

Research and Demonstration Pest Control

A Guide for Kentucky Applicators in Category 10



*Kentucky Pesticide Education Program copyright © 2023
University of Kentucky Department of Entomology*

Laws and Regulations

Federal Authority

Pesticides provide important benefits when used correctly. However, they can cause serious harm if used improperly. The **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** is the most important law regulating the registration, distribution, sale, and use of pesticides in the US. However, the Endangered Species Act and Migratory Bird Treaty Act also impact pesticide regulation, application and pest management. FIFRA gives the Environmental Protection Agency (EPA) the authority to oversee the sale and use of pesticides. Commercial applicators can be fined as much as \$5,000 for FIFRA violations. Criminal penalties can be as much as \$25,000 and/or 1 year in prison. In addition, Kentucky can enact legal requirements that may be more restrictive than federal law. In Kentucky, the Kentucky Department of Agriculture administers the EPA-approved certification program and enforces FIFRA regulations.

FIFRA give EPA Authority to:

- Impose civil and/or criminal penalties on anyone who misuses a pesticide or commits any other listed unlawful acts. Fines can be up to \$1,000 for each offense. However, you have the right to ask for a hearing in your own city or county.
- Stop the sale or use of any pesticide.
- Issue removal orders and seize products to keep them out of the market if it determines the products pose an unreasonable risk.
- Reevaluate older pesticides to ensure that they meet more recent safety standards.
- Protect agricultural workers and pesticide handlers from occupational pesticide exposure.

Exceptions to Pesticide Labeling

Unless the label specifically prohibits it, you can apply a pesticide

- To control a pest that is not on the label as long as the specific crop or site is listed
- By any method that is not prohibited. For example, some pesticides cannot be applied by air.
- At a lower dosage, concentration, or less frequently than specified on the label
- In a pesticide-fertilizer mixture.

All pesticides are classified according to their potential hazards under the circumstances in which they are to be used. The two main classifications are **Restricted Use (RUP)** and **unclassified or general use**. The EPA has officially classified very few pesticides as general use. Most that might be expected to fit into the general-use category currently are unclassified. Normally, general-use pesticides have a lower toxicity than RUPs so they are less likely to harm humans or the environment. The general public can buy general-use pesticides without special permits or restrictions. Restricted Use Pesticides can only be purchased and used by a certified applicator in Kentucky.

Endangered Species Act

Plants and animals classified as endangered or threatened must be protected, and this includes from the effects of pesticides. Some pesticides may have specific restrictions on their use in areas of endangered species habitat. This may include special label instructions to check with an EPA website to determine if there are specific precautions to take when using the product in their area.

Kentucky Laws and Regulations

The Division of Environmental Services of the Kentucky Department of Agriculture (KDA) regulates federal and state pesticide laws and regulations, including the Kentucky Fertilizer and Pesticides Storage, Pesticide Use and Application Act of 1996 (KRS 217b) which was revised in 2022. The Kentucky Department of Agriculture implements the provisions of KRS 217b through the administrative regulations, 302 KAR 026. It is responsible for regulating the registration, sale, distribution, proper use, storage, disposal, and application of pesticides in the Commonwealth. The Division strives to educate the pest control industry and consumers about the proper use of pesticides through education and training programs.

KDA personnel give exams to certify and license qualified citizens who wish to apply or to sell pesticides. Field inspectors from the Agricultural Branch inspect facilities of the businesses which sell and/or apply pesticides and review their records. They can impose fines on businesses and/or individuals who neglect to follow federal and state laws concerning the proper storage, containment, sale, distribution, application, record keeping, or disposal of

federally registered pesticides. They also investigate potential pesticide application complaints and violations.

You are responsible for learning about and complying with pesticide laws and regulations before making any applications. In addition, you are responsible for any consequences of actions that result from an application. **Ignorance of the law is never an excuse for noncompliance or violations.**

Important Definitions

- **Application** - placing of a pesticide or pesticide impregnated fertilizers for effect, including mixing and loading.
- **Certification** - recognition by the KDA that a person has demonstrated a minimum level of competence by examination and continuing education units and is authorized to use or supervise the use of pesticides in the area of certification.
- **Commercial Pesticide Applicator** - any individual employed by an operator to apply pesticides. Applicators must be certified in the appropriate category and must have a valid license issued by the KDA. The annual applicator license expires on December 31, the license fee is \$25.
- **Commercial Pesticide Operator** - owns or manages a business that applies pesticides on the lands of another for hire. Operators must be certified in the appropriate category and must have a valid license issued by the KDA. A licensed commercial pesticide operator also must be registered as a pesticide dealer or must be employed by a registered dealer. The annual operator license expires on December 31, the license fee is \$100.
- **Customer** - a person who makes a contract, either written or verbal, with an applicator for hire to make an application.
- **Dealer** - stores bulk fertilizer or a restricted use pesticide for redistribution or direct resale, OR is in the business (for compensation) of applying any pesticide to the lands of another.
- **Direct on-the-job supervision** - when a licensed operator or applicator is physically on site and is directly supervising or training an individual to apply a pesticide.
- **Lawn chemicals** - fertilizers, pesticides, or defoliants applied or intended for application to lawns.
- **License renewal** - There is a 25% fine for license holders who do not file a renewal before January 31. The licensee must take a new certification examination if the license is not renewed before this deadline.
- **Noncommercial applicator** - an employee of a golf course, municipal corporation, public utility, or other governmental agency certified and licensed to apply pesticides to lands owned, occupied, or managed by his or her employer. The annual non-commercial applicator license expires on December 31, the license fee is \$10.
- **Pests** - any animals (insects, snails, slugs, rodents, etc.); plant pathogens (nematodes, fungi, viruses, bacteria, or other microorganisms) or plants normally considered to be a pest, or which are declared to be a pest by the KDA.
- **Pesticide** - any substance or mixture of substances intended to:
 - prevent, destroy, control, repel, attract, or mitigate any pest;
 - be used a plant regulator, or a spray adjuvant, after being mixed with an EPA registered product;
 - be used as a plant regulator, defoliant, or desiccant.
- **Restricted Use Pesticide** - any pesticide classified as such by the EPA administrator, or by administrative regulation of the KDA. Only certified applicators can purchase and use them. Generally, the EPA classifies a pesticide as restricted use if:
 - it exceeds one or more human health toxicity criteria;
 - it meets certain criteria for hazards to non-target organisms or ecosystems, or the EPA determines that a product (or class of products) may cause unreasonable harm to human health and/or the environment without such restriction;
 - then the restricted-use classification designation must appear prominently on the top of the front panel of the pesticide label.
- **Structural pest** - a pest which commonly invades or attacks dwellings or structures.
- **Trainee** - an individual employed by a dealer and working under the direct on-the-job supervision of a licensed operator or applicator. Trainees must be registered with the Kentucky Department of Agriculture with the registration valid for 90 days and cannot be renewed. The fee for trainee registration is \$25.

Recordkeeping Requirements

State law requires that any certified applicator keep records of all applications of general and restricted use pesticides. **Keep the records for at least 3 years** from the date of application. USDA and/or KDA representatives have legal access to the records. Pesticide application records must be recorded within 14 days from the date of application. These records must include:

- name and address of person receiving application services;
- location of application;
- size of area treated;
- crop, commodity, stored product, or type of area treated;
- time and date of application;
- brand name or product name of pesticides applied;
- EPA registration number;
- total amount of each pesticide applied per location per application;
- name of person making the pesticide application;
- if application is made by a trainee, the name of the trainee;
- if application is made by a trainee, name and license number of the supervising applicator;
- records required related to trainee supervision;
- purpose of application; and
- any other record as required by the label.

Pesticide applications records:

- are invaluable documentation in the event of a complaint or lawsuit.
- can help determine which pesticide treatments work, which do not work, and why
- help you to plan purchases so that you buy only the amount needed
- provide information needed by medical staff
- document the steps taken to protect farmworkers and the environment
- are used for federal and state surveys

Certification and Licensing

Commercial and non-commercial pesticide applicators must be both certified and licensed. Both are accomplished by passing a written test (minimum score 70%) administered by the KDA. The test is based on information in this manual.

Evidence of Financial Liability

Pesticide dealers who apply pesticides to the lands of others must show evidence of financial responsibility. This can be a surety bond or a liability insurance policy of at least one million dollars (\$1,000,000) that would protect persons who may suffer legal damages as a result of the applicant.

How To Remain Licensed and Certified

1. Return the annual license renewal form before January 31. There is a 25% penalty added to the original fee for license holders who do renew and pay their fees before January 31. Failure to renew a license by January 31 of each year, will also result in the former license holder being required to retest as an initial applicant, after any applicable fines are paid.
2. Pay any required fees.
3. Earn Continuing Education Units (CEUs) in educational meetings approved by the KDA. Twelve CEU credits, with at least one related to each category of license held by the person within the three-year period prior to each annual license renewal application.

The Kentucky Cooperative Extension Service provides training materials and educational programs for certification and continuing education of commercial and non-commercial applicators through the Pesticide Safety Education Program.

Penalties

Anyone who uses a pesticide in a manner inconsistent with its labeling directions and restrictions may be subject to civil and/or criminal penalties. Generally, any applicator in violation of FIFRA may be assessed a civil penalty. However, the EPA may issue a warning instead of assessing a penalty. An intentional violation by a private applicator is a misdemeanor and will result in a fine and/or up to 30 days imprisonment. You must use all pesticides exactly according to labeling directions—the label is the law!

Practice Questions

1) The _____ is the most important law regulating pesticides in the US.

1. KRS 217b Ky Fertilizer and Pesticides Storage, Pesticide Use and Application Act of 1996
2. 1996 Farm Bill
3. Federal Insecticide, Fungicide, and Rodenticide act (FIFRA)
4. Ky Department of Ag Regulation 1262

2) Commercial and non-commercial pesticide operator and applicator licenses are good for ____ year(s).

1. 1
2. 3
3. 5
4. 10

3) Commercial and non-commercial pesticide applicator certifications are good for ____ year(s).

1. 1
2. 3
3. 5
4. 10

4) A pesticide is categorized as general use if it can harm humans or the environment even if it is used according to label directions.

1. True
2. False

5) A minimum score of ____ % is required on the test to become a commercial or non-commercial pesticide applicators.

1. 60
2. 70
3. 80
4. 100

6) According to state laws and regulations, anyone who is in the business of applying any pesticide to the lands of another is considered to be a pesticide dealer.

1. True
2. False

7) _____ applicators are people who apply pesticides to lands owned, occupied, or managed by a golf course, municipal corporation, public utility, or other governmental agency.

1. Certified commercial
2. Registered
3. Non-commercial

8) Non-commercial applicators may apply pesticides to residential or commercial properties for hire without any additional certification.

1. True
2. False

9) A certified commercial or non-commercial pesticide applicator can stay certified by earning _____ continuing education units (CEUs) before their certification expires.

1. 12 CEU hours with at least one in the category held
2. 9 general and 3 specific CEU hours
3. 12 CEU hours in each category held
4. none, you must take a test every 3 years

10) According to Kentucky pesticide laws and regulations, commercial and non-commercial applicators must keep records of both general and restricted use pesticide applications.

1. True
2. False

11) A certified pesticide operator or applicator who fails to renew his/her license before _____ must take a new examination.

1. January 31
2. March 1
3. June 1
4. November 30

Answers

- 1: 3 2: 1 3: 2 4: 2 5: 2 6: 1**
7: 3 8: 2 9: 1 10: 1 11: 4

Agricultural Weed Pests

Weeds are plants that are growing where they are not wanted. They compete with crops for water nutrients, lights, and space. These plants can contaminate products at harvest, harbor pest insects, mites, vertebrates, or be a source of plant disease agents. Some can poison livestock or release toxins into the soil that inhibit growth of desirable plants. Weeds in cultivated crops are usually those that are favored by the crop production practices.

Many weeds produce large quantities of seeds that are easily carried by wind, rain, machinery, animals, and people. **Weed seeds can germinate after being dormant for long periods of time.** They also can tolerate extremes in weather such as temperature and moisture. **It is best to control weeds before they produce seeds.**

A typical weed has one or more of the following characteristics:

- Produces lots of seed
- Populations establish rapidly
- Seeds can lie dormant for a long time
- Have vegetative reproductive structures
- Adapted for easy spread
- Can adapt and grow across a variety of environments

Plant Development Stages

Most plants undergo 4 stages of growth and development.

1. **Seedlings** emerge from the soil soon after germination.
2. Leaves, stems, and roots grow rapidly during the **vegetative** stage; water and nutrient demands are relatively high.
3. After a period of vegetative growth, the plant enters the **reproductive** stage where most of the energy production in the plant is devoted to seed formation. Seed production is critical for survival of annual and biennial species.
4. Little or no energy production occurs during **maturity** when seed production is nearly finished. During this stage, the plant typically sheds its seeds and dies.

Plant Life Cycles

Annual plants complete their life cycle in one growing season, often in as little as 45 days. Biennials require two seasons while **perennials** live for more than two years.

Summer annuals grow from seeds that germinate in the spring. They grow, mature, produce seed, and die before winter. Examples include: crabgrass, foxtail, common cocklebur, pigweed, and common lambsquarters.

Winter annuals sprout from seeds that germinate in the fall. They grow, mature, produce seed, and die before summer. Examples: henbit and annual bluegrass.

Biennial plants complete their life cycles over **two growing seasons**. Most start from seeds that sprout in the fall or spring and grow through the summer, fall, winter, and following spring. During the first year, biennials develop a heavy root and compact cluster of leaves (called a rosette) that survives the winter. They mature, produce seed, and die during the second year. Examples include wild carrot, thistles, and mullein.

Perennials - Most perennials grow from seed but many species also produce tubers, bulbs, rhizomes (belowground rootlike stems), or stolons (aboveground stems that produce roots).

Simple perennials normally reproduce by seeds. However, root pieces left by cultivation can produce new plants. Examples: dandelions, plantain, trees, and shrubs.

Bulbous perennials may reproduce by seed, bulblets, or bulbs. Wild garlic produces seed and bulblets above ground and bulbs below ground.

Creeping perennials produce seeds but also produce rhizomes (below-ground stems) or stolons (aboveground stems that produce roots). Examples: Johnson grass, field bindweed, and Bermuda grass.

Woody species generally go dormant in the winter and resume growing from aboveground stems in spring. Aboveground parts of herbaceous perennials may die back but their underground storage organs survive the winter. Many are deep rooted so they continue to grow during summer droughts. Perennials can spread from seed and often from roots, tubers, bulbs, and rhizomes. Weeds in this group include quackgrass and field bindweed. **Perennials are often are the most difficult weeds to manage.**

Plant Classification

Weeds can be grouped into the following categories:

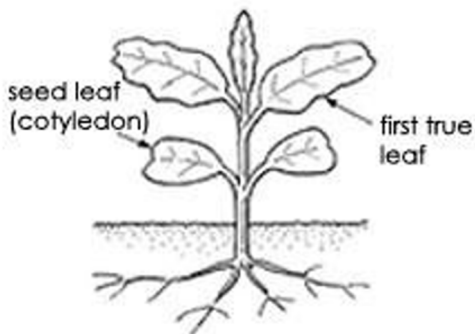
- grasses
- sedges
- lilies
- broadleaves.



Grasses have only one leaf as they emerge from the soil. Their leaves are two-ranked and typically upright, narrow with parallel veins. Grass stems are round and hollow. The root system of a grass is fibrous with the growing point located at or below the soil surface (surrounded by several layers of leaves). Perennial grasses can produce new shoots from growing points located on rhizomes (belowground) and/or stolons (aboveground).

Sedges resemble grasses but they have triangular stems with three rows (ranks) of leaves. Typically, sedges are listed under the grass section of an herbicide label. They prefer moist, poorly drained soils, but can grow in fertile, well-drained soils. Yellow nutsedge, is a perennial that reproduces by tubers and rhizomes. It is the principle sedge found in Kentucky.

Lilies resemble grasses and sedges but they have long, linear leaves and reproduce from underground bulbs. Two common species found in Kentucky are wild garlic and Star-of-Bethlehem.



Broadleaf seedlings have two leaves (cotyledons) as they emerge from the soil. The leaves are generally broad with net-like veins. Broadleaves typically have a taproot surrounded by a relative coarse root system. Actively growing broadleaf plants have exposed growing points at the end of each stem and in each leaf axil. Perennial broadleaves may have growing points on roots and stems above and below the surface of the soil.

Examples

Redroot pigweed is a summer annual broadleaved weed that usually grows about 2 to 3 feet tall but sometimes up to 6 feet. Seed leaves are narrow with pointed ends on smooth red-purple stems. True leaves are oval or long and narrow. Upper surfaces are green; lower surfaces can be green with a tinge of red or completely red. The plant can have a shallow pink to red taproot. A single redroot pigweed plant can produce up to one million seeds, 95 percent of which are viable.



Red root pigweed, photo: Phil Westra, Colorado State University, Bugwood.org

Most pigweeds are tall, erect-to-bushy plants with simple, oval- to diamond-shaped, alternate leaves, and dense flower clusters made up of many small, greenish flowers. The erect stems are green to slightly reddish and have many branches. Lower portions of the stem are thick and relatively smooth; upper portions are very hairy.

Pigweeds grow naturally in open, sunny areas with disturbed soil. Like other small-seeded annuals, they need to germinate close to the soil surface so they **do well in no-till fields**. They thrive in hot weather, tolerate drought, respond to high levels of available nutrients, and are adapted to avoid shading through rapid stem elongation. They compete aggressively against warm season crops, and reproduce by prolific seed production.

Buttercups flourish in overgrazed pastures with poor stands of desirable forages. Buttercups often grow as winter annuals, emerging during the fall or late winter. New seed are produced while petals are showy. Waiting until after flowers appear can be too late to implement control tactics. This is one reason buttercups can survive year to year and new plants emerge each year.

Pasture management practices that improve and promote growth of desirable plants during the fall and winter is one of the best methods to help compete against the emergence and growth of this plant. Overgrazing by livestock is one of the main factors that contribute to buttercup problems.



Buttercup, photo: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org

Marestail (horseweed) can follow either a winter or summer annual life cycle. The majority of plants emerge in the fall but some emerge in the spring, perhaps even into early summer. Spring-emerging plants do not mature until late summer so they compete with soybean during the growing season and interfere with harvest. One plant can produce up to 200,000 wind-borne seeds. Multiple-resistant plants may survive applications of glyphosate and ALS inhibitor herbicides.

Jimsonweed is a summer annual plant. Mature plants are erect with coarse stems that are often deep purple. The football to egg-shaped leaves have wavy toothed or lobed edges that are hairless or nearly hairless. Mature plants



Marestail, photo: Charles T. Bryson, USDA Agricultural Research Service, Bugwood.org

can be up to 4 feet tall with single, white, trumpet-shaped flowers. Jimsonweed seedlings have hairy, purple stalks and thick, narrow cotyledons.



Jimsonweed, photo: Bruce Ackley, The Ohio State University, Bugwood.org

Yellow foxtail is a shallow-rooted summer annual grass that tends to grow in clumps because the stems often tiller, or root, at the lower joints. This grass has a hairy ligule and smooth sheath. There are many long straggly hairs on the upper surface of leaves near the base. Leaf blades often appear to have a spiral twist. Stems grow 1 to 2 feet tall and branch at the base.

In addition to competing with crops for nutrients, yellow foxtail can cause abnormal growth in certain crops, including corn and some vegetables.



Yellow foxtail, photo: Chris Evans, University of Illinois, Bugwood.org

Fall panicum is an upright branching summer annual but some of the outer stems lie flat. Germination begins in the spring and continues throughout the summer. This native grass thrives in wet, open areas of fields and tolerates

flooding. It does not tolerate shade. Establishing a crop canopy before the weed emerges is an effective control and will greatly improve crop yield. Fall panicum is susceptible to barley yellow dwarf virus and has been blamed for causing nitrate poisoning and extreme sensitivity to light in livestock (called photosensitivity) of any skin that is not protected from the sun.



Fall panicum, photo: Howard F. Schwartz, Colorado State University, Bugwood.org

Honeyvine milkweed or climbing milkweed is a perennial vine with opposite heart-shaped leaves with white veins. The stem starts as a single vine but will branch, trailing and climbing as it grows. It does not have the milky sap of other milkweeds.

Honeyvine milkweed is common along fencerows and in minimum-tillage or no-till fields. This plant can reproduce by seeds or spreading taproots. It can be mistaken for field bindweed. Honeyvine milkweed has opposite heart-shaped leaves; field bindweed has alternate arrowhead-shaped leaves.



Honeyvine milkweed, photo: Theodore Webster, USDA Agricultural Research Service, Bugwood.org

Ivyleaf morningglory is a summer annual twining or climbing vine with distinctive 3-lobed leaves and large showy purple to blue or white flowers. It is a common weed of agronomic, horticultural, and nursery crops found

throughout the southeastern and into the north central and northeastern United States.



Ivyleaf morningglory, photo, Rebekah D. Wallace, University of Georgia, Bugwood.org

Common cocklebur is a broadleaved annual plant with dull green coarsely toothed leaves with 3 to 5 shallow lobes. Seeds germinate from early spring through summer, from depths of up to 6 inches. The plant grows along roadsides; in cultivated fields, bottomlands, abandoned land, and poor pastures. It is very competitive in many crops, especially in soybeans, because of similarities in emergence time and growth habit.



Cocklebur, photo, Jan Samanek, Phytosanitary Administration, Bugwood.org

Johnsongrass is a non-native warm season perennial that forms dense, thick patches of plants that can grow to over 6 feet tall. It reproduces from rhizomes and seeds. Seedlings can initiate rhizomes as early as 19 days following emergence. Plants can produce an extensive system of rhizomes in the top 10 inches of soil.

Established Johnsongrass is a more severe problem than seedlings because of its increased vigor and reproductive capacity. The rhizomes release chemicals that inhibit the growth of other plants, causing yield reductions in competing crops. This weed can reduce corn and soybean yields over 30% and 40%, respectively.

Maize Dwarf Mosaic Virus (MDMV) and Maize Chlorotic Dwarf Virus (MCDV) can survive between crops in underground rhizomes. MCDV is moved between corn, Johnsongrass, and sorghum by leafhoppers. Symptoms only appear in corn. MDMV, carried by aphids, infects over 250 species of grasses.



Johnsongrass, photo: Steve Dewey, Utah State University, Bugwood.org



Johnsongrass, photo: Steve Dewey, Utah State University, Bugwood.org

Practice Questions

1) _____ plants germinate in the spring, grow, mature, produce seed, and die in summer or early fall.

1. Summer annual
2. Sedge
3. Winter annual
4. Broadleaf

2) _____ plants appear in the fall and die in late spring or early summer of the following year.

1. Summer annual
2. Sedge
3. Winter annual
4. Broadleaf

3) Annual plants are easiest to control in the _____ stage.

1. seedling
2. vegetative
3. reproductive
4. mature

4) The _____ stage of plant development is characterized by rapid uptake of water and nutrients and fast growth.

1. seedling
2. vegetative
3. reproductive
4. mature

5) Biennial plants are easiest to control in the _____ stage.

1. seedling
2. vegetative
3. reproductive
4. mature

6) Removing the aboveground vegetation will stop perennial plants from spreading in a field.

1. True
2. False

7) _____ plants can reproduce by stolons, rhizomes, tubers, or bulbs.

1. Annual
2. Biennial
3. Perennial

8) The rosette stage is part of the live cycle of a _____.

1. biennial weed
2. pathogenic fungus
3. sap-feeding insect
4. winter annual weed

9) Which of the following is not a form of vegetative reproduction of a weed?

1. seed
2. stolon
3. rhizome
4. bulb

10) Pigweed is a _____ plant.

1. winter annual
2. summer annual
3. perennial
4. winter or summer annual

11) Marestail/horseweed is a _____ plant.

1. winter annual
2. summer annual
3. perennial
4. winter or summer annual

12) Which of the following is a perennial?

1. honeyvine milkweed
2. buttercup
3. fall panicum
4. common cocklebur

13) Seedling Johnsongrass plant is more competitive than rhizome Johnsongrass.

1. True
2. False

14) An emerging _____ plant has 2 seed leaves.

1. grass
2. broadleaf
3. sedge

15) Annual plants reproduce from underground stems and tubers.

1. True
2. False

16) It is best to control weeds before they produce seeds.

3. True
4. False

17) The growing point of a grass is always above the soil surface.

1. True
2. False

18) All actively growing _____ have exposed growing points at the end of each stem and in each leaf axil.

1. sedges
2. broadleaves
3. grasses

19) _____ usually have a taproot and a relatively coarse root system.

1. Broadleaves
2. Grasses
3. Sedges

Answers

1-1	2-3	3-1	4-2	5-1
6-2	7-3	8-1	9-1	10-2
11-4	12-1	13-2	14-2	15-2
16-2	17-2	18-2	19-1	

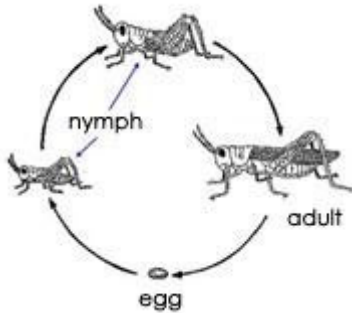
Agricultural Insect Pests

Insects and Other Arthropods

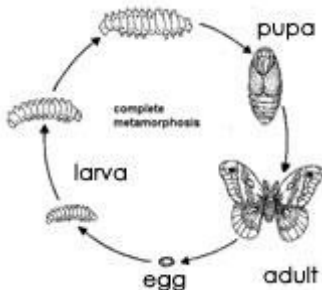
Insects, spiders, scorpions, millipedes, centipedes, ticks, and mites are arthropods. They have hard external skeletons and segmented legs and bodies. Most insects have 3 main body regions and 3 pairs of legs; they are the only arthropods that can fly.

Insect Life Cycles and Growth

Insects go through a series of changes during their development from egg to adult in a process called **metamorphosis**. When the insect hatches from an egg, it is either a **nymph** (gradual metamorphosis) or a **larva** (complete metamorphosis). The immature stage must shed its external skeleton, a process called **molting**, in order to grow.



Grasshoppers undergo **gradual metamorphosis**, passing through three stages of development: egg, nymph, and adult. Nymphs resemble adults. They eat the same food and live in the same environment. The change in form from nymph to adult is gradual. Only the adult state has wings. Other examples are aphids, stink bugs, and leafhoppers.



Insects with **complete metamorphosis** include butterflies and moths, beetles, flies, bees, and ants. There are four stages in complete metamorphosis – egg, larva, pupa, and adult. The larvae are specialized for feeding and look very different from the adult. They have general

names such as caterpillar, maggot, white grub, or wireworm. Larvae usually live in very different situations and often feed on different foods than adults.

A variety of insects and mites can attack plants but most are not pests. Some are beneficial, providing natural control or pollination services. Others are scavengers on dead or dying plants so they recycle nutrients. **Just because an insect is around damage does not mean it was the cause.**

Mouthparts and Feeding

The type of mouthparts an insect has will determine the type of damage it can cause to plants. Pest insects may be divided into major groups according to how they feed:

1. piercing-sucking
2. chewing
3. rasping plant tissue

Piercing-Sucking

Sap feeders with piercing-sucking mouthparts can cause wilting, leaf curl, or stunted foliage. Chemicals injected by some species of leafhoppers can cause leaf burn. Stink bug feeding can cause distorted leaves or fruit. Several aphid and leafhopper species can carry virus diseases.



Brown marmorated stink bug,
photo: UK Entomology

Stink bugs are sap feeders that are attracted to a variety of cultivated crops and weeds. Soybeans are a favorite late summer host, and dramatic growth in soybean acreage during the recent years has contributed to steadily increasing numbers of these insects. The principal damage comes from loss of plant fluids, injection of digestive enzymes that can deform plant parts or kill developing seeds. Feeding wounds can provide entry points for plant pathogens.



Aphids, photo: UK Entomology

Aphids are soft-bodied insects that use their piercing sucking mouthparts to feed on plant sap. They usually occur in colonies on the undersides leaves and on tender terminal growth. Heavily-infested leaves can wilt or turn yellow because of excessive sap removal. Some aphids produce lots of liquid waste (honeydew) that supports the growth of sooty mold. This can reduce yield quality. Some aphids can move virus diseases from infected to healthy plants.

Chewing

Chewers include caterpillars and beetles. They feed on leaves, fruit, or grain. The amount of feeding a plant can tolerate without significant impact on growth or yield varies with a plant's age, growth stage, or stress (drought, etc.).

Caterpillars



Armyworm, photo: UK Entomology

The **armyworm** is a common early season pest that occasionally causes significant damage in corn, wheat, or pastures. Infestations usually develop in fields of small grains, pastures, or in crops planted into grass cover crops. These insects chew inward from leaf edges. Moths lay masses of eggs on grasses so large numbers of the worms can be present in "hot spots" in fields. After eating all of the plants in an area, large numbers of armyworms

will crawl as a group in search of food plants. Cool, wet, spring weather usually favors armyworm development.



Fall armyworm, photo: UK Entomology

The **fall armyworm** looks similar to the armyworm but cannot survive the winter in Kentucky. Moths arrive from the Gulf Coast states in mid-summer and lay eggs on late-planted whorl stage corn. Large larvae eat large amounts of leaf tissue leaving ragged leaves, similar to grasshopper damage. The worms usually found deep in the whorl often below a "plug" of yellowish brown frass. The frass protects them from insecticide applications. Plants often recover from whorl damage without any reduction in yield unless the caterpillars feed on developing ears.



Green cloverworm, photo: UK Entomology

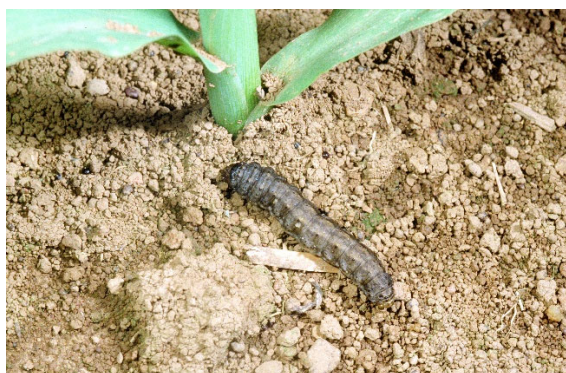
The **green cloverworm** is one of the most common leaf feeding insects in Kentucky soybeans. However, it rarely reduces yield because of the soybean plant's ability to compensate for foliage losses. The slender, light green caterpillars have three pairs of white stripes that run the length of the body. There are three pairs of legs near the head, three pairs of fleshy legs near the middle of the body, and a pair of fleshy legs at the tail end. Most soybean caterpillars have four pairs of legs near the

middle of the body. GCW larvae wiggle violently when disturbed.



Corn earworm, photo: UK Entomology

The **corn earworm**, also called the **soybean podworm**, is common in corn and soybean fields. The caterpillar feeds in the tips of corn ears damaging some kernels but control is usually not practical. However, this insect **can cause significant yield loss in late-planted soybeans where it feeds on pods**. Pod feeding directly reduces yield and is much harder to notice than leaf feeding.



Black cutworm, photo: UK Entomology

The **black cutworm** is an early season pest that can cause stand loss in corn and tobacco **fields that had significant infestations of winter annual weeds prior to planting**. Cutworm moths lay their eggs on weeds. The larvae feed on crop seedlings when the weeds are removed by herbicide application or tillage. **Cutworm problems tend to be worse when wet springs allow weed growth and delay planting**. Cutworms feed mostly at night and hide during the day under clods of soil or in burrows below the soil surface. Regrowth of cut seedlings is possible in some instances in corn depending on where the damage occurred relative to the growing point.

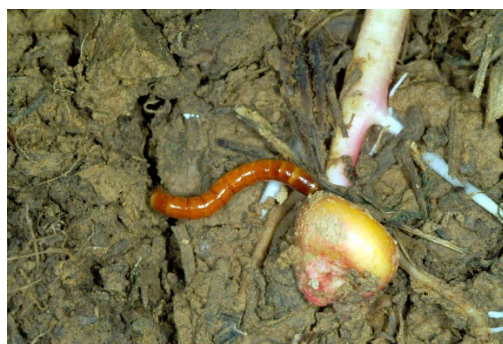
Beetles



Japanese beetle, photo: UK Entomology

The **Japanese beetle** feeds on many plants, including corn and soybeans. These insects will congregate in corn fields during pollination. There is concern that **silk feeding** by this insect can interfere with pollination. Pollination can occur as long as there is at least one-half inch of silk present during pollen shed. Large numbers of adults also will feed on soybean leaves, especially in fields where smartweed is present.

The **larval stage of the Japanese beetle is a white grub that feeds below ground on plant roots**. Females usually lay their eggs in pastures and grassy areas but may deposit some in corn and soybean fields. The grubs do most of their feeding in late summer. There is rarely enough damage to the root systems of these crops to affect yield. The grubs feed little, if any, in the spring so there is no danger to crops planted the following year.



Wireworm, photo: UK Entomology

Wireworms are the larval stage of other beetle species that will feed on seeds and tunnel into plant stems. They are **most common in crops planted into sod or grassy fields**.

Rasping



Thrips, photo: UK Entomology

Tiny **thrips** tear plant cells and feed on sap. These tiny insects may leave feeding scars or distorted leaves; some can carry plant disease.



Slug laying eggs, photo: UK Entomology

Slugs are soft-bodied non-arthropod creatures with rasping mouthparts that destroy seedlings in reduced tillage fields that have a significant amount of crop residue on the surface. The residue, such as corn stalks, provides food and shelter. Slugs are active during cool, moist periods in the spring and move below ground as the soil becomes warmer and drier. Molluscicides, pesticides that are toxic to slugs, may provide some control.

Beneficial Insects

Beneficial insects play an important role in regulating populations of crop pests. Parasitic wasps and flies hunt and attack specific caterpillars. Four species of lady beetles feed on aphids in Kentucky's major crops. General predators like spiders and damsel bugs eat what they can catch but also have an impact on pests.



Seven-spotted lady beetle, photo: UK Entomology



Lady beetle larva, photo: UK Entomology

Vertebrate Pests

Birds, moles, raccoons, deer, or other animals may eat or injure agricultural or horticultural crops. The usual management strategy is to keep their numbers to a level where the damage or injury is economically acceptable. **Local and state laws may prohibit the killing or trapping of some vertebrate animals without special permits. Before you begin a control program, check with local authorities.**

Methods of vertebrate pest control include: mechanical control, baits, sanitation, and exclusion. Few pesticides are available for control of pests other than rodents and most of them require special local use permits. Most are applied as baits. Examples of chemicals used to control vertebrate pests include rodenticides and avicides (birds).

Practice Questions

1) Gradual metamorphosis has ____ developmental stages.

1. 1
2. 3
3. 4
4. 7

2) Complete metamorphosis has ____ developmental stages.

1. 1
2. 3
3. 4
4. 7



3) Which picture above is a white grub?

1. 1
2. 2
3. 3
4. 4

4) Which picture above is the larval stage of picture 3?

1. 1
2. 2
3. 3
4. 4

5) A white grub has _____ mouthparts.

1. sucking
2. chewing
3. rasping
4. no

6) Feeding by _____ can deform plant parts or kill developing seeds.

1. caterpillars
2. Japanese beetles
3. stink bugs
4. grasshoppers

7) Which soil insect chews on plant roots?

1. white grub
2. corn root aphid
3. wireworm
4. green cloverworm

8) Which of the following is NOT a sap feeder?

1. stink bug
2. black cutworm
3. leafhopper
4. aphid

Answers

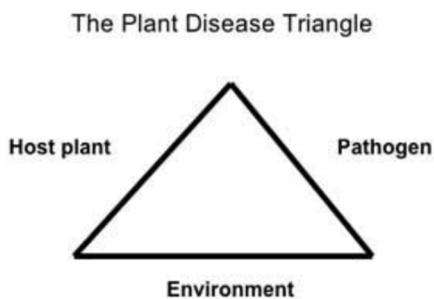
- 1-3 2-4 3-1 4-4
 5-2 6-3 7-1 8-2

Agricultural Plant Diseases

Plant Diseases

A **plant disease** is any harmful condition that affects a plant's appearance or function. Common pathogens that cause disease include: fungi, bacteria, viruses. Some nematodes are plant disease agents. Temperature extremes or nutrient deficiencies are examples of disorders caused by non-infectious factors.

The **disease triangle** is a fundamental concept in plant pathology. Disease occurs only when all three sides of the triangle are present: a susceptible host, a pathogen (the agent that causes disease), and an environment favorable for disease to develop. Plant diseases are managed by manipulating the disease triangle: the plant, the pathogen, and/or the environment.



Infection begins when the pathogen enters the plant. The disease process starts when it arrives at a part of a plant where infection can occur. If environmental conditions are favorable, the pathogen begins to develop. The plant is diseased when it responds.

Plants respond to disease in 3 main ways:

overdevelopment of tissue - galls, swellings, or leaf curls;

underdevelopment of tissue - stunting, lack of chlorophyll, or incomplete development of organs; or

tissue death - blight, leaf spot, wilting, and cankers.

Plant disease pathogens may be spread in many ways:

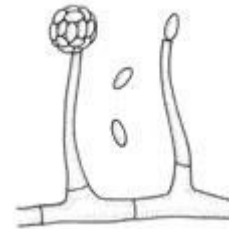
- by wind;
- rain;
- animals;
- soil;
- nursery grafts;
- vegetative propagation;
- contaminated equipment and tools;
- infected seed stock;

- pollen;
- dust storms;
- irrigation water; and
- people.

Infectious Organisms that Cause Disease

Fungi are the most common infectious organisms causing plant disease. They do not have chlorophyll so they cannot make their own food. They must get it by living on another organism.

Most fungi are beneficial. They contribute to soil fertility by releasing nutrients from dead plants or animals. Those that cause plant diseases are parasites on living plants. They may attack plants and plant products both above and below ground. Some fungal pathogens attack many plant species; others have to only one host species.



Most fungi **reproduce by spores**, which function like seeds. Fungus spores are often microscopic and are produced in tremendous numbers. Often spores can survive for weeks, months, or even years without a host plant. **Excessive water or high humidity** is nearly always needed for spore germination and active fungal growth.

Spores can spread from plant to plant and crop to crop through wind, rain, irrigation water, insects, and by people through infected clothing and equipment.

Fungal infections frequently are identified by the vegetative body of the fungus (mycelium) and the fruiting bodies that produce the spores. Often, they are large enough to see.

Symptoms of fungal infections include

- soft rot of fruits,
- plant stunting,
- smuts,
- rusts,
- leaf spots,
- wilting, or
- thickening and curling of leaves.

Powdery and downy mildew, smut, root and stem rots, and sooty and slime molds are examples of fungus diseases.

Bacteria are single-celled organisms that usually reproduce by simple cell division. Some divide as often as every 30 minutes. They can build up quickly under warm, humid weather conditions. Leaf, growing shoots, and fruit diseases are the most common types in Kentucky.

Bacteria can be carried from plant to plant in water droplets, by wind, rain splash, insects, or on equipment. They often survive between growing seasons in crop residue, in seeds or cuttings, or in weeds.

Leaf Diseases Caused by Fungi and Bacteria

Leaf Spots

Bacteria or fungi can cause **leaf spots** that vary in size, shape, and color. Usually, the spot has a distinct margin and may be surrounded by a yellow halo. A fungal leaf spot nearly always has a growth of some type in the spot, particularly in damp weather. It may be a tiny pimple-like structure or a moldy growth of spores. Often the structures are visible through a hand lens. Nearby diseased areas may join to form irregular "blotches."



*Photo: Paul Bachi, University of Kentucky
Research and Education Center, Bugwood.org*

Septoria brown spot is a common fungal disease of soybeans. It causes small angular red-brown spots to develop on upper and lower surfaces of trifoliate leaves 2 to 3 weeks after planting. Numerous spots will cause leaves to yellow and drop. The disease will develop many irregular, tan lesions on trifoliate leaves that later turn dark brown. Individual spots will frequently coalesce to form large blackish-brown blotches.

Defoliation from the bottom to the top of severely diseased trifoliate leaves is common during wet seasons.

Early season brown spot will appear annually in almost every field in Kentucky. Late-season brown spot is much more variable in occurrence and severity.

The fungus survives from season to season in crop debris and seed. Warm, moist weather promotes the sporulation of the fungus; the spores are spread by wind and rain. Hot, dry weather can stop disease development.

Leaf Blights

Leaf blights generally affect larger leaf areas and are more irregular than leaf spots.



*Photo: Margaret McGrath, Cornell University,
Bugwood.org*

Northern corn leaf blight (NCLB), caused by a fungus, first develops on the lower leaves of corn plants that are from waist to shoulder high. The telltale sign of northern corn leaf blight is the **1-to-6 inch long cigarshaped gray-green to tan-colored lesions** on the lower leaves. As the disease develops, the lesions spread to all leafy structures.

Wet weather and moderate temperatures favor NCLB. Symptoms can be confused with bacterial wilt, especially late in the season.

NCLB will be **more severe in fields with corn following corn under reduced tillage**. Other hosts include sorghum, Johnsongrass, and some other grass species. The pathogen overwinters in plant debris and is transferred by wind to new plants. **Severe yield loss can occur when leaves become blighted during early grain fill.**

Rusts

Rust fungi often produce bright yellow, orange-red, reddish-brown or black "pustules". The pustules are usually raised above the leaf surface. Rust can be rubbed off the leaf surface.



Photo: Donald Groth, Louisiana State University AgCenter, Bugwood.org

Wheat leaf rust first appears as small yellow flecks on the upper leaf surface which turn to orange pustules. The disease reduces plant vigor, seed fill, and root growth. Losses are greatest when the disease is active before or during flowering. **Leaf rust is a potentially explosive disease; it requires a very short time to go from low to epidemic levels on a susceptible variety.** In severe cases, infected leaves wither and die rapidly. Warm temperatures and high humidity or rain favors its development. Rust is present almost every year in some part of Kentucky, however most years it develops too late to cause extensive damage.

Powdery Mildews

Powdery mildews are diseases caused by some closely related fungi. The mildew can be diagnosed by a grayish white powder mat leaves and in some cases stems. Affected leaves usually turn yellow, wither and die rapidly.



Photo: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org

Powdery mildew of wheat is easily diagnosed by the **white, powdery patches that form on the upper surfaces of lower leaves and stems.** The patches turn a dull gray-brown and may have small black embedded specks. This disease can spread to all aboveground parts of the plant.

The fungus responsible for powdery mildew **can persist between seasons in infested wheat stubble and in overwintering wheat.** Spores then infect plants during periods of **high moisture** (not necessarily rain) and cool to moderate temperatures. **Low light intensity, which accompanies dreary weather, and a dense, lush crop canopy favor this disease.** Hot daytime temperatures (80°F plus) and moderate nighttime temperatures will stop powdery mildew development.

Downy Mildews



Photo: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org

Downy mildews are caused by organisms similar to fungi. Colonies often appear first on the underside of leaves, and they sometimes have a bluish tinge. Many can grow systemically throughout the plant. **Downy mildews are generally favored by cool temperatures (58-72° F) and relative humidity above 85% at the leaf surface.** Blue mold of tobacco is a downy mildew disease. Deformed plant growth ("crazy top") may result from downy mildew as in the case of sorghum downy mildew of corn or grain sorghum.

Wilts, Root and Crown Rots

The main symptoms of these three diseases are **wilting, stunting, and death.** The causal organisms are usually soil-borne, that is they are already present in the soil when the host crop is planted. Most other diseases are usually spread through the air. Some of these diseases may be controlled through the use of soil fungicides and/or soil fumigants but most are controlled with resistant varieties and cultural practices. Good controls are not available for many of these diseases.

Wilts

Most wilt diseases are caused by fungi -- *Fusarium* and *Verticillium* -- and a bacterium, *Erwinia*. Each parasite causes wilts on a wide range of crop plants. A light to dark brown streaking often can be seen when the stem of a diseased plant is cut lengthwise. However, it is often difficult to determine which of these wilt diseases a plant may have.

Plants with *Fusarium* or *Verticillium* wilt grow slower than healthy plants and may show stunting effects before wilting occurs. The lower leaves usually turn yellow and wilt first, then yellowing and wilting slowly progress up the plant. It may take several days to a few weeks from first wilting and plant death.



Photo: J.K. Pataky, University of Illinois at Urbana-Champaign, Bugwood.org

Stewart's wilt of corn is a bacterial disease with two phases. The seedling wilt stage occurs when young plants have a systemic infection. The leaf blight stage occurs when plants are infected after the seedling stage. The bacterium spends the winter in the corn flea beetle. The bacterium enters the plant at wounds made when an infected flea beetle feeds on a susceptible plant.

Stewart's wilt is **controlled effectively by planting resistant corn hybrids**. Resistance restricts the movement of bacteria in the vascular system of plants and prevents plants from becoming infected systemically. Most field corn hybrids are moderately to highly resistant; sweet corn hybrids range from highly susceptible to resistant.

Crown Rots



Photo: Ernesto Moya, Bugwood.org

Crown rots include causal organisms that attack the plant at/or near the soil line. Crown rots are called various names such as **collar rot, stem blight, stalk rot and southern blight**. Affected plants are generally, at first, unthrifty with leaves smaller and lighter green than normal. Leaves usually turn yellow and, in advanced stages of disease, wilt and die. The crown or base of the stem will be water-soaked, discolored or decayed. With some diseases, this area may dry rot and become shredded. A moldy growth and various colored fungus fruiting bodies often form in this diseased area.

Most crops are affected by one or more of this type of disease.

Root Rots



Photo: Mary Burrows, Montana State University, Bugwood.org

Above-ground symptoms of **root rot** diseases are variable. Some plants may show wilt type symptoms and die rapidly; others may become yellow, stunted, slow growing and may not die for some time after the first symptoms are seen. **Roots are reduced in size and will be light brown to black in color, with both taproots and feeder roots decayed.** Most plants are susceptible to root rots.

A great variety of fungi can infect the crown of the alfalfa plant, which is the portion of the taproot just below the soil line. The alfalfa plant stores food reserves for winter in the crown. Crown rot diseases interfere with this process, making plants more susceptible to winter injury.

Seed and Seedling Diseases

Seed and seedling diseases occur on plants from after germination until about 1 or 2 weeks after seedling emergence. Fungi that are on the seed at planting or are present in the soil are the cause. They often are responsible for poor emergence and thin stands.



Photo: Paul Bertrand, University of Georgia, Bugwood.org

If the disease occurs before emergence, the seedling may rot before it has a chance to get out of the soil. This is referred to as **pre-emergence damping-off**. After emergence, seedling stems may be attacked at or below the soil line in what is termed **post-emergence damping-off**.

Two general symptoms are **brown to red-brown or black cankers at the soil line and a soft watery rot**. If the canker girdles the stem, the seedling falls over and dies. The plant may continue to live but will be stunted with partial girdling. In the second instance, the soft watery rot continues until the entire seedling decays.

Seed and seedling diseases are most common in cool, wet soils. They are controlled by planting crops in warm soil, by fungicide seed treatments and by use of in-furrow, broadcast, or band-applied fungicides.

Smuts



Photo: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

Smut disease fungi attack grasses and cereal tops. The most destructive smuts attack small grains, often causing the kernels of grain in the head to be replaced by a mass of dark powdery fungus spores. Corn smut disease results in a swelling of the affected plant part with the galls produced on the plant containing a mass of dark, powdery spores.

Viruses

Viruses are too small to be seen with a microscope. They are generally recognized by their effects on plants. There can be a variety of responses: stunted growth; change in plant color; abnormal formation of infected roots, stems, leaves, or fruit. **Mosaic diseases, characterized by light and dark blotchy patterns,** usually are caused by viruses.

It can be **difficult to distinguish between diseases caused by viruses and those caused by fungi and bacteria.** A positive diagnosis requires sophisticated testing, such as inoculating indicator plants and observing the results or using specifically identified antibodies to test for the presence of the organism.

Viruses depend upon living organisms for food and reproduction; they cannot exist very long outside a host. **Viruses are commonly spread from plant to plant by mites, aphids, leafhoppers, or whiteflies.** A few are spread in the seeds of the infected plant.



Photo: Mary Ann Hansen, Virginia Polytechnic Institute and State University, Bugwood.org

Maize Dwarf Mosaic Virus (MDMV) and **Maize Chlorotic Dwarf Virus (MCDV)** can survive between crops in underground rhizomes. MCDV is moved between corn, Johnsongrass, and sorghum by leafhoppers. Symptoms only appear in corn. MDMV, carried by aphids, infects over 250 species of grasses.

Nematodes

Nematodes are small, usually microscopic roundworms with mouthparts like hollow needles – called stylets. Stylets are used to puncture and feed on the contents of plant cells. Nematodes may develop and feed inside or outside of a plant. They are easy spread on footwear, tools, and equipment.

The life cycle of a nematode includes an egg, several larval stages, and an adult. Most larvae look like small adults. In unfavorable conditions, females of some species form inactive, resistant forms called cysts. The cyst is the hard, leathery, egg-filled body of the dead female, which is difficult to penetrate with pesticides. A cyst may protect eggs for as long as 10 years.

Typical aboveground symptoms are stunting, yellowing, loss of vigor, general decline, and eventual death of plants. Since many other problems can cause symptoms root and soil samples need to be examined when nematode injury is suspected. Nematodes are controlled with cultural practices such as crop rotation, resistant varieties and nematicides.



Cysts (bodies of female nematodes) are visible on diseased roots from four weeks after planting through the rest of the season, Photo: Gregory Tylka, Iowa State University, Bugwood.org



Soybean cyst nematode damage to different soybean varieties, photo: Paul Bachi, University of Kentucky REC, Bugwood.org

In Kentucky, the **soybean cyst nematode (SCN)** is the most damaging nematode disease. It feeds on the roots of soybean and other host plants. Feeding removes nutrients and disrupts nutrient and water movement. An infestation also reduces the production of nitrogen-fixing nodules and encourages other root diseases.

SCN in Kentucky

- Causes up to 30% yield loss without any obvious problem until harvest.
- Eggs can survive in the soil for many years even without host plants.
- Reproduction occurs on resistant soybeans.
- Moves every way that soil moves.
- SCN can be present in a field for many years before it is detected.
- Symptoms may look like those due to other causes.

Diagnosis of Plant Diseases

A **correct diagnosis** is the first step in disease management. To recognize a disease condition, you must know the plant's normal growth habits. When you are trying to identify the cause of a plant disease, you need to look for **symptoms** - the host plant's reaction to the disease agent, and **signs** - visible presence of the disease agent.

Many different plant diseases cause similar symptoms. Different pathogens and agents that are not pathogens can cause leaf spots, wilts, root galls, or stunted growth.

For example, similar symptoms may be a result of mechanical injury, improperly applied fertilizers and pesticides, or frost. Often, the only way to pinpoint the cause is to **find the observable signs that the particular disease agent is present** -such as fungal spores and mycelium or bacterial ooze.

Accurate identification and diagnosis of plant diseases is an art, as well as a science, and experience is essential. For more accurate disease diagnosis, consult your county Extension agent.



Practice Questions

1) Which of the following causes a plant disorder?

1. fungus
2. bacteria
3. nematode
4. nutrient deficiency

2) _____ are the most common infectious organisms causing plant disease.

1. Bacteria
2. Fungi
3. Sunscalds
4. Viruses

3) _____ reproduce by spores.

1. Nematodes
2. Bacteria
3. Fungi

4) _____ reproduce by simple cell division.

1. Bacteria
2. Fungi
3. Nematodes
4. Viruses

5) _____ is an example of a fungal disease.

1. Root cyst
2. Mosaic pattern on leaves
3. Root rot
4. Leaf blight

6) _____ diseases are commonly spread by aphids or leafhoppers.

1. Virus
2. Mildew
3. Abiotic
4. Root rot

7) Wilting is an example of a disease sign.

1. True
2. False

8) Infection begins when the pathogen _____.

1. enters the plant
2. arrives at a part of the plant where infection can occur
3. symptoms appear

9) _____ move from plant to plant on in water droplets, rain splash, or being carried by insects.

1. Fungi
2. Viruses
3. Bacteria
4. Nematodes

10) Powdery mildew, root rots, and stem rots are examples of diseases caused by _____.

1. fungi
2. bacteria
3. nematodes
4. viruses

11) _____ causes small angular red-brown spots on trifoliate soybean leaves 2 to 3 weeks after planting.

1. Soybean cyst nematode
2. Septoria brown spot
3. Soybean aphids
4. Rust

12) Northern corn leaf blight overwinters in _____.

1. flea beetles
2. grasses
3. plant debris
4. cysts in the soil

13) _____ diseases usually produce pustules on plant leaves.

1. Mosaic
2. Bacterial
3. Rust
4. Virus

14) Leaf rust is rarely is an explosive problem because it develops so slowly.

1. True
2. False

1. True
2. False

15) _____ is the first step in disease management.

1. Waiting for symptoms to appear
2. A correct diagnosis
3. Selection of the most effective fungicide

16) Many different plant diseases cause similar symptoms.

Answers

- | | | | |
|--------|--------|--------|--------|
| 1 - 4 | 2 - 2 | 3 - 3 | 4 - 1 |
| 5 - 3 | 6 - 1 | 7 - 2 | 8 - 1 |
| 9 - 3 | 10 - 1 | 11 - 2 | 12 - 3 |
| 13 - 3 | 14 - 2 | 15 - 2 | 16 - 1 |

Pesticide Application Equipment

The application method you choose depends on such factors as the nature and habits of the target pest, characteristics of the target site, and properties of the pesticide formulation. You also must consider the suitability of the application equipment, cost, and efficiency of alternative methods.



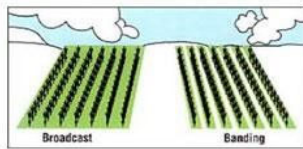
Foliar spray



Post-emergence directed (Wylie Sprayers)



Rope-wick applicator (Rogers Sprayers)



Broadcast and banded sprays (Wylie Sprayers)

Here are some common pesticide application methods:

- **Band** —applied in parallel strips, such as between or over rows of crops.
- **Broadcast**—uniformly applied to an entire area or field.
- **Directed-spray** —targeted applications to minimize contact with non-target plants and animals.
- **Foliar** —directed to the leafy portions of a plant.
- **Rope-wick or wiper treatment**—released onto a device that is wiped onto weeds taller than the crop, or wiped selectively onto individual weeds in an ornamental planting bed.
- **Soil** —placed directly on or in the soil instead of on a growing plant.
- **Soil incorporation**—use tillage, rainfall, or irrigation equipment to mix pesticide into the soil.
- **Soil injection**—applied under pressure beneath the soil surface.
- **Space treatment**—applied in an enclosed area.
- **Spot treatment** —applied to small, distinct areas.

Safety Systems

Closed mixing and loading systems, enclosed application systems (e.g., enclosed cabs), and pesticide containment systems are excellent investments if you use large quantities of pesticides or products that are very hazardous to humans or to the environment.

Closed Mixing and Loading Systems



Closed pesticide mixing system (PMB Supply)

Closed mixing and loading systems are designed to prevent pesticides from contacting handlers or other persons during mixing and loading. The labels of pesticides with a high risk of causing human health effects may require the use of a closed mixing and loading system. There are two primary types. One uses mechanical systems to deliver the pesticide from the container to the equipment. The other uses water-soluble packaging.

Mechanical systems often consist of interconnected equipment that allows the safe removal of a pesticide concentrate from its original container by gravity or by suction. These systems also minimize exposure when rinsing empty containers and transferring the pesticide and rinsate to application equipment. Openings vary in shape and size so no single closed system works with all containers. Typically, pump-and drive units deliver the product. A meter allows accurate measuring from the minibulk tank to the sprayer. Usually, empty tanks are returned to the dealer for refilling. This eliminates the need to triple rinse or pressure rinse multiple small containers and reduces the number of used plastic containers.

Enclosed Cab



Photo: Howard F. Schwartz, Colorado State University, Bugwood.org

An **enclosed cab** (such as a tractor cab, cockpit, or truck/vehicle cab) surrounds the occupant(s) and may prevent pesticide exposure as long as the doors, hatches, and windows are closed during the application. Enclosed cabs are considered a supplement to personal protective equipment (PPE) —not a replacement for it. **Applicators must wear all PPE specified on the label while working inside enclosed cabs.** However, the labeling of some agricultural use pesticides may allow exceptions to the label specified PPE requirements for applicators in enclosed cabs. Check with the Kentucky Department of Agriculture for any other requirements regarding PPE and enclosed cabs.

Remember, **outside surfaces of the application equipment and cab are contaminated. Be sure to wear appropriate PPE when getting in and out of the cab or performing routine equipment maintenance.**

Pesticide Containment Pad

If you often store, handle, mix and load pesticides, or clean equipment at the same location, you may have to install a pesticide containment pad. Check EPA and Kentucky state regulations to determine when a containment pad is required. These pads are designed to contain spills, leaks, overflows, and wastewater for reuse by the applicator or for disposal by a commercial waste management contractor. They make it easier to clean up spills and help to prevent environmental contamination.



Impervious containment pad

Generally, the containment pad must be made of impermeable material. It should be concave or have curbs, berms, or walls high enough to hold the largest amount of spill, leak, or equipment wash water likely to occur at the site. It also must have a system to remove and recover spilled, leaked, or released material by either an automatic sump system or a manually operated pump. Smaller, portable pads and lightweight trays made of heavy-duty plastic may be used when mixing and loading at the application site.

Application Equipment

Hydraulic Sprayers

The application equipment or device **must be able to apply the pesticide to the intended target at the proper rate.** The label specifies the legal application rate and may suggest the appropriate equipment for use with the product.

Hydraulic sprayers range from large powered units with multiple-nozzle booms to small manual backpack or hand-held compressed-air sprayers. In all cases, pressure from either a pump or compressed gas or air is used to atomize the spray mix at the nozzle.



Nearly 90% of all pesticides are formulated for dilution in water or some other liquid for application



Manual sprayers are designed for spot treatments and for areas unsuitable for larger units. They are relatively inexpensive, simple to operate and maneuver, and easy to clean and store. Adjustable spray guns are often used with these units but some models have the option for a spray boom. The air-blast (or mist) sprayer uses both water and air as carriers. Spray droplets are formed by the nozzles and delivered to the target by an airstream. Airblast sprayers are typically used for disease and insect control on fruit trees, vineyards, vegetables, and Christmas trees.

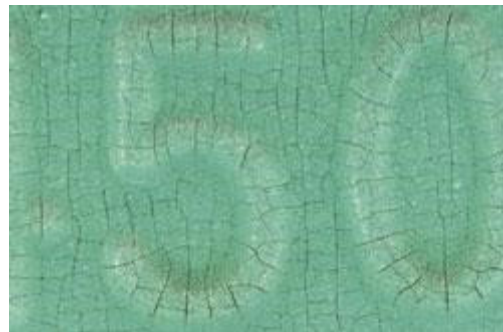


Photo: Omafra.gov.ca

Sprayer Components



Tank

A **tank** is necessary to contain the spray mix. **Choose one made of, or coated with, a material that does not corrode and that can be cleaned easily.** Cleaning prevents accumulations of corrosion and dirt that clog screens and nozzles, increasing wear on the equipment. Large tanks require an opening in the bottom to aid in cleaning and draining. A large top opening is useful for filling, cleaning, and inspecting the tank. The opening must have a watertight cover to prevent spills. A **tank agitation system/device** is useful for most sprayable formulations, especially for wettable powders or dry flowables. Constant mixing of a pesticide and liquid carrier produces a uniform spray mixture (suspension) and results in an even application of the chemical.

Exposure to sunlight and corrosive chemicals can shorten the life of polyethylene tanks.

Three common signs of wear and potential tank failure are:

- **Scratches** are on the surface and can be seen and felt.

- **Crazing** is a network of fine lines or cracks that may look like a patchwork, but often cannot be seen with a visual inspection. Crazing can be seen when using one of the testing methods explained below. **Crazing occurs within the tank wall and can be a sign of deterioration of the plastic, which may lead to cracks.** Tanks that show signs of crazing will still hold liquids, but the integrity of the tank is questionable. For this reason, caution should be used when putting any hazardous substance in tanks that show crazing.

- **Cracks** extend through the plastic wall and can be visually seen and felt. Cracks may run parallel or at right angles to each other.

Pump

A **pump** agitates the spray mixture and produces a steady flow to the nozzles. Pump parts must resist corrosion and abrasion, especially when wettable powders or similar formulations are used. Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. You may damage the pump if it is operated dry or with a restricted flow at the inlet or outlet. Pumps depend on the spray liquid for lubrication and to prevent overheating.

Nozzles

The proper selection of a **nozzle** type and size is essential for proper pesticide application. **The nozzle is a major factor in determining the amount of spray applied to an area, the uniformity of application, the coverage obtained on the target surface, and the amount of potential drift.**

Nozzles break the liquid into droplets, form the spray pattern, and propel the droplets in the proper direction. Nozzles determine the amount of spray volume at a given operating pressure, travel speed, and spacing. Drift can be minimized by selecting nozzles that produce the largest droplet size while providing adequate coverage at the intended application rate and pressure.

Standard Parts



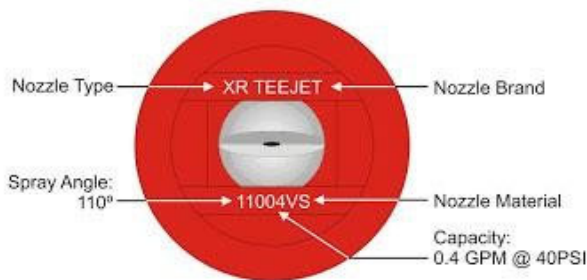
TeeJet

Nozzle parts:

- The **nozzle body** holds the strainer and tip;
- A **strainer** screen prevents a clogged nozzle. It is the best defense against nozzle plugging and pump wear. The screen can remove dirt and rust flakes from the spray liquid before it reaches the nozzle;
- **Tip gasket** to reduce leaks and dripping;
- The **spray tip** determines the flow rate and droplet pattern;
- The **cap** holds the nozzle body and tip in place.

The Spray Tip

The **spray tip** determines the flow rate and droplet pattern.



11004 nozzle

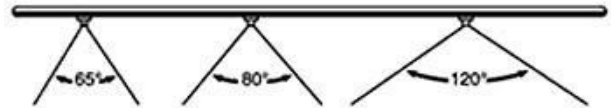
110 is the spray angle in degrees, 04 is the output - 0.4 gallons per minute at 40 psi (Source: TeeJet)



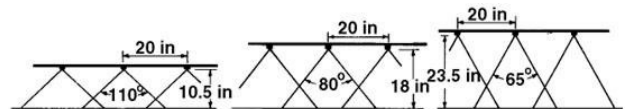
Equip nozzle tips with **check valves** to help prevent dripping when the pump is off. Be sure the spring-loaded ball valves are working properly.

Nozzle Spray Angle, Spacing, and Boom Height

Nozzle spray angle is formed by the edges of the spray pattern. Common angles are 65°, 80°, and 120°. A wide-angle nozzle (110°) produces a thinner sheet of water with smaller droplets than a narrow angle nozzle (65°) with the same delivery rate.

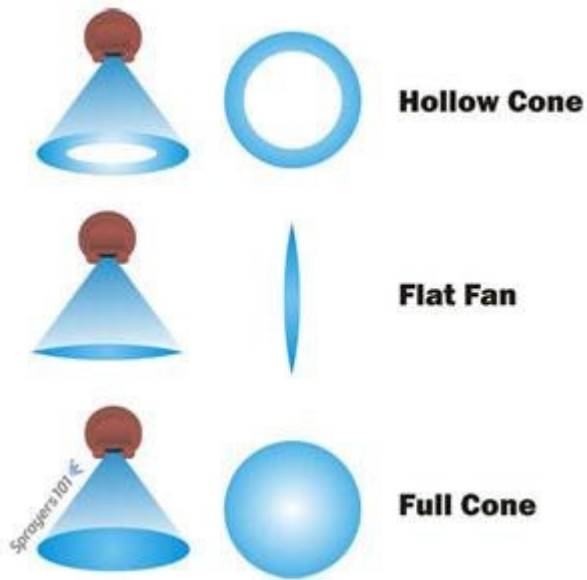


Nozzle spacing on the boom, spray angle, and boom height determine proper overlap of the spray. The drawing below shows the effect of nozzle spray angle on nozzle height, need for proper overlap, and spray coverage. Notice the height difference between the 110°, 80°, and 65° nozzles. Wide angle nozzles are placed closer to the target for proper overlap. A lower nozzle height reduces the risk of spray drift.



Flow meters and other devices measure the uniformity of nozzle flow rate from nozzles along a boom. They are very useful when calibrating sprayers with multiple nozzles.

Common Nozzle Spray Patterns



Three common nozzle spray patterns: hollow cone, full cone and flat fan. (sprayers101.com)

Hollow cone nozzles produce a fine spray pattern to completely cover leaf surfaces. **Full cone nozzles** produce large, evenly distributed droplets at high flow rates. These two cone nozzles are best suited to apply fungicides and insecticides. **Flat fan nozzles** form narrow, oval patterns with tapered ends. They are spaced along a boom and overlap by 30% to 50 % for even broadcast spray distribution to the soil surface or plant canopy.

Nozzle Maintenance



Nozzles are available in various materials: brass, aluminum, plastic, stainless steel, hardened stainless steel, and ceramic. Select the material best suited for the pesticide formulation being used.

Never use brass or aluminum tips to apply abrasive materials (such as wettable powders and dry flowables) because they wear too fast. This wear increases the opening size of the nozzle, which increases its output. Reduce wear by using nozzle tips made of a hard, wear-resistant material: plastic, hardened stainless steel, or ceramics.

Be sure you have the correct screen size for each nozzle.

Clean nozzle tips with a soft brush, not wire or a knife tip.

Sprayer Cleanup

Clean your equipment thoroughly after each use or when changing chemicals. Pesticide residues can corrode metal, plug hoses, or damage pumps and valves unless removed immediately after use. Sometimes residues react with pesticides used later, reducing the effectiveness of the pesticides or causing crop damage. Some pesticide labels provide specific information on cleaning spray equipment; consult the label for guidelines. **Do not clean spray equipment in areas where rinse water will contaminate water supplies, streams, or injure susceptible plants.**



Mixing, loading, and application equipment should be cleaned and rinsed as soon as you finish a pesticide application (USDA)

Pay special attention to areas that can be missed or are difficult to clean:

- Spray surfaces or components **where buildup of dried pesticides might occur.**
- Sprayer **sumps and pumps.**
- **Inside the top of the spray tank and around baffles.**
- **Irregular surfaces** inside tanks caused by baffle.
- **Plumbing fixtures**, agitation units, etc.
- **Collection points** where the hoses connect to the nozzle fittings in dry boom sprayers.

Special tank-cleaning nozzles are available to clean the interior walls of spray tanks. For all application scenarios, **make sure the entire spray system is cleaned, not just the tank.** This is especially true for commercial row-crop boom sprayers. Besides the spray tank, problem spots for pesticide contamination include the inductor; plumbing, which includes valves and hoses; filters and screens; boom segments; nozzle bodies; and nozzles and screens.

When possible, **thoroughly rinse equipment with a strong water-detergent solution (8 to 16 ounces of detergent in 30 to 40 gallons of water). Allow the water-detergent solution to circulate through the system for several minutes.** Remove the nozzles and screens, then flush the sprayer system twice with clean water. **Some pesticide labels may require triple rinsing** to rid the spray system of any possible pesticide contamination. Regardless of how the spray system is cleaned, make sure all visible deposits are removed.

Sloppy cleanup practices are one of the main causes of equipment failure or malfunction. Pesticides allowed to dry in the application equipment tend to clump and stick and cannot be easily removed. These deposits may eventually dissolve into the spray solution. Thus, **improper cleanout may lead to contamination of tank mixes and damage to susceptible crops.** Several commercial compounds will aid in tank cleaning. These can neutralize and remove pesticide residues, remove mineral deposits and rust, and leave a protective film on tank walls to help prevent corrosion.

Storing Your Sprayer

When preparing to store your sprayer, **add 1 to 5 gallons of lightweight oil (depending on the size of the tank) before the final flushing.** As water is pumped from the sprayer, the oil leaves a protective coating on the inside of the tank, pump, and plumbing. To prevent corrosion, **remove nozzle tips and screens and store them in a can of light oil, such as diesel fuel or kerosene.** In addition, **add a small amount of oil and rotate the pump four or five revolutions by hand** to coat interior surfaces completely.

It may be necessary to **winterize the spray system to prevent damage from freezing temperatures.** Be sure to **either drain all water from the spray system or replace the water in the pump and other critical parts with an antifreeze material** (RV antifreeze is commonly used). After thoroughly cleaning and draining the equipment, store it in a dry, clean building. Replace worn-out, deteriorated, or broken parts. **If you store the sprayer outside, remove the hoses, wipe them clean of oil, and store them inside** where they will not become damaged. When using trailer sprayers, you may want to put blocks under the frame or axle to reduce tire pressure during storage.

As with any pesticide-related procedure, **remove contaminated clothes and take a shower immediately after cleaning equipment.** Waiting until the end of the

day to clean up may allow additional absorption of the pesticide through the skin.

Granular Applicators



Granular applicators

Banded over row



Rotary spreader - broadcast



Drop spreader - broadcast

Granular applicators are available for either band or broadcast applications. They may be operated as separate units but often are attached to other equipment, such as planters or cultivating equipment, to combine two or more operations. Granular applicators usually operate by gravity feed and have an adjustable opening to regulate the flow.

Band applicators use hoses or tubes with deflectors on the bottom to drop the pesticide along a row. Broadcast applicators use a system of tubes and deflectors or a spinner to spread the granules. The application rate is affected by ground speed; granule size, shape, and density; field terrain; and even relative humidity and air temperature. Calibrate each unit of a multiple band applicator with the specific material to be applied to ensure accurate application.

Rotary and drop spreaders are two common types of granular applicators. Rotary spreaders distribute granules to the front and sides of the spreader, usually by means of a spinning disk or fan. In a drop spreader, an adjustable sliding gate opens holes in the bottom of the hopper. Granules flow out of the hopper by gravity feed. **Drop spreaders are superior to rotary spreaders when more precise placement of the pesticide is desired.**

Additional types of application equipment include:

- **Bait dispensers** to control rodents, insects, and predators.
- **Foggers** for indoor pest control and for some outdoor insect control.
- **Chemigation systems** for greenhouses and field crops.

Practice Questions

1) The nozzle ___ determines the flow rate and droplet pattern.

1. body
2. tip
3. cap
4. strainer

2) Drift can be minimized by selecting a nozzle that produce the smallest possible droplet size.

1. True
2. False

3) Applicators driving sprayers with enclosed cabs are exempt from wearing any personal protective equipment.

1. True
2. False

4) The strainer screen in a nozzle assembly _____.

1. increases spray pressure
2. stops dripping during turnaround
3. eliminates spray drift
4. keeps the nozzle tip from clogging



5) The spray angle and flow rate of this nozzle is ___ degrees and ___ gallons per minute.

1. 800 and 4
2. 40 and 0.8
3. 80 and 0.4
4. 80 and 4

6) If a nozzle with a 65° spray angle is changed to one with a 110° spray angle, the boom must be _____ to keep the same coverage pattern.

1. lowered
2. raised
3. unchanged

7) Hollow cone and full cone spray nozzles are best suited to apply pesticides evenly to the soil surface.

1. True
2. False

8) Strainer screens ARE NOT needed to catch product particles when applying only _____ formulations.

1. DF
2. WDG
3. F
4. EC

9) Which nozzle material is the best choice when applying mostly WP, DF, or WDG formulations?

1. aluminum
2. stainless steel
3. brass

10) Clean a clogged nozzle tip with a _____.

1. soft brush
2. knife blade tip
3. piece of stiff wire

11) A check valve will help to _____.

1. keep the nozzle flow steady if the pressure drops
2. reduce drift
3. calibrate the nozzle
4. prevent dripping when the pump is off

12) Flushing spray equipment with water is an effective way to remove residues of growth regulator herbicides.

1. True
2. False

13) Switching between granular products with smaller OR larger or lighter or heavier granules requires adjusting the flow rate of a rotary spreader.

1. True
2. False

14) Which spreader will give a more even application of a mix of different sized or weight granules?

1. flat fan
2. rotary
3. drop



15) A network of fine lines or cracks on polyethylene spray tanks indicates _____ (See above).

1. a strong tank agitator
2. residues of spreader stickers
3. cracking due to excessive sprayer pressure
4. crazing due to sunlight and corrosive chemicals

16) Pesticide residues on and in spray equipment are easier to remove if they are allowed to dry first.

1. True
2. False

17) Any pesticides in rinse water from cleaning spray equipment are so dilute that they will not contaminate water supplies, streams, or injure susceptible plants.

1. True
2. False

18) When cleaning spray equipment, make sure the entire system is cleaned, not just the tank.

1. True
2. False

19) Sloppy cleanup practices are almost never one of the main causes of equipment failure or malfunction.

1. True
2. False

20) When preparing to store your sprayer, it is best to _____.

1. add 1 to 5 gallons of a light weight oil before the final flushing
2. leave some of the last spray mixture used in the system
3. leave the system completely dry

Answers

1 - 2	2 - 2	3 - 2	4 - 4
5 - 3	6 - 1	7 - 2	8 - 4
9 - 2	10 - 1	11 - 4	12 - 2
13 - 1	14 - 3	15 - 4	16 - 2
17 - 2	18 - 1	19 - 2	20 - 1

Managing Pesticide Resistance

Pesticide resistance presents an increasing challenge to growers. A **resistant pest** is one that is no longer controlled by a pesticide that has been effective in the past. Using the highest labeled rate and the minimum waiting period between applications does not improve control. **Resistance is not limited to a single product or active ingredient. It occurs with all products that belong to the same pesticide class, that is, that have the same mode of action.** The mode of action is the way the pesticide controls the pest. New labeling practices on some products make it easy to identify the modes of action of some products.

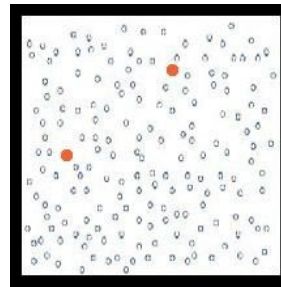
Sources of Resistance

Pesticides are important tools in pest management. Unfortunately, one of the risks of using them is that populations of resistant pests may develop. Thus, products may become less effective - or even useless for controlling resistant pathogens and pests.

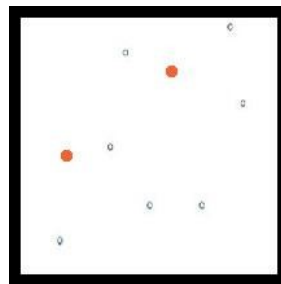
Resistance can only develop in pest populations where there is the genetic potential to resist the pesticide. Normally, only extremely low numbers of resistant individuals are present: perhaps many fewer than 1 in a million, but that can be enough to start the process. Usually, many pests are killed when a pesticide is applied. However, a few resistant individuals survive along with some susceptible ones that "escaped" the treatment, perhaps from incomplete spray coverage. The percentage of resistant individuals will be higher in the next generation. Each time the same pesticide is applied, the percentage of resistant individuals increases in the population and control decreases.

Development of resistant populations is a form of evolution resulting from **genetic variability**: some individuals happen to be resistant and this resistance has a genetic component that can be passed to the next generation. The genetic potential is largely out of human control. The mutation either exists in the field or does not.

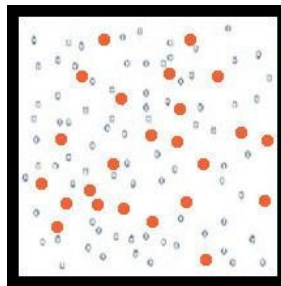
The second factor is **selection**. Repeated use of the pesticide selects for individuals that can survive the presence of the toxin. That condition is under human control. It is a natural outcome of the use of at-risk pesticides. **At-risk pesticides are those against which resistance is most likely to develop.**



A population of pests (circles) before pesticide use. Most are susceptible (open circles) to the pesticide but a very low number are genetically resistant to the pesticide (filled circles).



The resistant individuals survived. A few sensitive one (open circles) escaped the treatment, perhaps due to some factor like reduced spray coverage.



Under favorable conditions, the next pest generation will have a higher percentage of resistant individuals. Continued use of the pesticide selects for more resistant individuals. The labeled rate of the pesticide no longer is effective so a control failure occurs.

Herbicides

Herbicide resistance can develop from natural weed populations that are continuously exposed to herbicides that have the same mode of action. Kentucky has documented cases of herbicide resistance in marestail (horseweed), common ragweed, waterhemp, palmer amaranth, Italian ryegrass, and Johnsongrass. Populations of **smooth pigweed are resistant to triazine herbicides (i.e. Atrazine and Princep) in some areas** of Kentucky where corn is grown in consecutive years.



Marestail and Palmer amaranth, Photo:
www.foragefax.tamu.edu and www.ecosalon.com

Glyphosate-resistant marestail (horseweed) can be found in most counties west of I-65 and is spreading eastward. It can emerge in the fall or overwinter or from early March through the summer. **Glyphosate-resistant Palmer amaranth and waterhemp** is present across the agronomic production acres of Kentucky. These species were first observed in fields located in flood plains or river bottoms but are now appearing in upland fields.

The **common rotation of 3 crops over a 2-year period** contributes to suppressing cases of resistance in the state. Corn is planted in the spring of the first year, followed by fall-planted wheat. Soybeans are planted the second year in early to mid-June after wheat harvest. This rotation accounts for about 1/4 of the soybean, 1/3 of the corn, and nearly 3/4 of the state's wheat acres.

Herbicide resistance can be intentional. For example, soybean varieties and corn hybrids have been developed that are resistant to glyphosate products. However, this can result in glyphosate-resistant corn increasing either as **volunteer plants or as unwanted stands in replanting situations.**

Prevention is a key to avoiding development of herbicide resistant weed populations. Here are management strategies to consider in preventing and dealing with herbicide resistant weeds:

Scout fields regularly and identify weeds present. Respond quickly to shifts in weed populations to restrict spread of weeds.

- Select a herbicide based on weeds present and use a herbicide only when necessary.
- Rotate crops. Crop rotation helps disrupt weed cycles and some weed problems are more easily managed in some crops than others.
- Rotate herbicides. Avoid using the same herbicide or another herbicide with the same site of action (i.e. herbicides that inhibit the same process in target weeds) for two consecutive years in a field.

It is possible for a herbicide used in one crop to have the same site of action as a different herbicide used in another crop. For example: Accent, Classic, Harmony Extra, Harmony SG, Scepter, Osprey, Permit, Pursuit, Python, Resolve, Steadfast, Stout, and Synchrony “STS” contain active ingredients with the same site of activity in plants (i.e. these herbicides are ALS/AHAS inhibitors).

Herbicide group numbers help to identify modes of action. Group 2 herbicides are ALS/AHAS inhibitors.

Group	2	Herbicide
-------	---	-----------

- Apply herbicides with different sites of action as a tank mixture or sequential application during the same season.
- Combine other weed control practices such as cultivation with herbicide treatments where soil erosion potential is minimized.
- Clean tillage and harvest equipment to avoid moving weed problems from one field to the next.
- Utilize preemergence herbicides that offer alternative sites of action to common postemergence herbicides.

Fungicides

A diversified plant disease management program will slow down the development of fungicide resistance.

Furthermore, even if resistance develops, it will not be as damaging, as compared to a farm where only fungicides are used for disease control. A diversified plant disease management program is buffered against severe damage from fungicide-resistant strains, since there are other tactics that are contributing to disease management. The best way to protect the utility of fungicides is by not over-relying on them. Many crop-management practices can help reduce the reliance on fungicides.

Strategies for managing fungicide resistance are aimed at delaying its development and limiting crop losses if resistance develops. A management strategy should be in place before resistance becomes a problem.

Appropriate disease control practices may include:

- Crop rotation;
- Resistant varieties;
- Management of irrigation and leaf surface moisture;
- Fertility practices that impact disease;
- Planting dates that reduce disease risk;
- Sanitation in many forms;
- Plant spacing and sowing practices that reduce disease;

- Management of vectors and other pests;
- Improved surface and subsurface drainage;
- Raised beds;
- Cover crops that reduce disease pressure;
- Addition of organic matter to soil;
- Mulching;
- Pathogen-free seed.

How Fungicide Resistance Can Develop

The use of fungicides increases the risk of resistance. **Anytime a fungus is exposed to a fungicide, even if fungal activity is low, the selection pressure is increased towards resistance.** Resistance to strobilurin fungicides is a worldwide concern because these fungicides are known for being prone to resistance development.



Frog eye leaf spot of soybean, photo: www.agproduction.com

Strobilurin-resistant isolates of *Cercospora sojina*, the cause of frog eye leaf spot of soybean, have been found in several states, including Kentucky. This is a "warning shot" when it comes to strobilurin use for both soybean and corn. Specifically, the widespread occurrence of strobilurin-resistant *C. sojina* in a field in west Tennessee shows that **resistance can develop in field crops in response to overuse in a production setting.**

The DMI or triazoles family of fungicides, commonly used on corn, also are prone to the development of fungal resistance. For decades, scientists have watched as fungi all over the world have become incrementally more resistant to DMI fungicides. The **use of any fungicide for "plant health" reasons increases the risk of developing resistance.** Other than never using them, there is no way to prevent resistance to strobilurins and DMI fungicides.

The only hope is to **slow down resistance development.** The best way to do that is to **minimize the use of the at-risk fungicides.** Factors that increase the potential for fungicide resistance include:

- **Over-use or repeated applications of fungicides with the same chemistry,** alone or in mixes with other fungicides.

- **Applying fungicides at half-rates.** Using lower than label rates of DMI fungicides will not killing all the target pathogens. Those that survive are likely to be less sensitive to the fungicide the next time it is applied. In the case of strobilurin fungicides, resistance development is usually not impacted by application rate and can occur equally at low or high rates of application.
- **Applying a pesticide when disease pressure is already high.** A field that has been severely damaged by disease cannot be cured and there is a good chance that surviving target organisms could result in the development of resistance.

The **only way to absolutely prevent resistance is to not use a fungicide that can cause resistance to develop.** This is not practical because many currently-used fungicides that provide highly effective, broad-spectrum disease control are at risk for resistance. Mode of action group and resistance management strategies are now clearly included on the registration labels of most site-specific fungicides. These allow you to identify mode of action groups for rotation programs.

Group	11	Fungicide
-------	----	-----------

Insecticides

IRAC numbers help you to identify the mode of action of insecticides. Products with the same group number attack the same target in the pest. **Rotation among products with different modes of action delay development of resistant populations. Repeated use of products in the same group select for resistant individuals.**

Insecticide group numbers appear on some labels making it easy to rotate modes of action to reduce the potential for development of resistant populations. For example, pyrethroid insecticides belong to Group 3. Continued use of insecticides in this group can lead to resistance. Rotate with other numbered groups to manage potential resistance problems. **Insecticide resistance can develop rapidly in populations of arthropods with short life cycles (aphids and mites) living in closed production situations like greenhouses.** The potential for resistance to *Bt* toxins in corn pests, such as the European corn corer, is high because of the large percentage of *Bt* corn acreage planted each year.

Group	3	Insecticide
-------	---	-------------

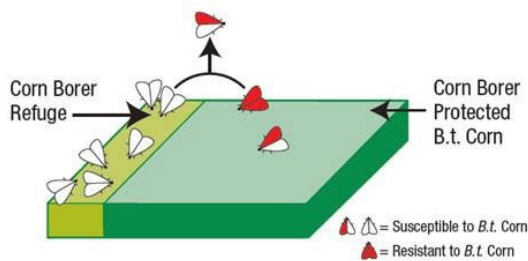
IRAC code numbers appear on the front of insecticide labels to identify insecticide mode of action groups, photo, www.msue.anr.edu

amount of non-Bt is mixed with the seed to provide susceptible pests enough refuge plants on which to develop.

Managing Resistance in Bt Corn

Bt corn hybrids have been modified to contain a gene from the soil bacterium *Bacillus thuringiensis* (Bt) that codes for production of insect-specific toxins in corn tissue. Lepidoptera Bt strains are specific for caterpillars (European corn borer, cutworms, armyworms, etc.) while others kill corn rootworm larvae. Widespread adoption of Bt varieties has increased the number of acres where pests are exposed to the Bt active ingredient. **With much of the pest population exposed to Bt toxins every season, resistant pest populations can develop through a selection process.**

An insect resistance management (IRM) plan was developed to prolong the effectiveness of Bt crops. The initial IRM strategy was to prevent or delay resistance to Bt varieties by planting refuge acres of the crop on each farm that do not have the trait used in the Bt planting. This is the structured refuge strategy and is used for non-refuge-in-the-bag Bt corn lines. The refuge needed to be 20% of the corn acreage on each farm with specific arrangement and distance requirements. The goal of a refuge is to produce target pests that are not exposed to the Bt toxin. These Bt-susceptible individuals would mate with potentially resistant individuals that developed on the plants with the Bt gene. Matings between susceptible and resistant individuals keeps Bt-susceptibility in the pest population.



The goal of a refuge is to produce susceptible individuals to mate with resistant individuals. (www3.syngenta.com)

- **Structured refuges** for the Lepidoptera-protected Bt corn (must be at least fixed percentage [specified on the bag label] of the total corn acreage on the farm, within 1/2 mile of the Bt-corn, and managed by the same grower.
- Refuges of Bt rootworm-protected corn has the similar acreage requirements but must be within or directly next to the Bt rootworm field due differences in behavior of the insects.
- An alternative is to use a **refuge-in-the-bag** Bt corn which no not require a refuge planting. A small

Practice Questions

1) A resistant pest is one that is no longer controlled by a pesticide that was effective in the past.

1. True
2. False

2) Pesticide resistance is limited to a single active ingredient, all other pesticides with the same mode of action are still effective.

1. True
2. False

3) Pesticide resistance has a genetic basis; the trait is passed along to the offspring of resistant individuals.

1. True
2. False

4) Development of resistance is a selection process resulting from _____ in pest populations.

1. genetic variability
2. random luck
3. using only non-chemical control

5) Resistance is most likely to develop against _____ pesticides.

1. synthetic
2. narrow spectrum
3. at-risk
4. wettable powder

6) Historically, relatively few documented cases of herbicide resistance have developed in Kentucky grain crops because of _____.

1. low pesticide use
2. heavy reliance on non-chemical control
3. wide use of a corn-wheat-soybean rotation
4. avoiding pesticide rotations

7) Prevention is the key to avoiding pesticide resistance

1. True
2. False

8) Using the same pesticide or a different brand of pesticide with the same mode of action for 2 or more consecutive years _____ the chances of problems with pesticide resistance.

1. increases
2. decreases
3. does not affect

9) Using a combination of chemical and non-chemical pest control practices is an effective way to reduce development of pesticide resistance.

1. True
2. False

10) It is best to use resistance management practices only after a problem develops.

1. True
2. False

11) Which of the following IS an appropriate disease control practice?

1. Plant only varieties that are very susceptible to diseases
2. Leave crop residues on the surface from one season to the next
3. Use planting dates and plant populations that reduce disease
4. Do not rotate crops to reduce disease

12) Using pesticides as "plant health" chemicals when no potentially damaging pest population is present _____ the risk of developing resistance.

1. decreases
2. increases
3. has no effect on

13) Applying a fungicide at half of the label rate is a generally recommended resistance management practice.

1. True
2. False

14) It is best to begin fungicide applications only after disease pressure is high.

1. True
2. False

15) The words "Group 3 Insecticide" on a label means that you can use the product for 3 seasons before rotating to a product with a different mode of action.

1. True
2. False

16) The widespread adoption of Bt-corn for caterpillar control _____ the chances for the development of resistance.

1. increases
2. decreases
3. does not affect

17) The goal of a refuge in the resistance management strategy for Bt crops is to _____.

1. reduce the need for extra fungicide applications
2. produce Bt-susceptible individuals
3. produce Bt-resistant individuals

18) The EPA _____ the planting of refuges or refuge-in-the-bag in order to allow the registration and sale of Bt-crops.

1. recommends
2. requires
3. has no regulation about

Answers

1 - 1 2 - 2 3 - 1 4 - 1

5 - 3 6 - 3 7 - 1 8 - 1

9 - 1 10 - 2 11 - 3 12 - 2

13 - 2 14 - 2 15 - 2 16 - 1

17 - 2 18 - 2

Demonstration and Research Design

Demonstrations

Demonstrations are conducted to show the effectiveness of proven or new treatments or specific practices.

There are two basic types.

- A **method demonstration** shows how to do a specific task in a step-by-step process; for example, calibrating a sprayer.
- A **result demonstration** shows the effective use of a piece of application equipment or the effectiveness of a fungicide for disease control.
 - Demonstrations effectively persuade by being visually convincing. Usually, they are conducted at a specific site for a short time and not replicated.

Effective result demonstrations require:

- A complete plan with clear, simple objectives and differences that will be easy to measure.
- Appropriate production practices.
- A good cooperater that is interested in the project and is known and respected in the area.

Experiments

An **experiment** is a test under controlled conditions that is designed to test a hypothesis or to determine the efficacy of something previously untried.

Data from a well-designed experiment can be used to:

- Support new pesticide uses or methods: new rates, or application frequencies.
- Add new target pest species to the label.
- Support existing knowledge.
- Close gaps in existing information.
- Develop new information.

Experiments require careful design and close management. The data must be collected and analyzed in a way that produces scientifically sound conclusions.

Scientific Method

Steps in the scientific method

Most research experiments follow these fundamental steps:

- Formulate a hypothesis (a suggested solution or explanation for a specific problem or question).
- Design an experiment to test the hypothesis objectively.
- Collect, analyze and interpret the data.
- Accept, reject, or alter the original hypothesis.

Definitions

Bias – a prejudice in favor of or against an outcome. A researcher can consciously or unconsciously bias an experiment by unequal or unfair (non-random) assignment of plots or animals to treatment and control groups.

Block – experimental subjects are first divided into similar blocks before they are randomly assigned to treatment groups. This helps to reduce known variability in an experiment, such as differences in weed pressure across a field.

Border rows are used around test plots or between treatments when one treatment may affect the results in adjacent plots, such as through spray drift. Also, field margins may have different fertility, weed pressure, sunlight and moisture availability so normally they are not used.

Check or control plots are experimental units that do not get any treatments or to which a standard treatment is applied for comparison to other treatments.

Experimental error or variation refers to the inherent variability among experimental units or plots against which differences among treatments will be tested.

Experimental unit – land area or animal

Hypothesis – a suggested solution or explanation for a specific problem or question.

Randomization - assign treatments to experimental units by a purely objective method. The simplest way is literally to pull the treatment options out of a hat. Assign each treatment a number, write the numbers on individual pieces of paper, mix the slips of paper up, and then select the slips one at a time without looking at them first. The order in which the numbers are drawn is the order in

which they will be arranged in a block. Repeat these steps for each block in the experiment.

Replication - each treatment appears two or more times in an experiment. This is necessary because all test plots are not identical. Replication increases the ability to detect differences between treatments.

Sample - representative unit(s) taken from an experimental unit or plot (e.g. the number of infected plants, percentage ground covered by weeds, etc.)

Treatment - the factor being tested in an experiment (e.g. different herbicides to control velvetleaf).

Experimental Design

Designing an experiment is an extremely important step. **Errors in the design can affect the results of the entire experiment and can prevent you from reaching valid conclusions.**

It is generally best to avoid complex experiments that involve elaborate designs unless you check with a statistician. If you have trouble with a design or doubt its validity, get help before starting the research. Variations in soil type, drainage, compaction, erosion, or pest infestation can affect the outcome of an experiment. They may change with time and location in a field. Select plots carefully to avoid ones that may differ from others. Sources of bias may be minimized by randomization.

Some Types of Experimental Designs

A	B	C	D
A	B	C	D
A	B	C	D
A	B	C	D

Non-random design with 4 treatments (letters) replicated 4 times.

The **arrangement of treatments in rows or repeating several treatments in the same order (above) is a common design mistake.** One treatment can affect nearby treatments and lead to incorrect conclusions. It is difficult to draw conclusions from this design.

C	A	B	A
B	C	D	B
C	D	A	C
D	A	B	D

Completely randomized design with 4 treatments (letters) replicated 4 times.

The **completely randomized design** (above) is simple and flexible. It can be used when the test units are very uniform. All treatments are assigned randomly to plots. This design allows any number of treatments to be tested. It is best to assign the same number of plots to each treatment. **This design may be better for livestock tests than for field crop work.**

B	A	D	C
C	C	B	A
A	D	A	D
D	B	C	B

Randomized complete block design with 4 treatments (letters) replicated 4 times.

The **randomized complete block design** (above) is a common design in agricultural field research if you can identify patterns of non-uniformity, such as changing soil types, drainage patterns, etc. Plots are first assigned to groups of similar characteristics relative to the non-uniformity (e.g. sandy vs. clay soils). The 4 treatments are then assigned randomly *within the groups* of plots called blocks (columns).

The experimental units or plots that are not treated commonly are called **controls or checks**. Control plots are recommended for all statistically sound experimental field work. They **should be selected with the same objectivity as that of other plot selection.** Variable factors that may affect treatment plots will affect control plots. Control plots should not be arbitrarily assigned, like along a fence row, lane, or simply in the middle or side of the field.

Important Design Points

Good experimental technique should minimize error and bias. Reduce or eliminate these problems through appropriate experimental designs.

To help eliminate experimental error and bias:

- apply all treatments uniformly.
- Measure all treatment effects in an unbiased way.
- Prevent gross errors.
- Control external influences so that all treatments are affected equally.

Properly designing and implementing an experiment is a logical process.

Practice Questions

1) An experiment is conducted to show the effectiveness of proven treatments or specific practices.

1. True
2. False

2) The _____ is the suggested solution or explanation for a specific problem or question.

1. design
2. interpretation
3. hypothesis
4. data

3) Showing how to calibrate a sprayer at a field day is an example of a(n) _____.

1. experiment
2. result demonstration
3. method demonstration

4) _____ is the inherent variability among experimental units or plots.

1. Experimental error or variation
2. Randomization
3. Bias

5) The treatments in an experiment are assigned randomly to avoid bias.

1. True
2. False

6) A _____ design can be used when the experimental units or plots are very uniform.

1. non-random
2. randomized complete block
3. completely randomized

7) A _____ design must be used when you can identify patterns (differences in soil type, weed pressure, etc.) in the experimental area.

1. non-random
2. randomized complete block
3. completely randomized

8) Good experimental design and technique should minimize experimental error and investigator bias.

1. True
2. False

9) Experimental units in the experiment that do not receive a treatment do not have to be assigned randomly.

1. True
2. False

10) A researcher can unconsciously bias an experiment.

1. True
2. False

Answers

- | | | | |
|-------|--------|-------|-------|
| 1 – 2 | 2 – 3 | 3 – 3 | 4 – 1 |
| 5 – 1 | 6 – 3 | 7 – 2 | 8 – 1 |
| 9 – 2 | 10 – 1 | | |

Educational programs of Kentucky Cooperative Extension serve all people regardless of economic or social status and will not discriminate on the basis of race, color, ethnic origin, national origin, creed, religion, political belief, sex, sexual orientation, gender identity, gender expression, pregnancy, marital status, genetic information, age, veteran status, or physical or mental disability. Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Nancy M. Cox, Director, Land Grant Programs, University of Kentucky College of Agriculture, Food and Environment, Lexington, and Kentucky State University, Frankfort. Copyright © 2022 for materials developed by University of Kentucky Cooperative Extension. This publication may be reproduced in portions or its entirety for educational or nonprofit purposes only. Permitted users shall give credit to the author(s) and include this copyright notice.