Agricultural Plant Pest Control

A Guide for Kentucky Applicators in Category 1a

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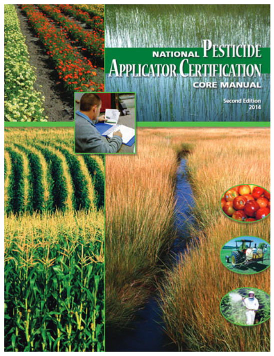
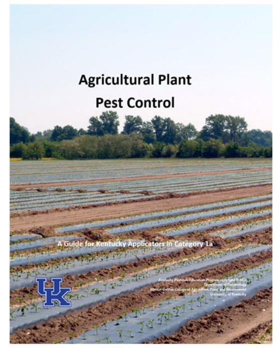
This manual*, **Agricultura Plant Pest Control,*** is intended to be used in combination with the National Pesticide Applicator Certification Core Manual. These resources contain basic and category-specific information to prepare applicators for the exam required to become a certified commercial applicator in Category 1a. The certification exam is based on information found in these manuals.





Practice questions are provided at the end of each chapter in this manual to relate important learning objectives to help you prepare for the exam, but these are not the exam questions. When you feel you are prepared to take the certification exam, you must visit the Kentucky Department of Agriculture website, https://www.kyagr-apps.com/AgExternal/Security/Provisioning/Login, where you can take the exam online or preregister to take the exam in person. A minimum score of 70% is required to pass the exam.

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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 n 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 of 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, o 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 to pay the annual fee by January 31 will result in suspension of the license. Failure to renew a license by November 30 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

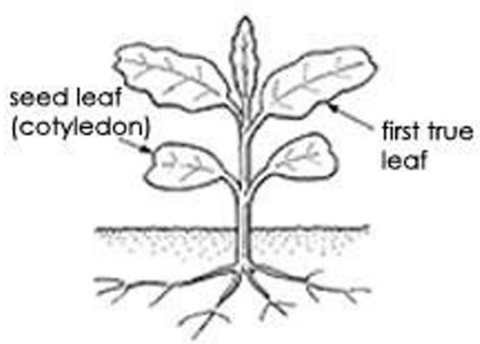
Weeds can be grouped into the following categories:

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

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

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 above ground 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	

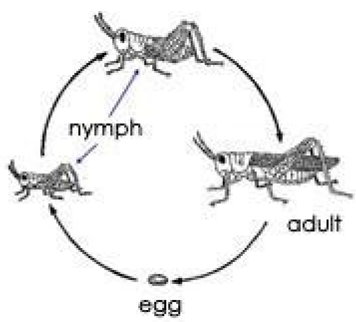
Agricultural Insect Pests

Insects and Other Arthropods

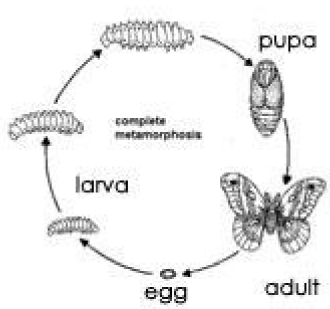
Insects, spiders, scorpions, millipedes, centipedes, ticks, and mites are arthropods. They have hard external skeletons and segmented legs and bodies. Most insects have 3 main body regions and 3 pairs of legs; they are the only arthropods that can fly.

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:

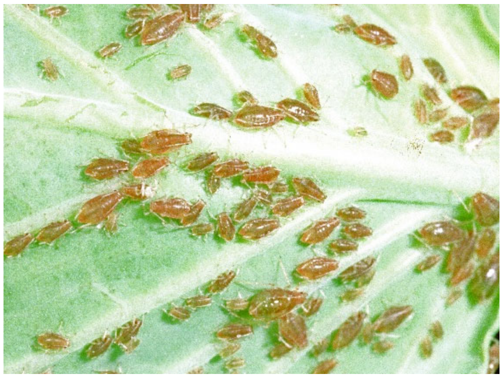
1. piercing-sucking
2. chewing
3. rasping plant tissue

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 in pastures or 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. cutworm
    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 – 2	2 – 3	3 – 1	4 – 4
5 – 2	6 – 3	7 – 1	8 – 2

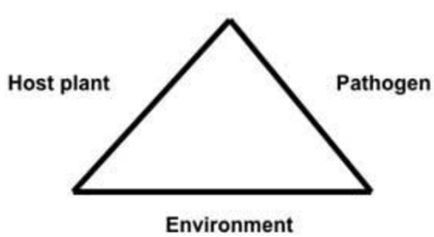
Agricultural Plant Diseases

Plant Diseases

A plant disease is any harmful condition that affects a plant's appearance or function. Comm on pathogens that cause disease include: fungi, bacteria, viruses. Some nematodes are plant disease agents. Temperature extremes or nutrient deficiencies are example 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.

The Plant Disease Triangle



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

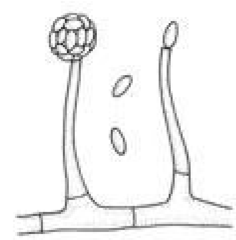
tissue death - blight, leaf spot, wilting, and cankers.

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

<u>Rust</u> 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

<u>Powdery mildews</u> 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

<u>Powdery mildew of wheat</u> 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

<u>Downy mildews</u> 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 **<u>correct diagnosis</u> 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 **<u>symptoms</u>** - the host plant's reaction to the disease agent, and **<u>signs</u>** - 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

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.

    1. True
    2. False

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		

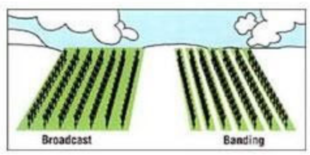
Pesticide Application Equipment

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.

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.

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.

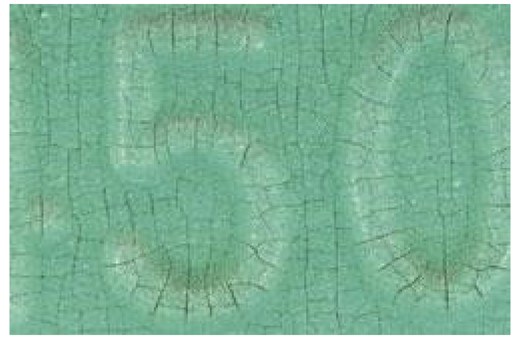


Photo: Omafra.gov.ca

- **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.

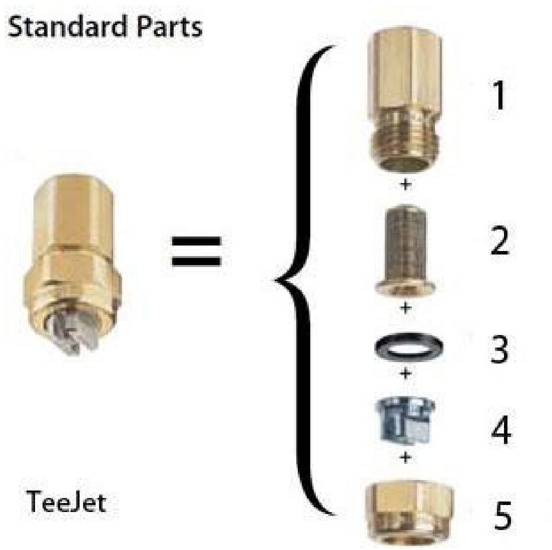
Pump

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.

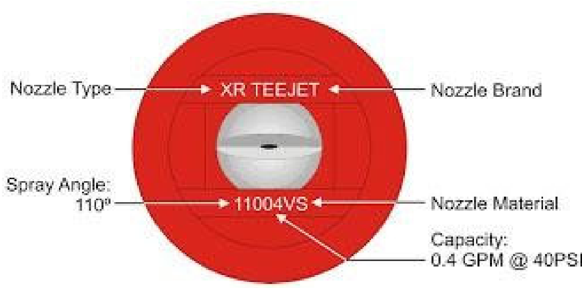


Nozzle parts:

- 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.



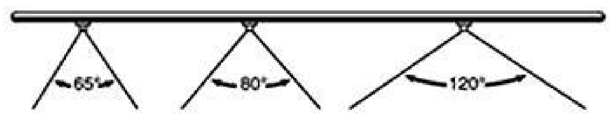
11004 nozzle

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

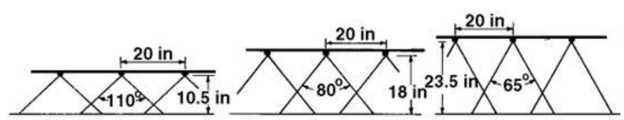
Equip nozzle tips with **check valves** to help prevent dripping when the pump is off. Be sure the spring-loaded ball valves are working properly.

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.

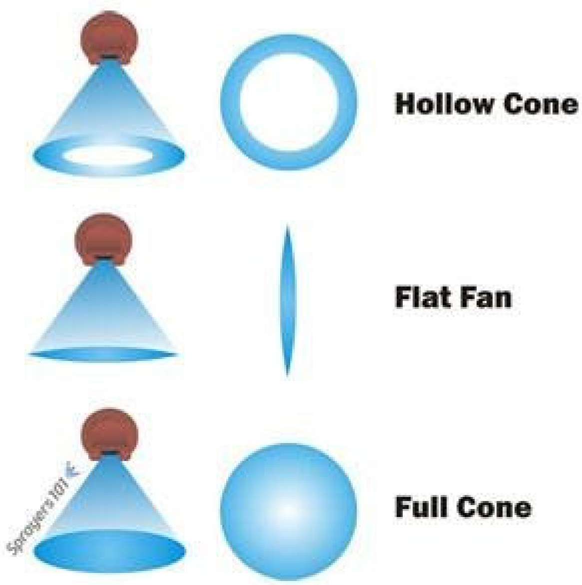


Nozzle spacing on the boom, spray angle, and boom height determine proper overlap of the spray. The drawing below shows the effect of nozzle spray angle on nozzle height, need for proper overlap, and spray coverage. Notice the height difference between the 110°, 80°, and 65° nozzles. Wide angle nozzles 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__ 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

Calibration

Calibration is the process of measuring and adjusting the amount of pesticide your equipment will apply over a target area. It is a critical "first step" in making certain that your equipment is applying pesticide uniformly and at the correct rate. Proper calibration of agricultural pesticide application equipment can mean the difference in control or failure of a pesticide against the targeted pest and potentially thousands of dollars of savings. Improperly calibrated pesticide equipment may cause either too little or too much pesticide to be applied. Too little may result in unsatisfactory control, while too much pesticide may result in illegal residues or phytotoxicity to the crop.

Calibration should occur at least once every year immediately prior to pesticide applications. Recalibration is needed when nozzles, speed through the field, or spray pressure is changed. The process of calibration begins with cleaning and testing your sprayer, evaluating your coverage, and determining your output.

Cleaning and Checking your Sprayer

Before calibrating your sprayer, make sure it is clean and in good working order. Use gloves and googles when working on your sprayer.

- Replace or carefully clean nozzles and screens with a soft brush or compressed air.
- Before reinstalling the screens and nozzles, partially fill the tank with water and thoroughly flush the lines. Reinstall the nozzles and screens. Make sure they are the same type and flow rate.
- Refill the sprayer, engage the pump and collect the water from each nozzle for 1 minute and determine the average nozzle output.
- Replace any nozzles that are more than 10% different from the average. Retest if any nozzles were replaced or cleaned.

Evaluating Coverage

To achieve maximum effectiveness of a pesticide, it must be applied in a way that provides optimal coverage. Spray coverage and the volume of spray per acre are affected by several variables. Spray nozzles, nozzle filters, pressure, tractor speed are variables that can affect coverage, and the amount of water applied.

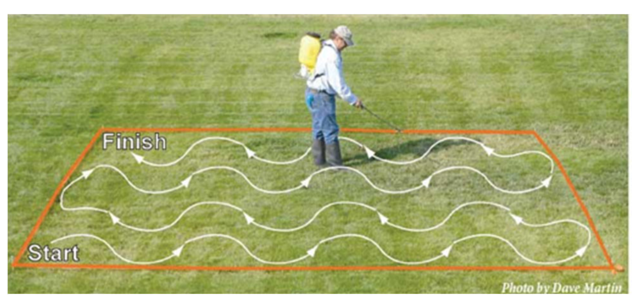
Different types of pesticides may require different types of coverage to be effective. This is often listed on the pesticide label. Water-sensitive paper can be hung in various locations in the crop to assess spray coverage. Where you hang water-sensitive paper may depend on the type of pesticide you are using, but potential locations could be in the interior canopy, attached to the underside of leaves, or at the bottom of the plant.

Applicators can change nozzles, modify nozzle angle, adjust spray pressure, or alter sprayer speed to improve coverage. Once the coverage is correct, record the nozzle type, pressure, and speed needed to get that coverage. Now you are ready calibrate the sprayer.

Calibrating your sprayer before the application is a three-step process. First determine the sprayer output, then calculate the area that needs to be treated, and finally determine the amount of material that needs to be applied.

1. Determining Output

Once you know what you must do to get proper coverage (nozzles, speed and pressure) and your nozzles are providing uniform out, then you may determine your actual sprayer output (GPA, gallons per acre). The GPA of your sprayer must be assessed while taking into account pressure, nozzle flow rate, and speed while spraying. There are many methods used to calibrate sprays, some use nozzle output over a period of time, nozzle spacing, boom width, and tractor speed to determine the sprayer output per acre. This method is outlined on pages 8 and 9 in "Recordkeeping Manual for Private Applicators" available through your county extension office.



Another method that can be used for a variety of sprayers (boom sprayers, air-blast, and backpack) is to spray an area on known size with a sprayer full of water, then to measure the water needed to refill the sprayer. With the known area and water needed, it is easy to calculate the number of gallons needed to treat and acre (GPA). Here's the procedure:

- Mark out a known area, say 10 by 20 feet for a backpack sprayer or 200 feet for a boom sprayer. For the boom spray, use whatever width that sprayer uses.
- Completely fill the sprayer with water.
- Spray the area as you would if applying a pesticide.
- Carefully record the amount of water it takes to refill the sprayer.

- When doing this with a tractor, repeat the producer but spray in the opposite direction to take into account tire slippage on uneven ground. Then use the average amount of water needed from the two ruins.

Use the following formula to determine the output in gallons per acre:

Gallons sprayed* 43560 / area sprayed (ft^2) = GPA

<u>Example 1</u>: We calibrated a boom sprayer with a 20-foot boom and measured out an area 200 feet long. We will spray this area at the same speed and pressure that we plan to use for the pesticide application. The area sprayed is

20 ft * 200 ft = 4000 ft^2

It took an average of 2.25 gallons to refill the tank after the two sprayer runs. So, the GPA output would be:

2.25 gal * 43,560 / 4000 ft^2 = 24.5 GPA

It will require 24.5 gallons of spray to cover one acre with the nozzles, pressure, and tractor speed used during calibration.

<u>Example 2</u>: We calibrated a backpack sprayer and measured out an area 20 wide by 20 feet long. We will spray this area at the same walking speed as we would for the pesticide application. The area sprayed is:

20 ft * 20 ft = 400 ft^2

It took 30 fl. oz. of water to refill the tank. First, we convert this to gallons:

30 fl. oz. / 128 fl. oz. per gal = 0.234 gal

To spray 400 ft^2 it needed 0.234 gallons of spray. So, the GPA output would be:

0.234 gal * 43,560 / 400 ft^2 = 25.5 GPA

It will require 25.5 gallons of spray to cover one acre. There are 43,560 ft^2 per acre. Some pesticide labels use rates per 1000 ft^2, so we will now calculate the output rate per 1000 ft^2 in fluid ounces using this formula:

Fl oz sprayed * 1000 / area sprayed = oz per 1000 ft^2

We just plug 30 fl. oz. we sprayed over 400 ft^2 into the above formula:

30 fl oz * 1000 ft^2 / 400 ft^2 = 75 fl oz per 1000 ft^2

Using this method, we can determine the output of various types of sprayers. However, whenever we change nozzle types or sizes, spray pressure, tractor or walking speed we will need to recalculate the output rate.

2. Determining Area to be Treated

As with determining output, there are different ways to determine the size of the area to be treated. One method with irregular shaped areas involves breaking the area to treat into geometric shapes then using formulas to determine the size of the area:

Rectangle:	**Area = height * width**
Triangle:	**Area = base * height / 2**
Circle:	**Area = 3.14 * radius^2**

Another method is to use online map programs to calculate areas. For example, with Google Maps, bring up the satellite image of the area to treat, right click on one edge of the area. A drop-down menu will come up and select "measure distance", then continue to click around the area to be treated until it is completely encircled. The total number of square feet is provided. To convert to the number of acres, just divide the number of square feet by the number of square feet in an acre, 43,560.

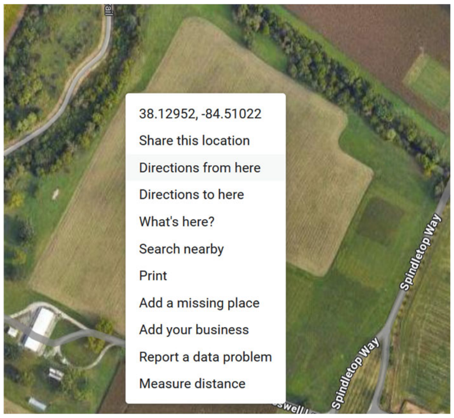


Figure 1. To use google maps to calculate area, right click on an edge of the location to be measured and select "measure distance" from the menu.

Figure 2. Continue to add points to completely encircle the area.

The area outlined in the above figure is 680,041.79 ft^2 or 15.38 acres (calculate that by dividing 680,041.79 by 43,560).

680,041.79 / 43,560 = 15.38 acres

From the first example above with the boom sprayer, we found 24.5 gallons of spray were needed to treat an acre. So, by multiplying 24.5 GPA by 15.38 acres we would need 377 gallons of spray to treat this field using the boom sprayer example above.

15.38 acres * 24.5 GPA = 377 gallons needed

3. Amount of Pesticide Needed

Find the pesticide rate on the label for the crop and pest needing control. Most agricultural pesticide labels express these are per acre rates, but a few list these as rates per 100 gallons of spray. Convert the rate per acre by multiplying the rate from the pesticide label by the acres needing to be treated.

Let's do this for the example above using the boom sprayer and the 15.38-acre field. Reading the label of the pesticide we will use we find that it lists a range of 4 to 8 fl. oz. for the pest we intend to control on the crop we will treat. Generally, low rates are for small stages of pests, small plants, light infestations, or maintenance sprays. High rates on the label are for large pest stages, heavy infestations, or larger plants needing to be protected. We cannot exceed the upper rate. In this example we will use an average of the lower and upper rate which is 6 fl. oz. So, with the example above, we multiply the number of acres (15.38) by the rate per acre (6 fl. oz.) to give us the amount of pesticide needed for the entire field.

15.38 acres * 6 fl. oz. = 92.28 fl. oz.

To treat the 15.38 acre field above at 6 fl. oz. per acre, we would need 92.28 fl. oz. of the pesticide.

Practice Questions

1. What is the purpose of calibration in pesticide application?
    1. To increase pest resistance
    2. To ensure pesticides are applied evenly and at the correct rate
    3. To reduce the amount of pesticides used
    4. To mix different pesticides together
2. What may happen if too little pesticide is applied?
    1. Illegal residues may form
    2. Phytotoxicity may occur
    3. Unsatisfactory control of pests
    4. Excessive control of pests
3. When should calibration occur?
    1. Once a month
    2. At least once a year, before pesticide applications
    3. Only when new pesticides are used
    4. After every application
4. What should you do before calibrating your sprayer?
    1. Clean and check the sprayer
    2. Mix the pesticide
    3. Increase the spray pressure
    4. Spray a small test area
5. How should you clean nozzles and screens?
    1. By soaking in pesticide
    2. Using high pressure water jets
    3. Running them under water
    4. Using a soft brush or compressed air
6. What is the recommended action if a nozzle's output differs by more than 10%?
    1. Adjust the pressure
    2. Replace the nozzle
    3. Clean the nozzle again
    4. Continue using it
7. What tool can be used to assess spray coverage?
    1. Water-sensitive paper
    2. Pressure gauge
    3. Measuring tape
    4. pH tester
8. What is the first step in calibrating a sprayer?
    1. Determining the pesticide rate
    2. Determining sprayer output
    3. Testing the soil pH
    4. Adjusting tractor speed
9. Which factor should NOT be considered when determining sprayer output?
    1. Nozzle flow rate
    2. Tractor speed
    3. Boom width
    4. Wind direction
10. How many square feet are there in one acre?
    1. 1,000
    2. 4,356
    3. 43,560
    4. 435,600
11. If it takes 2.25 gallons to refill the sprayer after a test run on a 4000 sq. ft. area, what is the GPA?
    1. 12.2 GPA
    2. 24.5 GPA
    3. 36.7 GPA
    4. 50 GPA
12. What should you do if you change nozzle types or sizes?
    1. Use the same calibration
    2. Recalculate the output rate
    3. Adjust the walking speed
    4. Lower the pressure
13. What formula is used to calculate the area of a triangle?
    1. Base * height / 2
    2. Height * width
    3. Radius squared * 3.14
    4. Length * width / 2
14. How can Google Maps help with calibration?
    1. By calculating pesticide amounts
    2. By providing real-time weather
    3. By measuring the area to be treated
    4. By showing crop growth

15. What does the "GPA" stand for in calibration?

    1. Gallons Per Application
    2. Gallons Per Area
    3. General Pesticide Amount
    4. Gallons Per Acre

16. What is the purpose of measuring the area to be treated?

    1. To reduce the amount of pesticide needed
    2. To avoid over-application
    3. To calculate how much pesticide is needed for the field
    4. To adjust tractor speed

17. If a pesticide label lists 4 to 8 fl. oz. per acre for a particular pest, what rate should you use for large stages of the pest?

    1. 4 fl. oz.
    2. 5 fl. oz.
    3. 6 fl. oz.
    4. 8 fl. oz.

Answers

1 - 2   2 – 3   3 – 2   4 – 1   5 – 4

5 – 2   7 – 1   8 – 2   9 – 4   10 – 3

11 – 2   12 – 2   13 – 1   14 – 3   15 – 4

16 – 3   17 - 8

Integrated Pest Management (IPM) Explained

Pests can be insects, weeds, vertebrates, and diseases. With agriculture, these pests of crops, forests, landscapes, livestock, or humans should be managed to avoid economic losses. While pesticides play an important and critical role in the management of pests, we use them in combination with other management tactics for more effective control, slow the development of resistance to pesticides, reduce costs, and reduce unintended consequences to applicators, communities, and environment. This combined approach is called integrated pest management, or IPM.

IPM was formalized in the 1970s, to address high levels of insecticide resistance that had developed due to over reliance on pesticides to manage pest populations. IPM became a framework of pest management that utilizes a set of tactics to suppress a pest population, rather than relying on pesticides alone. While some may define IPM as the avoidance of pesticides, IPM does not necessarily exclude pesticide use or consider pesticides as a last resort. IPM is a judicious use of all appropriate management tools that will help to suppress pest populations sustainably.

Components of IPM

Monitoring

Monitoring insects, weeds, and diseases, or the conditions that promote these pests, allows pests to be caught when they are easiest to manage, and efforts will be more successful. Without regular monitoring, pest problems may not be recognized until a high amount of damage has occurred and pest populations are difficult to manage. Lack of monitoring can result in the application of a pesticide when it is not needed or applied at the wrong time. How to monitor:

- Regularly check plants, especially new growth, flowers, leaves, fruits, and stems. You need to sample enough plants across a field to represent the field. Areas on the edges of fields may not represent the interior of fields.
- Plants should be checked for signs (the actual pest organism) and symptoms (the evidence a pest leaves behind). A hand lens can help to magnify signs of early stages better identification.
- Traps can monitor some insect pests. Traps can be sticky cards, pheromone traps, or light traps, depending on the pest. Traps can alert you to when pests are active and their relative levels.
- Track diseases and weeds using weather and climate models. For example, fire blight has certain conditions for its development, so it can be predicted so need for management can be evaluated.

Pests and damage must be properly identified to realize the benefits of monitoring. Despite the power monitoring gives growers, it is often the most neglected aspect of pest control. Monitoring should be a regularly scheduled activity.

Identifying Pests

Many types of organisms will be encountered when monitoring but only a few may be pests. Once a pest has been captured or seen, or its damage has been observed, it is necessary to figure out its identity. Proper identification is necessary for IPM, as knowing what pest you're dealing with helps you choose the best control methods. With specimens you cannot identify, County Extension Agents or State Extension Specialists may be able to help.

Using Economic Thresholds

The economic threshold is the pest level at which we take action to prevent economic losses relative to the value of the crop and cost of control. Pest monitoring allows us to compare pest levels to economic thresholds to decide when to take action against pests. Economic thresholds have been established for many, but not all, agriculture agricultural pests. Different pests have different thresholds based on crop value, the cost of pest damage, and the cost to control them.

Evaluating Results

After applying a control method, continue to monitor to evaluate to see if the control was effective. This helps you understand if the method was ineffective due to issues like poor timing, pesticide resistance, poor pesticide selection, or improper application.

Methods of IPM

IPM uses various strategies to manage pests. Some strategies prevent pests, while others respond to problems found during monitoring.

Cultural Control

IPM uses preventive cultural practices as a foundation to reduce pest pressure or damage from pests. This can include changes to irrigation, fertilization, and planting dates, or varietal resistance and sanitation in efforts to reduce or avoid pest problems.

Resistant or Tolerant Varieties: Some plants are bred to resist or tolerate pests. It is more difficult for pests to develop on resistant plants, they often support little or no pests. A tolerant plant cultivar has been bred to be able to host pests, sometimes for extended periods of time, without exhibiting symptoms or only minimal impact of yield. Plants can be resistant or tolerant to insects and pathogens.

Irrigation and Fertilization: When possible, proper irrigation practices and fertilization help plants stay healthy and resist pests. However, excessive water and fertilizer can stress a plant and open it to pest infestation. Fertilization can also sometimes favor pest development; insects such as aphids can increase rapidly on plants overfertilized with nitrogen. Overirrigating can stress a plant but also creates ideal conditions for pathogens to thrive.

Sanitation: Keep fields clean by removing heavily infected plants and plant debris. Sanitation can be done during and after the growing season by rogueing heavily infected or infested plants from the field or reduction of plant debris after the growing season. This helps remove pests and disease inoculum that might overwinter and remain active the next season.

Crop Rotation: Growing the same plants year after year in the same field is a recipe for pest problems. Pests will be able to persist and increase in numbers when a suitable crop is planted in the same location. Crop rotation is the foundation of IPM in Kentucky in row crop agriculture alternating corn, wheat, and soybeans. By switching between unrelated crops, we disrupt the development of pests and lead to fewer problems in the future. Another benefit of crop rotation is to better manage soil nutrient levels, as different crops will utilize nutrients differently. Some may even fix nitrogen. Switching among crops can help replenish fertility and reduce stress levels for future plantings.

Appropriate Planting Dates: Different crops have different recommended windows for planting. For some crops, planting too early into cold wet soils will predispose plants to damping off and soil insects. Planting too late may synchronize vulnerable plant stages with larger pest populations that need time to migrate from the South.

Biological Control

Use of biological control helps to reduce over reliance on chemical control. Biological control takes advantage of the natural enemies of pests to manage or slow buildup of pest populations to reduce their numbers.

- **Predators**: Animals that hunt and eat pests. One predator typically kills many pests. Some predators may specialize more than others, only feeding on specific types of prey.
- **Parasitoids**: Parasitoid insects often inject their eggs into a host, which then often stop feeding within a day or two but may live for a week or more before they are killed. One parasitoid usually kills one pest.
- **Beneficial Microorganisms**: Viruses, bacteria, nematodes, and protozoans are also natural enemies that may help to manage some pest populations. While they aren't as visible as predators and parasitoids, they do persist in nature and may provide suppression. While many of these occur naturally, some have been commercialized. Microorganisms can be used against insects, mites, weeds, and pathogens.
  - ***Bacillus thuringiensis* (B.t.)**: A bacterium that produces toxins killing certain insects. When ingested by a susceptible insect, it paralyzes the insect's gut, causing the insect to stop feeding and die within a few days. It is most effective on the youngest life stages. B.t. can be applied but is also deployed through GMO crops, to manage insects feeding on crops like field corn and cotton. There are multiple strains of B.t. that can be purchased. Here are a few examples:
  - **Parasitic Nematodes**: Tiny worms that attack soil-dwelling pests. After a host has been destroyed, the next generation of nematodes may burst forth from its body and then infest other nearby hosts.
  - **Fungi**: Like *Beauveria bassiana*, which infects pests like aphids and thrips.

Biological control is constantly occurring without human intervention. Biocontrol can have a high upfront cost when first purchasing biological control agents, especially when compared with traditional pesticides. For this and other reasons, release of purchased biological control agents is most often done in enclosed areas like greenhouse or under row covers where they can be contained to prevent dispersal.

Unlike what might be seen after a pesticide application, **biological control will never fully eliminate a pest population**. But, if properly utilized and supported, biological control methods result in fewer pesticides being applied into the environment, can provide season-long suppression of pests, and may be more cost-effective in the long run.

Chemical Control

Pesticides include fungicides, herbicides, and insecticides and are important tools of an integrated pest management program. Sometimes, pesticides are the only option for controlling certain pests. However, **over reliance on pesticides may foster the development of pesticide resistance, interfere with pollination of some crops, and reduce the contribution of biological control**. Pesticides can also pose a hazard to the applicator, as well as anyone else who may be exposed to residues after the application.

Further, pesticides can have impacts on the environment; this can come from misapplication or through circumstances like drift. The goal when using pesticides is to choose the least toxic material that will satisfactorily manage a pest in the most economical way possible. All pesticides have an inherent hazard; they pose a potential to harm. However, hazards can be avoided by minimizing risk, which is a combination of hazard and exposure.

Choosing Pesticides

When using pesticides, pick the least toxic option that will effectively control the pest. Always aim to reduce the risk of harm by careful application. If multiple applications are needed, rotating among pesticide modes of action (how it kills the pest) can be used to slow or prevent the development of resistance.

By combining these cultural, biological, and chemical controls, IPM helps manage pests in a balanced way, reducing harm to people, wildlife, and the environment while keeping pest populations under control.

Practice Questions

1. What is IPM?
    1. Intensive Pest Management
    2. International Pest Monitoring
    3. Integrated Pest Management
    4. Independent Pest Mitigation
2. What was a major reason for the formalization of IPM in the 1970s?
    1. Lack of pesticide availability
    2. High levels of insecticide resistance
    3. Development of organic farming
    4. New government regulations
3. Which of the following is NOT part of IPM monitoring?
    1. Inspecting plants for pests and symptoms
    2. Using traps for insect monitoring
    3. Applying pesticides without inspection
    4. Tracking diseases using weather models
4. Why is proper pest identification important in IPM?
    1. To ensure effective pesticide use
    2. To select appropriate management approaches for the specific pest
    3. To avoid using biological methods
    4. To reduce pesticide resistance
5. What is an economic threshold in IPM?
    1. The total cost of using pesticides
    2. The pest level at which pest control measures should be applied
    3. The amount of pesticide used per acre
    4. The time it takes to apply pesticides
6. What is the purpose of evaluating results after applying pest controls?
    1. To determine if the pest control tactic worked
    2. To find new pest control methods
    3. To eliminate pests completely
    4. To increase pesticide use
7. Which of the following is a cultural practice in IPM?
    1. Crop rotation
    2. Applying more fertilizer
    3. Using stronger pesticides
    4. Ignoring pest symptoms
8. How does crop rotation help in IPM?
    1. It increases the use of chemical pesticides
    2. It improves the growth of weeds
    3. It allows pests to adapt to new environments
    4. It reduces pest populations by switching between unsuitable crops
9. Which of the following is NOT a benefit of using resistant plant varieties?
    1. Plants support fewer pests
    2. Pesticides are no longer needed
    3. Plants may tolerate pests with minimal yield impact
    4. Plants are less susceptible to diseases
10. What can excessive irrigation and fertilization cause in IPM?
    1. Healthier plants
    2. Increased pest resistance
    3. Conditions that favor pests
    4. Pest-free crops
11. What is sanitation in IPM?
    1. Removing infected plants and plant debris
    2. Spraying pesticides regularly
    3. Ignoring minor pest infestations
    4. Applying fertilizers frequently
12. What is a key benefit of biological control in IPM?
    1. It eliminates the need for monitoring
    2. It can suppress pest populations over the long term
    3. It is always less expensive than pesticides
    4. It eradicates pests completely
13. Which method does NOT typically encourage biological control?
    1. Releasing predators
    2. Releasing parasitoids
    3. Spraying synthetic pesticides
    4. Using beneficial microorganisms

14. Which is a potential downside of using chemical pesticides in IPM?

    1. They can cause pesticide resistance
    2. They always eliminate pests immediately
    3. They improve biological control agents' effectiveness
    4. They are completely safe for the environment

15. What should be considered when using pesticides in an IPM program?

    1. Use the most toxic pesticide available
    2. Use pesticides that are least toxic and cost-effective
    3. Always apply pesticides regardless of pest population
    4. Avoid all forms of pesticides

16. What role do beneficial microorganisms play in IPM?

    1. They eliminate pests through chemical reactions
    2. They replace the need for resistant plant varieties
    3. They increase plant growth rates
    4. They can act as natural enemies of pests

17. What is a major goal of IPM?

    1. Completely eliminate pests using pesticides
    2. Sustainably suppress pest populations below economic levels
    3. Increase pest populations to monitor them better
    4. Avoid using any form of biological control

Answers

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

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.

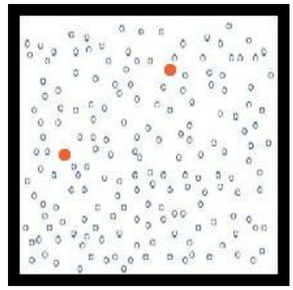
Sources of Resistance

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.

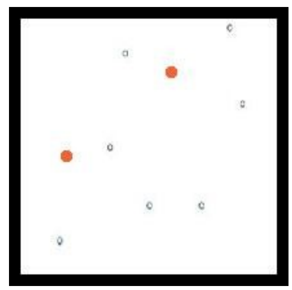
Resistance can only develop in pest populations where there is the genetic potential to resist the pesticide. Normally, only extremely low numbers of resistant individuals are present: perhaps many fewer than 1 in a million, but that can be enough to start the process. Usually, many pests are killed 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.

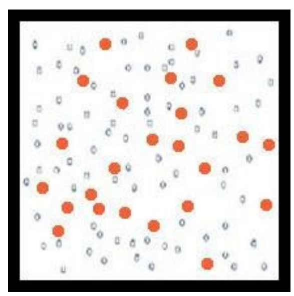
The second factor is **selection**. Repeated use of the pesticide selects for individuals that can survive the presence of the toxin. That condition is under human control. It is a natural outcome of the use of at-risk pesticides. **At-risk pesticides are those against which resistance is most likely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

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.**

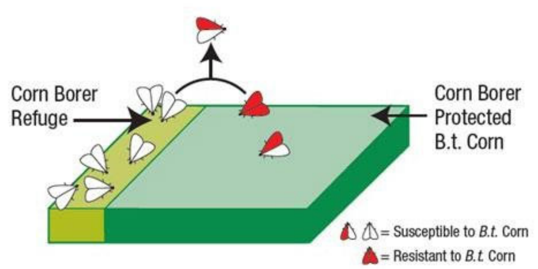
Insecticide group numbers appear on some labels making it easy to rotate modes of action to reduce the potential for development of resistant populations. For example, pyrethroid insecticides belong to Group 3. Continued use of insecticides in this group can lead to resistance. Rotate with other numbered 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 borer, is high because of the large percentage of *Bt* corn acreage planted each year.

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

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 potentaily resistant individuals that developed on the plants with the *Bt* gene. Matings between susceptible and resistant individuals keeps *Bt*-suceptibility 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 amount of non-Bt is mixed with the seed to provide susceptible pests enough refuge plants on which to develop.

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	

Potential Consequences of Pesticide Use

Pesticides can be very important and effective tools to manage specific Agricultural production problems but applying pesticides within diverse landscapes has the risk of unintended consequences. While these concerns are not unique to production agriculture, potential problems due to drift, phytotoxicity, persistence, and effect on non-target organisms must be managed.

Drift

Pesticide spray drift is the off-target movement of pesticide dust, droplets, or vapors through the air at the time of application or soon after, out of the intended area. Pesticide droplets are produced by spray nozzles used in application equipment. Pesticide drift can affect people's health, the environment, and damage nearby plants. Drift can result in less effective control as less material remains on target. Some products and formulations are more prone to drift, but to a limited degree there is a degree of drift associated with nearly all pesticide applications. For these reasons, drift should be considered and managed with all pesticide applications. Many factors can affect drift and damage caused by drift including weather conditions (wind speed and direction, humidity, temperature), type of pesticide and its formulation, distance to sensitive areas, spraying techniques (nozzle type, pressure, carrier volume, nozzle height, etc.), and applicator decisions. Drift can lead to liability issues for your business and support arguments to ban some pesticides.

Situational Awareness

Before making an application, understand what and where are the sensitive areas near the area to be treated. These can include commercial crops as well as sensitive fruit and vegetable crops, streams and ponds, managed pollinators, organic farms, residential areas, or habitat for threatened or endangered species. You should always avoid making applications when prevailing winds will favor drift toward these areas.

While some soil-applied pesticides need to be incorporated to be effective, others may require applications to be completed covered with soil after application to avoid risk to non-target organisms. These requirements are clearly specified on product labelling.

Weather Conditions

Wind speed is a critical factor that move pesticide dusts and droplets out of the intended areas. Some labels have specific restrictions on use based on wind speed, so applicators must be aware of those restrictions on the labeling. For those without specific restrictions, wind speeds of between 3 and 10 mph in a safe direction are recommended. Wind direction away from nearby sensitive areas can greatly reduce the risk of harm to sensitive areas, but wind direction should be used as a reason to apply pesticides when conditions favor excessive drift.

Temperature inversions also play a role in increasing the risk of damage due to off-target movement of some products. A temperature inversion is when air temperature increases with height which can trap pesticide drift near the ground causing it to only move horizontally. Wind speeds over 3 to 5 mph will significantly weaken temperature inversions. Dew or fog can be signs of an air inversion. Avoid spraying during an inversion as fine sprays and volatized pesticides can float for long distances.

Drift and Pesticide Product Type

Some products are more prone to drift, and some products are more prone to cause damage when they do drift. Some of the auxin-mimicking herbicides are prone to volatilize and move off-site. Non-selective herbicides are more likely to damage surrounding vegetation when they drift. The risk is elevated in plantings with a diversity of plant types and species.

Drift Reduction Technology

One rule of drift is that small droplets travel much farther than large droplets. To increase droplet size, applicators can increase the size of nozzles to deliver more spray volume per area, reduce sprayer pressure and speed of applications, or switch to drift reduction nozzles. Each of these techniques will require that the equipment be recalibrated for each change in nozzle type and size, and spray pressure.

Phytotoxicity and Persistence

Both phytotoxicity and persistence can be more of a concern in areas with a high diversity of plants. Persistence of some pesticides can result in phytotoxicity to some sensitive plants due to pesticide residues remaining in the soil as plantings are changed over time. Phytotoxicity can also be the result of drift. Phytotoxicity can take many forms and may cause a delay of seed germination, inhibition of plant growth or any adverse effect on plants including deformed growth, chlorosis, spotting, marginal burn, or tissue death.

Spray tank mixtures of insecticides, miticides or fungicides may result in plant injury that does not occur from use of any one of the materials alone. Before materials are tank mixed, study the manufacturer's label carefully. Mixing pesticides that require different types of adjuvants should be done with caution. It is best to treat just a few plants with a new combination of pesticides and wait a week for any phytotoxic effects to appear.

Non-Target Effects to Other Organisms

Always read and follow all label directions and restrictions. Application equipment should be calibrated regularly to ensure the dosages applied are within the labeled range. Applications of agricultural pesticides that include the Worker Protection Standards labelling require an Application Exclusion Zone (AEZ) to keep people away from application equipment when in use. The minimum size of the AEZ will depend on how the pesticides are being applied and moves with the equipment as it travels through the field. Keep people out of treated areas during the Restricted Entry Interval (REI) as required by the label, as well as post fields and greenhouses and notify workers as required.

Pollinator Protection

Kentucky has a pollinator protection plan that is available online that addresses best management practices for pesticide applicators. Insect pollinators are particularly sensitive to some insecticides when they drift to their nests or contaminate flowers that they pollinate. Many native trees, shrubs, and wildflowers are dependent on insect pollinators in addition to the agricultural crops that rely on them.

Pesticide Applicator Best Management Practices:

- Be aware of honey bee hives and habitat for other pollinators near areas to be treated.
- Use IPM and thresholds when available for making application decisions.
- Avoid using dusts and wettable powders in pollinator-sensitive areas.
- Consider impacts on pollinators when making pesticide application decisions.
- Always use pesticides according to the label and follow all pollinator protection restrictions.
- Minimize pesticide drift and avoid applications when weather conditions favor pesticide movement toward honey bee hives.
- Notify nearby beekeepers prior to application if required by the pesticide labeling.

Endangered Species

Fish and Wildlife Service administers the Endangered Species Act

The Endangered Species Act (ESA) protects and promotes recovery of animals and plants that are in danger of becoming extinct due to the activities of people. Under the Act, the Environmental Protection Agency (EPA) must ensure that the use of pesticides it registers will not result in harm to the species listed by the U. S. Fish and Wildlife Service as endangered or threatened, or to habitats critical to the survival of those species. The EPA has implemented labelling measures on some new and revised labels requiring applicators to visit the *Bulletins Live! Two* website no sooner than 6 months prior to each use of the product to determine if site specific mitigation measures must be followed for the products to protect listed species. Pesticides requiring applicators to check the *Bulletins Live! Two* website have an Endangered Species Protection Requirement section on the label. Just as with the pesticide labeling itself, applicators must follow the any additional restrictions provided by the *Bulletins Live! Two* website.

Practice Questions

1. The pesticide restrictions on the *Bulletins Live! Two* website are not required as they are not part of the pesticide label.
    1. True
    2. False
2. What should applicators check on the Bulletins Live! Two website?
    1. If their pesticides are expired
    2. If specific mitigation measures are needed to protect endangered species
    3. If the weather is suitable for spraying
    4. If their equipment needs maintenance
3. Which of the following practices can help reduce the risk of drift?
    1. Spraying during high winds
    2. Using smaller nozzle sizes
    3. Increasing boom height
    4. Using lower pressure and drift reduction nozzles
4. Small droplets travel much farther than large droplets with the wind.
    1. True
    2. False
5. What is the importance of following Restricted Entry Intervals (REI)?
    1. It ensures crops grow faster
    2. It keeps workers safe from pesticide exposure
    3. It reduces cost of pesticide application
    4. It prevents pesticides from breaking down too quickly
6. What role does the U.S. Fish and Wildlife Service play in pesticide regulation?
    1. Approving all pesticide products
    2. Enforcing the Endangered Species Act
    3. Monitoring pesticide storage facilities
    4. Setting pesticide prices
7. Which of the following can affect pesticide drift?
    1. Weather conditions
    2. Type of pesticide
    3. Application techniques
    4. All of the above
8. It is only the beekeeper's responsibility to keep the bees safe from pesticide applications.
    1. True
    2. False
9. What is an Application Exclusion Zone (AEZ)?
    1. An area where pesticide use is prohibited
    2. A buffer zone around the sprayer to keep people safe
    3. The maximum area that pesticides can cover
    4. A location for pesticide storage
10. Restrictions listed on the *Bulletins Live! Two* website for a particular application are only suggestions and not required since they are not on the pesticide label.
    1. True
    2. False
11. Which of the following is NOT a factor that can affect pesticide drift?
    1. Wind speed
    2. Temperature
    3. Type of pesticide
    4. Soil type
12. Which of the following is NOT a symptom of phytotoxicity?
    1. Increased plant height
    2. Deformed plant growth
    3. Delayed seed germination
    4. Chlorosis

Answers

1 - 2 2 - 2 3 - 4 4 - 1 5 - 2
6 – 2 7 – 4 8 – 2 9 – 2 10 – 2
11 – 4 12 - 1

Professionalism

How the public views pesticides and pesticide applicators is greatly influenced by the professionalism they view among pesticide applicators. Consequently, both private and commercial applicators have an EPA-required core competency for professionalism as a certified applicator. This competency area is broken into three specific areas: chemical and pesticide security, communicating information about pesticides and exposures with customers and public, and appropriate product stewardship.

So, what is professionalism? It is the skill, good judgment, and consistent behavior expected from a person who is properly trained. It involves fair treatment of neighbors and customers, respect for others, and being an asset to your community through exercising good judgement. An applicator or a supervisor needs expertise and good judgment to make decisions on issues affecting security, safety, health, or the environment not addressed by regulations or the pesticide label. Certified applicators should learn how to communicate the benefits and risks of pesticide use with customers, employees, and the public so they understand why they are needed. The impression you make on others depends on your ability to answer questions from others about the work you do.

A professional does not take shortcuts that may harm customers, the public, or the environment. Integrated pest management (IPM) is also part of your professional training because it guides selection of sound pest management decisions, identifies when pesticides are needed, and helps to protect sensitive organisms and sites from harm.

Chemical Security

When not being used, pesticides must be stored in a well-marked, locked area. Warning signs must be posted to alert others that pesticides are stored inside. Applicators must restrict access of non-employees and untrained individuals to pesticide storage areas. To protect water resources, pesticides should not be stored in areas prone to flooding and the floor of the storage area should be impervious to contain spilled pesticides. Pesticides should always be stored in their original containers with labels that are intact and legible. Storage of mini-bulk and bulk tanks require additional containment measures.

Accidents happen unexpectedly. A professional should have a basic plan on how to react to a pesticide spill, fire, or flood. This would include the materials needed to contain spilled pesticides, persons or agencies that need to be contacted, and procedures that need to be followed to respond to an emergency.

Employees should be trained in security and emergency procedures associated with pesticides and their storage. Employees can provide early warnings when something seems out of place, or something is of concern. At a minimum, instruct all employees on pesticide inventory control, security of storage facilities and application equipment, and emergency preparedness and response. There should be a written plan that is communicated with employes on how to respond to fire, theft, pesticide spill, or other incident. Post telephone numbers of emergency response agencies in a prominent location.

Communication with the Public

Communicating with the public is a skill developed over time. When speaking with the public, it is better to use simple, direct language than to use technical jargon. Be proactive and reach out to neighbors, customers, and others who may have concerns about nearby sensitive sites where pesticides are applied. Explain what it means to be a certified applicator because many people do not know. Be familiar with your company's or organization's policy for talking to customers, neighbors, or the media.

Keep accurate records of all pesticide applications. Good records provide the facts of what was done and demonstrate professionalism. If there is a complaint or legal action following an application, having good records may be a valuable defense. Having no or insufficient records makes an applicator vulnerable to baseless accusations and additional scrutiny. In summary, being an effective pesticide applicator is more than just the skills and knowledge needed to conduct an application. It also requires good judgment and professional behavior.

Integrated Pest Management

Pesticide stewardship involves use of pesticides as part of an overall Integrated Pest Management (IPM) program to minimize impacts, enhance sustainability, and maximize profitability. IPM includes the use of proper:

- Weed, pest, and disease identification,
- Preventive cultural controls, which includes crop rotation, use of resistant or tolerant varieties, cover

cropping, adjusting planting and harvest dates, optimizing irrigation and fertility regimes, and using sanitation to disrupt pest, pathogen, and weed life cycles.

- Maximizing biological control reducing factors which interfere with natural enemies or providing resources that natural enemies need in their environment,
- Mechanical controls such as row covers or screens on greenhouses to limit pest establishment or movement of pathogens vectors with specialty crops,
- Weed, pest and disease scouting and monitoring,
- Evaluation of pest problems though use of economic or action thresholds when appropriate,
- Use of forecasting models for pests and disease when available,
- And selection of the most appropriate pesticide when needed based on the situation.

Pesticides will remain a cornerstone of production agriculture. However, they are a number of practical issues associated with pesticide use including pests, weeds and diseases developing resistance to commonly used products, the rising cost of pesticides, regulatory restrictions with some products, and off-target effects on groundwater, beneficial insects, and endangered species. Using pesticides as part of an IPM program helps to justify pesticide use by determining when applications are needed and using pesticides in combination with other methods of control to prevent, slow or reduce the development of pests, weeds, and diseases.

The benefits of using IPM strategies include:

- Preserving the effectiveness of pesticides by reducing or delaying the development of resistance by weeds, disease, or pests,
- Minimizing impacts on beneficial insects including pollinators and natural enemies to increase their value for agriculture,
- Minimizing impact on endangered or threatened species,
- Identifying when pesticides are needed to limit the use of pesticide applications when not needed and maximize their value by using them when they provide the greatest benefit for pest, weed, and disease control,
- Using pesticides in a way to get the greatest return in investment,
- Lessening the environmental impacts of pesticides, and
- Minimizing the health and safety concerns with workers, customers, and public related to pesticide use.

Practice Questions

1. What is a key factor that influences public perception of pesticide applicators?

    1. The type of pesticides used
    2. The length of time the applicator has been certified
    3. The cost of pesticide application
    4. The professionalism of the applicator

2. Which of the following is NOT a part of professionalism for pesticide applicators?

    1. Fair treatment of neighbors and customers
    2. Taking shortcuts to save time
    3. Respect for others
    4. Exercising good judgment

3. What does professionalism in pesticide application include?

    1. Exercising expertise and good judgment beyond regulations
    2. Making decisions that only follow pesticide the label
    3. Using only chemical controls
    4. Avoiding communication with the public

4. What is an important aspect of chemical security in pesticide storage?

    1. Storing pesticides in unmarked containers
    2. Allowing public access to storage areas
    3. Posting warning signs to alert others
    4. Storing pesticides in areas prone to flooding

5. What is the purpose of Integrated Pest Management (IPM)?

    1. To eliminate the need for pesticides entirely
    2. To minimize impacts, enhance sustainability, and maximize profitability
    3. To increase the amount of pesticides
    4. To focus only on chemical controls for pests

6. What should be done if there is a pesticide spill or fire?

    1. Wait for authorities to arrive before taking action
    2. Have a basic plan that includes materials, contacts, and procedures
    3. Ignore the spill if it's small
    4. Only report the incident to your supervisor

7. Why is it important to communicate the benefits and risks of pesticide use to the public?

    1. To increase public fear of pesticide use
    2. To reduce the cost of pesticide applications
    3. To avoid legal actions
    4. To help them understand why pesticides are needed

8. Which of the following is a benefit of using Integrated Pest Management (IPM) strategies?

    1. Preserving the effectiveness of pesticides by reducing resistance
    2. Increasing the use of pesticides
    3. Applying pesticides without considering environmental impacts
    4. Avoiding the use of biological controls

9. Why should pesticide applicators keep accurate records of applications?

    1. To avoid paying taxes
    2. To reduce the cost of pesticide products
    3. To hide information from regulatory agencies
    4. To provide a defense in case of complaints or legal actions

10. What is a critical component of emergency preparedness for pesticide applicators?

    1. Training employees in emergency response procedures
    2. Keeping the pesticide inventory a secret
    3. Storing pesticides in accessible areas for convenience
    4. Allowing only the supervisor to respond to emergencies

11. The best strategy to communicate with the public about pesticides is to ___________________.

    1. stay silent
    2. tell them all pesticides are safe
    3. explain the risks and benefits of pesticide use
    4. tell them you don't use pesticides

12. An emergency plan for a pesticide fire is not needed as the chance of that happening is almost zero.

    1. True
    2. False

13. Professionalism means consistently maintaining high standards of ethics and excellence, in the work you do and the way you act.

    1. True
    2. False

Answers

1 - 4 2 - 2 3 - 1 4 – 3 5 – 2
6 - 2 7 - 4 8 – 1 9 - 4 10 – 2
11 - 3 12 – 2 13 - 1