IPM
INTEGRATED PEST MANAGEMENT
& PESTICIDE SAFETY EDUCATION

Noxious Weeds

K-STATE
Research and Extension

Kansas State University Agricultural Experiment Station
and Cooperative Extension Service

Category 9A

Inside front cover blank

Table of Contents

Directions for Using this Manual

This is a self-teaching manual. At the end of each major section is a list of study questions to check your understanding of the subject matter. These study questions represent the type that are on the certification examination. By studying this manual and answering the study questions, you should be able to gain sufficient knowledge to pass the Kansas Commercial Pesticide Applicators' Certification examination. Correct answers appear on page 62.

Laws and Regulations

Learning objectives

After completing this chapter, you should be able to:

- Recognize the responsibilities of the Kansas Department of Agriculture, the county commissioners, the noxious weed supervisor, and the landowner in regards to the Kansas Noxious Weed Law.
- Identify the two classes of pesticides.
- Know what information you are required to record on all restricted use applications and how long to keep these records.
- Understand what records of sale must contain.

Kansas Noxious Weed Law

Under the Kansas Noxious Weed Law (K.S.A. 2-1314 et seq.), the state legislature declares certain weeds to be noxious, and requires landowners in the state to use approved methods to control and eradicate these weeds. The Kansas Department of Agriculture is charged with adopting the appropriate control measures for noxious weeds and for publishing these methods, entering into agreements with the federal government concerning noxious weed control, and advising and rendering assistance to county noxious weed supervisors. This work is currently handled by the Plant Protection and Weed Control Program.

While it is the Department of Agriculture's responsibility to advise and assist the various counties in the control of noxious weeds, it is the responsibility of the various boards of county commissioners and the county weed supervisors to control noxious weeds within their respective counties. The county weed supervisor is responsible for offering assistance and direction in the control of noxious weeds to the landowners in the county, making annual surveys of infestations, sending enforcement notices and submitting reports to the county commissioners and to the Department of Agriculture. The supervisor also assists in the investigation of violations and reports these to the county attorney for prosecution. The board of county commissioners, with the aid of their weed supervisor, is responsible for filing an annual weed eradication progress report and an annual noxious weed management plan with the Department of Agriculture.

Based on reports filed by the county weed supervisor, the board of county commissioners (or other governing body) is authorized to make a tax levy on the citizens to pay a portion of the cost of control and eradication of noxious weeds within that county or other governmental unit. The money collected is used for controlling noxious weeds on county-owned land and right-of-ways, for purchasing equipment and herbicides, and for the salary of the county weed supervisor. The board of county commissioners is required to sell herbicides, approved by the Kansas Department of Agriculture for noxious weed control, to landowners within the county for the control of noxious weeds on privately owned land. In most cases, herbicides are sold for a cost of from 50 percent to 75 percent of the total cost of purchasing, storing, and handling the chemicals. Counties whose levy is 1.5 mills or greater may charge up to 100 percent of cost. The Board of County Commissioners may adopt a cost share certificate system where by landowners may purchase herbicides for noxious weed control from pesticide dealers and receive a cost share benefit.

Counties may publish a General Notice in the county newspaper advising landowners of their responsibility to control noxious weeds. When the county weed supervisor finds an infestation of noxious weeds, a Warning or Official Notice is sent to the owner or manager of the property. This notice informs the landowner of the law and his or her obligation to treat the infestation within a certain time period and contains the appropriate control procedures as prescribed by the Department of Agriculture. Either a General Notice may be

published, a Warning Notice may be sent, or both, in any given year. If an inspection by the county weed supervisor reveals the landowner has not controlled the noxious weed, a Legal Notice is sent by certified mail. The Legal Notice is required to include the following: 1) a legal description of the infested land; 2) the name of the owner and operator or supervising agent of the land; 3) the approximate acreage of each noxious weed in the infestation or infestations involved; 4) a copy of the official methods and regulations for controlling each named noxious weed; 5) a specified time within which weed control methods are required to be completed; 6) a statement that says unless the owner takes the appropriate steps within the specified time, the county weed supervisor will enter the property and use such approved methods as are necessary for the eradication and control of the noxious weeds; and 7) a statement to inform the owner, operator or supervising agent that they may be prosecuted pursuant to K.S.A. 2-1323, and amendments thereto, and if convicted, fined as established by law. When it becomes necessary for the county weed supervisor to control weeds on private land due to the owner's failure to control them, the full cost of the treatment is assessed to the landowner along with a 10 percent penalty. Failure to control noxious weeds on land that you own or supervise is a violation of this law. Violators are subject to prosecution for failure to control noxious weeds. It is also unlawful to sell screenings, nursery stock, packing material, soil, sod, animal fertilizer, or livestock feed material that contains noxious weed seeds unless this material has been processed in such a way as to destroy the viability of the seeds. Bringing farm equipment into the state or moving such equipment from an infested field to an un-infested field, without first making certain that the equipment is free from all weed seeds and litter is also unlawful. Violations of this act are punishable upon conviction by a fine of $100 per day for each day of noncompliance up to a maximum fine of $1,500. The county noxious weed supervisor is advised to consult with the county attorney before beginning any enforcement action.

Kansas Pesticide Law

The Kansas Pesticide Law (K.S.A. 2-2438a et seq.) regulates the use of pesticide products within the state. Under this statute, pesticide applicators who use restricted use pesticides are certified; businesses that apply pesticides for hire are licensed; government agencies which apply pesticides on property which they do not own or control are registered; and pesticide dealers are registered. The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) (7 U.S.C. 136 et seq.) requires the U.S. Environmental Protection Agency to classify pesticides as either general use or restricted use. Those pesticides which are classified as restricted use may legally be sold only to or used only by certified applicators or persons under their direct supervision. Individuals wishing to use restricted-use pesticides in the control of state or federally declared noxious weeds must be certified in Noxious Weed Control-Category 9A. To be eligible for certification in this category, individuals must be employees of state, federal or other governmental agencies. Landowners or their employees may apply restricted use pesticides to their own property to control noxious weeds if they obtain private applicator certification. Non-government applicators can apply restricted-use pesticides to control noxious weeds on agricultural lands if they have commercial applicator certification in 1A-Agricultural Plant Pest Control or certification in 6-Right-of-Way Pest Control, which pertains to control of noxious weeds on rights-of-way.

As a certified applicator, you are required to keep certain records. For each restricted-use pesticide application made by you or someone under your direct supervision, you are required to prepare a written statement, which includes the following information:

Laws and Regulations

Laws and Regulations

- name and address of the certified commercial applicator,
- name and address of the owner or operator of the property treated,
- common or scientific name of each pest to be controlled or prevented,
- complete product name and the EPA registration number of each pesticide applied,
- quantity of pesticide mixture actually applied,
- total area to which the pesticide is applied,
- rate of application of each pesticide if rates are prescribed on the product label,
- concentration of the active ingredients of each pesticide if given on the label,
- date and location of each and every pesticide application,
- wind direction and velocity,
- signature of the pesticide applicator or supervisor of the application, and
- conspicuously state on application record if pesticide is applied at less than label rate.

Such records must be maintained for three years from the date of application and shall be open to inspection by employees of the Kansas Department of Agriculture (KDA). All applications of restricted-use pesticides and general-use pesticides must be made in accordance with the directions for use shown on the product's label.

Before a governmental agency can legally apply pesticides on ground which it does not own or control, that agency must obtain a government agency registration from KDA. To obtain a government agency registration, the agency must submit a completed application form and a $50 fee to KDA. Government agency registration expires at the end of each calendar year and must be renewed annually. When the applicant is a township located within a county that has a valid government agency registration, no fee is required.

If a pesticide applicator wishes to contract independently for commercial pesticide application services, that is, if he or she wishes to charge another individual for the application of a pesticide product to that person's property, the pesticide applicator must first obtain a pesticide business license from KDA. In order to receive a business license, an application and fees of $140 per category plus $15 for each uncertified applicator employee must be submitted; the business owner or an employee must have commercial certification in each category for which the business license is desired; and proof of financial responsibility must be submitted in the form of a surety bond, letter of credit, escrow account or a certificate of liability insurance. If a surety bond, letter of credit or escrow account is used, the amount of the coverage cannot be less than $6,000 per year. The requirements for liability insurance are that the minimum coverage must be $25,000 for bodily injury liability for each occurrence and $5,000 for property damage liability for each occurrence. Once issued, business licenses expire at the end of each calendar year and must be renewed annually.

Those noxious weed departments that sell, or distribute, pesticides directly to landowners within their counties, are required to register with KDA as pesticide dealers. Those departments that use a voucher program and therefore do not distribute pesticides directly to landowners, are not required to register as pesticide dealers. To become a registered dealer, a completed application and fee must be submitted to KDA. Current fees are $25 for dealers with annual sales less than $2,500 or $100 for dealers with annual sales equal or greater than $2,500. Registrations expire on June 30th following issuance and must be renewed annually. Records are required for each sale of restricted-use pesticide products. The records must be made available to KDA representatives and must be maintained for a

minimum of two years after the date of the sale. Records of the sale of restricted-use pesticides must contain the following information:

- name of the person to whom the restricted-use pesticide product has been sold or conveyed as verified by the person's presentation of a federal or state government-issued identification card, address of either the residence or principal place of business of each person to whom the restricted-use pesticide product has been sold or conveyed,
- name and address of either the residence or principal place of business of the individual to whom the restricted-use pesticide product has been delivered or conveyed, if different from the purchaser,
- applicator's certification number,
- the name of the state issuing the certificate,
- expiration date of the certificate,
- if the applicator is a certified commercial applicator, the categories and subcategories in which the applicator is certified,
- registered name of the restricted-use pesticide product, the EPA registration number, and if applicable, the "special local need" state registration number,
- quantity of the restricted-use pesticide product sold or conveyed, and
- date of the transaction.

If the pesticide dealer makes a restricted-use pesticide product available to an uncertified person for use by a certified applicator, then the following records shall be kept in addition:

- The name of the uncertified person to whom the restricted-use pesticide product has been made available, as verified by the uncertified person's presentation of a federal or state government issued identification card;
- address of either the residence or principal place of business of the uncertified person to whom the restricted-use pesticide product has been made available;
- name of the certified applicator who will use the restricted-use pesticide product; and
- the address of either the residence or principal place of business of the certified applicator who will use the restricted-use pesticide product.

Each pesticide dealer is required to submit an annual report on sales of restricted use pesticides to KDA. This report must include the registered name, EPA registration number and the quantity of the restricted-use pesticide product sold or otherwise conveyed. If applicable, the "special local need" state registration number of the restricted-use pesticide product must be included in the report.

Violations of the Kansas Pesticide Law such as using pesticides in a manner inconsistent with the pesticide's label, failing to maintain the required records or applying pesticides commercially without a pesticide business license may result in suspension or revocation of a business license or certification, criminal penalties that may include one year in jail and/or a $2,500 fine, and/or civil penalties of up to $5,000 per offense.

Applicators are responsible for periodically reviewing the Kansas Pesticide Law and Regulations at http://agriculture.ks.gov to acquaint themselves with any changes in laws or regulations occurring after the publication date of this study manual.

Laws and Regulations

Laws and Regulations

Study Questions

Laws and Regulations

These study questions are to aid you in learning the material on pages 4 through 7.

1. *The county weed supervisor is responsible for:*
   a. offering assistance and direction in controlling noxious weeds
   b. locating infestations of noxious weeds
   c. making annual surveys of noxious weed infestations
   d. all of the above
2. *The law which regulates the use of pesticide products within Kansas is the:*
   a. Kansas Hazardous Products Law
   b. Kansas Noxious Weed Law
   c. Kansas Pesticide Law
   d. Kansas Commercial Applicator Law
3. *Records on the use of restricted use pesticides to control noxious weeds must be kept for __ years.*
   a. 3
   b. 4
   c. 5
   d. 6
4. *Government agencies must obtain a government agency registration from KDA when applying pesticides:*
   a. that are restricted-use pesticide products.
   b. to areas greater than one linear mile or one acre in size.
   c. to property not owned or controlled by the government agency.
   d. near or in environmentally sensitive areas.

Kansas Noxious Weeds

Learning objectives

After completing this chapter, you should be able to:

- List the noxious weeds in Kansas.
- Identify which two noxious weeds are county option weeds.
- Explain why noxious weed control is important.
- Identify management options used to control specific noxious weeds.

The Kansas Noxious Weed Law was first enacted in 1937. It requires the control and eradication of the following plants designated as noxious weeds by the Kansas Legislature. These noxious weeds are non-native invasive plants with the exception being Bur ragweed and Pignut, which are considered native species. Controlling noxious weed species is important because they displace desirable vegetation, interfere with agriculture production, cause human health problems, or invade and degrade the environment. Many of these plants have been introduced accidentally from places as far away as Europe, Asia, and Africa. In some cases, they were brought here intentionally as ornamentals or forage crops, but then invaded their new environment. Noxious weeds impact our agricultural lands by competing for resources.

There are currently 12 species on the noxious weed list with 2 additional species listed as county-option weeds. Each county is able to decide on its own to declare either or both of the species as noxious in that county. When it is declared noxious, it is treated the same as the other 12 species.

Bull Thistle

(*Cirsium vulgare* (Savi) Ten.)

Description

Bull thistle is a biennial that reproduces solely by seed. The deeply lobed rosette leaves are green on the upper side and light green on the lower side. The woolly character of the lower side may give it an almost grayish appearance. Mature leaves are moderately to coarsely lobed, with 3 to 4 points per lance-shaped lobe. Each point ends in a long stout, yellow spine, with numerous shorter spines between. Short, stiff hairs and frequently spines are found on the upper leaf surface. Leaves are short and broad, usually less than 12 inches in length, and very wavy or crinkled. Mature leaves are alternate and growing down the stem beyond their bases, causing the stalk to appear "winged" and prickly with lobed leaf-like ridges. The stems are stout, erect, branched and leafy to the heads. Considerable branching may be found in very young flower stalks.

One to several small to intermediate sized purple flowers can be found at the ends of short, prickly-winged branches. Bull thistle flowers from July to September.

Seeds are light straw-colored and oblong. The seeds are attached to parachute-like hairs (pappus), which allow for their dispersal by wind currents.

Bull Thistle

Distribution and Adaptation

Bull thistle may be found throughout the state but occurs most frequently in the central and south central counties of Kansas. Bull thistle is a county option noxious weed and is therefore not reported from each county.

Life History

Bull thistle reproduces only by seed. The likelihood of new infestations will be reduced by any action to prevent the production and movement of seed.

Management Options

The control of bull thistle shall mean preventing the production of viable seed.

1. **Prevention**
   Planting weed-free seed, feeding hay free of seed, and cleaning equipment before leaving infested areas are methods that will prevent the spread of bull thistle.

Kansas Noxious Weeds

Burr Ragweed

2. **Cultural and Mechanical Practices**
   Mowing: Mow with a rotary mower between the first appearance of color and the first appearance of brown on the pappus of the earliest heads. Mow cleanly and closely and repeat as needed for control.

   Hand Cutting – Digging: Dig the root at least two inches below ground level and remove all soil from the roots. Pick heads that are beyond the bud stage and place in a tight container. Bury the container at a landfill or other site that will not be unearthed.

3. **Biological Controls**
   Any biological plan must meet the requirements of K.A.R. 4-8-41

4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   2,4-D Amine or LV Ester

   Chlorsulfuron (Telar)

   Dicamba (Banvel, Vanquish, Clarity and others)

   Dicamba + 2,4-D (Banvel, Vanquish, Clarity + 2,4-D)

   Picloram (Tordon)

   Picloram + 2,4-D (Tordon + 2,4-D)

   Metsulfuron methyl (Escort XP and several others)

   Metsulfuron methyl + 2,4-D (Escort XP + 2,4-D)

   Imazapic (Panoramic, Plateau)

   Clopyralid + Triclopyr (Redeem R&P)

   Triasulfuron + Dicamba (Rave)

   Diflufenzopyr + Dicamba (Overdrive)

   Imazapic + Glyphosate (Journey)

   Aminopyralid (Milestone)

   Clopyralid (Stinger)

   Clopyralid + 2,4-D (Curtail)

   Diflufenzopyr + Dicamba + 2,4-D

   Diflufenzopyr + Dicamba + Picloram

   Diflufenzopyr + Dicamba + Metsulfuron methyl

Bur Ragweed

(Woollyleaf Bursage)

(*Ambrosia grayi* (A. Nelson) Shinners)

Description

Bur ragweed is a perennial, reproducing by underground root stocks and seeds. The plant is erect, 1 to 2 feet high, somewhat bushy, usually branching from the base, and covered with fine, woolly hairs. The plant is blueish white in appearance and grows from a well-developed root system. Leaves are alternate or opposite, broadly ovate, pinnately 3 to 5 parted or entire, with a long petiole and dusty white in color. The end segment of the leaves is much larger than the other segments.

Flowers are composite heads in short racemes. Male flowers are in small drooping heads at the top of the plant with female flowers in the axils of the leaves, usually one per leaf.

The seed cone (or bur) is shaped in heads, 3 to 7 mm. long, with hooked spines or curved at tip.

Distribution and Adaptation

Bur ragweed is found in moist cultivated fields, waste places, pastures, and irrigated areas if poorly drained. In 2012, bur ragweed infestation was reported in 30 counties in central and western Kansas. The highest county infestations were primarily in southwest Kansas.

Life History
Bur ragweed is native to the central plains states. Its distribution has not changed a great deal but it does spread locally forming dense colonies because of its creeping root system. It can tolerate flooding as well as prolonged drought. Bur ragweed remains a rosette in May-June, elongates and flowers during July-August, and produces seed in September-November.

Management Options
Control of bur ragweed means preventing the production of viable seed and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   Cleaning harvesting and tillage equipment before leaving infested areas can reduce new infestations of bur ragweed.
2. **Cultural and Mechanical Practices**
   Intensive cultivation following application of 2,4-D applied in the ester form in early summer (May 25 to June 20) gives good control. This is followed by seeding a winter small grain and the following year intensive cultivation is started immediately after harvest. Except for the first cultivation after harvest, 2,4-D may be substituted for some of the tillage operations provided soil moisture is ample, and bur ragweed is growing rapidly.

   Rapid stand reduction can be obtained by using alternate crop and fallow, but one year of fallow followed by two small grain crops may be used.
3. **Biological Controls**
   There are no biological controls approved for bur ragweed at this time.
4. **Herbicides**
   The following herbicides may be used for cost share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   2,4-D LVE

   Dicamba + 2,4-D (Banvel, Vanquish, Clarity + 2,4-D)

   Dicamba (Banvel, Vanquish, Clarity)

   Glyphosate + Dicamba (Roundup + Banvel + nonionic surfactant)

   Picloram (Tordon 22K)

   Picloram + 2,4-D (Tordon 22K + 2,4-D)

   Imazapic (Panoramic, Plateau)

Canada Thistle
(*Cirsium arvense* (L.) Scop.)

Description
Canada thistle is an introduced perennial from Eurasia. Plants are 2 to 4 feet tall, branched above, with a well-developed, freely branching, fibrous root system. Leaves are alternate, simple, oblong or lance-shaped, irregularly lobed and spiny toothed, hairy when young and dark green.

The flowers of Canada thistle are rose-purple colored, occasionally white, in composite heads grouped at ends of top branches. They are usually dioecious, i.e. male and female flowers on different plants. For viable seed of Canada thistle to be produced both the male and female plants need to be present.

Seeds are approximately ⅛ inch long, smooth, light to dark brown color, oblong, slightly flattened and slightly curved. The seeds have a white hairy pappus (parachute) at the top that helps support the seed in the air.

Distribution and Adaptation
This persistent weed is found in all crops and open areas including pastures, ditches, bottomlands, and waste areas. Infestations of Canada

Canada Thistle

thistle were reported in 31 counties in 2012, primarily in west and north Kansas. The highest infestations were reported in Phillips and Sherman counties.

Life History

Canada thistle reproduces by whitish, creeping rootstocks that send up new shoots every 8 to 12 inches and by seeds that are spread by the wind. The seedlings start growth slowly and are quite sensitive to competition from crops or other weeds. They grow poorly if shaded and thus invade disturbed grazing areas or open non-cropped sites. Small broken fragments of the underground material can also give rise to new plants. Forage consumption is reduced in pastures since animals will not graze near the plants because of the sharp spines on the leaves. Canada thistle is difficult to eradicate because of a deep, spreading root system, which may extend 10 or more feet on either side of the parent plant.

Management Options

Canada thistle control means preventing the production of viable seed and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   Planting weed-free seed, using livestock feeding materials free of Canada thistle seed, and cleaning equipment before leaving infested fields can reduce new infestations of Canada thistle. Pay close attention to feed or seed materials imported from the northern and northwestern United States. Quick identification and eradication of Canada thistle plants is essential to keep it from spreading.
2. **Cultural and Mechanical Practices**
   Destroy plants by pulling or hoeing before they become securely rooted. Canada thistles usually appear above ground in early spring. Begin cultivation in early summer when plants bloom and are weakened due to declining food reserves in the roots. Persistent cultivation assists in eradication by destroying roots and rootstocks and exhausting food reserves. Avoid planting continuous small grain or row crops.

   Combination of cultivation, crops, and chemicals: One season of intensive cultivation followed by winter wheat or winter rye will eradicate a high percentage of Canada thistle. Bromegrass established in a thistle-infested area, sprayed with ¾ pound of actual 2,4-D acid per acre over a two-year period is an effective control.
3. **Biological Controls**
   There are no biological controls approved for use on Canada thistle at this time.
4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share.

Be sure to follow all label directions and precautions. For additional information consult the K-State Research and Extension publication, Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland.

2,4-D (Low Volatile Ester or Amine)

Picloram (Tordon)

Dicamba (Banvel, Clarity, Vanquish and others)

Glyphosate (Roundup and others)

Chlorsulfuron (Telar)

Clopyralid (Stinger)

Clopyralid + Triclopyr (Redeem R&P)

Clopyralid + 2,4-D (Curtail)

Aminopyralid (Milestone)

Diflufenzopyr + Dicamba + Picloram

Field Bindweed

(*Convolvulus arvensis* L.)

Description

Field bindweed is a perennial from Eurasia that reproduces by means of seeds and creeping rootstocks. The plant's extensive root system may extend 20 to 30 feet deep. Smooth, slender stems twine or spread over the soil and other vegetation. The leaves are up to 2 inches long, alternate, simple, with a petiole. They are quite variable in size, and highly variable in shape. The leaf blade may be oblong to elliptical, rounded to pointed, with spreading basal lobes.

The funnel-shaped flowers are white, pink, or white with pink stripes. They are approximately 1 inch across and are usually borne singly in the axils of leaves. The flower stalk has two small bracts ½ to 2 inches below the flower. These bracts, along with leaf shape and small flower size, distinguish this plant from hedge bindweed.

Seeds are dark, brownish- gray, are about ⅛ inch long, and have one rounded and two flattened sides.

Distribution and Adaptation

Found in cultivated grounds, pastures, and roadsides, field bindweed is able to persist and spread in all non-cultivated areas and under most cropping systems. It infests all counties in Kansas. In 2012, counties that reported infestations above 40,000 acres were Dickinson, Ellis, Finney, Ford, Hodgeman, Lincoln, Marion, Ness, Rush, and Russell.

Life History

Field bindweed seed has a very hard coat that enables the seed to be viable after remaining dormant in the soil for many years. Seeds brought near the soil surface by tillage, rodents, or other means will germinate under favorable conditions, resulting in new bindweed infestations. The plant has a very large reservoir of root material, some at a great depth, which makes the plant difficult to eradicate once it colonizes an area. A good cover of perennial grass will suppress field bindweed.

Management Options

Control of field bindweed shall mean preventing the production of viable seed and destroying the plant's ability to reproduce by vegetative means.

Effective field bindweed control can be achieved by applying appropriate control practices. In developing a bindweed control program, one should consider the various alternative control practices and use one or more appropriate control practices for a particular cropland or noncropland area.

1. **Prevention**
   Clean crop seed before planting to remove bindweed seed and other weeds. If possible do not feed bindweed seed-infested feed to livestock or if it is fed, do not spread manure on bindweed-free land. Clean harvesting and other machinery before leaving infested fields.

2. **Cultural and Mechanical Practices**
   Control Practices for Cropland: Practices approved for controlling bindweed on cropland are: (1) Plant competitive crops, (2) Appropriate and timely cultivation, and (3) Application of herbicides registered for use in infested crops or on cropland with no growing crop. Often a combination of control practices results in a more effective program than does a single practice.

   Competitive Cropping - Close-drilled sorghum or Sudangrass seeded about July 1, after a period of intensive cultivation, provides effective competition for field bindweed. Narrow row grain sorghum may also be used. The effectiveness of competitive crops depends on intensive cultivation during the bindweed growing season when land is not in crop.

   Appropriate and Timely Cultivation - Intensive cultivation, if properly used, is effective in killing established bindweed. Intensive cultivation alone, however, is not usually practical

Field Bindweed

Hoary Cress

because no crops can be grown during the cultivation period. Cultivation used with competitive crops can control bindweed. With small grains, the most favorable times for beginning cultivation are in the spring after bindweed growth has started, or in the fall after the grain has been harvested. The depth for cultivation in medium heavy soil is 4 inches. Bindweed cannot be controlled satisfactorily if cultivation is delayed as long as 20 or 28 days after bindweed emergence.

Control Practices for Noncropland: Practices approved for controlling bindweed on noncropland are hoeing and application of appropriate herbicides.

Hoeing - In noncropland areas such as home gardens and flower beds and for horticultural or forestry plants, thorough hoeing every 10 days to 2 weeks during the growing season can control bindweed effectively.

It is essential to cut off all plants at each hoeing. Bindweed plants missed in hoeing replenish their reserves, which delays killing time. Results will not be satisfactory if bindweed plants are left outside the hoed area because those plants will supply food to the roots for a distance of about 10 feet, preventing the killing of established bindweed in the hoed area.

3. **Biological Controls**
   There are no biological controls approved for field bindweed at this time.

4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   2,4-D Amine or LV Ester

   Dicamba (Banvel, Clarity, Vanquish and others)

   Dicamba + 2,4-D (Banvel + 2,4-D)

   Glyphosate (Roundup and others)

   Dicamba + Glyphosate (Banvel + Roundup)

   Glyphosate + 2,4-D (Roundup + 2,4-D)

   Picloram (Tordon)

   Picloram + 2,4-D (Tordon + 2,4-D)

   Imazapyr (Arsenal)

   Imazapic (Panoramic, Plateau)

   Quinclorac (Facet, Drive)

   Diflufenzopyr + Dicamba (Overdrive)

   Imazapic + Glyphosate (Journey)

Hoary Cress

(*Cardaria draba* (L.) Desv.)

Description

Hoary cress is an introduced perennial from Eurasia that reproduces by an extensive spreading root system and by seed. Plants are upright and grayish-green in color. Leaves are 1 to 3 inches long, alternate, simple, oblong, wavy edged, toothed, with the upper leaves lacking petioles and attached directly to the stem with a broad clasping base. The leaves are also covered with a whitish pubescence.

Flowers of hoary cress are white, ⅛ inch across, very fragrant, and occur in showy compact racemes produced from April to July.

Seed pods are heart-shaped, flattened, and approximately 1/10 inch long. The seeds of hoary cress occur singularly in each valve of the fruit and are slightly flattened, granular, reddish-brown, and mature from June to August.

Distribution and Adaptation
Hoary cress can be found in fields, roadsides, sandy ridges, and waste places in dry areas, as well as in established crops, especially pastures and meadows. In 2012, infestations were reported in 16 counties throughout Kansas with greatest infestations in Nemaha and Gray counties.

Life History
Hoary cress forms dense colonies due to its extensive creeping and branching rootstocks. It is highly competitive and difficult to eradicate once established.

Management Options
Control of hoary cress shall mean preventing the production of viable seed and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   Planting weed-free seed, providing feeding materials free of hoary cress seed, and cleaning machinery before leaving infested areas, may prevent new infestations of hoary cress.
2. **Cultural and Mechanical Practices**
   Cultural control practices have not been developed at this time.
3. **Biological Controls**
   There are no biological controls approved for the control of hoary cress at this time.
4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland."

   2,4-D LV Ester

   Dicamba (Banvel, Clarity, Vanquish and others)

   Metsulfuron methyl (Escort)

   Metsulfuron methyl + 2,4-D + Dicamba (Cimarron Max)

Johnsongrass
(*Sorghum halepense* (L.) Pers.)

Description
Johnsongrass is an upright perennial grass native to the Mediterranean region that reproduces by large rhizomes and seeds. The plant is well adapted to hold its own in competition with crop plants. The stems of Johnsongrass can be up to 6 to 8 feet or more in height and arise from a freely branching, stout, rhizome-possessing, fibrous root system. The plants leaves are alternate, simple, ⅓ to 1½ inches wide and 4 to 36 inches long.

The flowers of Johnsongrass occur in large, open panicles and consist of a cluster of three, 1-flowered, spikelets. One sessile, bisexual, spikelet and two pedicellate, staminate, spikelets make up the cluster.

The fruit of Johnsongrass is a caryopsis or grain that is finely striate and reddish-brown in color.

Distribution and Adaptation
Found especially on rich soil, Johnsongrass is a common weed in croplands, roadsides, ditches, and field margins. Johnsongrass is especially troublesome in crops on overflow bottoms with moist ground. Infestations were reported in all but eleven Kansas counties in 2012 with the largest acreage of Johnsongrass infestation occurring in southeast and south central Kansas.

Life History
Johnsongrass is a very heavy seed producer but its superior ability to compete with other plants results from its long, vigorous, rhizomatous root system. A high temperature is necessary for renewed activity of rhizome buds after a dormant period. The plants grow rapidly and develop a perennial nature within 60 days. The species is used for pasture and hay in the southeastern United States.

Johnsongrass

Johnsongrass often flowers from May till the first autumn frost with seeds ripening shortly after flowering until frost.

Management Options

Control of Johnsongrass shall mean preventing the production of viable seed and destroying the plant's ability to reproduce by vegetative means.

Procedures to be used to control Johnsongrass should include cultural control practices and chemical control or a combination of these two controls.

1. **Prevention**
   Planting Johnsongrass-free seed may reduce new infestations of Johnsongrass, as well as using livestock feed that is free of Johnsongrass seed and cleaning machinery before leaving infested fields.

2. **Cultural and Mechanical Practices**
   Cultivation may begin any time during the growing season. The goal should be to cut off the entire plant at each operation (using a duckfoot or blade-type implement). Cultivate 3 to 5 inches deep every 14 to 18 days. When plants weaken and begin to emerge more slowly, cultivation intervals can be extended to allow plants to grow, typically no more than 10 days after emergence with no more than 3 weeks between intervals. Continue until plants have been eradicated or suppressed so that remaining plants can be destroyed more economically, either by hand or by applying approved chemicals to individual plants.

   In lawns and flower gardens and near trees and shrubs, hoeing or other means to cut Johnsongrass at regular intervals, (no more than 14 days during the growing season) is considered intensive cultivation.

   A combination of small grains and intensive cultivation may be used. Close grazing or mowing at 2- or 3-week intervals throughout the growing season, followed by late fall plowing to expose the rhizomes and roots through the winter, is an accepted control practice.

3. **Biological Controls**
   There are no biological controls approved for Johnsongrass control at this time.

4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland."

   Glyphosate (Roundup and others)

   Sulfometuron (Oust XP)

   Trifluralin (Treflan)

   Fluazifop-P-butyl (Fusilade)

   Sethoxydim (Poast, Poast Plus)

   Fluazifop-P-butyl + Fenoxaprop-ethyl (Horizon 2000, Fusion)

   Primisulfuron (Beacon)

   Nicosulfuron (Accent)

   Imazapic (Panoramic, Plateau)

   Quizalofop (Assure II and Targa)

   Sulfosulfuron (Outrider)

   Imazapic + Glyphosate (Journey)

   Nicosulfuron + Rimsulfuron (Steadfast)

Kudzu

(*Pueraria lobata* (Willd.) Ohwi)

Description

Kudzu is an introduced, long-lived, coarse, vining, legume that covers the ground with long runners. The stems of kudzu are semi-woody with a rough bark-like covering and the

long runners often root at the nodes to form new plants. The leaves are comprised of three leaflets with each leaflet being 2 to 8 inches in length, 2 to 3 lobed, and abruptly tapered to a pointed tip.

The flowers of kudzu occur in racemes, 6 to 8 inches long, in the axils of the leaves. The pea-shaped flowers are lavender to reddish-purple in color and may not occur every year due to winterkill of floral buds. The papery seed pods of kudzu are 1½ to 2 inches long and covered with fine hairs and contain several reddish-brown seeds.

Distribution and Adaptation

Introduced for its edible starchy root and fiber, this species was later planted as a ground cover, for green manure, hay, and forage. Found from the southeastern United States to Kansas, it has escaped over much of the southeast to become a serious invasive weed. During 2012, reported infestations in Kansas were limited to Riley County.

Life History

Kudzu was introduced to the United States from China. Crowns taken from old stands are used for plantings, which grow very quickly, often choking out competing vegetation. Kudzu flowers in the late summer but seldom produces seed in Kansas. It has a deep taproot and spreads by means of stolons and rhizomes. In most years, the above ground parts of kudzu are frozen back to the ground during winter and resprout from the taproot the following spring. Grazing locations with a kudzu infestation may help suppress further colonization by the species.

Management Options

Kudzu should be eradicated as quickly as possible using approved chemicals. Control of kudzu shall mean preventing the production of viable seed and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   Preventing the movement of root crowns or seed from infested areas can reduce the occurrence of new infestations of kudzu.
2. **Cultural and Mechanical Practices**
   Cultural control methods for kudzu are not developed at this time.
3. **Biological Controls**
   There are no biological controls approved for kudzu control at this time.
4. **Herbicides**
   The following herbicides may be used for cost share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   Dicamba (Banvel, Clarity, Vanquish)

   Glyphosate (Roundup and others)

   Picloram (Tordon)

   Triclopyr (Remedy, Garlon)

Leafy Spurge

(*Euphorbia esula* L.)

Description

Leafy spurge is an introduced perennial from Europe that reproduces via seed and creeping underground rootstocks. The creeping rootstocks give rise to new shoots every few inches. The young stems are bright green, 8 to 24 inches tall, with milky sap and often occur in clusters as buds from the spreading root system sprout. Older stems are often branched at top, very stiff, and semi-woody when mature. The leaves of leafy spurge are oblong, scattered, and alternate up the stem with a whorl of lanceolate to oblanceolate leaves, at the base of the flower cluster.

Kudzu

Leafy Spurge

The flowers of leafy spurge occur in a terminal umbel from May to September. Each "flower" of leafy spurge is actually a specialized cluster of flowers consisting of two yellowish, heart-shaped bracts topped by one female flower and 12-25 male flowers. The individual flowers of leafy spurge are very small and greenish in color with the female flower surrounded by four yellow, horned, glands.

The fruit of leafy spurge is a three-lobed capsule with one seed per lobe. The seeds are oval-shaped, silver-gray mottled with brown and ripen from June to August.

Distribution and Adaptation

In Kansas leafy spurge is found in fields, pastures, waste areas, and roadsides in a variety of soil types. In 2012, leafy spurge was reported in 10 counties, primarily in north and northeast Kansas.

Life History

Leafy spurge is an introduced perennial weed from Europe first discovered in the United States in 1827. The plant can become a serious problem in range and pasture situations where it displaces useful forage plants. Leafy spurge contains a toxin that can be fatal to cattle and horses; although, sheep will graze the plant and are currently being used in the northern plains to help keep leafy spurge from spreading.

Management Options

Control of leafy spurge shall mean preventing production of viable seeds and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   Planting weed free seed, feeding livestock materials free of leafy spurge seed, and cleaning equipment before leaving infested fields may prevent the occurrence of new infestations of leafy spurge. Close attention should be placed on any feed or seed materials imported from the northern and northwestern regions of the United States. Quick identification and destruction of leafy spurge plants is essential to prevent its spread.
2. **Cultural and Mechanical Practices**
   Cultivate every two weeks from the beginning of spring growth to August 1 and every three weeks thereafter until fall. Intensive cultivation between harvest and sowing of winter wheat or rye will reduce the stand of leafy spurge. Leafy spurge roots are easily transplanted. Clean all equipment before moving from the infested area to prevent spreading the infestation.
3. **Biological Controls**
   No biological control practices are approved for leafy spurge control at this time.
4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   2,4-D LV Ester

   Picloram (Tordon)

   Picloram + 2,4-D (Tordon + 2,4-D)

   Imazapic (Panoramic, Plateau)

   Imazapic + Glyphosate (Journey)

   Diflufenzopyr + Dicamba + Picloram

   Glyphosate (Roundup and others)

Multiflora Rose

(*Rosa multiflora* Thunb.)

Description

Multiflora rose is a perennial shrub that reproduces by seeds and,

sometimes vegetatively, by rooting at the tips of drooping side stems called canes. The stems are up to 10 feet long, in clumps, and are arching or trailing, usually growing about 6 feet high with the tips drooping almost to the ground. The stems are covered with many stiff recurved prickles. The leaves are pinnately compound, usually with 7 to 9 leaflets. The leaflets are ¾ to 1½ inch long, elliptic, toothed on the margins, nearly smooth on the upper surface and paler with short hairs on the underside.

The flowers of multiflora rose are mostly white, sometimes pinkish, approximately ¾ to 1½ inches wide, and are borne in a many-flowered panicle in May and June.

The fruits, called hips, ripen in July and are bright red, nearly round, about ¼ inch in diameter and contain several angular seeds called achenes.

Distribution and Adaptation

Multiflora rose is locally common in Kansas along roadsides, in pastures, open woodlands, stream valleys, and waste areas. In 2012, multiflora rose was reported from ten counties in the eastern half of the state. Multiflora rose is a county option noxious weed and therefore is not reported from each county.

Life History

Multiflora rose is an introduced perennial shrub from eastern Asia. First planted as an ornamental in the United States, multiflora rose has spread throughout most of the country and is especially problematic on grazing land in southeast and south central Kansas.

Management Options

Control of multiflora rose shall mean preventing the production of seed and destroying the plants ability to reproduce by vegetative means.

1. **Prevention**
   Multiflora rose spreads primarily by seeds. Birds readily eat the fruits of multiflora rose and spread the seeds by passing them through their digestive tract. Multiflora rose may also reproduce vegetatively by rooting at the tips of drooping side canes. There is no practical action that can be taken to prevent the spread of multiflora rose.
2. **Cultural and Mechanical Practices**
   Mowing pastures several times a year will prevent multiflora rose seedlings from becoming established. Mowing may be difficult, however, in the rough, wooded pastures where the rose is most apt to be a problem. Once large bushes become established, a bulldozer may be the only practical mechanical control. However, even after bulldozing, some resprouting may occur, and seeds that have been spread readily germinate in the disturbed soil.
3. **Biological Controls**
   There are no biological controls approved for multiflora rose control at this time. Rose rosette, a disease of multiflora rose native to Kansas continues to reduce the incidence of multiflora rose. Look for branches that display the characteristic "witches broom" effect and are reddish in color. The disease, which is fatal to multiflora rose, is caused by a virus or virus-like disease, such as a phytoplasm, and is spread by a very small wingless mite that can travel on wind currents.
4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   2,4-D LV Ester

Multiflora Rose

Kansas Noxious Weeds

Musk Thistle

Dicamba (Banvel, Clarity, Vanquish)

Glyphosate (Roundup and others)

Picloram (Tordon)

Imazapyr (Arsenal)

Tebuthiuron (Spike 20P)

Triclopyr + 2,4-D (Crossbow)

Metsulfuron methyl (Escort XP, Cimarron)

Metsulfuron methyl + Dicamba +2,4-D (Cimarron Max)

Musk Thistle

(*Carduus nutans* L.)

Description

Musk thistle is primarily a biennial or winter annual but may occur as a summer annual. The leaves of musk thistle are deeply lobed, hairless, and are dark green with a light green midrib. Each leaf has a characteristic whitish to silvery-gray margin along each spine tipped lobe. The base of the leaves on the stem extends downward giving the plant a winged appearance.

Musk thistle is the first of the Kansas thistles to bloom in the spring. The large terminal flower is 1 to 3 inches in diameter, solitary, purple in color, globe-shaped, and usually nodding or bent over slightly. The plant is freely branched and each branch may have one flower or more in addition to the terminal flower.

Seed dispersal of musk thistle begins 7 to 10 days after blooming. Seeds are straw-colored, oblong, and ⅛ inch in length. The seeds are attached to parachute-like hairs (pappus) that allow for their dispersal by wind currents.

Distribution and Adaptation

Musk thistle is locally abundant to infrequent in pastures, prairie ravines, hillsides, open wooded stream valleys, fields, roadsides, and waste areas. Musk thistle may be found throughout Kansas with the heaviest infestations found in the northern one third of the state. In 2012, musk thistle was reported in 97 of the 105 Kansas counties with infestations of more than 40,000 acres reported for Wabaunsee and Washington counties. Counties with no or low musk thistle infestations were primarily in southwest Kansas.

Life History

Musk thistle germinates in the spring and/or fall and spends 90 percent of its life cycle as a rosette. Plants typically bolt (sends up a flowering stalk) in May and June with some sporadic flowering during the summer. Musk thistle is a prolific seed producer and readily invades sites with disturbed soils. For plants that germinate early in the year, seedling mortality is greatest in the late spring and summer. However, plants that germinate late in the fall often have greater mortality, lower growth rates, later flowering times, and produce fewer seeds per plant.

Management Options

The control of musk thistle shall mean preventing the production of viable seed.

1. **Prevention**
   Musk thistle reproduces only by seed. The likelihood of new infestations will be reduced by any action to prevent the production and movement of seeds. Planting weed free seed, feeding hay free of musk thistle seed and cleaning equipment before leaving infested areas are methods that will prevent the spread of musk thistle.
2. **Cultural and Mechanical Practices**
   Mowing: Mow with a rotary mower before the first appearance of pink on the flowers. Mowing at full bloom will prevent seed production. Mow cleanly and closely and repeat as needed for control.

   Hand Cutting - Digging: Cut between the first appearance of pink and the first appearance of brown on the pappus of the earliest heads. Cutting 2 inches

below ground level at any stage should kill the plant. Pick heads that are beyond the bud stage and place in a tight container. Bury the container at a landfill or other site that will not be unearthed.

3. **Biological Controls**
   Two insects, musk thistle head weevil (*Rhinocyllus conicus*) and musk thistle rosette weevil (*Trichosirocalus horridus*) are approved for biological control of musk thistle but must meet the requirements set forth in K.A.R. 4-8-41. Consult with your County Noxious Weed Director for more information.

4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   2,4-D Amine or LV Ester

   Chlorsulfuron (Telar)

   Dicamba (Banvel, Clarity, Vanquish, and others)

   Dicamba + 2,4-D (Banvel + 2,4-D)

   Picloram (Tordon)

   Picloram + 2,4-D (Tordon + 2,4-D)

   Metsulfuron methyl (Escort XP, Ally, Cimarron)

   Metsulfuron methyl + 2,4-D (Escort XP + 2,4-D)

   Imazapic (Panoramic, Plateau)

   Clopyralid + Triclopyr (Redeem R&P)

   Triasulfuron + Dicamba (Rave)

   Dicamba + Diflufenzopyr (Overdrive)

   Imazapic + Glyphosate (Journey)

   Aminopyralid (Milestone)

   Metsulfuron methyl + 2,4-D + Dicamba (Cimarron Max)

   Clopyralid (Stinger)

   Clopyralid + 2,4-D (Curtail)

   Dicamba + Diflufenzopyr + 2,4-D

   Dicamba + Diflufenzopyr + Picloram

   Dicamba + Diflufenzopyr + Metsulfuron methyl

Pignut

(Indian rush-pea, hog potato)

(*Hoffmannseggia densiflora* Benth.)

Description

Pignut is a perennial legume with deep roots on which develop nut-like tubers 10 to 15 inches below the surface. Due to the depth at which they develop these tubers are especially difficult to remove from the soil. The plant has simple to branched stems, 8 to 12 inches high with a tuft of leaves at the stem base. The leaves are twice divided, 3 to 5 inches long, with 3 to 5 pairs of leaflets. The leaflets are oblong in shape, 1/10 to ¼ inch long, and have characteristic glandular dots.

The flowers are of the pea type, yellow or orange-red in color, approximately ½ inch long, and covered with peculiar tack-shaped glands.

The fruits of pignut are flat pods, approximately 1 to 1½ inches long, and few to several seeded.

Distribution and Adaptations

Pignut is infrequent on rocky or sandy prairies, stream valleys, fields, and roadsides within Kansas. In 2012, only Meade County reported infestations of pignut.

Life History

Pignut is a native legume from the southwestern United States. It reproduces by seed, by vegetative propagules near the soil surface, and

Pignut

Quackgrass

by tubers deep in the soil. Pignut forms dense colonies in cropland but is usually more widely scattered in pastures.

Management Options

Control shall mean preventing the production of viable seed and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   New infestations of pignut may be reduced by planting weed free seed and by cleaning machinery prior to leaving infested areas.
2. **Cultural and Mechanical Practices**
   Cultivation: Cultivate three to five inches deep at intervals so as to permit the weeds to grow not more than 10 days after each emergence of first plants, but not to exceed intervals of three weeks. Cultivation shall be continued until the plants have been eradicated or have been suppressed to such an extent that remaining plants may be more economically destroyed by other treatment, such as the application of approved chemicals to individual plants or by hand cultivation.

   Grubbing: Small infestations should be grubbed out, taking care to remove all the tuberous nut-like roots.
3. **Biological Controls**
   There are no biological controls approved for use on Pignut at this time.
4. **Herbicides**
   The following herbicide may be used for cost share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   Picloram (Tordon)

Quackgrass

(*Agropyron repens* (L.) P. Beauv.)

Description

Quackgrass is a perennial grass species that reproduces by seed and underground rhizomes. The rhizomes are pale yellow or straw-colored, cord-like, approximately ⅛ inch in diameter and vary from 2 to 18 inches in depth, depending on soil type with roots arising only at the nodes. The stems of quackgrass grow up to 3 feet tall with 3 to 6 joints per stem. Leaves are ¼ to ¾ inch wide, 3 to 12 inches long, shiny, and dark green in color. In addition, the leaf bases of quackgrass typically have very conspicuous horn-shaped appendages called auricles that clasp the stem. The lower, dried leaf sheaths, leaf blades, and stems of quackgrass are also typically hairy while the upper leaf sheaths and blades are glabrous or nearly so.

The flowers of quackgrass occur in terminal spikes that are 2 to 4 inches long and have 3 to 7 short-awned florets in each spikelet.

The seed of quackgrass is a grain or caryopsis, ¼ to ⅜ inch long, elongated toward the slender tip and tapered to a blunt base with each spikelet falling intact as one unit.

Distribution and Adaptation

Quackgrass is an uncommon weed in gardens, pastures, cropland, waste areas, and in other relatively moist areas. In 2012, infestations of quackgrass were reported in Miami, Nemaha and Shawnee counties.

Life History

Quackgrass is a cool-season grass introduced from Eurasia. It starts growth in early fall, remains green during the winter, and makes maximum growth in the spring. The creeping rhizomes may extend 3 to 8 feet laterally with shoots along the entire length. Quackgrass is palatable

to livestock and can be used for grazing and hay. Good management of tame pastures usually reduces quackgrass invasion.

Management Options

Control of quackgrass shall mean preventing production of viable seed and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   The occurrence of new infestations of quackgrass can be reduced by planting weed free seed, transplanting nursery stock free of quackgrass rhizomes, using livestock feed materials free of quackgrass seed and cleaning equipment before leaving infested fields. Particular attention should be given to grass seed or grass seed mixtures imported from the northern United States.

2. **Cultural and Mechanical Practices**
   Cultivation: Roots and rhizomes are killed by drying on the soil surface. Tillage with a heavy duty spring-tooth cultivator should be at a depth of 3 to 4 inches. The shovels of such an implement should be operated at a slightly lower depth after each successive tilling. The first operation should begin when growth starts in April. Succeeding cultivations should be made at intervals of approximately 1 week even though no growth of quackgrass is apparent.

   Shallow cultivation or plowing in the late fall will expose rhizomes to freezing and drying during the winter months and reduce the rapidity and stand vigor of spring growth. Intensive grazing before cultural operations are started is beneficial.

   Competitive Crops: To be most effective in controlling quackgrass competitive crops should be planted only after quackgrass has been partially weakened by tillage. Closely drilled stands of Sudangrass or forage sorghum may be used. In gardens, a relatively close spacing of squash or pumpkins is effective in controlling quackgrass.

3. **Biological Controls**
   There are no biological controls approved for use on quackgrass at this time.

4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with the label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   Glyphosate (Roundup and others)

   Fluazifop-P-butyl (Fusilade)

   Nicosulfuron (Accent)

   Nicosulfuron + Rimsulfuron (Steadfast)

   Primisulfuron (Beacon)

Russian Knapweed

(*Centaurea repens* L.)

Description

Russian knapweed is an introduced perennial from Asia that reproduces by roots and seeds. The stems of Russian knapweed can be up to 3 feet in height and arise from a particularly well-developed, branching, black-colored, root system. The stems are often branched, have fine ridges, and are covered with downy-white hairs. The rosette leaves of new Russian knapweed shoots are oblanceolate, irregularly pinnately lobed, and somewhat white-hairy underneath with short petioles. The leaves of flowering stems are smaller, lanceolate and narrowed to a sessile base with entire to toothed margins.


Russian Knapweed

The flowers of Russian knapweed are numerous, tubular florets, rose to purple in color, and in composite heads which are flask-shaped, approximately ⅜ to ¾ inch long, and solitary on the ends of leafy branches. The bracts surrounding the flower heads are oval in shape, occur in several series, and have papery, translucent, margins that are rounded with a pointed tip.

The seeds of Russian knapweed are ivory to light-brown in color, 1/10 inch long, flattened, oval-shaped with a capillary pappus and longitudinal ridges, and have a basal scar that is not oblique.

Distribution and Adaptation

Found primarily in fields, pastures, roadsides, waste places, or dry-land areas, Russian knapweed persists in cultivated fields when established. Russian knapweed was reported from Meade and Wabaunsee counties in 2012, with a total infestation of only 3 acres.

Life History

Russian knapweed is a pioneer species that spreads rapidly and colonizes disturbed soils because of an extensive root system. It suppresses other vegetation and survives over a long period of time due to its deep root penetration. Plants tend to increase in dry locations but often decrease on moist sites because of competition with perennial grasses. Shoots typically emerge in the spring, form rosettes, bolt from May to June, flower in June and August, and then set seed from August to September.

Management Options

Control of Russian knapweed shall mean preventing production of viable seed and destroying the plant's ability to reproduce by vegetative means.

1. **Prevention**
   Planting weed free seed, feeding materials free of Russian Knapweed seed and cleaning equipment before leaving infested fields, may prevent new infestations of Russian Knapweed. Close attention should be placed on any feed or seed materials imported from the northern and northwestern regions of the United States. Quick identification and destruction of Russian knapweed plants is essential to prevent its spread.
2. **Cultural and Mechanical Practices**
   Cultural control methods have not been developed at this time.
3. **Biological Controls**
   There are no biological controls approved for use on Russian Knapweed at this time.
4. **Herbicides**
   The following herbicides may be used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information consult the current KSU publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland".

   2,4-D Low Volatile Ester

   Dicamba (Banvel, Clarity, Vanquish and others)

   Picloram (Tordon)

   Imazapic (Panoramic, Plateau)

   Imazapic + Glyphosate (Journey)

Sericea Lespedeza

(*Lespedeza cuneata* (Dum. Cours.) G. Don)

Description

Sericea lespedeza is an introduced perennial legume that reproduces primarily by seeds. The plant has wedge-shaped, trifoliate, leaves that are arranged alternatively on the stem. The individual leaflets of sericea lespedeza are less than 1 inch long and less than ¼ inch wide. The stems are erect, reaching up to 5 feet tall,

with stiff hairs occurring along longitudinal ridges on the stems.

The flowers of sericea lespedeza emerge in the axils of the leaves from mid to late July thru October and are white to cream-colored with a purple throat.The fruit is a flattened pod approximately ⅛ inch long, rounded, with pointed ends in outline.

Distribution and Adaptation

Sericea lespedeza is commonly found in the eastern third of Kansas, but has been moving steadily westward through the CRP program. In 2012, sericea lespedeza was reported most heavily in the eastern half of Kansas with infestations of more than 40,000 acres reported for Crawford, Elk, Greenwood, Wabaunsee, and Woodson counties.

Life History

Sericea lespedeza is native to eastern Asia. It was introduced in the United State in 1896 for use as forage crop for livestock and for erosion control. It was not widely used for pastures until the late 1940's when it was promoted for wildlife habitat. Unfortunately, sericea lespedeza aggressively competes with native plants and has invaded many natural prairies and rangelands.

Management Options

Control of sericea lespedeza shall mean preventing production of viable seed.

1. **Prevention**
   Sericea lespedeza spreads primarily by seeds. The method of seed dispersal is probably by animals. Persons planting mixtures of seeds for erosion control and for wildlife habitat should ensure sericea lespedeza is not included in the mix.
2. **Cultural and Mechanical Practices**
   Rangeland: Prescribed burning at the proper time (late spring) followed by intensive-early stocking (double stock until July 15 and then remove cattle) may reduce the occurrence of sericea lespedeza. Mature cattle grazing early in the season are more apt to utilize sericea lespedeza.

   Tame Pasture: Proper fertilization and grazing during April and May might reduce the occurrence of sericea lespedeza. However, late grazing or no grazing will increase sericea lespedeza.

   Grazing infested areas with sheep and goats will provide effective control of sericea lespedeza.

   Mowing in the late bud stage for 2 to 3 consecutive years from mid-July to late summer should help reduce the vigor of sericea lespedeza stands.
3. **Biological Controls**
   There are no biological controls approved for sericea lespedeza at this time.
4. **Herbicides**
   The following herbicides maybe used for cost-share with landowners. Other products labeled and registered for use on this noxious weed in Kansas may be used in accordance with label directions but are not available for cost-share. Be sure to follow all label directions and precautions. For additional information, consult the current Kansas State University publication of "Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland."

   Metsulfuron methyl (Escort XP, Ally, Cimarron)

   Triclopyr (Remedy, Garlon)

   Triclopyr + Fluroxypyr

Sericea Lespedeza

Invasive Weed Watch List

Have you seen any of these plants?
If so, notify the Kansas Department of Agriculture's Plant Protection and Weed Control program.

PURPLE LOOSESTRIFE

HYDRILLA

SPOTTED KNAPWEED

DIFFUSE KNAPWEED

EXOTIC BUSH HONEYSUCKLE

DALMATIAN TOADFLAX

YELLOW TOADFLAX

AD ASTRA PER ASPERA
Kansas
Department of Agriculture
Plant Protection and Weed Control

Kansas Department
of Agriculture
Plant Protection and
Weed Control
1320 Research Park Dr.
Manhattan, KS 66502
(785) 862-2180
www.agriculture.ks.gov

NON-NATIVE BLUESTEMS

BLACK SWALLOWWORT

Study Questions

Kansas Noxious Weeds

These study questions are to aid you in learning the material on pages 9 through 26.

1. *Bur ragweed is found in Kansas primarily in the:*
   a. southeast
   b. southwest
   c. northwest
   d. northeast
2. M*anagement options for bur ragweed include:*
   a. prevention
   b. cultural and mechanical practices
   c. herbicides
   d. all of the above
3. *The highest infestations of Canada thistle are found in ____ counties.*
   a. Finney and Kearny
   b. Norton and Wallace
   c. Harper and Sumner
   d. Phillips and Sherman
4. *Field bindweed root system may go down _____ feet in depth.*
   a. 1 to 2
   b. 4 to 7
   c. 10 to15
   d. 20 to 30
5. *Hoary cress:*
   a. leaves are alternate and wavy edged
   b. leaves are covered with thick, whitish pubescence
   c. a and b above
   d. none of the above
6. *The leaves of bull thistle:*
   a. are moderately to coarsely lobed
   b. have short, stiff hairs and frequently yellow spines on the upper surface
   c. grow down the stem from the point of attachment to form a winged ridge
   d. all of the above
7. *Management options for pignut include:*
   a. prevention
   b. cultural and mechanical practices
   c. herbicides
   d. all of the above
8. *Johnsongrass is found especially:*
   a. on sandy, dry soils
   b. on rich, moist soil
   c. in abandoned gravel pits in northwest Kansas
   d. on overgrazed rangeland
9. *Kudzu has:*
   a. trailing or climbing stems
   b. flowers in axillary racemes
   c. reddish-brown seeds
   d. all of the above
10. *Leafy spurge flowers are:*
    a. medium to large and yellow in color
    b. small and greenish in color
    c. medium and orange in color
    d. large and lavender in color
11. *Leafy spurge is found primarily in ----- Kansas.*
    a. north and northeast
    b. southeast and south central
    c. south central and southwest
    d. only Marshall County
12. *Multiflora rose is found primarily in ----- Kansas.*
    a.northwest
    b. south central
    c. eastern
    d. southwest
13. *Musk thistle is:*
    a. a perennial
    b. usually a biennial
    c. 3 to 6 feet tall
    d. b and c above
14. *Quackgrass is a:*
    a. summer annual
    b. perennial
    c. biennial
    d. winter annual
15. *Russian knapweed flowers are :*
    a. single clusters
    b. 1 inch long
    c. rose to purple in color
    d. all of the above
16. *Sericea lespedeza reproduces:*
    a. by thick, scaly rhizomes
    b. primarily by seeds
    c. vegetatively by rooting at the tips of stems
    d. all of the above

Herbicides for Noxious Weeds

Learning objectives

This chapter will help you:

- become familiar with the different types of herbicides;
- recognize the environmental factors that affect herbicide efficacy;
- understand what ask when selecting a control option; and
- identify different types of herbicides used to control noxious weeds.

Herbicides are a type of pesticide used to control unwanted vegetation commonly referred to as weeds. In the context of this manual, the focus will be on herbicides used to control noxious weeds. Noxious weed species are highly invasive. They cause concern because they compete with agricultural crops for light, water, nutrients, and space. It is important to understand the effects and limitations of herbicide use in noxious weed control. A successful weed control program may use other integrated control methods such as proper grazing practices, re-seeding, and hand pulling in conjunction with herbicides to achieve a successful weed management program. Consult the herbicide label for complete information on safe and proper use.

Types of Herbicides

Herbicides can be classified as:

- preemergence versus postemergence;
- contact versus systemic (translocated);
- selective versus nonselective;
- persistent versus nonpersistent.

Preemergence herbicides are those applied prior to weed emergence. These chemicals kill young seedlings during germination and emergence. Preemergence herbicides need to be activated by irrigation or rainfall in order to be moved into the soil solution where they can be absorbed by the germinating weed seedling. Preemergence herbicides often are not effective on emerged plants. Herbicides that are applied to actively growing plants are referred to as postemergence. In this case, the plant absorbs the herbicide through the foliage, stem/bark, and roots, so the plant must be actively growing at the time of application. Examples of preemergence herbicides used for noxious weed control include tebuthiuron (Spike) and trifluralin (Treflan). Postemergence herbicides include 2,4-D, glyphosate, and triclopyr (Garlon). Some herbicides can have both foliar and soil activity, such as metsulfuron (Escort), imazapyr (Arsenal), and picloram (Tordon).

Contact vs. Systemic

A contact herbicide is one that kills only the portion of the plant on which it is applied. These compounds react so rapidly that the herbicide does not move in the plant. It is extremely important to obtain good coverage when using a contact herbicide. Contact herbicides are commonly used for control of annual weeds, since they don't resprout from root or rhizome tissue. Contact herbicides can provide control of top-growth of perennial weeds, but generally don't provide good long-term control as these plants can typically resprout from the roots or rhizomes. A systemic herbicide is translocated through the plant. For this reason, these herbicides are useful for control of perennial weeds because they can move and destroy the growing points in the roots, rhizomes, leaves, and shoots. The majority of herbicides used to control noxious weed are systemic, including dicamba, glyphosate, imazapyr (Arsenal) and sulfometuron (Oust). Diquat (Reward) is an example of a contact herbicide.

Selective vs. Nonselective

A selective herbicide controls only certain types of plants. For example, 2,4-D kills susceptible broadleaves, but will not kill grasses. Examples of selective herbicides include metsulfuron methyl(Escort), dicamba, picloram (Tordon), and triclopyr (Garlon). A nonselective herbicide generally controls all types of plants and is used where complete control

is required. Glyphosate is an example of a herbicide that has been considered fairly nonselective, but is actually highly selective in Roundup Ready crops. Rate, timing, method of application, and plant characteristics all play a role in herbicide selectivity. Products that are considered selective in some situations, like imazapyr (Arsenal) and sulfometuron (Oust) in forestry, may be fairly nonselective in other circumstances, such as in rights-of-ways depending on application rate and how they are applied.

Persistent vs. Nonpersistent

Persistent herbicides are those which remain active in the environment for a long time. The chemical structure of these herbicides is not easily broken down by microbial and chemical degradation in the soil. Nonpersistent herbicides are short-lived in the environment. It is important to recognize that the persistence of a herbicide can be affected by temperature, rainfall, soil texture, and application rates. A persistent herbicide can be beneficial in situations when long-term (residual) weed control is desired, like around medians, substations, and rail yards, but could be undesirable in other situations. Routine use of persistent herbicides may increase the chance of a bare ground environment, which could facilitate the development of weed populations that are difficult to control. Examples of persistent herbicides include imazapyr (Arsenal), picloram (Tordon), sulfometuron (Oust), and tebuthiuron (Spike). Common short persistent herbicides include 2,4-D, glyphosate, and triclopyr (Garlon).

Environmental Factors

The previous section discussed the different types of herbicides. However, it is important to also recognize the efficacy of these herbicides can be affected by environmental conditions as outlined below.

Precipitation

Rainfall and soil moisture can affect herbicide efficacy. Postemergence herbicides should not be applied when rainfall is imminent. Rain will wash the herbicide off the foliage of the target plant before it can be absorbed. Allow foliage to dry before spraying to achieve the best results. Some rain is beneficial after application of soil-active (residual) herbicides because it moves the herbicide into the soil solution where it can be absorbed by the plants. Excessive rainfall can cause too much herbicide movement or leaching through the soil. This can result in poor weed control because the herbicide is moved below the seed germination zone. It may also lead to damage of non-target plants if the herbicides move into the root zone of susceptible trees and bushes. Herbicides can remain on the soil surface during dry periods, thus reducing their effectiveness. Herbicides tend to perform best with moderate rainfall and soil moisture.

Temperature

Temperature also can play a role in herbicide performance. Postemergence herbicides are most effective when applied to actively growing plants with ideal temperatures for plant growth. Herbicides generally work more quickly as temperatures increase, but will not work as well if the plants are under heat or drought stress. Herbicides should never be applied when the ground is frozen or when snow is on the ground because of the potential for off-site movement and environmental contamination. Temperature also effects herbicide persistence, as warmer temperatures increase microbial activity in the soil and results in more rapid degradation and short residual activity.

Wind Speed and Direction

Wind can greatly impact the spray pattern and cause off site movement of particles (drift). It is important to be aware of wind conditions, because small particle droplets can move a considerable distance. Always carry a wind gauge to determine field conditions. Spraying operations should cease when wind velocities are such that they can carry droplets off target.

Herbicides for Noxious Weeds

Herbicides should not be applied when the wind is blowing towards a susceptible crop. It is not advisable to apply with wind speeds greater than 10 mph.

It is important to recognize that severe crop injury can occur with low wind velocity, especially under conditions that result in an inversion. Inversions are most common near sunrise and are associated with windless or low wind conditions (< 2 to 3 mph). A temperature inversion occurs when air near the soil surface is cooler or similar in temperature to higher air. Vertically stable air can be indicated by the presence of ground fog, hanging dust or smoke, and the presence of dew or frost.

Soil Type

Herbicide performance, persistence, and use can be affected by soil texture, organic matter, and pH. Herbicides are generally more active with coarse texture and low organic matter. Soil pH also can affect both the activity and persistence of some herbicides, but it is very dependent on the herbicide chemistry. Consequently, application rates and use guidelines may vary with soil type. Always refer to the pesticide label for specific use guidelines and restrictions regarding soil characteristics and geography. Some herbicides may be prohibited in certain soils or geographies because of the risk of crop injury or environmental contamination.

The applicator makes the final decision on whether conditions are appropriate for spraying. Additional site conditions and factors not addressed in this manual may need to be considered to ensure the most effective herbicide application, such as type and species of plant controlled, slope, and existing vegetation (target and nontarget). Be sure to read and follow all label directions and precautions to ensure proper results.

Considerations in Selecting a Control Practice

- Where is the infestation of noxious weeds? Is it cropland, grazing land, or non-cropland?
- Can you accurately identify the plant is a noxious weed? Is it an annual, biennial, or perennial?
- How effective are cultural, mechanical, biological, and/or chemical controls?
- What herbicides are registered for control of noxious weeds in crops, fallow, grazing land, and/or non-cropland? Can herbicide(s) be used that will not damage the crop or affect succeeding crops?
- What is the most cost-effective and legal control practice available?

Once the decision is made to use chemicals to control noxious weeds, it is important to select the proper herbicide for the target species. Choice of herbicide depends upon the noxious weed and other target weed(s), site of application (cropland or non-cropland), soil type, slope, as well as the desired duration of control and cost. Be certain the herbicide has been registered for the crop and non-cropland site.

Use the rate recommended for your soil or for foliar application for the target weed(s). Do not exceed the rate specified on the label. In cropland, a higher rate may injure the crop or carry over to injure the following crop. It is also important to properly time the application and use proper application techniques to achieve acceptable control.

Herbicide Selection

A variety of herbicides exist that can be used to control noxious weeds. The brand names, a brief description, and information on the use of some of the products available for cost share, are listed below. It is important to consult the label of a product prior to purchase and use to ensure it is the correct herbicide for the intended use. Read and follow the application rates and precautions listed on the label. Other products labeled and registered for control of noxious weeds can be used in accordance with label directions. This list is not inclusive. Common names and trade names

Herbicides for Noxious Weeds

are listed to help identify herbicides. The listing of a product does in no way serve as an endorsement, nor is any criticism of similar products not mentioned.

Active ingredient: 2, 4-D

Brand name(s): Amine 4, Hi-Dep, Weedar, various other brand names

Mode of action: Auxin growth regulator

Signal word (toxicity): Danger-Caution (varies with differing formulations)

Typical formulation: Liquid

Environmental characteristics: Ester formulations are volatile and may injure non-target plants through vapor drift. Low volatility (LV) esters are less prone to vapor drift, but can still volatilize at temperatures above 85 degrees. Amine formulations should be used during warmer weather as they are less likely to volatilize. This herbicide has very little soil activity and mainly is taken up through the foliage.

Uses: 2, 4-D is a selective herbicide used to control broadleaf weeds. Higher rates are needed to control or suppress perennials. This product is not effective on grasses, kochia, or knapweeds.

Active ingredient: Aminopyralid

Brand name(s): Milestone

Mode of action: Auxin growth regulator

Signal word (toxicity): Caution

Typical formulation: Liquid

Environmental characteristics: Do not apply directly to water and do not use on irrigation ditchbanks. There are no grazing restrictions. This herbicide is taken up through the foliage and translocated to the root.

Uses: Broadleaf weed herbicide that provides systemic post-emergence control of noxious weeds such as Canada thistle and biennial thistles. This product is not effective for controlling grass species, kochia, or bindweed.

Active ingredient: Dicamba

Brand name(s): Banvel, Clarity, Rifle, Sterling, Vanquish

Mode of action: Auxin growth regulator

Signal word (toxicity): Caution

Typical formulation: Liquid

Environmental characteristics: Dicamba is prone to causing off-target drift damage to susceptible plants. This product is water soluble, so do not apply near water. Also do not apply near desirable trees and shrubs.

Uses: A postemergence herbicide used to control kochia and many other annual broadleaf species. Higher application rates can provide suppression of Canada thistle, field bindweed, and biennial thistles.

Active ingredient: Fluazifop-P-Butyl

Brand name(s): Fusilade 2000, Fusilade Fiv, and various others

Mode of action: Lipid synthesis inhibitor

Signal word (toxicity): Caution

Typical formulation: Emulsifiable concentrate

Environmental characteristics: It binds tightly to soil particles; therefore it is not likely to contaminate ground water or surface water. This product can be highly toxic to fish and aquatic invertebrates, so don't apply near water.

Uses: Selective postemergence herbicide used for control of most annual and perennial grasses, including johnsongrass and quackgrass.

Active ingredient: Glyphosate

Brand name(s): Roundup, Rodeo, current brand names too numerous to list

Mode of action: Enolpyruval-shikimate-phoshate synthase (EPSP) inhibitor, non-persistent

Signal word (toxicity): Caution

Typical formulation: Liquid

Herbicides for Noxious Weeds

Environmental characteristics: It is active only through foliar uptake and has no soil activity. It is labeled for use up to water's edge. Rodeo is a product labeled for use in and around water.

Uses: Postemergence non-selective herbicide used to control grasses, most broadleaf weeds, and woody plants in noncropland, fallow, and Roundup Ready crops. Good product for control of established grasses, especially perennials. The product will injure most plants it comes in contact with, except Roundup Ready crops.

Active ingredient: Imazapyr

Brand name(s): Arsenal

Mode of action: Acetolactate synthase (ALS) inhibitor, persistent

Signal word (toxicity): Caution

Typical formulation: Liquid

Environmental characteristics: It breaks down rapidly in water, but is persistent in the soil. Plants can absorb this herbicide through foliage and roots.

Uses: Imazapyr provides effective control of woody species by foliar application or cut-stump treatments. It is a non-selective herbicide that control grasses, broadleaf plants, and brush. This product can be used to control multiflora rose and bindweed.

Active ingredient: Metsulfuron

Brand name(s): Ally, Cimarron, Escort XP and various others

Mode of action: Acetolactate synthase (ALS) inhibitor, persistent

Signal word (toxicity): Caution

Typical formulation: Dry flowable granules that mix with water

Environmental characteristics: Metsulfuron requires vigorous agitation to go into solution. Do not apply directly to water or under desirable trees or shrubs. The use of a nonionic surfactant is essential to the product effectiveness.

Uses: Selective herbicide used at low rates to control noxious weeds such as bull thistle, sericea lespedeza, musk thistle, and hoary cress. It is not effective for controlling grass species, kochia, or Canada thistle.

Active ingredient: Picloram

Brand name(s): Tordon, Outpost

Mode of action: Auxin growth regulator

Signal word (toxicity): Caution

Typical formulation: Liquid

Environmental characteristics: It is important to note this product is persistent in the soil and is soluble in water. Do not apply near water, on ditchbanks or bottoms, and under desirable trees and shrubs.

Uses: A long acting selective herbicide used to control field bindweed, Canada thistle, biennial thistles, leafy spurge and other woody species. This product is a restricted use product, so a license is required to purchase. It is not effective for grass control, but can suppress certain established pasture grasses, such as smooth bromegrass.

Active ingredient: Primisulfuron

Brand name(s): Beacon

Mode of action: Acetolactate synthase (ALS) inhibitor

Signal word (toxicity): Caution

Typical formulation: Water dispersible granules

Environmental characteristics: Moderately persistent in the soil.

Uses: Selective postemergence herbicide use to control grass weeds and many kinds of broadleaves.

Active ingredient: Triclopyr

Brand name(s): Amine form (water soluble): Garlon 3A; Ester form (oil soluble, though it can be mixed in water): Garlon 4, Remedy, Crossbow (also contains 2, 4-D)

Mode of action: Auxin growth regulator

Signal word (toxicity): Danger-Caution (varies with differing formulations)

Typical formulation: Liquid

Environmental characteristics: Ester formulations can be volatile, so it is best to not apply above 85 degree

temperatures. Triclopyr is primarily taken up through the foliage and/or vascular tissue, but can have some activity in the soil.

Uses: Postemergence herbicide used to control broadleaf weeds and woody plants. It has little to no effect on grasses.

Herbicide-resistant weed populations can result from the repeated used of a single herbicide, or the use of herbicides with the same mode of action without rotation. Be sure to rotate herbicides (site of action) and utilize an integrated weed management approach that includes cultural practices such as cultivation, cover crops, and mowing to help reduce the potential for developing herbicide resistant weed populations.

Some herbicides have been formulated in combination and are available as a "package mix," while some may be applied as a "tank mix." More weed species may be controlled by using herbicides in combination than separately. Remember to follow all use limitations on labels of all products used in combination.

Spray Adjuvants

Spray adjuvants are added to the spray solution to enhance pesticide handling or efficacy. Common classes of adjuvants include nonionic surfactants, crop oil concentrates, nitrogen-surfactant blends, esterified seed oils, and organo-silicone surfactants. Consult the product label for the recommended adjuvant type and rate for the target weed you are trying to control.

Herbicides for Noxious Weeds

Study Questions

Herbicides for Noxious Weeds

These study questions are to aid you in learning the material on pages 28 through 33.

1. *Spike is a:*

   a. persistent herbicide

   b. pre-emergent herbicide

   c. post-emergent herbicide

   d. both a and b

2. *The efficacy of a herbicide can be impacted by:*

   a. temperature

   b. precipitation

   c. soil type

   d. all of the above

3. *Fusilade 2000 is a selective herbicide for control of:*

   a. annual and perennial broadleaf weeds

   b. biennial broadleaf weeds

   c. annual and perennial grasses

   d. annual shrubs and trees

4. *Do not apply Remedy in the vicinity of sensitive plants when temperatures are expected to exceed* _____.

   a. 65 ° F

   b. 75 ° F

   c. 85 ° F

   d. 95 ° F

5. *Milestone, Banvel, and Outpost are all products representing what type of mode of action?*

   a. amino acid inhibitor

   b. auxin growth regulator

   c. lipid synthesis inhibitor

   d. acetolactate synthase (ALS) inhibitor

6. *Some herbicides are formulated in combination and are called:*

   a. tank mix

   b. package mix

   c. chemical mix

   d. physical mix

7. *What can result from using a herbicide with the same mode of action repeatedly?*

   a. herbicide resistant weeds

   b. persistence

   c. adsorption

   d. all of the above

Equipment and Calibration

Learning Objectives

1. List the requirements for spraying noxious weeds.
2. List the components comprising a spraying system.
3. List the procedure to size a pump for a spraying system.
4. Describe the difference between spraying systems equipped with positive displacement and non-positive displacement pumps.
5. List the locations on a spraying system, strainers that should be used and the recommended strainer size for each location.
6. List nozzle families and types used to apply pesticides.
7. List the six droplet-size categories used in the nozzle classification system standard, which has been adopted by the ASABE and used by the application industry.
8. List the five steps to select the correct nozzle.
9. List the steps to calibrate a sprayer using the ounce method.
10. Describe what an applicator should do to minimize particle and vapor drift.

Achieving the desired performance with any pesticide depends on proper distribution over a given area at the correct rate. This section covers equipment and calibration requirements of ground pesticide application equipment used to control noxious weeds. Noxious weed control may be required on cropland and non-cropland including ditch banks, highway shoulders, railroads, pipelines, power lines, storage yards, and waste areas.

Areas considered as rights-of-way in the United States amount to over 34.4 million acres. Right of ways are the areas involved in common transport including federal, state, county and township roads, public airports, railroads, utilities, pipelines, drainageways, waterways, and trails. Because these areas are in public view, pesticides should be applied carefully. Although multiple kinds of application equipment can provide excellent results, each piece of equipment must be accurately calibrated for the situation.

Sprayer Requirements

Commercial sprayers and components typically modified to treat for noxious weeds include a combination of high-pressure sprayers designed for shade tree, orchard, or vegetable treatment and low-pressure field crop sprayers. In most cases the sprayer includes characteristics and components from each type. This hybridization has been needed to meet the special requirements and adapt to diverse situations involved in noxious-weed spraying.

A few of these requirements, their effects, and ways noxious-weed spraying differs from other types of spraying:

1. Spraying speeds for wide roadsides and fields should be 4 to 10 mph and 10 to 20 mph for narrow rights-of-way. High speeds are desirable to increase efficiency and to improve traffic safety. In addition, they may decrease the effective swath width of a boomless broadcast nozzle and increase the required pump and nozzle output. These speeds require operators to be highly alert to miss obstacles, avoid skipping areas, and prevent spraying susceptible plants.
2. Rapid variation of swath width must be possible in roadside operations. Distances from the pavement to the edge of the right-of-way vary not only with different sections of the roadway, but also with each cut or fill area. Varying the swath width without increasing or decreasing the application rate is difficult with boomless broadcast nozzles. Swinging the boom back or down decreases coverage, but increases the application rate. Cutting off one broadcast nozzle usually decreases coverage by 12 to 20 feet, which may be more than what is desired.

Equipment and Calibration

3. Frequent changes in soil profile require a boom that can be quickly and easily changed in height and/or angle. The boom should be capable of being angled to 45 degrees above horizontal in a cut area and lowered to 30 degrees below horizontal on the next fill area.
4. Full coverage is needed to the edge of the swath. Usually the entire roadside from the shoulder to the right-of-way markers is sprayed in one pass, meaning there is no chance to compensate for light applications using proper swath overlap. Unless carefully set at a specific angle, height, and pressure, most boomless broadcast nozzles will apply a lighter rate at the outer portion of the swath than elsewhere. As is true of other nozzles, wear markedly affects the spray pattern.
5. Drift control is essential, so spray pressures must be kept low. Crop or rangeland is typically bordered on at least three sides by land that is not close to homes or gardens. Conversely, homes, gardens, and susceptible crops are almost always close to roadways. Any drift damage is likely to be reported and claims made to a public agency.
6. Control valves and rapid movement of the boom, both laterally and vertically, are needed to ensure proper coverage. To conserve materials and avoid spraying near homes and susceptible plants, the sprayer must be started and stopped often. To avoid obstacles while covering the entire roadside, there must be extremely rapid action of the controls, and of the boom swing and lift. At 10 mph a boom that takes five seconds to return to position has missed 73 feet of coverage. To allow the operator to perform efficiently, controls must be well located and easily operated.
7. Pressure regulation is absolutely essential. Low pressure is used to control drift and must be maintained even when pump and nozzle outputs are changed. When roadsides are sprayed at 10 mph with 20 gallons of solution per acre, each foot of the swath requires 0.4 gallons per minute (gpm) of nozzle output. An output of 16 gpm for 40 feet of swath is cut to 8 gpm when the swath is reduced to 20 feet. This reduction increases bypass flow by 8 gpm. The bypass-type regulators used on low-pressure field sprayers are often unable to accommodate such increases in by-pass flow rate without an excessive rise in boom pressure. These pressure risings create small spray particles that are prone to drift. Fittings and hoses must be large to avoid changes in friction loss due to changed flow rates. Varying friction losses make it virtually impossible to maintain constant pressures.
8. Rapid tank refilling is necessary to increase the efficiency of the unit. Tank trucks and high-capacity transfer pumps are frequently used to avoid delays due to a lack of water.
9. Reliable equipment and readily available repair parts are needed to avoid spraying delays during good weather.
10. Boomless broadcast nozzles or nozzle clusters with wide coverage areas may be used to allow the boom to avoid many obstacles and to keep the boom length reasonable. Such nozzles may have larger orifices and produce fewer small spray particles than other types.
11. Clearance under the boom should be 10 or 12 feet laterally from the edge of the truck. This distance should be adequate to clear most traffic signs, bridge rails, and mailboxes.

Sprayer Components

In assembling a spray rig, it is easy to include seemingly helpful features that may actually cause problems. For

Equipment and Calibration

example, undersize lines and fittings, inconveniently located gauges, nozzles, and controls, poor spray distribution, inadequate clearance, and unsafe equipment.

Tanks

Sprayer tanks should meet the following requirements:

- sufficient capacity,
- easy to fill and clean,
- corrosion resistance,
- shape suitable for easy mounting and maintaining effective agitation,
- graduated with accurate and clear markings, and
- top opening with cover to prevent spills and large enough to clean tank.

Tanks are typically made from polyethylene or stainless steel. Polyethylene tanks are relatively inexpensive and can be made in many sizes and shapes. They are noncorrosive and can be used with liquid fertilizers with the exception of ammonium phosphate solutions or complete-analysis liquid fertilizers. Polyethylene tanks must be properly mounted and supported on a saddle to support the tank over a large area. If saddle mountings are not used to support the tank, the weight of the liquid in the tank may result in the tank breaking as the sprayer bounces over obstructions or rough terrain. If a polyethylene tank is cracked or broken, it must be replaced, as effective repair is difficult.

Stainless steel is the highest quality material for pesticide and fertilizer applicator tanks. It is strong, durable, and resistant to corrosion by most crop chemicals. It is the most expensive material commonly used for tanks. As a result, only high annual use sprayers are equipped with stainless steel tanks. Poor mounting may result in cracking where the tank is welded.

How Much Is In The Tank?

Cylindrical spray tanks are mounted horizontally. Occasionally the capacity scale on the tank is difficult to read making it challenging to determine the quantity of liquid in the tank. The first question is "What is the total capacity of the tank?" The volume of a cylindrical tank is:

$$V = \frac{3.146 \text{ X } D \text{ X } D \text{ X } L}{4}$$

This assumes the end of the tank is square, not oval or spherical. For example, if the tank diameter is 36 inches and the length is 48 inches, the volume is:

$$V = \frac{3.1416 \text{ X } 36 \text{ X } 36 \text{ X } 48}{4} = 48{,}858 \text{ cubic inches}$$

Because one gallon contains 231 cubic inches, the tank capacity in gallons is:

$$\frac{48{,}858}{231} = 211.5 \text{ gallons}$$

Now, if the tank is only partially filled, how much does it contain? To determine this, measure the depth of the liquid, then consult the graph. Considering the same tank (36" X 48") as above, assume the liquid depth is 9 inches. The d/D x 100 becomes 9/36 x 100 or 25. Using Figure 1, reading up from the bottom axis, then over, the graph indicates that the tank is 20 percent full, or 20 percent x 211.5 gallons equals 42.3 gallons.

Pumps

A major component of the plumbing system is the pump. The characteristics of a particular pump will usually define the plumbing system. Most pumps are categorized as positive displacement or nonpositive displacement pumps.

The positive displacement pump moves a specific volume of liquid with each stroke or revolution. The pump output is proportional to speed and virtually independent of pressure. Examples of positive displacement pumps include piston, roller and diaphragm.

The output of nonpositive pumps (Figure 2) varies directly with pump speed and is sensitive to pressure. Typically, output will decrease dramatically with increasing pressure. An example of a nonpositive pump

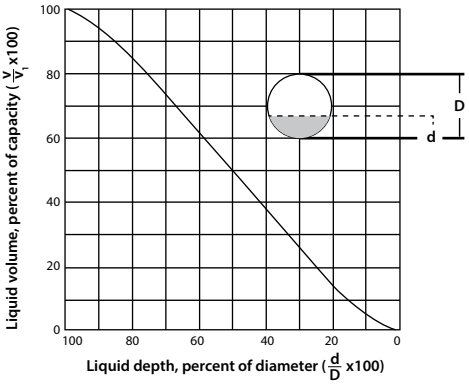


Figure 1. Depth-to-volume relationship for a cylindrical tank.

Equipment and Calibration

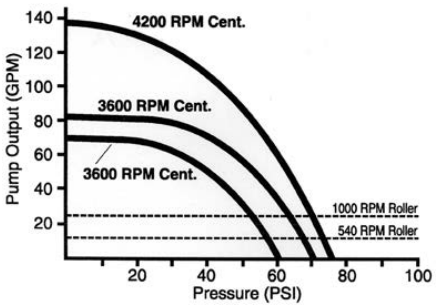


Figure 2. Centrifugal and roller pump performance.

is a centrifugal pump, which has an impeller with curved vanes that rotates at high speeds. The liquid is drawn into the center of the impellers. Then the liquid is dispersed by centrifugal force around the edge of the pump casing and through the outlet.

Characteristics of several pump types are outlined in Table 1. Of these types, roller, centrifugal, and piston pumps are the most widely used on agricultural spraying equipment.

An important factor in pump selection is discharge capacity. The pump should have sufficient capacity to supply all the nozzles and other accessories, provide agitation and offset pump wear (20% greater capacity). Use the following to determine pump capacity:

$$\text{Pump Capacity (gpm)} = \left(\begin{array}{l}\text{Boom Requirement (gpm) +}\\ \text{Agitation Requirements (gpm) +}\\ \text{Self Cleaning Strainers (gpm) +}\\ \text{Other Accessories (gpm) +}\\ \text{1 (gpm)}\end{array}\right) \times 1.2$$

Where:

Boom Requirements (gpm) = Number of nozzles x flow discharge per nozzle (gpm).

Agitation Requirements (gpm) = Use guidelines given in section "Agitation,"

Self Cleaning Strainer (gpm) = Extra flow needed to clean strainer, see section on "Strainers,"

1 (gpm) = Extra flow to assure proper operation of the bypass valve, and

1.2 = 20% extra capacity for pump wear.

If the output from a pump fails to meet the sprayer nozzle and agitation requirements, the pump should be overhauled or replaced.

Plumbing System for Nonpositive Displacement Pumps

The centrifugal pump is widely used to apply pesticides. One reason for its popularity is the simplicity of the flow control system. The pump is recommended for solutions that require additional mixing and agitation (e.g., wettable powders). Because this is a nonpositive displacement pump, the output can be completely shut off without needing a pressure relief valve. The discharge of the system is controlled by a throttling valve or electrical regulating valve. If used for agitation, the spray solution for jet agitation is routed before the flow control valves.

If a combination of manual and electrical control valves are used, proper sequencing of valves is important. Incorrect valve placement can lead to pressure surges and premature failure of the electric regulator or pressure gauges. Proper arrangement as shown in Figure 3 will allow the manual throttling valve to regulate major pressure changes while the electric regulating valve can be used to "fine tune" nozzle pressure from the operator's platform.

The following are operational guidelines for using a spraying system with a centrifugal pump:

1. Prime pump with all valves fully open.
2. Close the throttling valve while opening the boom solenoid valves.

Table 1. Pumps for agricultural sprayers.

Pump Type	Pressure Ranges (psi)	Operating Speeds (rpm)	Flow Rates (gpm)	Displacement Type
Centrifugal	5-80	2000-4500	0-120	nonpositive
Diaphram	50-850	200-1200	1-60	nonpositive
Piston	400-1000	600-1800	5-60	positive
Roller	50-300	300-1000	1-45	positive
Turbine	5-60	600-1200	10-80	nonpositive

3. With the pump running, adjust the throttling valve until the pressure gauge indicates the desired pressure.
4. Check for uniform discharge from the nozzles.

Plumbing System for Positive Displacement Pumps

A positive displacement pump requires a mechanism to release pressure and prevent damage when all outlets are closed. A spring actuated pressure relief valve insures a safety route to a bypass line (Figure 4). Use the pressure relief valve (or regulator) to make large pressure adjustments.

The pressure relief valve adjusts the flow between the nozzles and the bypass line back to the tank. An electric regulating valve can be used to "fine tune" the required nozzle pressure.

When positive displacement pumps are used, pressure relief valves designed to handle the system's maximum pressure are needed. As with nonpositive displacement pumps, the sequencing of the valves is very important to avoid performance problems. The following are operational guidelines for using a spraying system with a roller pump:

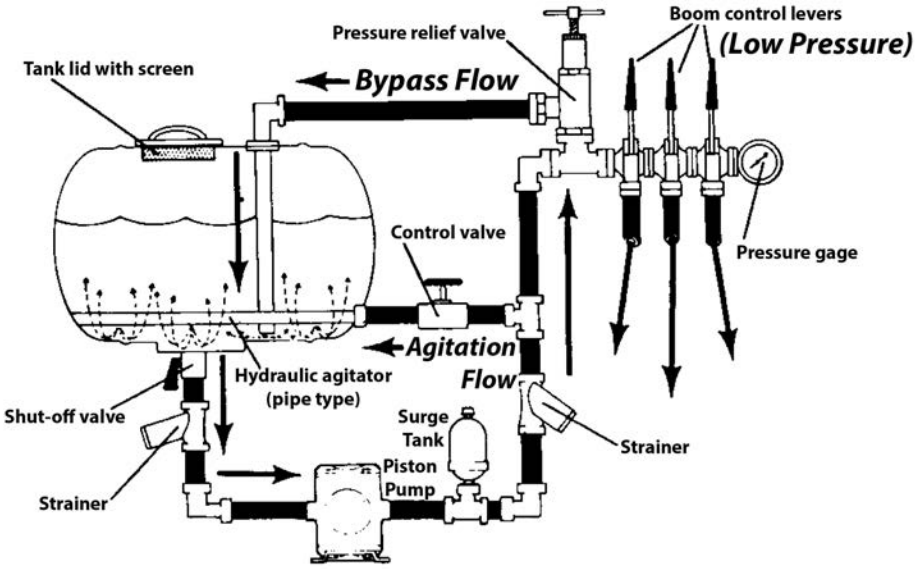


Figure 3. Plumbing diagram for a centrifugal pump (nonpositive displacement pump).

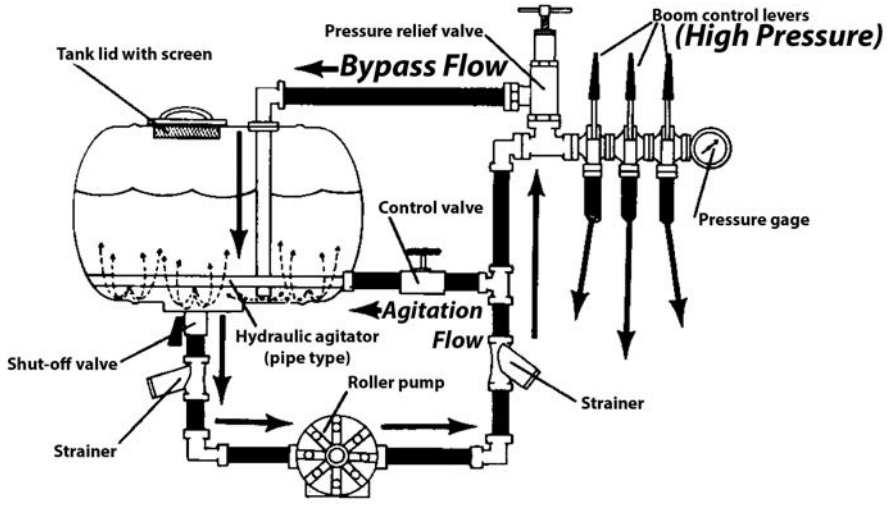


Figure 4. Plumbing diagram for a roller pump (positive displacement pump).

Equipment and Calibration

Figure 5. Pressure gauge

Figure 6. Nozzle tip strainers

Figure 7. Nozzle slotted strainer

1. Fully open the agitation valve, pressure relief valve, and boom electric ball valves (or spray gun).
2. Start the sprayer. Make sure the nozzles have uniform discharge rates. Adjust the pressure relief valve until the pressure shows about 10 to 15 psi above the desired spraying pressure.
3. Use the electrical regulating valve to "fine tune" the pressure.
4. Shut off the boom valves. If pressure increases more than 10 psi, the pressure relief valve should be replaced with a larger capacity valve or the bypass line may be too small for the excess flow.
5. Check for uniform discharge from the nozzle.

Pressure Regulators and Relief Valves

Pressure regulators serve two purposes: to regulate operating pressure and to serve as a system relief valve. Adjusting the flow to the bypass line regulates pressure. A decrease in flow to the bypass increases pressure to the nozzles. Increased flow to the bypass line decreases nozzle pressure.

The pressure regulators used on most roadside sprayers are of the bypass flow-control type. Some use high-low regulators with two control springs, one with a low spring constant and one with a high constant. Other sprayers use a high-pressure regulator from pump to tank with a medium pressure setting and a low-pressure regulator from the boom to the tank. Sprayers using low-pressure pumps use only the low-pressure type of bypass regulator.

When shutting off nozzles decreases boom flow, the bypass-type regulator limits pressure rise by permitting more flow to be bypassed to the spray tank. At least four factors make it difficult to hold the pressure at the nozzle constant: 1) the opening to the bypass line is held closed by a spring, thus increasing the area of the opening requires increased pressure to compress the spring; 2) the increased bypass flow through the regulator increases friction losses, and the pressure required to overcome them; 3) the increased flow in the bypass line increases the friction loss and requires pressure; and 4) the decreased flow in the boom reduces the friction losses between the regulator and the nozzle, which raises the pressure at the nozzle.

On the basis of lowest permitted pressure rise, the single-spring, glass-ball, low-pressure regulator will perform best, followed by the diaphragm-type, two-spring, low-high-pressure regulator.

The reducing type of pressure regulator theoretically provides a fixed outlet pressure over the entire range of flows for which the regulator is designed. It also has the advantage of sensing the outlet pressure and using the change in outlet pressure to change the flow rate. If the reducing-type regulator is used in conjunction with a bypass type so that the bypass type limits the pressure rise on the inlet side of the reducing regulator, pressure rise is further limited. The bypass regulator can be placed so that it permits bypass flow from the pump outlet to pump inlet or from the pump outlet back to the tank. In either case, the bypass regulator should be set to the pressure needed to provide the maximum required flow to the boom.

Pressure Gauge

The importance of a pressure gauge is often underestimated, but you cannot regulate pressure if you cannot measure it. The pressure gauge (Figure 5) is also a valuable tool for diagnosing spray problems.

Pressure gauges should have a total range of, at least, twice the expected operating pressure. To ensure accurate readings, a pulsation damper is needed to smooth pressure surges from piston pumps.

Strainers

Line and nozzle strainers are an important component of the sprayer's plumbing system. Properly sized and located strainers will prevent plugged

or partially plugged nozzles, which may cause uniformity problems. The mesh size of a strainer refers to the openings in a screen per linear inch.

For most positive displacement pumps, a suction line strainer between the tank and pump is required. This strainer should have a 30- to 50-mesh screen. A large suction line strainer should be used with a centrifugal pump (12 to 16 mesh) to keep out rocks, rust, sand and other foreign materials, and to protect the pump. The strainer mesh must be larger so the inlet of a centrifugal pump is not restricted. Restricted, a centrifugal pump will create a vacuum within itself, and starve the pump. A smaller strainer of 50 mesh should be located on the pressure side of centrifugal pump to protect nozzles and the agitation system.

A beneficial addition for sprayers is a self-cleaning line strainer. These strainers have a high velocity flow over the screen that provides continuous washing. The additional flow required for this washing action is 6 to 8 gpm per strainer. Additional plumbing and a throttling valve are required to control the flow of wash water.

Screening should be progressively finer from the tank to the nozzles (Table 2). The largest mesh screens should be in the filler opening and in the suction line. The screens need to be keyed to the nozzle orifice size. Screen area should be large enough to prevent pump starvation or excessive pressure losses. As a rule of thumb, use at least 2-square inches of screen area for each gpm of flow in the suction line. Strainers, between pump and nozzles, should have at least 1 square inch of screen area for each gpm of flow.

Nozzle screens are important, because they are the last chance to prevent plugged nozzles. Nozzle screens come in assorted sizes and materials (Figures 6 and 7). The mesh size of a nozzle screen is dictated by the nozzle orifice size as suggested by the manufacturer's manual. As a general rule, avoid nozzle orifice sizes that require greater than a 50-mesh size (i.e., 80 or 100 mesh). Because well water is usually used as a carrier source, the water may contain a small amount of sand and foreign material. A mesh of 80 or greater will easily plug and require frequent cleaning. Also, some pesticide materials may plug small nozzle openings and screens.

Clean strainers frequently. A shut-off valve between the tank and suction line will allow cleaning of the strainers without draining the tank. Always replace damaged or deteriorated strainers.

Agitation

The amount of flow required for sufficient agitation depends on the chemical formulation. For example, wettable powders require more agitation than emulsifiable concentrates to keep them in suspension. Applications that require vigorous agitation may need mechanical agitation such as propellers or paddles on a rotating shaft. For most spraying situations, hydraulic agitation is sufficient.

Hydraulic agitation requires a portion of the flow from the pump to be diverted back to the tank. The amount of flow for agitation will depend on

Table 2. Progressive screen mesh in a sprayer.

Where:	Mesh
Filler Opening	12-25
Suction Line (Roller Pump)	15-40
Suction Line (Centrifugal Pump)	12-16
Discharge Line	25-100*
Nozzle	50-100*

* Nozzles requiring greater than 50-mesh size (i.e., 80 or 100 mesh) are prone to frequent plugging.

Equipment and Calibration

chemical formulation and tank size and shape. As a rule of thumb, use 5 to 10 percent of the tank's capacity for agitation flow. For example, a 300-gallon tank should have between 15 and 30 gpm of flow into the tank. After selection of the agitation flow rate, select the correct orifice size required (Table 3).

The use of siphon caps on the jet agitators can reduce flow requirements by half. The siphon caps increase the flow by venturi action, which increases the mixing potential.

Some pumps feature a separate line and agitation valve for agitation. Often, sprayers are plumbed with the agitation coming from the bypass line. This arrangement does not give the operator control over the amount of flow for agitation. For example, when a nozzle needs a large flow, there may be insufficient flow from the bypass line for adequate agitation. But when the nozzles are shut off, all of the flow is diverted into the bypass line, causing foaming in the tank.

Hose and Lines

All hoses and fittings should be constructed with quality materials and sufficient strength to handle liquids under maximum pressure. These hoses and lines should be selected based on composition, construction, and size.

Hoses should be flexible, durable, and resistant to sunlight, oil, chemicals, and general abuse such as twisting and vibration. The outer coatings of the hose should be resistant to chemicals because they may come in contact with the spray solutions. Sunlight-resistant materials increase durability. Two materials that are chemically resistant are ethylene vinyl acetate (EVA) and ethylene propylene dione monomer (EPDM).

A special reinforced hose must be used for suction lines to prevent collapsing. It should be airtight, noncollapsible, as short as possible, and as large as the intake port. A collapsed suction hose can restrict flow and "starve" a pump, causing decreased flow and damage to the pump and seals. When spray pressure cannot be maintained, check the suction line for restrictions.

Lines between the pressure gauge and nozzles should be as direct as possible with minimum fittings, throttle valves, and restrictions. These lines should be plumbed to the center of each spray boom. Spray lines and hoses must be of the proper size. The proper size of these lines will depend on the inside diameter of the hose and the flow capacity (gpm) of the line. Sufficient flow velocity is required so that suspended particles will not settle in the lines. If lines are too small, excessive pressure drop will occur and the flow at the nozzle will be insufficient. A flow velocity below 5 feet per second is recommended. Table 4 gives suggested hose sizes for various flow rates.

Many sprayers are constructed with "wet" booms and are fitted with nozzle assemblies that protrude one-third to one-half the diameter of the boom. These nozzle assemblies take the spray solution out of the middle of the boom. The wet boom makes it possible to flush out materials like sand and rust in the bottom of the spray boom. Equip a wet boom with plugs or hose-end

Table 3. Tank agitation capacity.

Orifice Size (in)	Inlet Flow* (gpm)	Outlet Flow* (gpm)
1/8	2.9	9.5
5/32	4.1	13.2
3/16	5.3	15.4
1/4	6.5	19.5
JET-Spring-Loaded	0-15	2.5 times inlet orifice

*Rates given at 30 psi.

caps on the boom ends so they can be easily flushed. PVC schedule 90 can be used for a wet boom if supported adequately. Some pesticides will damage PVC so review the compatibility tables. Stainless steel is the best material and can be fixed with hose-end caps to make flushing and draining convenient.

Nozzle Types

In spraying systems, nozzles break the liquid into droplets and form the spray pattern. Nozzles determine the application volume at a given operating pressure, travel speed, and spacing. Selecting nozzles that produce the largest possible droplet size, while still providing adequate coverage at the intended application rate and pressure, can minimize drift. The size of the spray particle is important because it affects both efficacy and spray drift of the application of an herbicide, insecticide, or fungicide. If the size of the spray particle (for example, 250–500 microns) is doubled and the application volume stays the same, you have only one-eighth as many spray droplets (Figure 8).

For example, to gain optimum efficacy in weed control, 10 to 20 gallons per acre (GPA) as a spray volume is typically recommended. In this case, a medium droplet size is suggested for contact nontranslocating herbicides and a "coarse" droplet size for contact translocating herbicides. Concern for drift may cause you to consider using larger droplet sizes and higher spray volumes.

Nozzle types commonly used in low-pressure agricultural sprayers include: fan, hollow-cone, full-cone, among others (Table 11). Special features are available for some nozzles such as air induction (AI) and drift reducing (DG).

Fan Nozzles

The most common type of nozzle used in agriculture is the fan nozzle. A fan nozzle is widely used for spraying pesticides—both banding (over and between rows) and broadcast applications. These nozzles produce a tapered-edge, flat-fan spray pattern (Figure 9). On boom sprayers used for broadcast applications, nozzles are positioned so that their output overlaps. Fan nozzles fall into several categories, including:

- standard flat-fan,
- even (E) flat-fan,
- low-pressure flat-fan, and
- extended-range (XR) flat-fan.

Special nozzle types:

- off-center (OC) flat-fan and
- twin-orifice (TJ) flat-fan.

New designs to reduce drift include turbo, flood, raindrop, and air-induction nozzles. Some fan nozzles combine several of these design elements. Fan nozzles that produce very large droplets at all pressure ranges include Spraying Systems Co.'s Turbo TeeJet Induction, Turbo FloodJet, and TurfJet.

The standard flat-fan nozzle normally operates between 30 pounds per

Equipment and Calibration

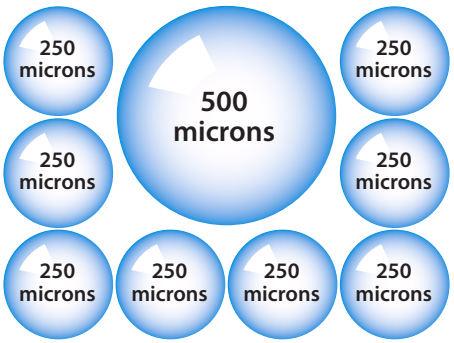


Figure 8. Cutting droplet diameter size in half results in eight times the number of droplets.

Table 4. Recommended hose sizes for various flow rates.

	Hose Size Inside Diameter (inch)	
Highest Flow Capacity (gpm)	**Suction Hose**	**Discharge Hose**
0- 1	½	¼
1- 3	½	⅜
3- 6	¾	½
6-12	¾	⅝
12-25	1	¾
25-50	1-¼	1
50-100	1-½	1-¼

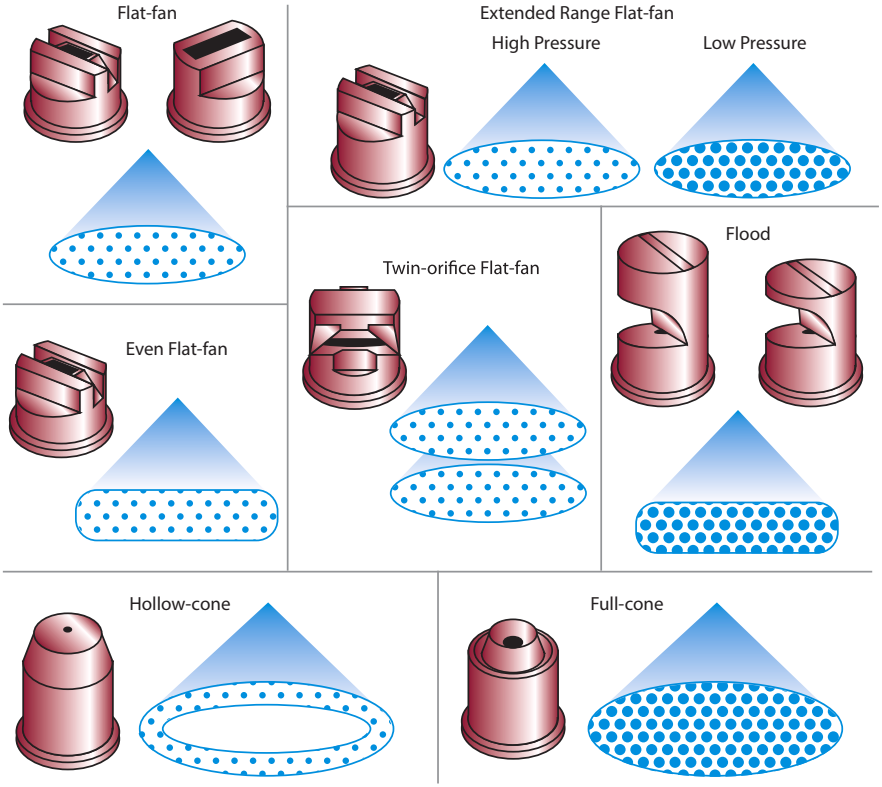


Figure 9. Relative droplet size for nozzles shown in patterns.

square inch (psi) and 60 psi, with an ideal range of 30–40 psi. The even flat-fan nozzles apply uniform coverage across the entire width of the nozzle's spray pattern. They are used for banding and should not be used for broadcast applications. The bandwidth can be controlled with the nozzle-release height and the spray angle.

The extended-range flat-fan nozzle provides fair drift control when operated at less than 30 psi. This nozzle is ideal for an applicator who likes the uniform distribution of a flat-fan nozzle and wants lower operating pressures for drift control. Because extended-range nozzles have an excellent spray distribution over a wide range of pressures (15–60 psi), they can be used on sprayers equipped with flow controllers.

The special-feature fan nozzles, such as the off-center fan, are used for boom-end nozzles so the swath is uniform end-to-end vs. tapered at the edges. The twin-orifice fan produces two spray patterns: one angled 30 degrees forward and the other directed 30 degrees backward (Figure 9). The droplets are small due to the atomizing by two smaller orifices. The two spray directions and smaller droplets improve coverage and penetration—a plus when applying postemergence contact herbicides, insecticides, and fungicides. Because of the small spray droplets, drift is a concern. To produce "fine" droplets, the twin-orifice usually operates between 30 psi and 60 psi.

Fan nozzles are available in several spray angles. The most common spray angles are 65 degrees, 80 degrees, and 110 degrees. Recommended nozzle heights for flat-fan nozzles during broadcast application are given in Table 5.

The correct nozzle height is measured from the nozzle to the target, which may be the top of the ground, growing canopy, or stubble. Use 110-degree nozzles when booms are less than 30 inches high with 30-inch nozzle spacing; use 80-degree nozzles when the booms are higher. Although wide-angle nozzles produce smaller droplets, the lower boom height reduces the drift potential more than the corresponding decrease

in droplet size. The nozzle spacing and orientation should provide 100 percent overlap at the target height. Most fan nozzles should not be oriented more than 30 degrees back from vertical.

Spraying Systems Co. identifies its flat-fan nozzles with a four- or five-digit number designation. The first numbers are the spray angle and the other numbers signify the discharge rate at rated pressure. For example, the "8005 nozzle" has an 80-degree spray angle and will apply 0.5 gallons per minute (GPM) at the rated pressure of 40 psi. The "11002 nozzle" has a 110-degree spray angle and applies 0.2 GPM at the rated pressure of 40 psi. Additional designations are:

BR: brass material

SS: stainless steel

HS: hardened stainless steel

VP: polymer with color coding

VK: ceramic with color coding

VH: hardened stainless steel with color coding

VS: stainless steel with color coding

Some fan nozzles are identified by "LF" or "LF-R," which reflects the standard and extended-range fan nozzles. The first numbers are the spray angle followed by a dash, and then the discharge rate at rated pressure.

For example, an LF 80-5R is an extended-range nozzle with an 80-degree spray angle that will apply 0.5 GPM at the rated pressure of 40 psi.

The drift-reducing (DG) fan has a pre-orifice that controls the flow. The spray nozzle is approximately one orifice-size larger than normal, but a round orifice before the outlet controls the flow and, therefore, it produces larger droplets and reduces the number of small, drift-prone droplets.

New Fan Designs

The turbulence-chamber nozzle is a design that incorporates a pre-orifice concept with an internal-turbulence chamber. These design improvements have resulted in larger, less driftable droplets and improved spray-pattern uniformity. Turbulence-chamber nozzles are available in flat-fan and flood-nozzle designs.

The Turbo TeeJet (TT) and the Turbo TeeJet Induction (TTI) have the widest pressure ranges of the fan nozzles: 15–90 psi for the TT, and 15–100 psi for the TTI. Both nozzles produce large droplets for less drift and are available only in 110-degree spray angles. The Turbo flat-fan nozzle design develops an improved spray pattern compared to the extended-range flat fan and other drift-reducing flat-fan nozzles and is used in the application of postemergence products. Position the nozzle so that the preset spray angle is directed away from the direction of travel. The Turbo flat-fan nozzle is recommended for use with electronic spray controllers, where speed and pressure changes occur regularly.

The air-induction type nozzle produces large drops through the use of a venturi air aspirator for reducing drift. These include:

- Delavan AgSpray's Raindrop Ultra

Table 5. Suggested minimum spray heights.

	Spray Height (inches)			
	20" Spacing Overlap		30" Spacing Overlap	
Spray Angle (degrees)	50%	100%	50%	100%
65	22	24	NR	NR
80	17–19	26–28	26–28	37–39
110	10–12	15–17	14–18	25–27

NR: Not recommended

- Greenleaf Technologies' TurboDrop and AirMix
- Lurmark's Ultra Lo-Drift
- Spraying Systems Co.'s air-induction AI and TTI
- ABJ Agri Products' Air Bubble Jet
- Wilger Industries' Combo-Jet

By incorporating air into the solution, an air-fluid mixture is produced. The air-fluid mixture forms a larger spray droplet because air is entrapped in the spray solution within the nozzle. To accomplish the mixing, an inlet port and venturi are typically used to draw the air into the nozzle under reduced pressure.

Special calibration requirements may be necessary for some venturi nozzles. For example, Greenleaf Technologies—designer of the TurboDrop venturi two-piece nozzle—requires the exit orifice to be two times the size of the venturi orifice. Otherwise, the exit orifice may create a negative pressure-effect in the venturi area, resulting in failure of the nozzle to create the proper spray quality (actually reversing flow from the air inlets). Therefore, you will need to select and calibrate these nozzles based on the venturi orifice, which is color-coded to meet manufacturing specifications. A chart for this purpose is available from the manufacturer.

Flood Nozzles

Flood nozzles are popular for applying suspension fertilizers where clogging is a potential problem. These nozzles produce large droplets at pressures of 10 psi to 25 psi. The nozzles should be spaced closer than 60 inches apart. The nozzle spacing, orientation, and release height should be set for 100 percent overlap.

Nozzle spacing of 30 inches to 40 inches produces the best spray patterns. Pressure influences the spray patterns of flood nozzles more than fan nozzles. However, the spray pattern is not as uniform as with the fan nozzles and special attention to nozzle orientation and correct overlap is critical. Besides fertilizer suspensions, these nozzles are used with soil-incorporated herbicides, preemergence without contact herbicides, and with spray kits mounted on tillage implements.

Flood nozzles are designated "TK" or "TF" by Spraying Systems Co., and "D" by Delavan AgSpray. The value following the letters is the flow rate divided by 10 at a rated pressure of 10 psi. For example, TK-SS2 and D-2 are flood nozzles that apply 0.2 GPM at 10 psi.

The new Turbo flood nozzles (with preorifice and turbulence chambers) have excellent spray patterns and combine the precision and uniformity of extended range flat-fan spray nozzles with the plugging resistance and wide-angle pattern of flooding nozzles. The design results in larger droplets and improved distribution uniformity. Turbulence in the chamber portion of the spray nozzle lowers exit pressure, reducing the formation of driftable droplets. Orifice design improves pattern uniformity over older-style flooding nozzles. Turbo flood nozzles are recommended for soil applications, particularly when applying tank-mix combinations of fertilizers and herbicides.

TurfJet Nozzles

The TurfJet is a new nozzle designed for the turf industry. It is modeled after the Turbo flood nozzle, which is used for agricultural field crops. The major difference is that the TurfJet nozzle incorporates a larger orifice to accommodate heavier application volumes, which are common in the turf industry.

Hollow-Cone Nozzles

Hollow-cone nozzles (Table 11) are generally used to apply insecticides or fungicides to field crops when foliage penetration and complete coverage of leaf surfaces are required. These nozzles operate at pressures ranging from 40 to 100 psi. Spray-drift potential is higher from hollow-cone nozzles than from other nozzles due to the small droplets produced.

Full-Cone Nozzles

The wide-angle, full-cone nozzles produce large droplets. Full-cone nozzles, which are recommended for soil-incorporated herbicides, operate at pressures between 15 and 40 psi. Angling the nozzles 30 degrees and overlapping the spray coverage by 100 percent achieve optimum uniformity.

Nozzle Materials

Nozzles are made from several materials. The most common are brass, nylon, stainless steel, hardened stainless steel, tungsten carbide, thermoplastic, and ceramic. Ceramic and tungsten-carbide nozzles are longwearing and corrosion-resistant. Stainless-steel nozzles last longer than brass or nylon and generally produce a uniform pattern over an extended time period. Nylon nozzles with stainless steel or hardened stainless-steel inserts offer an alternative to solid stainless-steel nozzles at a reduced cost. Thermoplastic nozzles have good abrasion resistance, but swelling can occur with some chemicals, and they are easily damaged when cleaned. Nozzles made from hard materials cost more initially, but in the end they pay for themselves because of their long-lasting properties.

Nozzles and Droplet Size

Spray-drop size is one of the most important factors affecting drift. Because of the unusually small size of the target, good coverage is essential for those insecticides and fungicides that must come into contact with the pest insect or disease-causing organism Because untreated surfaces allow infection or crop damage to continue from feeding insects, thorough coverage is essential when using protectant fungicides and nonsystemic stomach poison insecticides. Fine- to medium-size droplets are desirable when applying insecticides and fungicides, as they usually provide better coverage. Although fine droplets are difficult to deposit on the target, and may remain airborne, drifting for long distances because of they are lightweight.

Spray-droplet diameters are measured in micrometers. A micrometer is approximately 1/25,000 of an inch and is usually referred to as a "micron." For reference, the thickness of a human hair is approximately 100 microns. Drops smaller than 150 microns in diameter (smaller than the diameter of a sewing thread) usually pose the most serious drift hazard. Drift is less problematic when droplets are 200 microns or larger in size. A study indicated that spray particles less than 50 microns in diameter remain suspended in the air indefinitely or until they evaporate. This should be avoided because there is no way to control deposition of very small droplets.

A classification system developed by the British Crop Protection Council (BCPC) and the American Society of Agricultural and Biological Engineers (ASABE) assigns a droplet-size category to a nozzle based on droplet-size spectrum (Table 6). This system allows for a comparison of droplet size between various nozzles, operating conditions (pressure), and manufacturers.

Table 6. Droplet-size classification chart.

Droplet Category[1]	Symbol	Color Code	Approximate VMD Range[2] (microns)
Very Fine	VF	Red	< 145
Fine	F	Orange	145–225
Medium	M	Yellow	226–325
Coarse	C	Blue	326–400
Very Coarse	VC	Green	401–500
Extremely Coarse	XC	White	> 500

[1] ASABE (American Society of Agricultural & Biological Engineers) Standard 572.
[2] VMD = Volume median diameter—a value where 50% of the total volume or mass of liquid sprayed is made up of droplets larger than this value, and 50% is made up of droplets smaller than this value. Reported VMD ranges vary widely, based on the type of laser analyzer used.

At a given pressure, a nozzle will produce a range of droplet sizes. However, manufacturers strive to design nozzles with uniform outputs while reducing the number of fine-sized droplets a nozzle produces. Nozzles are rated based on the typical droplet-size range they produce. Most, if not all, nozzle manufacturers'

Equipment and Calibration

catalogs have droplet-class charts. Additionally, pesticide labels may include droplet-size category recommendations.

Table 7 provides information on the effect of droplet size on coverage. Table 8 provides information on droplet evaporation and the distance various drop sizes will travel before evaporating. Table 9 shows wind-movement characteristics of various size droplets. Decreasing the droplet size from 200 microns to 20 microns will increase coverage by 10-fold, but, as Table 8 shows, a 20-micron water drop will travel less than one inch before it completely evaporates in under a second.

Table 7. Spray droplet size and droplet effects on coverage.

		Application Rate = 1 GPA	
Droplet Diameter (microns)	**Type of Droplet**	**Coverage Droplet (per square inch)**	**Relative to 1,000 Micron Drop**
5 (VF)[1]	Dry fog	9,220,000	200
10 (VF)	Dry fog	1,150,000	100
20 (VF)	Wet fog	144,000	50
50 (VF)	Wet fog	9,222	20
100 (VF)	Fine mist	1,150	10
150 (F)	Fine mist	342	7
200 (F)	Fine drizzle	144	5
300 (M)	Fine rain	61	3
500 (VC)	Light rain	9	2
1,000 (XC)	Heavy rain	1	1

[1]See Table 2 related to droplet-size classification.

Droplets smaller than 100 microns in size obtain a horizontal trajectory in a short time and evaporate rapidly. The pesticides in these droplets become aerosols, meaning they will move up into the atmosphere and will stay there until the next rain. Droplets larger than 150 microns in size resist evaporation to a greater degree than smaller droplets due to their larger volume. From these and other research results, we can conclude that the drift potential of droplets rapidly decreases as a diameter increases to about 150 microns.

Table 8. Spray droplets: evaporation and distance traveled.

Droplet Diameter (microns)	**Terminal Velocity (feet per second)**	**Droplet Diameter After Water Evaporates (microns)**	**Distance Traveled From Nozzle (inches)**
20	0.04	7	<1
50	0.25	17	3
100 (VF)[2]	0.91	33	9
150 (F)	1.70	50	16
200 (F)	2.40	67	26

[1]Conditions assumed: temperature = 90°F, relative humidity = 36%, spray pressure = 25 psi, pesticide solution = 3.75%.
[2]See Table 2 related to droplet-size classification.

Several factors determine if a spray particle will deposit on the surface of a plant. Very fine droplets (especially those smaller than 50 microns) are collected efficiently by insects or by needles on coniferous plants, but tend to remain in the airstream and carried around stems and leaves of weeds. "Medium" droplets applied when there is some air velocity will deposit more efficiently on stems and on narrow, vertical leaves such as grasses, while "coarse" droplets will deposit most efficiently on large, flat surfaces, such as broadleaved plants.

Table 9. Movement of spray droplets.

Droplet Diameter (microns)	**Droplet Size**	**Time Required to Fall 10 Feet**	**Lateral Movement in a 3-mph Wind**
5	Fog (VF)[1]	66 minutes	3 miles
20	Very fine (VF)	4.2 minutes	1,100 feet
100	Very fine (VF)	10 seconds	44 feet
240	Medium (M)	6 seconds	28 feet
400	Coarse (C)	2 seconds	8.5 feet
1,000	Extremely coarse (XC)	1 second	4.7 feet

[1]See Table 2 related to droplet size classification.

Be sure to review the pesticide label regarding droplet-size requirements because of the reduced coverage associated with large drops. Usually, systemic herbicides work very well with large drops. When applying contact-type fungicides for disease control, a smaller drop may be needed due to the need for better coverage. The same is true for stomach-poison insecticides and insecticides that must come into contact with the pest.

Droplet Size Range

In reality, a range of droplet sizes is needed to effectively deposit pesticides on the variety of plant types, sizes, and shapes encountered. The following describes how different droplet sizes vary in their effectiveness.

To control pests effectively, the actual range of droplet sizes will depend on the specific pesticide being used, the kind and size of the target plant, and weather conditions. Some new nozzles are specifically designed to reduce drift by reducing the amount of small, driftable fines in the spray pattern.

Insecticides and fungicides generally require smaller droplets than herbicide applications to obtain adequate target coverage. However, in most cases, applying medium droplets (vs. fine or very fine) should provide the coverage needed while reducing the risk of drift.

Experimental results with foliar herbicides suggest that droplet sizes in the range of 150 microns (fine) to 400 microns (coarse) do not significantly affect weed control unless application volumes are extremely high or very low. Exceptions to this guideline may exist for specific herbicides.

Droplet-Size Classification

Droplet-size information is useful for determining the correct nozzle for an application and pesticide. However, this information is not always readily available to the applicator. Instead, a classification system is used to define nozzle output (Table 10). Nozzle manufacturers use this standardized system to indicate the droplet size of their nozzles for different size and pressure combinations.

Product labels may specify an appropriate droplet classification recommended for the manufacturer's products. For example, herbicide labels recommend using a nozzle that produces medium size droplets.

From a sample nozzle-manufacturer's chart (Table 10), the applicator can select any nozzle and pressure combination with the "M" or yellow classification. This system allows the applicator to use many different combinations of nozzles and pressure settings, achieve the desired droplet size, reduce drift, and provide adequate coverage required for pest control.

Table 10. Droplet size-classification for nozzle size and pressure (example from Spraying Systems Co.).

	PSI						
	15	20	25	30	40	50	60
XR8001	M	F	F	F	F	F	F
XR80015	M	M	M	F	F	F	F
XR8002	M	M	M	M	F	F	F
XR8003	M	M	M	M	M	M	F
XR8004	C	C	M	M	M	M	M
XR8005	C	C	C	C	M	M	M
XR8006	C	C	C	C	C	C	C
XR8008	VC	VC	VC	C	C	C	C

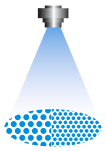
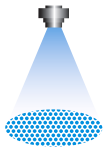
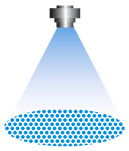
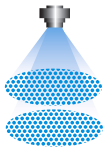
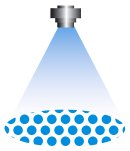
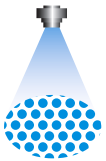
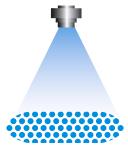
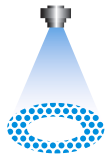
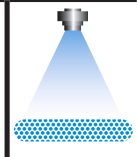
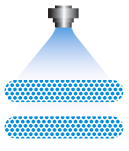
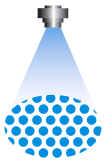
Spray Volume and Pressure for Foliar Herbicides

Some applicators reduce the spray volume of foliar herbicides. When you reduce spray volume, the herbicide concentration will increase to maintain the same dose of active ingredient. But as spray volume is reduced, the droplet size may decrease, causing greater drift potential. Research has also shown that control of some broadleaf weeds with contact herbicides is reduced when the spray volume is reduced. However, reduced spray volumes have little effect on weed control with most systemic herbicides—as long as the chemical is applied properly and at the recommended rate.

To compensate for the reduced spray volume, some applicators will increase spray pressure from 30-40 psi to 50-60 psi. They believe small droplets will be driven into the crop canopy and increase coverage. However, a large number of small droplets will quickly lose their velocity and evaporate before reaching the canopy (as shown in Table 8). In addition, small droplets have low momentum and insufficient energy to be driven into the canopy.

Therefore, increasing pressure should not be used as a substitute for spray volume. It is recommended to

Table 11. Nozzle guide for spraying.

	Broadcast Spraying								Band and Direct Spraying				
													
	Extended Range Flat Fan	**Standard Flat Fan**	**Drift Guard Flat Fan**	**Twin Flat Fan**	**Turbo Flood Wide Angle**	**Full Cone**	**Flood Nozzle Wide Angle**	**Raindrop Hollow Cone**	**Even Flat Fan**	**Twin Even Flat Fan**	**Hollow Cone**	**Full Cone**	**Disc and Core Cone**
Herbicides													
Soil-incorporated	Good		Very Good		Very Good	Very Good	Good	Good					
Pre-emerge	Very Good (on low pressure)	Good	Very Good		Very Good	Very Good		Good	Very Good	Good		Good	
Post-emerge Contact	Good	Good		Very Good					Good	Very Good	Very Good		
Post-emerge Systemic	Very Good (on low pressure)	Good	Very Good		Very Good			Good	Very Good	Good			
Fungicides													
Contact	Very Good	Good							Good		Good		Very Good
Systemic	Very Good (on low pressure)		Very Good		Very Good				Very Good				Good
Insecticides													
Contact	Good	Good		Very Good						Very Good	Very Good		Very Good
Systemic	Very Good (on low pressure)		Very Good		Very Good				Very Good				Good

maintain pressures less than 40 psi and, if you need coverage, to increase spray volume.

Boom Sprayer Set-up

Do not mix nozzles of different materials, types, spray angles, or spray volumes on the same spray boom. A mixture of nozzles produces uneven spray distribution. Fan nozzles produce a flat, oval spray pattern with tapered edges. Because the outer edges of the spray patterns of flat-fan nozzles have tapered or reduced volumes, nozzles must be carefully aligned at the proper height to prevent interference, so adjacent patterns along the boom will overlap for uniform coverage. Uniform pattern is achieved when the overlap is 50 percent to 100 percent of the nozzle spacing (Figures 10 and 11). Nozzle spacing is the amount of space between nozzles. To check spray overlap, spray clean water onto a flat surface (concrete) and observe its drying patterns. Effective application requires avoiding skips and major overlaps in the spray pattern. The fan nozzle is generally the best choice for the broadcast application of pesticides because of its ability to produce a uniform pattern when correctly overlapped.

Because worn nozzles increase application rates and change distribution patterns, the result is poor pest control, crop damage, residue problems, and increased costs. Checking the boom sprayer assures that each nozzle is delivering an identical volume of spray in a smooth pattern, with no heavy streams or blank areas. Should a nozzle become clogged, it is best to blow out the dirt with compressed air or use a soft-bristled brush such as a toothbrush. Wear chemical-resistant gloves when handling and cleaning nozzles to reduce pesticide exposure. NEVER use a wire or nail as a cleaner because the orifice can be easily damaged. NEVER put nozzles in the mouth. Remember, improperly functioning or worn nozzles are costly because they increase application rates and change distribution patterns causing poor pest control, crop damage, residue problems, and increased costs.

Most booms are arranged with 20-inch nozzle spacing. However, 30-inch nozzle spacing may have several advantages. If a boom is configured with nozzles spaced at 20 inches, operators should consider a 30-inch nozzle configuration during a rebuild or retrofit. Replacing an 80-degree nozzle spaced at 20 inches with a 110-degree nozzle spaced at 30 inches offers several advantages:

- Boom height remains the same.
- Orifice size is increased by one-third.
- Drift potential is reduced.
- Fewer nozzles to purchase and maintain.
- Potential to increase screen size (less clogging).
- Nozzle spacing matches 30-inch rows during field spraying.

Nozzle Selection

It is important to select a nozzle that develops the desired spray pattern and spray volume. The nozzle's intended use — possibly broadcast application of herbicides or insecticide spraying on row crops — determines the type of nozzle needed. Examine current and future application requirements and be prepared to have several sets of nozzles for a variety of application needs. In general, do not select a nozzle that requires a nozzle screen less than 50 mesh. Nozzles requiring 80–100 mesh screens clog too easily.

Follow the steps below to determine the correct nozzle type and capacity needed.

Step 1: Consult the label. The most important source of information when selecting a nozzle is the pesticide label. Not only will the label specify the application rates, controllable pests, and conditions needed to apply the pesticide, it often will provide information concerning the GPA, droplet classification, nozzle type, and spacing as well. Follow the guidelines outlined on the pesticide

Equipment and Calibration

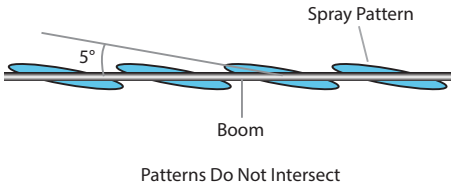


Figure 10. Flat-fan nozzles angled 5 degrees from the boom.

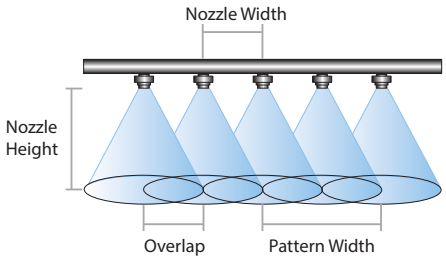


Figure 11. Nozzle overlap of 100 percent.

Equipment and Calibration

label. If nozzle recommendations are not stated on the label, use Table 7 to select a nozzle type best fitted to the application while considering the droplet size.

Step 2: Select operating conditions. Select or measure ground speed in miles per hour (mph). Select the desired nozzle spacing and spray volume. For most broadcast applications, 30-inch spacing is preferred. If the label does not recommend nozzle spacing or spray volume, follow university and chemical-company recommendations.

Correct selection of a spray volume is important. It will influence several spray characteristics such as drift potential, coverage, droplet size, acres per tank, and pesticide efficacy.

Step 3: Calculate required nozzle discharge. To select a specific orifice size, the spray volume, nozzle spacing, and travel speed are needed for the following calculation:

Equation 1:

$$\text{Nozzle discharge (GPM)} = \frac{\text{travel speed} \times \text{nozzle spacing} \times \text{spray volume}}{5940}$$

where: travel speed = miles per hour
nozzle spacing = inches
spray volume = gallons per acre (GPA)

Step 4: Consult a nozzle catalog. Once the nozzle discharge has been determined, consult a nozzle catalog for a specific nozzle number or size. Using the nozzle type selected from the application guide (Table 11), review the specification of these nozzles in the discharge capacity column. Several consecutive nozzles may meet your needs, but select a nozzle that operates at a low pressure and gives the desired droplet classification that allows a range for fine-tuning. Remember, most nozzles only perform well over a limited pressure range. Generally, the greater the operating pressure, the smaller the droplets. Smaller droplets increase drift potential. Conversely, larger orifices produce larger droplets.

A linear relationship does not exist between nozzle pressure and flow discharge. If the discharge rate is not found in the catalogs, calculate the operating pressure using known catalog conditions:

Equation 2:

$$psi_1 = psi_2 \times \frac{(GPM1)_2}{GPM_2}$$

where: 1 = the desired condition
2 = the known catalog specifications

Avoid high pressures. Higher pressures increase the drift potential and put strain on the sprayer components. Conversely, avoid pressures less than the recommended minimum pressure, because spray patterns begin to distort and cause poor spray uniformity.

Step 5: Calibrate the sprayer. Once the nozzles are selected, purchased, installed, and flushed, calibrate the spray system. Nozzle catalogs provide tables to show spray volumes for various nozzles, spacing, pressures, and ground speeds. Use these tables initially to set up the sprayer, and then use the "ounce" calibration method (below) to evaluate and adjust the sprayer for accurate application.

Table 12. Sprayer calibration with the "ounce" method.

Nozzle Spacing or Row Width (inches)	Distance (feet)	Nozzle Spacing or Row Width (inches)	Distance (feet)
48	85	30	136
44	93	28	146
40	102	24	170
36	113	20	204
32	128	16	255

1. Use Table 12 to determine the distance to drive into the field. Use nozzle spacing for booms. For directed and band rigs, use the row spacing.
2. Set throttle for spraying and operate all equipment. Note seconds required to drive measured distance.

3. Catch spray for the time (noted in Step 2, above) in a container marked in ounces (a calibrated bottle or measuring cup). If using a boom sprayer, catch spray from one nozzle during noted time. On directed rigs, catch spray from all nozzles per row for noted time.
4. Nozzle or nozzle-group output in ounces equals gallons per acre actually applied.
5. Repeat for each nozzle to assure uniform distribution.

Nozzle Selection Example

Suppose a postemergence herbicide is to be broadcast at 15 GPA at a speed of 5 mph.

Step 1: Using Table 11 as a guide, the best choice is a Turbo TeeJet. The recommended nozzle spacing is 30 inches.

Step 2: The operating conditions are provided above.

Step 3: Determine the nozzle output in GPM; calculate the required nozzle discharge using the following:

$$\text{Nozzle Discharge (GPM)} = \frac{5 \text{ mph} \times 30 \text{ in.} \times 15 \text{ GPA}}{5940} = 0.38 \text{ GPM}$$

Step 4: Consult a nozzle catalog. The selected nozzle must have a flow discharge of 0.38 GPM when operated within the recommended range for the nozzle. A nozzle performance table shows the discharge rate at various pressures for several nozzle sizes. Table 13 shows that four nozzles listed in the catalog are possible choices: TT11003, TT11004, TT11005, or TT11006 nozzles may be purchased for this application, but the TT11004 gives the most flexibility with a wide pressure range for fine-tuning.

Table 13. Nozzle data and comparison of pressures and discharge.

	Catalog		Calculated From Eq. 2	
Nozzle	**psi**	**GPM**	**psi**	**GPM**
TT11003	60	0.37	64	0.38
TT11004	30	0.35	36	0.38
TT11005	20	0.35	24	0.38
TT11006	15	0.37	16	0.38

Nozzle Manufacturers

Several principal spray-nozzle manufacturers supply local equipment dealers. Each manufacturer distributes nozzle catalogs that can be obtained from your local dealer or ordered from the following websites (accessed July 2013):

ABJ Agri Products
www.abjagri.com/

Albuz
www.albuz.saint-gobain.com/index.htm

BEX Inc.
www.bex.com/

Billericay Farm Services Ltd.
www.bfs.uk.com/bubblejet.htm

The CP Products Co.
www.cpproductsinc.com/

Delavan AgSpray Products
www.delavanagspray.com/

Greenleaf Technologies
www.turbodrop.com/

Hypro Global Spray Solutions
www.hypropumps.com/

Hardi North America
www.hardi-us.com/Home.aspx

Lechler Inc.
www.lechlerusa.com/

Spraying Systems Co. – TeeJet Technologies
www.teejet.com/

Wilger Industries Ltd.
www.wilger.net/

Equipment and Calibration

Managing Spray Drift

The operator is responsible for minimizing drift during application. Drift is the movement of pesticides to nontarget areas and occurs in two modes: spray or particle drift--occurs at the time of application and consists of spray droplets carried, and vapor drift--movement of fumes to nontarget areas due to pesticide evaporation or volatilization.

The quantity of drift is influenced by spray solution characteristics, application equipment, and environmental conditions. Chemical additives may be used to reduce drift. When using drift reduction additives, always start with the lowest recommended rate on the label and increase slowly to achieve the desired results. Vapor drift can be reduced by formulation selection (formulas with high vapor pressures will reduce volitlization of the active ingredient).

Characteristics Affecting Drift

Spray characteristics that influence drift include the pesticide formulation, size and density of droplets, and evaporation rate (temperature and relative humidity). Vapors from pesticides can cause damage to susceptible plants for days after applied. Vapor properties of pesticide products are known, and appropriate formulations can usually be obtained that will not produce unacceptable damage to off-target areas.

Any ingredient in a pesticide formulation that increases the size of spray drops will decrease the amount of drift. Increasing the spray viscosity and surface tension reduces drift potential by producing larger drops. Emulsifying agents and similar additives usually increase the spray viscosity, which increases the droplet size and decreases the drift potential. Surfactants on the other hand decrease the surface tension, which decreases the average droplet size and thus increases the potential for drift.

A variety of additives help control drift. They are usually called thickeners or drift-control agents and are added to the spray mixture at a designated concentration. A drift control agent should only be used for controlling drift. Most of these products are polyvinyl polymers which are relatively inexpensive to use. Follow label directions carefully when adding thickeners to the spray tank. Using too much thickener will cause non-uniform spray patterns and may actually increase the amount of fine particles produced.

The density of spray particles affects the distance particles will drift. Because oil drops are lighter than water drops, they tend to stay airborne longer and drift farther. Evaporation decreases the size of drops, increasing drift. Water evaporates more rapidly than oils (35 times faster than diesel fuel); therefore, small water drops may evaporate completely before they reach the ground leaving the pesticide suspended in the atmosphere.

Weather Conditions Affecting Drift

Wind speed is the major weather condition affecting drift. High winds significantly reduce the number of days that pesticides can be applied safely. In general, air is the least turbulent just before sunrise and just after sunset. Air is usually most gusty and turbulent during midafternoon. Wind velocities are lower closer to the ground. Thus, sprays should be released as close to the target as possible yet consistent with uniform applications. Do not apply pesticides during periods of calm or wind speeds in excess of label recommendations.

Temperature and humidity also affect drift. High temperature and low humidity increase the rate of evaporation from spray drops. Small drops that completely evaporate leave crystals of pesticide in the air that may be carried through the atmosphere for several days.

The amount of air turbulence is determined by the difference between the temperature at ground level and the temperature of the air above it. Normal daytime heating of the soil causes air near the soil surface to be warmer than the air aloft. The warm air rises, setting up air currents. The temperature differential is

usually least during early morning or late evening. As the temperature difference increases after sunrise, air currents may carry particles long distances. Do not apply pesticides when turbulent conditions exist.

If the air near the soil surface is cooler than the air above it, the warm air overhead remains on top, and no vertical mixing can occur. This condition is known as "inversion." Low wind conditions with high inversion (ground air 2° to 5° F cooler than the air above) may cause the small drops to remain suspended in the layer of cold, undisturbed air and eventually to move out of the target area. Do not apply pesticides when inversion conditions exist.

When applying chemicals near open water, care must be taken to avoid water contamination. Chemicals or compounds that affect the supply of oxygen entering the water can cause fish kill in ponds, lakes, and streams. Always check the pesticide label for the toxicity level of the pesticide to fish. Remember, the applicator is not responsible for damaging the surrounding environment.

References (adapted from)

Droplet Chart /Selection Guide. Virginia Cooperative Extension publication 442-031, May 2014; *http://pubs.ext.vt.edu/442/442-031/442-031.html* (accessed Sept. 2014)

Nozzle-Selection and Sizing. University of Nebraska-Lincoln Extension, Institute of Agricultural and Natural Resources, publication EC141, 2011; *http://www.ianrpubs.unl.edu/epublic/live/ec141/build/ec141.pdf* (accessed March 2013)

Nozzles: Selection and Sizing. Virginia Cooperative Extension publication 442-032, Virginia Polytechnic Institute and State University, 2009; *http://pubs.ext.vt.edu/442/442-032/442-032_pdf.pdf* (accessed March 2013)

Plumbing Systems of Agricultural Sprayers. Virginia Cooperative Extension publication 442-452, December 2009; *www.ext.vt.edu/pubs/442-452* (accessed March 2013)

Resources

Nozzle Types for Boom Sprayer Applications of Crop Protection Products. Kansas State University, Agricultural Experiment Station and Cooperative Extension Service, publication MF2541. April 2002.

Fine Tuning a Sprayer with the "Ounce" Calibration Method. Virginia Cooperative Extension publication 442-453, December 2001; *www.ext.vt.edu/pubs/442-453*

Sprayer Nozzles Selection and Calibration. University of Kentucky Cooperative Extension Service, PAT-3, March 1996; *www.uky.edu/Ag/PAT/pat3/pat3. pdf*

Sprayer Nozzle Selection. University of Georgia Cooperative Extension, bulletin 1158, August 2005; *www.tifton.uga.edu/eng/publications/spray%20nozzle%20 selection/sprayer%20nozzle%20selection.htm*.

Choosing Drift-Reducing Nozzles. North Dakota State University Extension Service, FS-919, July 2008; *www.ag.ndsu.edu/pubs/ageng/machine/fs919.pdf.*

Strategies to Reduce Spray Drift. K-State Research and Extension, publication MF2444, March 2000; *www.oznet.ksu.edu/library/ageng2/mf2444.pdf.*

Weight and Measure Conversions

Weight

16 ounces = 1 pound = 453.6 grams

1 gallon water = 8.34 pounds = 3.78 liters

Liquid Measure

1 fluid ounce = 2 tablespoons = 29.57 milliliters

16 fluid ounces = 1 pint = 2 cups

8 pints = 4 quarts = 1 gallon

Length

3 feet = 1 yard = 91.44 centimeters

16.5 feet = 1 rod

5,280 feet = 1 mile = 1.61 kilometers

320 rods = 1 mile

Equipment and Calibration

Equipment and Calibration

Area

9 square feet = 1 square yard

43,560 square feet = 1 acre = 160 square rods

1 acre = 0.405 hectare

640 acres = 1 square mile

Speed

88 feet per minute = 1 mph

1 mph = 1.61 kilometer per hour

Volume

27 cubic feet = 1 cubic yard

1 cubic foot = 1,728 cubic inches = 7.48 gallons

1 gallon = 231 cubic inches

1 cubic foot = 0.028 cubic meters

Common Abbreviations and Terms

FPM = feet per minute

GPA = gallons per acre

GPH = gallons per hour

GPM = gallons per minute

mph = miles per hour

psi = pounds per square inch

RPM = revolutions per minute

Study Questions

These study questions are to aid you in learning the material on pages 35 through 56.

Equipment and Calibration

1. *Noxious weed spraying requirements involve:*
   a. spraying speed
   b. rapid variation of swath width
   c. frequent changes in boom height
   d. all of the above
2. *This highest quality material for a sprayer tank is:*
   a. stainless steel
   b. fiberglass
   c. polyethylene
   d. aluminum
3. *Pressure gauges should have a total range of at least _____ the expected operating pressure.*
   a. twice
   b. three times
   c. four times
   d. five times
4. *What nozzle type is the most long-wearing and corrosion-resistant?*
   a. nylon
   b. ceramic
   c. brass
   d. stainless steel
5. *Worn nozzles:*
   a. result in poor pest control
   b. increase application rates
   c. change distribution patterns
   d. all of the above
6. *When the air temperature near the ground is cooler than the air above it, the condition known as an _____ exists.*
   a. proversion
   b. conversion
   c. inversion
   d. exversion
7. *What do you need to know in order to size a pump for your spraying system?*
   a. boom requirements
   b. agitation requirements
   c. extra flow needed to clean strainers
   d. all of the above
8. *Where should a spraying system strainer be placed when using a positive displacement pump?*
   a. pressure side of the pump
   b. in the suction line
   c. between the tank and the pump
   d. all of the above
9. *Vapor drift can be reduced by:*
   a. decreasing the droplet size
   b. using large amounts of drift control agents
   c. proper formulation selection
   d. decreasing the surface tension
10. *What component is important is preventing plugged nozzles?*
    a. strainers
    b. pressure gauges
    c. relief valves
    d. hoses
11. *A reduction in spray volume causes:*
    a. an decrease in droplet size
    b. greater drift potential
    c. a potential reduction in weed control
    d. all of the above
12. *Pressure regulators:*
    a. regulate operating pressure
    b. serve as a system relief valve
    c. are only important with piston pumps
    d. a and b above
13. *What do you need to know to calculate the nozzle discharge?*
    a. spray volume
    b. nozzle type
    c. the application rate
    d. droplet classification
14. *The most important source of information is:*
    a. a nozzle catalog
    b. the pesticide label
    c. the nozzle manufacturers
    d. all of the above

Environmental and Safety Concerns

Learning Objectives

After completing this chapter, you should be able to:

- Identify the common environmental hazards
- Define the different types of drift
- Know what personal protective equipment should be worn to safely apply pesticides to noxious weeds

Environmental Hazards

Minimizing Spray Drift

Drift is the airborne movement of spray, granule, or dust particles to places other than the target area. Although drift cannot be completely eliminated, the use of proper equipment and application techniques will help maintain drift deposits within acceptable limits. The initial recommendation for drift control is to read the pesticide label. Instructions are given to ensure the safe and effective use of pesticides with minimal risk to the environment. When drift occurs it is likely that the product you are using is wasted, and due to the high potential for sensitive areas in crop settings and right-of-ways (flowers, gardens, and other aesthetic plants, water, etc), it is very possible some damage will occur outside the target area. The type and size of nozzle and orientation, pressure, boom height, and spray volume, all play a role in the amount of spray drift that occurs.

There are two ways pesticides move downwind to cause damage: particle and vapor drift. Vapor drift is associated with the volatilization of pesticide molecules and the movement off-target (2,4-D ester). Volatilization is not as common as particle drift, but has the potential to move the herbicide a greater distance. Particle drift is the off-target movement of spray particles formed during or after the application. The amount of particle drift depends mainly on the number of small "driftable" particles produced by the nozzle. Spray drift can damage susceptible plants adjacent to cropland or right-of-ways or unintentionally expose animals or people to a chemical. Although excellent coverage can be achieved with extremely small droplets, decreased deposition and increased drift potential limit the minimum size that will provide effective control.

Protecting Groundwater

Some pesticides can travel (seep or leach) through soil and enter groundwater which may be used for drinking water. Users of pesticides are advised not to apply pesticides where the water table (groundwater) is close to the surface and where soils are permeable, i.e. well drained soils such as loamy sands. Pesticides can reach groundwater from applications onto crop fields, accidental pesticide spills, misuse, and improper storage and disposal. The amount of herbicide lost to leaching depends on adsorption (the attraction between soil particles and herbicide particles), soil texture, herbicide solubility, amount and intensity or rainfall, and degree of soil compaction.

Herbicide Movement from Soils

Nontarget soil areas can be contaminated as the result of improper use of herbicides. Overland flow is a major hazard on slopes and on bare ground. The herbicide may be carried by surface runoff or soil movement and desirable plants down slope can be severely damaged or destroyed. To prevent damage to desirable non-target vegetation:

- Do not apply a herbicide on sloping land that may injure or destroy non-target plants down slope.
- Do not drain or flush equipment where runoff or leaching to desirable plants may occur.
- Do not use a herbicide that may injure or destroy desirable plants by root adsorption if roots of desirable plants extend under area to be treated.

Personal Safety

Every Noxious Weed Department should have protective and safety equipment for the personal safety

Environmental and Safety Concerns

of the employees. The following is a list of required safety equipment for county noxious weed buildings and vehicles.

Eyewash Equipment and Shower

Where the eyes or body of any person may be exposed to injurious, corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body are to be provided within the work area for immediate use. (A) Eyewash and shower facilities are needed in the herbicide storage building in case of exposure to the eyes and skin of employees. (B) An eyewash facility (bottle or other) needs to be provided in the application and transportation trucks or vehicles.

- Eyewash bottles
  - One per vehicle.
  - 16 oz. or 32 oz.
  - Caution: Place in a shaded area; hot water will damage the eyes. Be sure to check the expiration date on the bottle.
- Eyewash fountains
  - One near chemical storage.
  - Wall-mounted eyewash bottle may be substituted for a permanent fountain.
- Shower
  - Should be located near chemical storage and mixing area.

First Aid Kit

First aid supplies should be readily available in case of emergency.

- One per vehicle.
- One near Chemical Storage Area.

Fire Extinguisher

- 40 lb. ABC or BC within 25 feet of chemical storage area.
  - Outside of storage room.
  - Top not more than 5 feet from the floor.
- 10 lb. ABC or BC in each vehicle.
- Shall be maintained in a fully charged and operable condition.

Pesticide Sign

Pesticide storage buildings should be identified by prominent and legible signs to give notice of the presence of pesticides. The identification sign should be made of durable material and display the word PESTICIDE in bold letters at least two inches in height. When a highly toxic pesticide is present, the word POISON and the skull and crossbones should be added.

Personal Protective Equipment

The most important thing that an applicator can do to reduce exposure is to wear the personal protective equipment (PPE) required by the herbicide label. Follow all directions on the label regarding protective clothing. The mentioning of only one piece of safety equipment does not rule out the use of additional protection. Understanding herbicide toxicity, route of entry, length of exposure, and mixing and application methods should help you assess the hazard and select the proper protective clothing. You must know and comply with all label requirements. The greatest potential for exposure occurs while handling concentrated products during mixing and loading. Hands and forearms offer the greatest potential for herbicide exposure. The product label or state regulations may specify additional protective clothing to be worn during loading that may not be required during application. The PPE required by the label is based on the LD50 or LC50 values, concerns about chronic exposure, and possible irritation of skin or eyes.

Hand Protection - Gloves

- Wear appropriate gloves when handling herbicide concentrates or when in contact with the spray solution, such as mixing herbicides, cleaning nozzles or adjusting the sprayer. Protection

for the hands should be used when operating a handgun.

- Gloves should be long enough to protect the wrist.
- Liquid-proof, unlined, chemical-resistant (neoprene or nitrile) gloves are best for liquid formulations.
- Gloves should NOT be fabric-lined because the lining absorbs herbicides.
- Most labels require wearing long-sleeved shirts. Shirt sleeves should be outside of the gloves to keep the herbicide solution from running down the sleeves and into the gloves. However, when spraying or working with your hands and arms over your head, the shirtsleeves should be inside the gloves to prevent the herbicide from running from the gloves on to unprotected skin of the hands and arms.
- Gloves should be washed with soap and water before you remove them to prevent being exposed to herbicides when you remove, store, or re-use them.
- Test your gloves for leaks by filling them with water and gently squeezing.
- Replace gloves when the exterior shows signs of tearing, staining, or distress.
- Place at least one pair in each vehicle and one pair near storage and mixing area.

Eye Protection - Goggles and Face Shield

Because eyes can readily absorb most herbicides, wear some form of eye protection, such as safety glasses with brow and side protection, goggles, or a face shield. Liquid products can splash and dry materials can bounce or be blown into unprotected eyes.

- Be aware that goggles can fog up and present a different type of hazard.
- It's best to purchase safety glasses with UVL protection. This will help protect the eyes from the herbicide and blocks the sun's rays.
- Wash your eye protection equipment after each use so you do not become exposed to herbicide with the next use.
- When not in use, store safety glasses or goggles in a container to help protect them against scratches and breaks.
- One pair of chemical splash goggles or face shield per vehicle and one near chemical storage and mixing area.

Head Protection - Hat

- Wear some form of head covering to protect your head anytime you are handling or applying herbicides.
- A wide-brimmed hat will help keep herbicides off your neck and face.
- Hats should not have a cloth or leather sweatband as they absorb chemicals and are difficult to clean.
- A separate sweatband should be easy to clean or be disposable.
- Baseball-type caps provide limited head protection from chemical exposure, and should be washed regularly with other clothes you wear during application.

Foot Protection - Shoes and Boots

- Sturdy shoes or boots are sufficient for most herbicide applications. Canvas or cloth boots can absorb herbicide and should be avoided.
- Boots are worn with trouser legs outside the boots to prevent the herbicide from running down your legs and into the boots.
- Neoprene or rubber boots are good precautionary gear when applying liquid herbicides in areas

Environmental and Safety Concerns

that must be walked through while making the application or when required by the product label.

- Rinse your neoprene boots before removing them to prevent exposure to chemicals when handling them.

Lung Protection - Respirators

The respiratory tract, including the lungs and other parts of the breathing system, is the fastest route for herbicide exposure. You must wear an approved respirator if required on the label. Very few herbicides require the use of a respirator, but follow label directions for those that do.

Surgical and Dust Mask

- Dust masks can trap dust particles and pollen, but should NOT be considered to be respirators for handling pesticides.

Cartridge Respirator

- A functional cartridge respirator absorbs herbicide vapors when the inhaled air is drawn through both a fiber filter pad and a cartridge. Cartridge respirators cover only the mouth and nose. For this reason, it is best to use one that is combined with goggles, or wear separate goggles that protect your eyes. Newer cartridge respirators are lightweight and disposable. Respirators are usually not required when using herbicides. Whether you are legally required to wear a NIOSH (National Institute of Safety and Health) approved respirator will depend on the herbicide label. If you do wear a respirator, wash it daily and check for proper fit before each use to prevent exposure to chemicals when wearing it again.
- While it is beyond the scope of this manual, applicators should never wear a respirator unless they have completed an OSHA (Occupational Safety and Health Act) approved medical questionnaire, been examined by a physician if required, and been fitted by a trained professional to ensure the proper respirator is selected. It is almost impossible to successfully fit a respirator to your face if you wear a beard.

Whole Body Protection - Coveralls and Safety Vests

- If you are wearing only a shirt and trousers, you should consider wearing coveralls or a liquid-proof apron when handling concentrates. If you wear a cover-all type garment, it should be made of woven or laminated fabric that has been manufactured for this purpose. Fabric garments should be laundered regularly. Disposable protective clothing can also be used for herbicide applications. Disposable fabrics are usually lightweight and strong and have the advantage of not requiring cleaning or decontamination after use.
- Bright reflective vests are required on many operations where applicator visibility is critical, such as roadsides and railroads.

There are hazards associated with weed control whether by applying herbicides or using mechanical equipment such as weed-eaters, mowers, and saws. There is no need to take short cuts when it comes to the safe handling of pesticides. Wearing the required personal protection equipment will reduce most hazards associated with the use of herbicides. A well-trained applicator will avoid unnecessary exposure and follow the directions on the label. The label is always the best source of information.

If nozzles clog or other trouble occurs in the field, be careful not to contaminate yourself while correcting the problem. Shut off the sprayer and move it out of the treated area before making repairs or corrections. Wear protective clothing while making repairs. You should clean plugged nozzles with a soft bristle brush, wooden pick, or something similar. Never use your mouth, wire, or pocketknife.

Public Safety

It is important to remember care must be taken to preserve not only the safety of the operator but also the public. Due to the fact noxious weed departments spray on township, county and state roads it is important to consult with the Department of Transportation and the local sheriff's department to ensure weed spraying vehicles are equipped with the appropriate warning devices.

Study Questions

Environmental and Safety Concerns

These study questions are to aid you in learning the material on pages 57 through 61.

1. *When wind carries the chemical and its carrier off the target area, this is called:*
   a. lateral movement
   b. leaching
   c. drift
   d. none of the above
2. *The movement of herbicide down through the soil is termed:*
   a. leaching
   b. drift
   c. brownout
   d. photodecomposition
3. *Eyewash equipment must be located in the:*
   a. pesticide storage building
   b. pesticide application vehicle
   c. pesticide transportation vehicle
   d. all of the above
4. *Face and hand protection equipment should be used when:*
   a. adjusting valves
   b. cleaning nozzles
   c. mixing herbicides
   d. all of the above
5. *The greatest risk of herbicide exposure occurs:*
   a. while reading the label on the container
   b. during mixing and loading
   c. during application
   d. all are equal
6. *Gloves worn when applying herbicides should be:*
   a. unlined
   b. liquid proof
   c. worn inside the shirt sleeve
   d. all of the above

Answers to Study Questions

Pages 4-7 (Laws and Regulations)

1. d 2. c 3. a 4. c

Pages 9-26 (Noxious Weeds)

1. b 2. d 3. d 4. d 5. c 6. d 7. d 8. b 9. d
10. b 11. a 12. c 13. b 14. b 15. c 16. b

Pages 28-33 (Herbicides)

1. d 2. d 3. c 4. c 5. b 6. b 7. a

Pages 35-56 (Equipment and Calibration)

1. d 2. a 3. a 4. b 5. d 6. c 7. d 8. d 9. c
10. a 11. d 12. d 13. a 14. b

Pages 57-61 (Environmental and Safety Concerns)

1. c 2. a 3. d 4. d 5. b 6. d

Photo Credits

Kansas Noxious Weeds

Howard F. Schwartz, Colorado State University (Bugwood.org). Bur ragweed

David J. Moorhead, University of Georia (Bugwood.org). Kudzu

Russ Kleinman, courtesy of Western New Mexico University Department of Natural Sciences and the Dale A. Zimmerman Herbarium. Pignut

Elizabeth Bella, USDA Forest Service. Quackgrass

Norman E. Rees, USDA Agricultural Research Service-retired (Bugwood.org) Russian knapweed

All others courtesy of the Kansas Department of Agriculture.

Inside back cover blank

Frannie L. Miller
Pesticide Coordinator

Authors: Appreciation is expressed to the following for preparation of the material in this manual:

Walter Fick, Agronomist, Range Management, Department of Agronomy

Scott Marsh, State Weed Specialist, Plant Protection and Weed Control, Kansas Department of Agriculture

Dallas Peterson, Agronomist, Weed Scientist, Department of Agronomy

John W. Slocombe, Agricultural Machinery Systems Engineer, Department of Biological and Agricultural Engineering

Appreciation is expressed to the following for cooperation in the Commercial Applicator Training Program:

Jeanne Fox, Certification and Training Section Chief, Pesticide and Fertilizer Program, Kansas Department of Agriculture

Jerry Wilson, Compliance Investigator, Pesticide and Fertilizer Program, Kansas Department of Agriculture

Kansas State University Agricultural Experiment Station and Cooperative Extension Service
S30 September 2014