphids and generally keeps populations to below threshold levels.

Insecticide treatments are warranted if an average of 100 or more aphids are present per linear foot of row in early spring before plants joint or when discoloration becomes prominent on small areas of foliage.

Hessian Fly
Mayetolia destructor

This pest of small grains produces 2 generations annually. Maggots from the first (fall) generation are the most damaging as they use rasping-sucking mouthparts to feed on tissue of the plant crown.

Damaged plants are often stunted and may die if feeding damage is severe. Plants that survive generally produce reduced yields and often lodge, causing harvest losses. Individuals of the second (spring) generation of Hessian fly are often heavily parasitized and seldom cause problems.

Resistant varieties, planting after “fly free dates” and elimination of volunteer wheat growing during early fall will help reduce the problem. Use of planting- time insecticide applications may be needed in fields where severe problems from this pest occur annually.

Diseases

Winter wheat grown in Missouri may be subject to seedling diseases, foliage diseases, root and crown rots, virus diseases and head diseases.

For more detailed information on wheat diseases and their management see MU Publication M160 “*Insect and Disease Management: Field Crops, Forages and Livestock*.”

Seedling diseases

There are a number of soil-borne and seed- borne pathogens which can cause seedling diseases in wheat. Seed may be rotted prior to germination, or developing seedlings may be infected before or after emergence. Root and crown tissue may be brown to black in color and seedlings may yellow, wilt and die.

Seedling diseases tend to be more severe if poor quality or diseased seed is used and if conditions at planting are not favorable for quick germination and stand establishment.

Management of wheat seedling diseases should include the following:

- Planting good quality, disease free seed under good seedbed conditions
- Using a fungicide seed treatment

Foliage diseases

Many different fungi and bacteria can cause wheat foliage diseases. These pathogens cause a wide range of leaf spots, leaf blights and similar symptoms.

Foliage diseases that can cause significant injury include; Septoria leaf blotch, Stagnosporaglume blotch, tan spot, leaf rust, stem rust and powdery mildew.

The fungi survive in infested wheat residues left on the soil surface. The next growing season, spores are produced during moist periods and are carried by wind currents to susceptible wheat leaves.

Disease problems tend to be more severe when wheat is planted in fields with wheat residue left on the soil surface.

Eventually, spores that are produced in initial lesions are wind blown to other leaves or other plants causing secondary infection.

Leaf rust and stem rust are two exceptions to this simplified explanation of disease development. The rust fungi do not survive in infested residue and, in fact, do not survive the winter months in this area at all. Rather, the rust fungi are reintroduced into this area each season when spores are carried on air cur- rents from southern states. Most diseases favor warm, wet or humid weather.

Frequently, infection begins on the lower portion of the plant. And in favorable weather conditions, the disease moves up the plant. Yield losses tend to be highest when the flag leaves are heavily infected.

Management of foliage diseases of wheat should include the following:

- Planting varieties with resistance to diseases likely to occur in your area
- Rotating with non-host crops
- Managing residues
- Planting disease free seed
- Maintaining good plant vigor with adequate fertility
- Using foliar fungicides if warranted

Root and crown diseases

Several soil-borne fungi can cause root and crown diseases of wheat. Affected plants may be stunted, less vigorous, yellow, wilt and die prematurely.

Dead plants may have a bleached or white appearance. And when affected plants are dug up, root systems are poor with roots and crown tissues discolored and deteriorated.

Take-all is one of the more common root and crown rot diseases in Missouri wheat. The fungus which causes this disease infects seedlings in the fall. Symptoms are usually most evident after heading when infected plants turn a bleached white and die prematurely. Plants with take-all usually have poorly developed root systems and a shiny black discoloration of the lower stem or culm.

This disease is more severe in wet soils, but in wet yea s it may occur in better drained soils. It may become more severe the more frequently wheat is in a rotation and if plants are suffering from inadequate fertility.

Management of root and crown diseases should include the following:

- Planting good quality seed of adapted, disease resistant varieties
- Rotating with non-host crops
- Using seed treatment fungicides
- Planting in well drained sites under good seedbed conditions
- Maintaining plant vigor with adequate fertility

Virus diseases

Barley yellow dwarf, wheat streak mosaic, soil-borne mosaic and wheat spindle streak are found in low levels throughout Missouri in most years but may be severe in some years.

These virus diseases tend to cause stunting of plants and discoloration of leaf tissue ranging from a green to yellow streaking or mosaic to a yellowing or reddening of individual leaves from the leaf tip in.

Many virus diseases are vectored or spread from diseased to healthy plants by certain insect species. Some of these viruses can also infect other grain crops and weed grasses.

Volunteer wheat may also serve as a reservoir for the viruses and serve as a source of inoculum for later wheat crops.

Management of virus diseases of wheat should include the following:

- Planting good quality seed of resistant varieties
- Rotating crops
- Destroying volunteer wheat and controlling weed grasses
- Maintaining good plant vigor with adequate fertility.

Head diseases of wheat

Diseases such as smuts, bunts and scab affect primarily the head of the wheat plant.

Smut and bunt diseases such as stinking smut or loose smut tend to replace the normal kernels in the head with galls that contain masses of powdery black spores.

Loose smut is very obvious as heads emerge from the boot. All portions of the head except the **rachis** are converted to masses of dusty black spores. These spores are eventually dislodged by wind and rain. So later in the season, the smutted stems are less evident.

Stinking smut (also called covered smut) is not as obvious. The kernels are covering the smut gall remains intact. At harvest, the pericarps are broken releasing clouds of dark spores.

Management of smut and bunt diseases should include the following:

- Planting disease free seed
- Using a systemic fungicide seed treatment

Confirm presence of mycotoxins

Contact the Veterinary Medical Diagnostic Laboratory:

D105 Vet. Med. Diag. Lab.
University of Missouri
Columbia, MO 65211
(573) 882-6811
FAX (573) 882-1411

Scab is caused by the fungus, *Fusarium graminearum.* Corn and sorghum, as well as, the small grains are hosts for this pathogen.

It can survive in infested residues including corn residues and wheat stubble and on wheat seed. On wheat, infection usually occurs through the flowers. Warm, wet conditions during flowering favor the development of scab in wheat.

Developing wheat heads may have single infected spikelets, groups of infected spikelets or the entire head may be infected. Infected spikelets tend to have a bleached white appearance. Careful examination of these bleached areas of the head may reveal tufts of pink, orange or salmon colored mold growth that is characteristic of the scab fungus.

An additional concern with wheat scab is the possibility of mycotoxin production in the infected grain.

Mycotoxins are naturally produced chemicals which in small amounts may be deleterious to animal or human health.

Swine and poultry may refuse to eat grain containing high levels of it. In cases where mycotoxin problems are suspected, a sample should be submitted to a qualified laboratory for mycotoxin analysis.

Management of wheat scab should include the following:

- Planting adapted varieties with tolerance to scab
- Rotating to non-host crops
- Managing residue
- Planting disease free seed (If planting seed from a field which had scab, clean seed thoroughly before planting and use a fungicide seed treatment.)

Forages and Pastures

Weeds

Annual and perennial broadleaf and grass weeds can become a serious problem unless proper management is practiced. Weeds interfere with forage and pasture crops by reducing the longevity and nutritional value of the crops.

Controlling weeds improves the quality of forage legumes since most weeds are lower in protein and less palatable to livestock. In addition, certain weeds are poisonous to livestock and can become a problem when pastures are overgrazed.

Goo d management practices that encourage a vigorous, thick stand of pasture or forage legumes are important for optimal weed control. Weed seeds germinate and become established wherever pasture or forage stands are thin.

Maintaining optimum soil fertility and p H gives the pasture or forage crop a competitive advantage over weeds. Additionally, rotational grazing and periodic mowing enhances the ability of grass to compete with most annual weeds.

Establishing and maintaining vigorous forage stands by using well-adapted, long-lived varieties, wee d-free see d, proper seedbed preparation and timely cutting reduces weed problems.

Deep rooted, broadleaf perennial weeds are a common problem in pastures and forage crops. Crop rotation with cultivated crops can reduce some perennial weed problems.

Herbicide application timing varies with the weed species. Annual and biennial weeds (1 and 2 year life cycles) are easier to control when they are young.

A fall or early spring application is usually best for winter annuals or for biennials in the rosette stage.

Spring and early summer treatments are best for summer annuals. Established perennials are most susceptible in the bud to bloom stage, or in the fall when foo d reserves are moving into the root s.

Spray woody brush species when they are fully leafed out and actively growing. Multiple applications are usually needed to obtain complete control of perennial weeds.

The use of herbicides without goo d cultural control practices will generally give poor weed control. The forage stand won't be able to fill in areas left empty before new weeds can become established. Use herbicides only where the pasture grass or forage stand is thick and vigorous enough to fill in the areas where weeds are killed.

Consider reestablishment if forage stands are sparse. Forage legumes are frequently grown with a companion crop such as orchardgrass. However, most herbicides registered for use in forage legumes will severely injure or kill a companion crop.

Be sure the herbicide is registered for both forage species before use. If the weed problem is severe, reestablishment may be necessary.

Established hay crops such as alfalfa, clovers and alfalfa-grass mixtures are relatively competitive during the growing season so weeds tend to invade during the winter dormant period and immediately after cutting.

Herbicide selection problems are encountered when a legume is mixed with a perennial grass.

Consult MU Publication MP581 *"Weed and Brush Control Guide for Forages, Pastures, and Non-Cropland in Missouri"* for more detailed information on herbicide selection.

Insects

The alfalfa weevil and potato leafhopper are the two most damaging insects of alfalfa in the state of Missouri.

The alfalfa weevil is a pest of first cutting alfalfa and the potato leafhopper of second and later alfalfa cuttings.

Problems from alfalfa weevil are more severe in southern Missouri where eggs are laid and hatch over a long period of time. Often, producers must treat twice for control. Biological control agents are growing in importance for their use in managing this annual pest.

Potato leafhopper problems are more sporadic, but depend greatly on spring winds and thunderstorms which transport this insect northward from overwintering sites in the gulf coast states. Few biological control agents are available for use on this pest in alfalfa.

Alfalfa weevil
Hypera postica

Problems with this pest are more severe in southern Missouri where eggs often hatch over a several week period. In northern counties, the egg hatch is confined to a few weeks.

Small larvae feed on the new growth terminals causing pin hole damage. They also skeletonize leaves, while larger larvae move downward on the plant to feed on older foliage. Heavily damaged fields can be stripped of leaf material causing the field to take on a “frosted” or grayish appearance.

Alfalfa producers should begin scouting fields in early March in southern Missouri and April for northern parts of the state.

If an average of one larva or more are found per alfalfa stem and 30 percent of the plants show feeding damage, treatment is warranted. Producers should pay special attention to south facing slopes because eggs often hatch first in these areas.

Three species of small parasitic wasps and a fungal pathogen are increasing in importance as control agents for this pest.

Many producers who have managed for greater numbers of beneficial insects are now experiencing less severe or fewer problems from the alfalfa weevil. Numerous insecticides are labeled for control of alfalfa weevil on alfalfa, but must be used selectively if beneficial insect populations are to be conserved and enhanced.

Potato leafhopper
Empoasca fabae

The potato leafhopper is a migratory insect which migrates into Missouri each spring to infest second and third cutting alfalfa.

Adults and nymphs possess piercing-sucking mouthparts that are used to suck plant juices from the leaves and stems. Mechanical damage results in alfalfa plants that form yellow v-shaped markings on leaf tips and stunted growth.

Both alfalfa quality and yields are reduced. Heavily infested fields will often develop a characteristic yellow appearance or cast.

Scouting for potato leafhopper should begin after removal of the first cutting and continue through the removal of the third cutting. Leafhopper numbers are best monitored with a sweep net.

The economic threshold for potato leafhopper varies depending on height of the alfalfa plants. Shorter plants are more susceptible than taller plants. Thresholds range from 0.2 leafhoppers per sweep on 3-inch or shorter alfalfa up to 2 leafhoppers per sweep on 12 inch or taller alfalfa.

Several insecticides are labeled for control of potato leafhopper on alfalfa.

Occasional alfalfa insect pests:

- pea aphids
- spotted alfalfa aphids
- blue alfalfa aphids
- variegated cutworms

Striped blister beetle
Epicauta vittata

Although this insect causes minor defoliation damage to alfalfa, it is an important pest because of its potential of being lethal to horses feeding on infested alfalfa hay.

Several species of blister beetles can be found in second and later cuttings of alfalfa hay in Missouri. The striped blister beetle is the most common and the most toxic of the blister beetles. It contains a toxin called cantharidin. This toxin is very stable and is found in both living and dead beetles. It has been found that as few as 25 - 100 blister beetles consumed over a 24-hour period can kill a horse.

This beetle can be found in large groups in alfalfa and soybean fields. Because immature blister beetles feed on grasshopper egg pods, beetle numbers are often higher in years following high grasshopper populations.

Scouting for this pest is an essential step in management of this pest. If they are found, it is recommended that this alfalfa not be used as horse feed. Although the risk of infestation cannot be eliminated from a field, several actions will result in reduced risk: (1) Producers should only use first cuttings as horse feed. Because of their life cycle, they rarely emerge as adults until after first cutting alfalfa has been harvested in Missouri. Although all hay should be checked for the presence of blister beetles when fed to horses. (2) Harvest alfalfa at the recommended 1⁄10 bloom stage or earlier. Blister beetles are attracted to flowering plants and cutting at 1⁄10 bloom will reduce the attractiveness as a possible food source. (3) Keep weeds out of alfalfa fields. Flowering weeds also attract the beetles. (4) Use harvesting equipment that does not crush the alfalfa stems and kill any beetles that may be present in the forage. Most problems with blister beetles occur in fields where hay conditioners are used and the beetles are killed before they can escape. (5) Do not run tractor and equipment tires over windrows of hay. This can cause the death of beetles in the hay and increase the risk of poisoning. (6) Scout fields and apply an insecticide treatment if necessary.

Alfalfa, in which blister beetles have been found, should be used for livestock (not dairy) other than horses. Although other livestock can be affected by cantharidin, most are sublethal effects which do not generally cause death unless very high numbers of beetles are consumed.

These recommendations will not eliminate the risk of blister beetle poisoning to horses, but will help reduce the risk.

Diseases

The principle diseases of alfalfa can be divided into seedling diseases, foliage diseases, crown and root rots and wilt diseases.

For more detailed information see MU Publication M160 "*Insect and Disease Management: Field Crops, Forages and Livestock*."

Seedling diseases

Several different soil-borne fungi can cause damping off of alfalfa seedlings. Stems of infected seedlings rot and collapse either before or just after emerging. Seedling diseases tend to be more severe when cool, wet weather follows seeding.

Management of seedling diseases of alfalfa should include the following:

- Planting varieties with resistance to Phytophthora and other seedling diseases
- Planting good quality seed of adapted varieties
- Using a fungicide seed treatment
- Planting under good seed bed conditions

Foliage diseases

There are at least eight leaf and stem diseases that can occur on alfalfa in Missouri. These diseases cause a variety of different lesions types on leaflets and in some cases on petioles and stems as well.

Most are caused by fungi which survive on infested plant tissue. And, most favor cool to moderate temperatures and wet or humid conditions.

When foliage diseases are severe, leaves on infected plants yellow and drop prematurely. Foliage diseases can reduce plant vigor, reduce yields from stands and can reduce quality of harvested hay.

Management of foliage diseases of alfalfa should include the following:

- Planting adapted varieties with resistance to diseases likely to occur in your area
- Cutting hay in late bud and early bloom stage before diseases become severe (This will reduce losses and prevent infected leaflets from building up in lower canopy of plants.)

Root and crown rots

Many different soil fungi can cause decay of alfalfa roots and crowns. In some cases, aggressive pathogens cause extensive damage to infected plants, while in other cases the pathogens develop in combination with other stresses such as winter injury.

Plants infected with root and crown rots may be less vigorous, appear stunted, turn yellow or red, wilt and die. When infected plants are dug up, the root systems are quite poor and the taproots show brown to black lesions. In severe cases, the taproot may be completely rotted.

These rots are more likely to occur in poorly drained sites and on heavy soils. Wet conditions and stress from winter injury, mechanical injury to crowns, etc. may also increase incidence and severity of root and crown rots.

Management of alfalfa root and crown diseases should include the following:

- Planting adapted varieties with resistance to diseases and with sufficient winter hardiness
- Planting in soil with good surface and internal drainage
- Supplying adequate balanced fertility
- Controlling insect infestations
- Avoiding damage to crowns
- Harvesting on a schedule that maintains plant vigor especially at last cutting in the fall

Wilt diseases

There are several very serious wilt diseases including bacterial, Fusarium and Verticillium. With these types of vascular wilt diseases the causal pathogen is blocking water conducting tissues within the plant leading to the characteristic wilting of the plant.

Other symptoms include discoloration of foliage, stunting of plants, discoloration on internal stem and taproot tissues and eventual death of portions of the plant or the entire plant.

Management options for wilt diseases of alfalfa should include the following:

- Planting disease resistant varieties
- If a field has been plowed because of a wilt disease, rotating to another crop until the old roots and crowns are thoroughly decomposed
- Maintain good plant vigor by proper fertilization, insect control and timely harvests

Fruit

Weeds

Application of contact herbicides in established orchards after weeds have emerged provides control at time of treatment. The addition of soil-active herbicides can provide season-long control. Some orchardists prefer to use only nonselective herbicides and reapply during the growing season.

Perennial weed species can be particularly troublesome in established orchards due to the lack of soil disturbance which allows their establishment and spread. A nonselective herbicide is the best option for their control.

Select herbicides that are effective against weed species that are present. In some cases, combining two soil- active herbicides will provide a wider spectrum of control. Most satisfactory weed control occurs when at least two soil-active herbicides are combined with one nonselective.

Ground cover management is an important factor in determining fruit tree vigor and yield. Maintaining young fruit trees, especially those on less vigorous root stocks, free of competition from weeds and sod results in more tree vigor. Trees maintained in weed-free conditions produce more fruit - a result of increased fruit set and fruit size.

Thus, orchardists tend to maintain a weed-free area in the tree row and a sod or cover crop in the alleyway to support vehicle travel and control erosion.

Orchardists depend primarily on herbicides to control most weeds growing in the tree row. Successful management frequently requires a combination of weed control practices that are rotated every several years. This requires knowledge of major weed species, their density and infested areas in the orchard. Beneficial cultural practices include mowing and fertilization of low vigor sods to prevent weed encroachment.

Resistance to Herbicides

Continuous use of the same herbicide for many years can result in weeds developing a resistance to that particular herbicide or infestations of weed species resistant to that herbicide. Long-term planting sites where crop rotation is not an option, such as orchards, are a potentially suitable site for such an occurrence. Rotate herbicide usage from year to year to help prevent such an occurrence.

Insects and mites

A wide array of insects occur in orchard situations; however, only a small portion of these would be considered pests. Many of these insects have functions that are beneficial, such as decomposers, pollinators and natural enemies of pest species.

Often, more than one type of control method can be used to effectively manage any pest, such as biological control or the use of selective insecticides (insecticidal soap or Bt).

There are five steps to effective insect management: (1) proper identification of key pests and beneficial organisms; (2) regularly monitoring pest populations; (3) determining the potential for economic loss from the pest; (4) proper selection of a pest control tactic, such as biological, cultural or chemical; and (5) evaluation of control option used.

For additional information including insecticide recommendations, consult MU Publication M161, "*Insect and Disease Management - Horticultural Crops and Structures*."

Scale insects
Coccoidea spp.

Several species of scale insects infest orchards in Missouri. Young scales winter on the bark and become active when trees bloom. In most species, the female deposits eggs under her shell or scale. When they hatch, "crawlers" move away from the maternal scale to locate new feeding sites.

They feed by sucking sap from trees and are capable of killing parts or the entire tree. Scale insect feeding can also reduce tree vigor, making it more susceptible to drought, severe winter, attack by other insects or infection by diseases.

Insecticidal control is achieved at two different times of the year. Horticultural oils may be applied in the dormant season to smother overwintering scales and/ or eggs, or an insecticide may be applied when the crawlers are active. Since insecticides don't penetrate the waxy scale covering, spraying must be timed to coincide with the presence of the crawlers. Repeated applications may be necessary to kill crawlers if there are multiple generations over the growing season.

Aphids
Aphididae spp.

Few plants exist that are not host to one or more aphid species. Like scale insects, aphids obtain their food by sucking sap from plant tissue.

Aphids are small (seldom over $\frac{1}{8}$-inch in length), soft-bodied, pear-shaped insects of many colors, such as green, black, gray or red. Most aphids attack in masses, preferring young shoots or leaves.

The feeding of large numbers of aphids can cause serious damage by (1) robbing plants of sap, (2) the toxic action of their salivary secretions injected during feeding, and (3) serving as vectors of viruses which cause plant diseases.

Aphid damage stunts growth, deforms leaves and fruit, or causes galls on leaves, stems and roots. Many aphids excrete a sticky substance known as "honeydew." This material falls onto the plant and a black, sooty mold soon begins to grow. This mold not only mars the appearance of the plant, but also restricts vital plant functions, such as **photosynthesis**.

Much variation is found in the biology of aphids; however, there are certain general biological facts that may be applied to the group as a whole. Aphids usually reproduce without mating and give birth to living young.

Species of aphids are usually rather restricted to specific host plants, feeding on a group of related plants. Aphids are frequently kept in check by natural forces, primarily adverse weather conditions, such as beating rains and extreme temperatures; fungus diseases; and naturally occurring insect predators and parasites. Natural insect enemies of aphids are lady beetles, syrphid fly larvae, lacewing larvae and small wasp parasites known as Braconids.

Spider mites
Tetranychidae spp.

Several mite species cause the plants to become an off-green color as a result of sap sucking. Severely infested plants lose their vigor and may die.

Mites are close relatives of insects, except they only have two body regions, no antennae and the adults have eight legs.

The two-spotted spider mite is one of the better known mites and is often called the common red spider mite. It feeds on the lower surface of leaves by sucking sap. Infested leaves become stippled with gray and may be covered with strands of silken webs. This mite overwinters in protected places (soil, debris, etc.) and are bright orange in color; whereas during the summer are usually cream to green color with two dark spots on their backs. The life cycle is only about two weeks. Thus, a mite population may build rapidly.

In general, cool, humid and rainy weather will hold mite populations down to nondamaging levels so that no control measures are needed. Hot, dry weather is ideal for their development. If natural enemies fail to reduce mite populations below damaging levels, miticide (acaricide) sprays will likely be needed. One should consider rotation of products (pesticide classes) to reduce the development of pesticide resistance.

Codling moth
Cydla pomonella

This serious pest overwinters as a full-grown larva. The caterpillar is one inch in length and pinkish-white in color and it overwinters inside a cocoon under loose scales on apple tree bark or other sheltered places. Adults emerge in May and June and eggs lay on or near clusters of apples. Larvae enter the apple at the blossom end or through the side of the apple.

Timing is very important in controlling this pest. Preventative sprays for control should begin 14 to 21 days after full bloom. The use of sex pheromone traps and the calculation of degree days can provide the proper time on when to spray.

Plum curculio
Conotrachelus nenuphar

The plum curculio is a native pest that will feed and reproduce on many fruits, including plum, peach, apple, grape, cherry and blueberry.

The adult beetle overwinters in debris in wooded areas adjacent to host plants. Then they emerge from hibernation near the end of blueberry bloom. Females deposit their eggs in the green fruit, usually one egg per fruit in blueberries.

A characteristic crescent-shaped scar is made on the surface of the fruit at the **oviposition** (egg-laying) site. The white, legless larvae burrows into the center of the fruit where it feeds until it is mature. Mature larvae leave the fruit and pupate in the soil and mulch under the plant.

Because the plum curculio is a pest of a wide array of fruits and insecticide recommendations vary dependent on the crop, consult MU Publication M161, "*Insect and Disease Management - Horticultural Crops and Structures*" for specific recommendations.

Diseases

Most fruit crops are subject to diseases at some time. Cultural and nonchemical practices help keep diseases under control. Resistant varieties offer another way to avoid diseases.

However, when these methods fail, there are available chemicals which are safe and effective.

For greater detail of chemical rates and application methods, see MU Publications M161, "*Insect and Disease Management - Horticultural Crops and Structures*," MP651, "*Missouri Commercial Fruit Tree Spray Guide*" and MX376, "*Missouri Small Fruit Pest Management Guide.*"

Also, Southwest Missouri State University publication MS-19, "*Missouri Commercial Grape Pest Control Guide*" is available from the State Fruit Experiment Station, Mountain Grove, MO 65711-9201.

Fruit diseases can be divided into two groups - **biotic diseases**, which are caused by living organisms, and **abiotic diseases**, which are caused by non-living agents. Most biotic diseases in Missouri are caused by fungi; however, some serious diseases are also caused by bacteria, nematodes and viruses.

On the other hand, abiotic diseases are non-infectious. They are caused by cultural or environmental conditions rather than by living organisms.

They can be caused by extreme temperatures, lack or excess of soil moisture, lack of oxygen, nutrient imbalances, unfavorable soil pH, pesticide toxicity and many other factors.

Scab

Scab is a serious and widespread disease of apples. It is characterized by small, dark, circular, olive to black spots on foliage, fruits and nuts. These spots may fuse to form large blackened areas. Severe infections will defoliate an entire plant. The loss of infected leaves weakens the plant.

Apple fruits can develop spots that resemble leaf spots when young but they then become brown and corky with age. The disease is most severe when high humidity and moderate temperatures occur during spring and early summer. Given wet plant surfaces and available spores, infections occur at temperatures from 36^{o}F to about 79^{o}F.

Fungicide applications should be made when swollen flower buds show a half inch of green tissue. Applications should continue as needed to protect the plant throughout the blooming period, whenever dew or rain threatens to wet leaves for a six-hour period.

Rusts

Cedar apple rust is the most prevalent of the rust diseases that affect Missouri fruit crops. As in many other rust diseases, the fungus that causes cedar apple rust has alternate hosts. It spends part of its life cycle infecting one type of host plant, the apple, and the rest of its cycle infecting another host plant, red cedars and junipers.

On apples, the first symptom is the development of small, bright yellow to orange spots on upper leaf surfaces during the spring. By midsummer, these spots have expanded into conspicuous, bright yellow spots with red borders.

Meanwhile, the fungus has grown through the leaf blade; when it emerges on the underside of the leaf, it produces spores that are carried by wind to red cedars and junipers. These spores cause new infections on susceptible red cedars and junipers. Although not practical, all cedars within two to three miles of apple trees should be removed. Fungicide sprays should begin at the pink bud stage.

Powdery mildew

Powdery mildew is one of the easiest plant diseases to identify. It occurs on leaves, flowers, shoots and fruit. On leaves, lesions first appear as whitish felt-like patches of fungus, most commonly on the lower leaf surface.

It commonly occurs on apple trees and can cause dwarfing, distortion and chlorosis of leaves. In some cases, fruit may be dwarfed.

This mildew is observed in the spring and fall, because spore production and infection are favored during cool, humid and cloudy conditions. The disease is usually more severe in shaded areas with poor air circulation and high relative humidity.

The fungus overwinters on living, infected plants and in the spring spores become airborne. Fungicide sprays should begin at third cluster.

Peach leaf curl

Infected leaves are thickened, puckered and often flushed with red or purple. It can result in severe defoliation, weakened trees, reduced fruit quality, set and yield. In addition to bearing plantings, leaf curl should be controlled on young trees or trees with no crop. Fungicide sprays should be applied after leaves fall but before bud swell in the spring.

Bacterial spot

This bacteria infects leaves, fruit and tender growing shoots. It can cause severe defoliation and fruit spotting of peaches. Leaf lesions are small and generally angular; and appear water soaked initially. As they mature, the centers of the spots fall out, and the margins have a reddish coloration. Severely infected leaves turn yellow and fall to the ground.

Fruit infected early in the season develop cracks in the skin and lesions can extend into the flesh, resulting in deep pits. Bacteria are often splashed from the soil onto wet foliage, where they enter a leaf through **stomates** or wounds. Antibiotic sprays are used to help control bacterial spot.

Fire blight

Fire blight is a bacterial disease which can cause devastating losses in apple orchards. Early in the season, fire blight may appear as a blossom blight. But as the disease progresses, a typical shoot blight develops.

The shoot tip curls, giving the branch a shepherd's crook appearance. Often, the leaves as well as twigs of these blighted branch tips turn dark brown or black.

Then the disease moves into leaves through the petiole and main veins and eventually kills the entire leaf. Fire blight cankers often move into supporting lateral branches, eventually girdling, wilting and killing the entire branch. Fruit may also be affected, developing brown to black areas of decay.

During warm wet weather, blighted tissues may develop droplets of sticky liquid or ooze containing vast numbers of bacteria. These droplets, and the disease, are spread rapidly by splashing rain. Fire blight bacteria survive the winter in cankers on larger branches or in the main trunk of the tree.

Various chemical sprays help in a fire blight control program. Depending on the material used, sprays may have to be repeated on a four- to five-day interval.

Vegetables

Weeds

Most vegetable herbicides are first registered for use on major field crops. Their use on vegetable crops annually is insignificant compared to the use on field crops. For this reason, it is usually cost prohibitive for a manufacturer to specifically develop a herbicide for vegetable use that is grown on only a few hundred thousand acres annually.

Compared to the major field crops, there are relatively few herbicides registered for use in vegetable crops. Most residual herbicides used in vegetables today are also used in field crops. These products may be lost to vegetable growers if the product can't remain competitive in the field crop pesticide market.

A recent example is Amiben. Amiben could not compete with less expensive and more effective soybean herbicides; consequently, it was lost from the market.

There have been many recent successes in the field of genetic crop engineering. Making vegetable crops resistant to nonselective herbicides would offer weed management alternatives to vegetable producers. Research has shown promise with some vegetable crops as well. Although this may not occur rapidly because of the cost factor, it does show potential.

Weed control in vegetable crops is more of a premium concern as compared to row crops. Like row crops, vegetables also have critical weed-free periods; these may range from four to nine week after crop emergence.

However, some vegetables are harvested using hand labor. Also, the relative high value of these vegetable crops places more of a premium on weed control. Typically, a residual herbicide is applied prior to or immediately following planting and postemergence weed control is achieved by hand and mechanical cultivation.

There are very few currently registered herbicides for postemergence weed control in vegetable crops. Because a postemergence herbicide may be labeled for use in a field crop, does not mean that it is approved for use in a vegetable crop. Consult the label prior to making a control decision.

Most of Missouri's commercial vegetable production occurs in the southeastern and southwestern portions of the state. Although not produced extensively, potatoes, southern peas, green beans, tomatoes, sweet corn and popcorn and cucurbits are among vegetable commodities commercially produced in Missouri. Because these are annual crops, often tilled several times per season, annual weeds tend to be the most common weeds encountered (Table 6).

Table 6. Common weeds and life cycles found in vegetables grown in Missouri.

Weed	Life cycle
Barnyardgrass	Annual grass
Fall panicum	Annual grass
Giant foxtail	Annual grass
Crabgrass spp.	Annual grass
Goosegrass	Annual grass
Common cocklebur	Annual broadleaf
Common ragweed	Annual broadleaf
Giant ragweed	Annual broadleaf
Common lambsquarters	Annual broadleaf
Pigweed spp.	Annual broadleaf
Jimsonweed	Annual broadleaf
Pitted and ivyleaf morningglories	Annual broadleaf
Pennsylvania smartweed	Annual broadleaf
Puncturevine	Annual broadleaf
Velvetleaf	Annual broadleaf
Carpetweed	Annual broadleaf
Common purslane	Annual broadleaf
Nightshade spp.	Annual broadleaf
Johnsongrass	Perennial grass
Yellow nutsedge	Perennial segde

Insects

Insects are the most abundant form of animal life on earth. There are far more species of non-destructive and beneficial insects than there are pests. It is not often that even populations of pest insects reach economically damaging levels in vegetable production.

Although many of the older and more traditional insecticidal chemicals are used for insect control, there have been many recent developments of biological pesticides. These are mimics of or are produced from biological systems and have generally been easily registered through the EPA. These newer class of pesticides are produced from systems such as soil organisms, naturally occurring fungi, bacteria; while some are insect growth regulators.

There are several concepts that are important to understand in a vegetable production system regarding the use of insecticides.

Some insect and mite populations have become resistant to once effective and widely used insecticides. Their inappropriate use may deplete the population of beneficial insects, such as parasitic or predatory insects, mites and honeybees, which are important as pollinators.

There are rigid use restrictions regarding insecticide application in vegetable production systems. Depending upon the commodity and insecticide used, the **pre-harvest interval** is a concept to keep in mind. Some of these waiting periods can be relatively lengthy.

Additionally, there are application restrictions with most of these compounds as far as the number of applications to be made in a single growing season and the total amount of pesticide which may be applied to a given site per growing season. Carefully consult labels of these products prior to making a control decision.

Because of Missouri's vegetable crop diversity and the vast number of available insecticides, consult MU Publication M161, "*Insect and Disease Management - Horticultural Crops and Structures*."

Aphids
Aphididae spp.

Aphids attack all vegetable crops. Damage results in curled and distorted leaves and stunted plants. They may also spread plant viruses through their feeding actions. Their presence may be detected by colonies of small, soft-bodied, usually green insects on leaves. Honeydew and black, sooty mold may be present.

Bean leaf beetles
Cerotoma trifurcata

Adult beetles are 1⁄4-inch long and reddish-yellow with black spots on their backs. They hibernate during the winter and attack bean plants in the spring.

Eggs are laid in the soil around bean plants and when hatched they feed on the roots. Pupation takes place in the soil. There are two generations per season.

Cucumber beetles
Galerucinae spp.

Like bean leaf beetles, these insects hibernate during the winter and have two generations. There are several species of cucumber beetles which attack cucurbits in Missouri: spotted and striped. Both emerge in the spring to feed on pollen and leaves of many plants until cucurbit plants are available. Beetles then feed on stems, leaves, blossoms, vines and fruits. They can cause great loss through their ability to transmit bacterial wilt.

Colorado potato beetle
Lepinotarsa decemlineata

Adults overwinter in the soil, emerging in the spring to feed on early planted or volunteer potatoes. They are 3⁄8-inch long with black and yellow stripes lengthwise on the wings.

Females lay orange-yellow eggs on the underside of leaves. The dark red larvae hatch and consume foliage. Adults and larvae feed on leaves and terminal growths, leaving only the main leaf vein and stems. When mature, they leave the plant, enter the soil, pupate and emerge as adults several days later. Thus two generations occur per year.

Potato flea beetle
Epitrix cucumeris

This very small black beetle eats small holes in the potato leaves. When disturbed, it jumps from the plant. Slow growing plants are frequently severely injured. The winter is spent in the adult stage.

Potato leafhopper
Empoasca fabae

These very small greenish-white insects suck sap from potatoes and many other vegetable species.

A condition known as "hopper burn" often results from their feeding. Adults are wedge-shaped, about 1⁄8-inch long and winter in the gulf states.

Squash bug
Anasa tristis

Adults and nymphs of this common cucurbits pest sucks sap. Leaves wilt rapidly and soon become blackened, crisp and dead. Attacked plant stems often are enlarged, but later wither and die.

Adults are 5⁄8-inch long brownish, flatback bugs. Nymphs vary from bright green with red head and legs to dark greenish-gray with black legs and head. There is one generation and adults hibernate.

Corn earworms
Helicoverpa zea

Also known as the tomato fruitworm, some consider the corn ear worm the worst corn pest. Early in the season, larvae feed on the central shoot; later they bore directly into the ear tip to feed on kernels.

Usually one worm per ear is found. On tomato, large caterpillars may be present in fruit which have large gouged-out areas. Worms range in color from light green, pink, brown or nearly black and grow to 2-inches. Adults have a 1.5 inch wingspan.

Diseases

Chemical products sold for controlling vegetable diseases can be grouped according to the ways they function. Many of these products work in more than one way. The product label explains how the material works; read it carefully before using the product.

Contacts kill disease-causing organisms simply by contacting them. **Systemics** are taken into the sap of a plant through the roots or foliage and spread within the plant. They kill the pest without harming the host. **Protectants** are applied to plants to prevent entry or damage by a disease-causing organism. **Fumigants** are gases that kill when they are absorbed by the disease-causing organism.

Certification in Category 7c, Fumigation Pest Control, is required for the purchase and use of fumigants by commercial pesticide applicators in

Missouri. Be sure to select fungicides labeled for vegetables. Label changes in several of these have removed many of the uses for vegetables.

For most diseases, the fungicide spray applications should be started early, before symptoms are observed. Attention to the time interval between the last application and harvest is necessary.

Control of insects is important in vegetable production, as many insects are carriers of diseases, such as bacterial wilt of cucurbits by cucumber beetles and viruses of beans, cucumbers, tomatoes and other vegetables by aphids.

For more information and specific recommendations, consult MU Publications MX384, "*Midwest Vegetable Production Guide for Commercial Growers*" and M161, "*Insect and Disease Management - Horticultural Crops and Structures*."

Fungal diseases

Rust affects some sweet corn hybrids and is noted by the appearance of rusty-brown pustules on above-ground plant parts, most commonly on the leaves. Although there are fungicides available for rust control, the best control is to plant corn hybrids which have been selected for resistance to rust.

Common smut of sweet and popcorn is the only smut disease of vegetables in Missouri. It is a very recognizable disease as conspicuous galls are produced on ears, tassels, stems or leaves. Young galls are covered with a greenish-white membrane; as they age, the membrane ruptures to expose masses of powdery black spores. Galls may grow up to 6-inches in diameter.

Smut infections are most severe during prolonged warm, dry weather, especially when plants have been wounded in some manner. Incidence of smut may be reduced by minimizing wounding; for example, by preventing mechanical damage to plants during cultivation and spraying operations. Smut-resistant hybrids are also available.

A vast number of fungi can cause leaf spot. A very common leaf spot disease on potato and tomato is early blight. Symptoms usually appear when the crop is well established and appear first on the lower (and older) leaves as circular brown spots with concentric rings (targets). These leaves will wither and die.

Tomato fruit spots are dark brown or black and leathery prior to rot development. In potatoes, tuber infection can result in brown to purple, slightly sunken areas with raised, well-defined borders.

Early blight spreads fast and causes the most damage during prolonged wet weather, when splashing rain moves fungus spores from leaf to leaf and plant to plant. Fungicide sprays applied at seven- to 10-day intervals throughout the season are often necessary, especially during wet years, to control early blight.

Powdery mildew is one of the easiest plant diseases to identify. It forms whitish, felt-like patches of fungus on surfaces of leaves, stems and flowers. This white material is actually a chain of spores; these spores are easily detached and carried by air currents to surrounding plants. The disease is promoted by heavy dews and high humidity.

Beans, cucurbits and peas are major Missouri vegetable commodities which serve as hosts for powdery mildew. Fungicides are available for control of this disease and applications should begin at the first sign of powdery mildew.

Anthracnose is a fungal disease which attacks all above-ground plant parts of beans and cucurbits. Small angular lesions appear on bean leaves and lower veins turn black. Tiny brown spots on bean pods will later enlarge and turn black with light brown to purplish borders. Mature spots appear as cankers and are circular to oval and sunken. These cankers may have pink centers and brown margins on cucurbit fruit.

On tomato, the disease begins infection on green fruit; but, more commonly appears after ripening. Depending upon commodity, various fungicides are available and may be necessary to apply on regular seven- to 14-day intervals, especially during wet years.

Several fungi are soilborne and are responsible for causing seed decay and damping off. These fungi are either native to most soils or can survive in soils for long periods of time if host plants aren't present.

In infested soils, preemergence death of seeds or seedlings may occur, as well as postemergence seedling death. Typical symptoms such as wilting and a brown discoloration of the vascular tissues are apparent. Affected plants tend to have small, poorly developed root systems with few feeder roots.

Laboratory testing may be needed to identify the particular fungus that is responsible. Various seed treatments are usually most practical and economical for control of soilborne diseases.

Bacterial diseases

Several bacterial species are responsible for disease problems in Missouri vegetable commodities.

Bacterial blight (halo blight) of beans causes leaves to have irregular, watery, light-green patches. They turn brown and brittle with yellow borders (halos). Pods have small, water-soaked spots that enlarge to irregular blotches. Later, they become brown, dry and sunken. If necessary, copper fungicides are available and should be applied at weekly intervals.

Stewart's wilt is a potentially severe disease of sweet corn which is transmitted by flea beetles. Insecticides should be used beginning at corn

Extension Plant Disease Clinic

There is no charge for most samples submitted to the clinic. The exceptions are some virus tests. The fee for seed or plant material for export certification is $10 per sample. The tomato spotted wilt virus assay costs $25 minimum to test 4 samples plus a healthy control, then $10 per sample. All other material is no charge. The clinic reserves the right to assess minimum fees by prior arrangement for firms or individuals submitting large numbers of samples for virus testing. Submit samples to:

Extension Plant Disease Clinic
42 Agriculture Building
University of Missouri
Columbia, MO 65211
(573) 882-3019
FAX (573) 884-5405

emergence and applied every three to four days in areas of flea beetle activity. Wilt-resistant hybrids are also available. Symptoms of Stewart's wilt are long, pale-green to yellow streaks in leaves that will eventually dry and die. Entire wilted plants may die.

Angular leaf spot causes a variety of symptoms depending up on the commodity. On cucumber, water-soaked angular leaf spots up to 1⁄8-inch appear on leaves. Later, these leaves dry up and drop out.

On watermelon, small circular spots are dark-colored with yellow halos. Fruit spots are circular and smaller than leaf spots. Tolerant or resistant varieties are available as well as fungicides applied at five- to seven-day intervals.

Bacterial wilt affects all cucurbits. The disease is noted by the presence of a white, sticky ooze which is emitted from ends of cut stems. Plants wilt rapidly and die. Like Stewart's wilt, this bacteria is spread by insects. Approved insecticides should be used to control cucumber beetles that transmit the disease. Spraying should begin just after plant emergence and continue through the season while the beetles are active.

Potatoes are affected by several bacterial organisms. Bacterial ring rot causes wilting in full-grown plants. Leaf margins will appear yellowed and upwardly rolled; the vascular tissues of stems and tubers are discolored. The most practical control of this disease is prevention — using good sanitation habits and not planting any tubers with discolored vascular tissue.

Black leg causes top growth to be stunted, yellowed and wilted. Leaflets appear reddish in color and the stem near the ground is blackened. Like bacterial ring rot, prevention is the key in its control. Seed pieces can be treated with streptomycin prior to planting.

Tomato bacterial spot and speck appears as small, angular greasy spots on leaves and stems. On fruit, water-soaked spots often are surrounded by white holes in early stages. Later, the spots turn brown and are slightly sun ken and scabby. Foliar fungicides are available for control of this disease.

Viral diseases

Vegetable crops are afflicted with many viral diseases. Once infected by a virus, the plant remains infected for life. Typical foliage symptoms include chlorosis, mottling, ring spots, crinkling or folding and sometimes dying tissue.

Often, the only indications are a loss of vigor, stunting and lowered yields. Infections usually occur by means of insects, especially aphids, mechanical spread or through infected stock. Some of the more common vegetable virus diseases are listed in Table 7.

At this time, control of virus diseases relies on disease-free planting stock, good insect control and proper sanitation practices.

Virus	Host(s)
Bean common mosaic	Snap bean
Bean yellow mosaic	Snap bean
Cucumber mosaic	Snap bean and cucurbits
Maize dwarf mosaic	Sweet corn
Potato virus x	Potato
Potato virus y	Potato
Leaf roll virus	Potato
Tomato mosaic	Tomato
Tobacco mosaic	Tomato
Tomato spotted wilt	Tomato

Nematode diseases

Nematodes are microscopic round worms. All species that attack vegetables live in the soil and feed in or on roots. Some nematodes, such as the root knot nematode, cause small swellings on roots; others cause no swellings, but instead kill the tips of feeder roots. Above the ground, a plant whose roots are damaged by nematodes may develop yellowed foliage, stunting or wilting.

It is difficult to distinguish between the symptoms of nematode damage and symptoms caused by root rot infection. Laboratory analysis of soil and roots from the affected plant is essential for a definite analysis. Samples may be submitted to the Extension Plant Nematology Laboratory for confirmation. Nematicides for application at planting are available to commercial growers and applicators; however, resistant varieties and crop rotation are the most practical control measures.

Tobacco

Missouri ranks thirteenth among states in tobacco production. Tobacco acreage is found in the counties of Boone, Buchanan, Chariton, Clinton, Howard and Platte, mainly along the river bottoms.

Weeds

In tobacco, problems that weeds cause include: (1) lower yield and quality; (2) increased production costs; (3) interference with harvesting;
(4) increase in the spread of some diseases through cultivation and, (5) some weeds serve as alternate hosts for some disease organisms.

Although there are several chemical weed control programs available for tobacco, not all weeds can be controlled chemically. Therefore, more attention has to be given to planning weed management systems. These include crop rotation, early stalk and root destruction, growing a healthy crop to better compete with weeds, cultivation and herbicide use.

Herbicides labeled for tobacco control weeds by restricting growth during seed germination. They do not affect weed seeds that do not germinate (dormant seeds) or weeds after they have emerged.

Crop rotation is important in tobacco weed management systems. Large-seeded broadleaf weeds, such as cocklebur, and small-seeded broadleaf weeds, such as common ragweed, are not controlled by most tobacco herbicides. Perennials, such as nutsedge, are difficult to control in tobacco.

Mechanical cultivation is still needed in tobacco since herbicides don't completely control all weeds. Excessive and late cultivations can spread viruses and injure root systems. When cultivation is done, it should be kept shallow so tobacco roots won't be pruned.

Insects

Sometimes it's easy to see how insects cost money. Several rows of tobacco destroyed by cutworms or grasshoppers is a serious loss. Other losses may be more difficult to see, such as stunting from wireworms, the extra costs of managing an uneven crop or quality loss from aphid damage.

When chemical applications are necessary, thorough coverage must be attained. Because of the size of the tobacco plants, drop nozzles need to be used to cover the underside of the leaves. This is especially important for complete aphid control.

A biological control program to control the pest larvae is available. Various formulations of *Bacillus thuringiensis*, a bacterium that attacks caterpillars, are labeled for application to tobacco.

The MU picture sheet available to aid in the identification of insects is PS 20, "*Tobacco Insects: An Aid to Identification and Control*. For specific control recommendations, consult MU Publication M160, *Insect and Disease Management: Field Crops, Forages and Livestock*."

Green peach aphid
Myzus persicae

The green peach aphid is a pale green, soft-bodied insect that is found in clusters on the underside of tobacco leaves. The 1⁄16-inch long "plant lice" use their sucking mouthparts to remove sap from plants. Feeding by large numbers of aphids results in thin, light-weight leaves that may ripen prematurely.

The sugar rich "honeydew" excreted by aphids builds on the leaf surface and supports growth of black, sooty mold. The honeydew may cause leaves to stick together and cure to a dark, off-color of poor quality.

They may also transmit viruses through their mouthparts. Aphid populations build up after winged females fly into tobacco fields, usually during the middle portion of the growing season. They settle on the leaf to feed and give birth to living young. Large populations can build up in a short period of time due to their short life cycle and the occurrence of several generations during the growing season. Many insecticides are available for aphid control in tobacco.

Hornworms
Sphingidae spp.

The tobacco and tomato hornworms are potentially the most destructive tobacco insect. They chew irregular holes in leaves and often feed along leaf margins.

Newly hatched larvae are 1⁄4-inch long, pale green with a large horn at the posterior end. Larger larvae (up to 4 inches) are bright green in color. The tobacco hornworm larvae has seven white diagonal stripes on each side and curved red horn.

Tomato hornworms have eight white V-shaped marks on each side and the horn is straighter and blue-black. Several insecticides are labeled in tobacco for hornworm control.

Budworms
Heliothis virescens

The tobacco budworm is one of the most destructive tobacco pests. When larvae are full grown, they are 1.5 inches in length. They are light to dark green and have several longitudinal pale stripes. They may chew small holes in the leaves before they reach the buds. Larvae then damage the bud or growing tip of the plant. And they may appear any time during the growing season. The leaves that expand from the buds are often ragged and distorted.

Because of their protected location on the plant, bud worms are difficult to control even though there are a number of registered insecticides. The corn earworm also attacks tobacco and is closely related to the bud worm in appearance and feeding habits.

Cutworms
Noctuidae spp.

Cutworms, including the black cutworm, are generally dingy gray, dark brown or black. Faint longitudinal stripes may occur on the body. Full grown larvae range from 1 to 1½ inches long.

Infestations are likely to occur in tobacco following sod, or in fields with an abundance of winter annual weeds prior to tillage. Larvae feed for a month and can reduce plant stands by cutting off newly set transplants. Cutworms feed at night and can be found in the soil around freshly cut plants during the day. They curl up when disturbed. Insecticides may be applied prior to transplanting, in transplant water or on an as-needed basis to the foliage.

Wireworms
Elateridae spp.

Wireworms are the major soil insects attacking tobacco. The yellow to brown, hard-bodied larvae are slender and cylindrical. The adult is a click beetle.

Wireworms hatch in the summer, spend the winter in the soil and are usually most destructive to newly transplanted tobacco. The larvae cut off small underground stems and roots and bore into larger stems and roots. And, they may be found tunneling in stems near the soil surface.

Affected plants may become stunted, wilt and die within a few days. Following sod, tobacco may be damaged by wireworms for one to five years because of some species' long life cycles. Insecticides should be applied to the soil prior to transplanting for wireworm control.

Diseases

Disease diagnosis in the field requires careful observation of all the symptoms, signs and related factors. An accurate diagnosis is not always possible with-out the aid of a microscope, laboratory culture or other special laboratory tests. Many of the common tobacco diseases can be diagnosed by the tobacco worker with a little experience and careful observation.

Virus diseases offer a special problem in diagnosis, because field identification is often difficult. Symptom patterns are helpful in identification, but they are much less reliable than with most diseases caused by other pathogens.

Symptoms vary greatly depending on the virus involved, time of infection, variety, environment and whether multiple infections exist. And, plants are often infected with two or more viruses.

Because symptoms overlap among various virus diseases and multiple infections are common, laboratory tests are needed for accurate diagnosis.

Serological tests are used for identifying most tobacco viruses. Host range reactions, in which the virus from the test plant is placed in a variety of plants, are also used. These tests are expensive, time consuming and are not used for routine diagnosis of grower samples. Instead, the opinion of trained diagnosticians are considered adequate for routine virus problems.

For more information, call the Extension Plant Disease Clinic at (573) 882-3019.

Detailed information concerning tobacco production, including disease and insect management, can be found in the following publications from the University of Kentucky, Department of Agriculture Extension, Lexington, KY 40546: ID-73, "*Tobacco in Kentucky;*" PPA-21, "*Chemical Controls For Tobacco Diseases;*" and AGR-35, "*Black Root Rot in Tobacco.*"

Also refer to MU publication G7899, "*Blue Mold in Tobacco,*" available through Extension Publications, University of Missouri, 2800 Maguire Bldv., Columbia, MO 65211.

R.J. Reynolds Tobacco Co., Winston-Salem, N.C., has a color publication, "*Burley Tobacco Field Manual,*" that illustrates disease, insect and cultural problems.

Angular leaf spot

Symptoms of angular leaf spot are circular to slightly angular to irregular water-soaked spots with halos 1- to 13-mm in diameter. After wet weather, spots may be numerous. The spots are tan at first but turn black with age. Centers of the spots may drop out producing a shot-hole or ragged appearance.

This bacterial disease is generally worse on the windward side of plants where watersoaking from driving rains or sandblasting tends to enhance infection. Streptomycin can be used in the field for control; but, it is generally not needed if plant bed infections are managed. Sprays have been effective if applied when the disease is first detected.

Blue mold

In Missouri, blue mold is an occasional disease problem. The disease may occur on the plant anytime from seeding to harvest; however, young tissue is more susceptible than old tissue.

The first evidence of blue mold usually occurs on leaves as yellow circular spots about the size of a nickel. The spots soon develop the characteristic bluish, downy fungal growth on the undersides of the leaves which is best seen in the morning when the leaf is wet. If spots develop on leaves which are expanding, a puckering soon occurs.

As spots age, they turn from yellow, tan or brown and often tear or drop out. If infection has occurred near or on a leaf vein, a localized systemic infection may occur. The affected vein becomes reddish-brown, and the area around the vein is yellowed and distorted. In newly set transplants, it is possible for the fungus to develop systemically, killing the main bud and resulting in stunting or death.

Splitting the stalk of systemically infected plants reveals a reddish-brown discoloration in the vascular tissues beneath the epidermis. A one-sided systemic infection results in a deformed stalk and lodging of affected plants.

During weather favorable for blue mold (cool, cloudy and wet), the disease can develop rapidly, causing numerous leaf lesions which can result in leaf blighting and severe leaf loss. The disease may develop during hot, humid periods if cool nights exists.

Chemical control options are available for blue mold; contact the Extension Plant Disease Clinic for current state labels.

Brown spot

Symptoms of the brown spot fungus first appear on the lower leaves. Spots are brown with sharply defined margins and may be surrounded by yellow halos. The primary distinguishing characteristics of brown spot are the dark concentric rings within the spots that give it a target-like appearance.

With magnification, reproductive structures of the causal agent are seen as tufts of black fungal spores. Under severe conditions, spots are numerous, may coalesce and give the leaf a ragged appearance as the infected tissue falls out. Usually chemical control is not necessary, especially when protectant fungicides are used for blue mold.

Viruses

Tobacco mosaic once was the major disease of burley tobacco but is not common now because most varieties have excellent resistance.

Its most distinguishing characteristic is the mosaic pattern of light and dark green areas in the leaf. But, there are numerous strains of tobacco mosaic virus, and the symptoms vary greatly from a mild mottling to gross distortion or puckering of the leaves. Burning or scalding of the leaves may also occur.

On resistant varieties, a series of localized dead spots may occur, while the remainder of the leaf is symptomless. The virus is spread from plant to plant by mechanical means. Weed control is important in controlling tobacco mosaic as several species also serve as hosts for this virus.

Tobacco ringspot has the most distinctive symptoms of the virus diseases. The name truly describes the disease because chlorotic or necrotic rings occur in the leaf. A concentric line pattern of chlorotic and necrotic tissue, often forming an “oak leaf” pattern, is very common. The symptoms occasionally are confined to one side of the plant.

The disease appears early in the season, usually with initial growth after transplanting. Most infected plants recover as new symptomless leaves develop. The virus is transmitted by nematodes, although weeds are also hosts. In the field, infected plants may appear alone or clustered.

Tomato spotted wilt affects plants of all ages. Yellow-green spots appear on young leaves, later turning red-brown and become concentric necrotic rings or zonate necrotic spots. Spots may coalesce and necrotic streaks develop along the stem. Plants are stunted and the bud region droops or bends over. In severe cases, plant death may occur. The virus is transmitted by thrips; therefore, control of thrips may be necessary.

Glossary

Abiotic diseases: state caused by unfavorable growing conditions.

Biotic diseases: condition caused by plant pathogens.

Burndown: application of a herbicide to control existing vegetation.

Coleoptile: newly emerging shoot tissue of grasses.

Contacts: a pesticide that kills pests simply by contacting them.

Epidermis: the cellular layer of tissue beneath the cuticle.

Flushing: flooding a field for a short period of time, usually one to three days.

Fumigants: pesticide that is a vapor or gas or forms a vapor or gas when applied and whose pesticidal action occurs in the gaseous state.

Germination: the process of initiating growth in seeds.

Hypocotyl: that part of the stem of the plant below the cotyledons.

Inoculum: that portion of a pathogen that can cause disease in a host.

Internodal: portions of a plant's stem between the nodes.

Interveinal: portions of a plant's leaf surface between the veins.

Microsclerotia: small, compact fungal resting body.

Mycelium: the mass of interwoven filaments that comprise the vegetative body of a fungus.

Mycotoxin: naturally produced chemical which in small amounts is deleterious to human and animal health.

Nematodes: small, slender, colorless round worms that live in soil or water; some are plant parasitic.

Oviposition: site at which an insect deposits its egg(s).

Pericarp: the seed coat of grasses.

Photosynthesis: process in green plants of synthesizing carbohydrates from carbon dioxide and water, utilizing light energy captured by chlorophyll.

Postemergence: applied after emergence of target weed or crop.

Preemergence: applied to the soil prior to emergence of the target weed or crop.

Pre-harvest interval: the minimum number of days permitted by law between the last pesticide application and the harvest date.

Protectants: pesticides applied to a plant or animal prior to infection or attack by pests in order to prevent infection or injury.

Pycnidia: flask-shaped structures which hold spores of certain fungi.

Rachis: an axis bearing flowers or leaflets.

Saprophytes: organisms which obtain food from dead or decaying organic matter.

Stomates: minute openings on the surfaces of leaves and stems through which gases and some dissolved materials pass into and out of plants.

Systemics: pesticides that are taken into the sap of a plant.

Vascular tissues: conducting tissues of plants composed principally of xlyem and phoem.

Appendix

Additional references available at University Extension Centers or by contacting
Extension Publications at 1-800-292-0969

Publication number	Title
EV 11	Weed Seedling Identification (Video)
MP 0575	Weed Control Guide for Missouri Field Crops
MP 0581	Weed and Brush Control Guide for Forages, Pastures and Non-Cropland in Missouri
G 4251	Cotton Weed Control
G 4851	Atrazine: Best Management Practices and Alter natives in Missouri
G 4856	Aqua tic Weed Control in Missouri
G 4871	Waterhemp Management in Missouri
G 4872	Johnsongrass Control
G 4875	Control of Perennial Broadleaf Weeds in Missouri Field Crops
G 4907	Herbicide Resistance in Weeds
MP 0686	Using Reduced Herbicide Rates for Weed Control in Soybeans
G 4252	Cotton Insect Control
G 4349	Sorghum Aphid Pest Management
G 4362	Controlling Insects in Rice
M 0123	Missouri Soybean Handbook
M 0139	Detecting, Identifying and Managing Alfalfa Pests in Missouri
MP 0651	Missouri Commercial Fruit Tree Spray Guide
MX 0366	American Soybean Association: Diagnostic Guide
MX 0368	Midwest Tree Fruit Handbook
MX 0384	Midwest Vegetable Production Guide for Commercial Growers
MX 0409	Insect and Disease Management: Picture Sheets
PS 0001	Principal Stored Grain Insects (Picture Sheet)
PS 0004	Corn Insects - Above Ground (Picture Sheet)
PS 0005	Corn Insects - Below Ground (Picture Sheet)
PS 0006	Common Soybean Insects (Picture Sheet)
PS 0007	Common Small Grain Insects (Picture Sheet)
PS 0008	Common Forage Legume Insects (Picture Sheet)
PS 0012	Cotton Insects and Mites (Picture Sheet)
PS 0020	Tobacco Insects: An Aid to Identification and Control (Picture Sheet)
PS 0150	Corn Herbicide Injure 1 (Picture Sheet)
RP 0063	Common Tree Fruit Pests
G 4025	Integrated Disease Control in Vegetable Crops
G 4153	Corn Stunting Virus Diseases in Missouri
G 4254	Cotton Seedling Diseases: Answers to Frequently Asked Questions
G 4261	Cotton Disease and Nematode Management

Publication number	Title
G 4317	Scab of Wheat
G 4318	Virus Diseases of Wheat
G 4319	Wheat Diseases in Missouri
G 4320	Foliar Fungicides for Wheat
G 4345	Wheat Take-All
G 4354	Controlling Diseases of Grain Sorghum
G 4356	Management of Grain Sorghum Diseases in Missouri
G 4441	Seed Treatment Fungicides for Soybeans
G 4450	Soybean Cyst Nematode
G 4452	Soybean Disease Management
G 4558	Sclerotinia Crown and Stem Rot of Alfalfa
G 7899	Blue Mold in Tobacco
MP 0645	Rice Blast: Identification and Control
MP 0646	Rice Sheath Blight Control
M 0160	Insect and Disease Management: Field Crops, Forages and Livestock
M 0161	Insect and Disease Management: Horticultural Crops and Structures

Emergency Telephone Numbers

Missouri Regional Poison Control Center 1-800-366-8888

For pesticide poisoning emergencies, the Missouri Poison Control Center is accessible through a toll-free number. The center is located and administered by Cardinal Glennon Memorial Hospital in St. Louis. It is staffed 24 hours daily with medical professionals. The center is equipped to refer poisoning accident victims to a local poison control emergency facility.

Missouri Emergency Response Team (573) 634-2436

For pesticide spill emergencies, the Emergency Response Team handles pesticide spills anywhere in Missouri. For information, call (573) 751-7929. Contact: Environmental Emergency Response Coordinator, Missouri Department of Natural Resources, Division of Environmental Quality, P.O. Box 176, Jefferson City, MO 65102.

National Pesticide Safety Team Network (Chemtrec) 1-800-424-9300

The National Agricultural Chemicals Association has a telephone network. This network can tell the applicator the correct contamination procedures to use to send a local safety team to clean up the spill. An applicator can call the network toll free at any time.

National Pesticide Tele-Communications Network 1-800-858-PEST

Call the NPTN network toll free.

U.S. Environmental Protection Agency (EPA) (913) 551-7000

All major pesticide spills must by law be reported immediately to the U.S. Environmental Protection Agency, Region VII Office, 726 Minnesota Avenue, Kansas City, KS 66101. The following information should be reported:

1. Name, address, and telephone number of person reporting
2. Exact location of spill
3. Name of company involved and location
4. Specific pesticide spilled
5. Estimated quantity of pesticide spilled
6. Source of spill
7. Cause of spill
8. Name of body of water involved, or nearest body of water to the spill area
9. Action taken for containment and cleanup

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