Forest Pest Control

originally prepared by Jim Newman, Extension Forestry Specialist
updated by Jeff Stringer, Extension Forestry Specialist, and Lee Townsend, Extension Entomologist, University of Kentucky

Kentucky's Forests

- Kentucky is third in the nation in hardwood production. Over 45% of the state's land surface (over 11 million acres) is forested.
- Kentucky lies in a transition zone between northern and southern forests. There are about 100 native species; about 50% have some commercial value and use.
- Threats to Kentucky forests from exotic invasive plants, animals, and pathogens have increased the need for people trained and certified in Forest Pest Control.

Knobs State Forest and Wildlife Management Area (forestry.ky.gov)

Kentucky's forests are dominated by deciduous or hardwood trees. **Hardwoods comprise over 90% of the marketable timber volume**, about half of that is various oak species. The **top three lumber species are white oak, yellow poplar and red oak.** The hardwood species found on any given land parcel vary with geographic location and site factors, such as aspect and soil depth, moisture, and structure. Past land use, harvesting practices, and fire history also affect species composition. Certain tree associations appear often and are classified as forest types. The principal hardwood forest types recognized by the US Forest Service in Kentucky are oak-hickory (over 4,700,000 acres), and mixed hardwoods (over 4,000,000 acres). Other hardwood forest types, which may be very important locally, are white oak, maple-beech, oak-gum-cypress, and elm-ash-cottonwood.

Conifers, including pines, redcedar, hemlock, and cypress, comprise less than 10% of the forest resource. Redcedar and Virginia pine are widely distributed and have considerable local economic importance. The pines are particularly important in and near the cliff section of the Cumberland Plateau in eastern

Kentucky. In addition, forest plantations, consisting of various species of pine, have been established throughout the state.

Principles of Forest Pest Management

An understanding of pest identification and biology, along with good forest management practices, are key elements in preventing or reducing losses to pests. Use of a combination of methods in an integrated pest management (IPM) program provides a sound approach to forest health. IPM is discussed in the "Applying Pesticides Correctly" core manual.

Pest monitoring should be a part of an overall forest management plan. It can allow early detection and accurate assessment of infestations. In many cases, sound long-term production practices can minimize the need for pesticide applications. When pest outbreaks occur, suitable management alternatives will vary with the specific pest, or pest complex, and will consider damage potential, control costs and benefits, and legal, environmental, and social factors.

Insect **pheromones** are chemicals that members of a species use to communicate with each other. Females of many species produce sex pheromones that attract males for mating. Traps baited with pheromone lures can be used to survey for invasive insects, or in some cases, to control limited infestations. These traps are used each summer in Kentucky to monitor for the gypsy moth.

Gypsy moth trap
(Chris Evans, University of Illinois, Bugwood.org)

Management decisions should consider potential pest impacts on the environment:

☑ Will the problem **increase, decrease, or remain** the same over time?

☑ What type of **damage** can occur and how many trees will be affected?

☑ What will be the **long term impact** of the pest on trees and the environment?

- For example, the southern pine beetle damages the cambium layer and introduces fungi that almost always kill the tree. However, many trees can recover from an almost total leaf loss from caterpillars in a single season without a long term impact on health. Insect outbreaks

that last for several years can cause severe stress that will kill trees or make them susceptible to other problems.

A key part of pest management is to use a pesticide only when it is needed to prevent an unacceptable amount of damage. Use of a pesticide may not be justified if the cost of control or potential harm to the environment is greater than the estimated damage or loss.

Before choosing a control method(s):

1. **Correctly identify the organism.**
2. **Assess the infestation and determine the potential economic damage.**
3. **Determine the available control methods.**
4. **Evaluate the benefits and risks of each method or combination of methods.**
5. **Are there threatened or endangered species or sensitive sites in the area to be treated?**
6. **Choose effective method(s) that will be least harm to humans and the environment.**
7. **Follow applicable local, state and federal regulations.**
8. **Correctly carry out the control practice(s) and keep accurate records so results can be evaluated.**

A pesticide application may be needed to control a pest outbreak or to eradiate limited infestations of an invasive species. **Select and use pesticides in a manner that will cause the least harm to non-target organisms in forests, seed orchards and nurseries, while still achieving the desired management goal.**

Pesticide applications may be needed in some cases (english.forestry.gov.cn)

Pesticides are labeled for specific pests, crops and land-use situations. Use of insecticides, fungicides, and herbicides is common in managed seed orchards, forest nurseries, intensive short-rotation plantations, and in Christmas tree production. In general, the **most commonly used forest pesticides are herbicides** used for site preparation, herbaceous weed control, and in pine release treatments. **Insecticide applications are seldom used in general forest management** because of high treatment costs and potential effects on non-target organisms. **Situations justifying the widespread use of fungicides also are rare.** In some cases, vertebrate animals must be controlled through trapping or hunting but use of repellents and poison baits may be

References

Brooks, R. Forest Herbicides and their mode of action. U of Idaho CES Tree Planting and Care No. 15. Forest pest control. U Georgia Special Bulletin 16 http://www.bugwood.org/pestcontrol/ Invasive plants of the eastern United States: Identification and Control. http://www.invasive.org/eastern Kentucky Woodlands Magazine Vol 1. SAF.

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Forest Pest Control - Vegetation

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Vegetation Management

Growth of desirable tree species can be increased significantly by using vegetation management practices to control undesirable species that compete for light, water and nutrients. Management also can be used to improve wildlife habitat, to reduce fire hazard, and to maintain right-of-way and recreation sites. Herbicides can be used with hand or mechanical clearing, prescribed fire, and / or weed mats in an integrated weed management strategy that is effective and environmentally sound. They can be important tools that provide safe and effective vegetation management with less risk than alternative control methods and often lower energy or labor inputs as well.

Exotic Invasive Plant Species

Invasive non-native plants can and do disrupt native plant and wildlife habitats and communities. Once established, limited infestations of these plants can spread over large areas.**Invasive plants may be second only to habitat destruction as a threat to biodiversity.** They are estimated to cost the US more than $34 million annually in lost productivity, lower quality, weed control, and containment on crop and range lands and in aquatic environments. Here are examples of some invasive plants and problems that they can cause.

Kudzu

Kudzu smothering vegetation (Kentucky.com)

Kudzu has massive tap roots (bjherbest.com)

Kudzu (*Pueraria montana* var. *lobata*) is a climbing, semi-woody, perennial vine in the pea family. It smothers plants with a solid blanket of leaves, girdles woody stems and tree trunks, and breaks branches or uproots trees and shrubs through the sheer force of its weight. Once established, Kudzu plants can grow about a foot per day.

Vigorous vines may be 100 feet long with stems ½ to 4 inches in diameter. Massive tap roots are 7 inches or more in diameter, 6 feet or more in length, and weigh as much as 400 pounds.

Thirty vines may grow from a single root crown. Long-term control requires destruction of the extensive root system because any remaining root crowns can lead to re-infestation. Mechanical methods involve cutting vines just above ground level and destroying all cut material. Close mowing every month for two growing seasons or repeated cultivation may be effective. If conducted in the spring, cutting must be repeated, as regrowth appears to exhaust the plant's stored carbohydrate reserves. Late season cutting should be followed up with immediate application of a systemic herbicide (e.g., glyphosate) to cut stems. This allows the herbicide to move into the root system. Repeated applications of several soil-active herbicides have been used effectively on large infestations in forestry situations.

Bush Honeysuckle

Egg-shaped honeysuckle leaves (discoverlife.org)

Using a weed wrench to extract honeysuckle stump (environmentalconsulting.com)

Bush honeysuckles (*Lonicera maacki* and other species) are upright deciduous shrubs that can be 6 to 15 feet tall. The 1 to 2-½ inch, egg-shaped leaves are opposite along the stem and short-stalked. Pairs of fragrant, tubular flowers less than an inch long are borne along the stem in the leaf axils. Flowering generally occurs from early to late spring but varies for each species and cultivar. The fruits are red to orange, many-seeded berries. Native bush honeysuckles may be confused with these exotic species and cultivars, so proper identification is necessary. Unlike the exotics, most of our native bush honeysuckles have solid stems.

Exotic bush honeysuckles can rapidly form dense shrub layers that crowd and shade out native plant species. They decrease light availability, deplete soil moisture and nutrients, and may release toxic chemicals that prevent other plant species from growing in the vicinity. Exotic bush honeysuckles may compete with native bush honeysuckles for pollinators, resulting in reduced seed set for native species. While the abundant fruits of exotic bush honeysuckles are rich in carbohydrates, they do not offer migrating birds the high-fat, nutrient-rich food sources needed for long flights that are supplied by native plant species.

Mechanical and chemical methods are the primary means of control of exotic bush honeysuckles. Hand removal of seedlings or small plants may be useful for light infestations but the soil should be as undisturbed as possible. Exotic bush honeysuckles in shaded forest habitats tend to be less resilient, so repeated clippings to ground level, during the growing season, may result in high mortality. Clipping must be repeated at least once yearly because bush honeysuckles that are cut once and left to grow will often form stands that are more dense and productive than they were prior to cutting.

Seedlings of exotic bush honeysuckles can also be controlled by application of a systemic herbicide, such as glyphosate. Established stands may be managed best by cutting the stems to the ground and painting or spraying the stumps with glyphosate.

Multiflora Rose

Multiflora rose (cipwg.uconn.edu)

Multiflora rose fruits
photo: James H. Miller, USDA Forest Service, Bugwood.org

Multiflora rose (*Rosa multiflora*) is a thorny, perennial shrub with arching stems (canes), and leaves divided into five to eleven sharply toothed leaflets. There are a pair of fringed bracts at the base of each leaf stalk. Beginning in May or June, clusters of showy, fragrant, white to pink flowers appear, each about an inch across. Small bright red fruits, or rose hips, develop during the summer. They become leathery and remain on the plant through the winter.

Multiflora rose was introduced to the East Coast from Japan in 1866 as rootstock for ornamental roses. In the 1930s, the US Soil Conservation Service promoted it for use in erosion control and as "living fences" to confine livestock. State conservation departments soon discovered value in multiflora rose as wildlife cover for pheasant, bobwhite quail, and cottontail rabbit and as food for songbirds. They encouraged its use by distributing rooted cuttings to landowners free of charge. However, it is extremely prolific and can form dense

thickets that exclude native plant species. This exotic rose readily invades open woodlands, forest edges, and succession disturbed land.

Multiflora rose reproduces by seed and by forming new plants that root from the tips of arching canes that contact the ground. Birds readily seek the fruit and are the primary seed dispersers. The average multiflora rose plant may produce a million seeds per year, which may remain viable in the soil for up to 20 years. Passing through the digestive tract of birds enhances seed germination.

Mechanical and chemical methods are widely used methods for managing multiflora rose. Frequent, repeated cutting or mowing (3 to 6 times per growing season for two to four years) has been effective in killing multiflora rose. In high quality natural communities, cutting of individual plants is preferred to site mowing to minimize habitat disturbance. Various herbicides have been used successfully in controlling multiflora rose. However, long-lived stores of seed in the soil make follow-up treatments necessary. Application of systemic herbicides (e.g., glyphosate) to freshly cut stumps or to regrowth may be the most effective methods, especially if done late in the growing season. Plant growth regulators have been used to control the spread of multiflora rose by preventing fruit set.

Winter Creeper

Winter creeper is an evergreen climbing woody vine that forms a very dense ground cover (nature.org)

Winter creeper (*Euonymus fortunei*), a woody evergreen vine, was introduced into the US from Asia in 1907 as an ornamental ground cover. Subsequently, it has invaded forests throughout the eastern US. The plant can be a small shrub, growing in mats along the forest floor to 3 feet in height or a vine climbing trees to heights of 40-70 feet. The opposite leaves are dark green, oval, slightly toothed, glossy, and thick. The young stems are green, becoming light gray and corky with age. Its inconspicuous, yellow-green flowers have 5 petals.

Winter creeper aggressively invades open forests, forest margins, and openings. The dense ground cover often resulting from an infestation can displace native understory species and restrict tree seedling establishment. Winter creeper can also smother and kill shrubs and small trees.

Juvenile plants with small root systems can be pulled by hand when the soil is moist. However, manual removal of larger plants must include destruction of all roots and runners because portions of the root system left in the soil can sprout. Applications of herbicides for containing glyphosate or triclopyr over successive years may give satisfactory control.

References

Brooks, R. Forest Herbicides and their mode of action. U of Idaho CES Tree Planting and Care No. 15. Forest pest control. U Ga Special Bulletin 16 http://www.bugwood.org/pestcontrol/ Invasive plants of the eastern United States: Identification and Control. http://www.invasive.org/eastern Kentucky Woodlands Magazine Vol 1. SAF.

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Forest Pest Control – Herbicide Application

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Classification of Herbicides

Herbicides can be grouped by silvicultural use, application methods, selectivity, or how they work (mode of action).

Silvicultural Objective	Herbicide Objective	Application Methods
Timber Stand Improvement	Improve growth of desirable trees and create growing space for tree reproduction	Frill girdle, tree injection, hatchet injection, basal application
Site Preparation	Control existing competing vegetation before planting or seeding or to increase browse value and to create openings for wildlife.	Foliar spray
Pre-commercial thinning	Control stand density by thinning dense thickets of conifers or hardwoods that have not reached merchantable size	Basal bark, tree injection, hatchet injection
Release of conifers	Low release or high release	Foliage spray, basal bark, frill girdle, stump treatment, tree injection
Release of planted trees that need special treatment	To control grasses weeds and other competing vegetation around newly planted Christmas tree or walnut seedlings	Direct spray

Herbicide Application Methods

Herbicides are the most commonly used pesticides in forestry. Applications may include high volume or low volume foliar spray treatment, basal bark treatment, stump treatment, tree injection and soil treatment with pellets.

Foliar Application

Foliar application includes both high and low volume techniques. **High volume spraying** is normally done with truck mounted equipment that deliver 60 to 400 gallons of solution per acre at high pressure through a hand-directed nozzle. This type of foliar spraying is fast and, in some instances, can deliver herbicide through dense brush. However, the risk of drift and unwanted effects on non-target plants is high. This technique requires more planning and precautions than other ground application techniques.

Foliage sprays should be made when leaves are fully expanded and the main spring sap flow has slowed (July through fall color change). Minimize pesticide drift from the treated site.

Weed control in newly planted plantation (superiorforestry.com)

Low volume spraying is normally done with hand-held equipment, such as backpack sprayers or low pressure ATV or tractor mounted sprayer, that deliver 10 to 60 gallons per acre at relatively low pressure through a hand-held wand. Low volume spraying also includes using boom sprayers and fixed height nozzles to apply herbicides to low growing grasses and weeds with a great deal of control over the amount and distribution of herbicide. It is often used for band or strip spraying. All types of low volume spraying are likely to cause fewer environmental problems compared to high volume techniques.

Both high volume and low volume hand-held wand techniques generally require that mixes contain a specific percentage of herbicide in the final water based solution. Labels also indicate that a specific amount of solution be applied per acre, ensuring that all foliage should be sprayed to a point of runoff.

Individual Stem Applications

Individual stem applications are used to apply herbicides directly onto or inside the stems of individual woody plants (trees or shrubs). Basal bark treatments are used to apply specific formulations of herbicides to the outer bark of the small woody plants. The herbicide is absorbed through the bark and eventually contacts the

transport tissues and growing portions of the stem. A number of different methods including the use of tree injectors, frill and squirt techniques, Hypo-Hatchets® or similar devices, and cut stump treatments are used to deliver herbicides directly to the transport and growing tissues beneath the bark of woody plants.

Hypo-hatchet (bladesandbushlore.com)

These treatments should not be applied to trees or shrubs where non-target plants of the same species or genera are nearby (generally within 10 to 20 feet). Trees and shrubs of the same species or genera may form root grafts, or may be sprouts from the same rootstock.

Basal bark treatments consist of several techniques to apply herbicides to the lower stem of small (less than 6 inches in diameter) trees and shrubs. Herbicides labeled for basal bark treatments are mixed with oil, instead of water. ***The full basal technique requires that the herbicide be thoroughly applied around the circumference of the lower 18 inches of tree.*** This is normally done using a backpack sprayer with a cone or flat fan tip. The streamline technique is used on trees or shrubs less than 3 inches in diameter and requires that a 6-inch wide band of herbicide be applied to one side of the stem. Enough of the solution should be applied to allow its spread around the entire circumference of the stem. The thinline technique is similar to streamlining, except that undiluted herbicide is used and only a thin band is sprayed completely around stem. The streamline and thinline techniques often are applied with a hand jet, which shoots a stream of solution, rather than a hand wand and nozzle used for the full basal technique.

Basal bark treatment (DowAgro.com)

Cut stump treatments are made on freshly cut stumps to prevent sprouting (coppicing) of hardwood trees and shrubs. Stumps should be treated with the undiluted herbicide within 1 to 2 hours after cutting. Once the cut surface dries, this treatment quickly loses its effectiveness. The entire surface area of stumps less than 10 inches in diameter should be covered. For larger stumps only the outer 3 to 4 inches should be treated. Backpack sprayers with hand wands, or handheld spray bottles, can be used to apply the herbicide.

Tree injection can be used to apply herbicide to the living tissues inside the bark of standing trees or shrubs. Tree injectors are specially designed 4- to 5-foot long tubes with an injection pump and 1.5 to 3 inch blade or injector on one end. They are used to apply either liquid or pellet herbicides to trees of any size. A liquid tree injector has a blade that produces a slit through the bark and then a pump delivers a calibrated amount of solution into the slit. Pellet injectors have a head on the tube which drives the pellet into the bark. The **frill and**

squirt technique is also used to apply herbicides inside the stems of woody plants. This is done by using a hatchet to slit the bark and then using a hand sprayer to apply a calibrated amount of herbicide into the slit.

Avoid application during heavy upward sap flow in the spring because sap flow out of the wound will prevent herbicide absorption.

Hack and squirt herbicide application (forestry.about.com)

The Hypo-Hatchet® and Silvaxe® are examples of devices which combine the squirt mechanism directly into a specialty-designed hatchet. The liquid herbicide is placed in a container on a belt or backpack and is attached to the hatchet with a hose. The hatchet has a pump mechanism and injection ports built into the head. Striking the stem creates a slit and injects a calibrated amount of solution into the slit. Herbicides labeled for tree injection will indicate the amount of herbicide needed per inch of stem diameter and the spacing of injections around the stem.

Soil applied pellets can be used in very small amounts by hand broadcasting or specific placement around the stems of trees and shrubs (e.g., multiflora rose) or brush. After a rain, the solution is moved into the roots of woody plants which have their root systems within the dispersal area of the herbicide.

Spraying a post-emergence herbicide (photo: Ralph Whiteside)

Products applied to the foliage are commonly referred to as post-emergence herbicides. They control weeds either by direct contact with the plant tissue or by translocation to other plant parts. Weeds sprayed with contact herbicides usually die within a few hours or days. There is very little, if any, residual control. Weeds treated with translocated herbicides generally require several days to die. These herbicides are often capable of controlling annuals, biennials and perennials. Glyphosate (Accord, Roundup) and 2,4-D (several trade names) are examples of translocated herbicides.

Herbicide Selectivity

Herbicides may be classified as selective or non-selective. **Selective herbicides kill some kinds of plants but have little or no effect on others.** The use of selective herbicides allows the removal of unwanted plants from desirable species. For example, 2,4-D is a selective herbicide which will remove broadleaf weeds but will not injure grasses. However, the selectivity of a herbicide depends on the rate that is used. At low rates, some herbicides are selective but at high rates they become non-selective. **Non-selective herbicides kill all vegetation.** An example is glyphosate (Accord).

How Herbicides Work – Modes of Action

Herbicides with similar chemical characteristics are grouped into families. Here are examples of some of the common herbicides used in silviculture. They are listed by common name with some example brand names in parentheses and some information on how they affect plants.

2,4-D damage to tulip poplar (lawn-care-academy.com)

2,4-D is a selective herbicide used to control annual and perennial broadleaf weeds. It is absorbed through the foliage and is translocated within the plant where it mimics natural plant hormones. Applications are made after weed emergence. Plants are most susceptible to damage when they are young and growing rapidly. Actively growing conifers are very susceptible to 2,4-D. Glyphosate (Accord) is a non-selective translocated herbicide. It acts by inhibiting amino acid production and protein synthesis.

Glyphosate is absorbed through the foliage and is translocated to the roots. It apparently has no soil activity. Accord can be used for site preparation, release, thinning, and removal of invasive plants.

Hexazinone (Velpar, Pronone) is a contact herbicide in liquid formulation that is applied to foliage (Velpar) or a granular (Pronone) formulation applied to the soil. It controls broadleaf and woody species and grasses and is used for selective weed control in conifers and for conifer release. Hexazinone can be applied when target plants are actively growing. Dormant season applications of Pronone granules over sensitive conifers will provide residual, soil active control for the next 1 or 2 growing seasons.

Imazapyr (Arsenal, Chopper, Contain) is a nonselective broad spectrum systemic herbicide with residual soil activity. It inhibits enzymes used to make some amino acids. Imazapyr is readily absorbed through foliage or roots. It is used to control most annual and perennial grasses, broadleaf weeds and woody species. It can be applied pre- or postemergence for long term control total vegetation on non-crop lands.

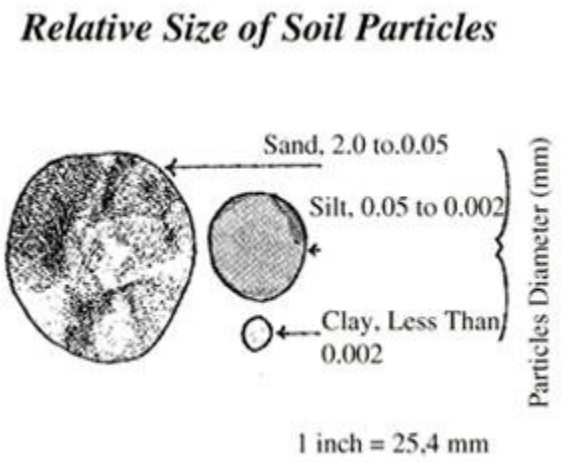
Metsulfuron (Escort, Ally) is a selective postemergence herbicide used at low rates to control broadleaf weeds and brush on non-cropland areas. It works in a plant by interfering with an enzyme which quickly stops cell division in roots and shoots. It can be used for site preparation or conifer release.

Picloram (Tordon) is a Restricted Use herbicide. It is a highly translocated, selective herbicide for broadleaf weeds and woody plants. It is active through the foliage and roots and has a long persistence in the soil, requiring precautions to avoid damage to desirable plants.

Triclopyr (Garlon 3) is a systemic growth regulating herbicide used to control woody and broadleaf perennial weeds in forests and rights of way. It also mimics natural plant hormones.

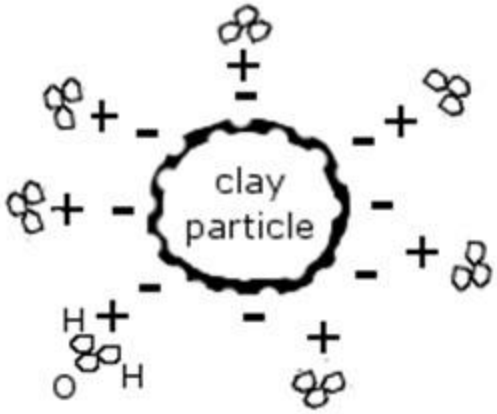
Soil Factors That Influence Herbicides

Soil texture, organic matter, pH and moisture content are some of the major soil properties that influence the efficacy of a soil-applied herbicide.



(blog.bolandbol.com)

Soil texture, the relative amounts of clay, silt, and sand in a soil, can determine the availability of certain herbicides. **Usually, as the clay content of the soil increases, the amount of herbicide available for uptake in the plant decreases.**

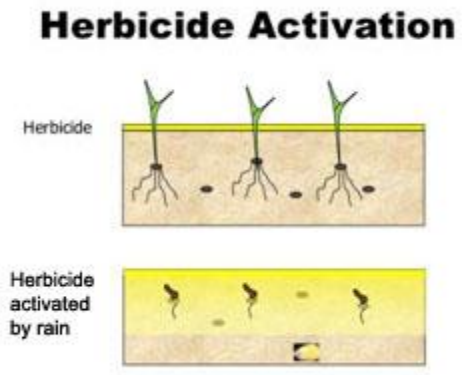


Clay particles tend to CLING to positively charged herbicides (blog.bolandbol.com)

Clay particles are primarily negatively (-) charged so they tend to attract or adsorb positively (+) charged particles. Herbicides which tend to be positively charged in the soil are bound to a greater extent by clay particles than herbicides which are negatively charged. This is why the **rates of certain herbicides vary with soil texture.**

Organic matter or humus content of the soil is primarily negatively (-) charged so herbicides can bind to it. In general, herbicides are more strongly adsorbed to humus than to clay particles. **A small increase in the organic matter content of the soil can greatly reduce the effectiveness of some herbicides.**

Soil pH can influence the effectiveness and persistence of certain herbicides. For example, metsulfuron (Escort) degrades rapidly when soil pH is less than 6.0. When soil pH is above 6.0, degradation rates are slower and depend more on soil microbes.



A certain amount of water is needed to activate a soil-applied herbicide (slideshare.net)

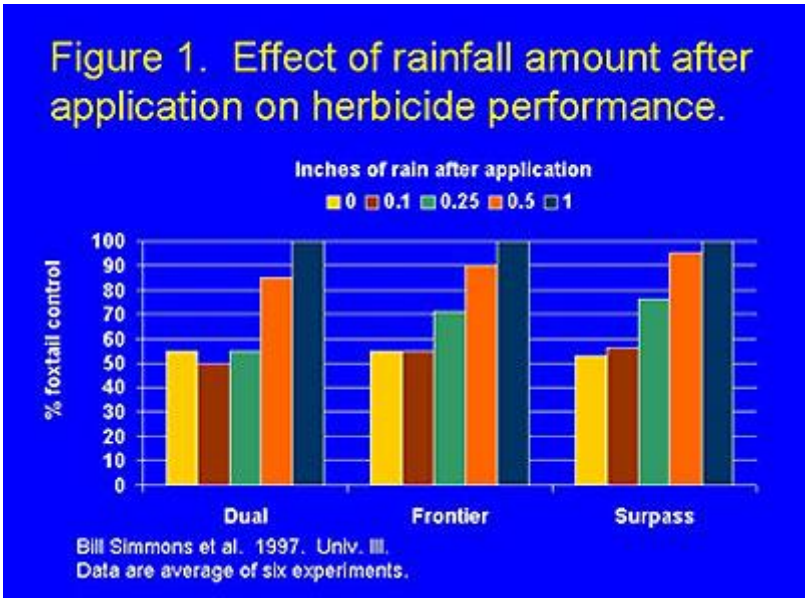
Herbicides applied to the soil surface must be moved into the root zone of the plants to be controlled soon after the application is made. Generally, soil-applied herbicides do not work as well under very dry conditions as they do when the soil moisture is adequate. Soil moisture also may indirectly affect the persistence of various herbicides by influencing their breakdown by microbes or certain chemical reactions. Soil-applied herbicides usually last longer when the soil is dry rather than when it is moist or wet.

Environmental Factors That Influence Herbicides

Results achieved from herbicide applications may vary greatly from one year to the next. This variability (often a lack of control) may be due to improper application (e.g., improper choice of herbicide, poor equipment, incorrect calibration, lack of agitation or ineffective product). Many of these problems can be prevented or corrected by the operator. However, much of the variability is due to factors which the applicator cannot control. These include environmental conditions, variation of soils and differences in susceptibility of various plant species.

Before considering the effect of environmental factors, it is essential to consider how the herbicide is applied. Herbicides may be applied as soil, foliage, stump or basal bark treatments. The influence of a given environmental factor may be quite different, depending on the type of application. Environmental conditions have very little effect on stump or basal bark treatments but they may have a great effect on soil and foliage applications.

Soil-Applied Herbicides



Effect of post-application rainfall amounts on control of a grass weed (weeds.iastate.edu)

Rainfall (soil moisture) and temperature are two environmental factors that have the most influence on the performance of soil-applied herbicides. **The amount of rainfall needed to move a herbicide depends on its water solubility.** For example, a herbicide that is very soluble in water has a higher potential to move in soil with water compared to many other herbicides. Leaching of water-soluble herbicides is greatest under heavy rain that falls in a short period of time. Excessive movement of herbicide in the soil may cause injury to desirable plants close to areas that have been treated.

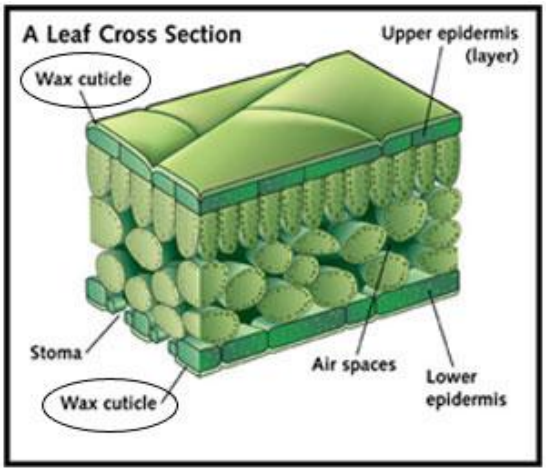
Temperature influences the performance of soil-applied herbicides by affecting chemical reactions in the soil, microbial activity and plant growth processes. Decomposition of herbicides by chemical reaction and microbial activity in the soil occurs more rapidly at high temperatures; therefore, herbicides are less persistent under these conditions. Temperature also has a profound effect on the absorption, translocation and metabolism of soil-applied herbicides by plants. Other factors being constant, the effects of these processes increase with increasing temperatures. **Herbicides usually perform best under temperatures at which plants grow rapidly**. Under conditions of extremely high or low temperatures, the toxicity and selectivity may be altered dramatically due to the influence of temperature on these physiological processes.

Herbicides Applied to Foliage

High humidity increases absorption of foliar-applied herbicide (pest.ca.uky.edu)

Humidity

Herbicides applied to foliage usually perform best when relative humidity is high. This greatly increases foliage absorption by delaying drying of spray droplets and by making the leaf cuticle more permeable. High relative humidity also may enhance translocation of systemic herbicides. Very light rainfall, such as a drizzle, dew or fog, increases absorption and effectiveness by remoistening the dry herbicide on the leaf surface. However, heavy rainfall shortly after application may wash the herbicide off the plant. The amount of the herbicide washed from the plant will depend on the quantity of precipitation, the rate of herbicide application, the chemical characteristics of the herbicide and the use of an additive. Water-soluble herbicides such as salt formulations of 2,4-D are washed off more easily than oil-soluble herbicides such as ester formulations of 2,4-D.



The cuticle is a waxy water-repellent layer that covers all aboveground areas of a plant. (study.com)

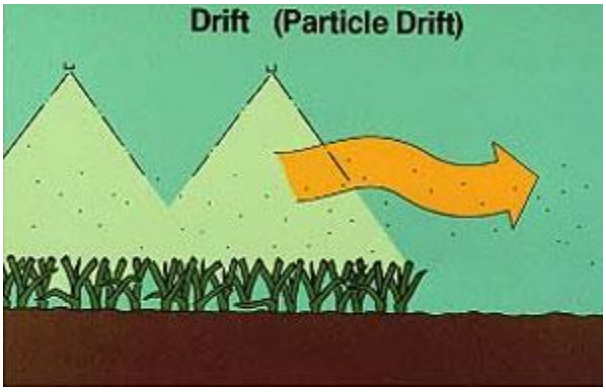
Temperature

In addition to the effect of temperature on the plant's physiological processes, temperature also influences absorption of herbicides into leaves. Plants grown under high temperature frequently develop a thicker cuticle which restricts herbicide absorption. Due to the interaction of these physiological processes, the effect of the temperature at the time of application on herbicide performance depends on the herbicide being applied. **In general, best results can be expected from foliar herbicides applied during warm weather to actively growing plants and followed by a period of several hours with no rainfall.**

Sunlight

Sunlight is an additional environmental factor that influences the performance of many soil and foliar herbicides. It is essential for the activity of certain herbicides but it is seldom a limiting factor in their performance. However, the herbicide paraquat kills plants more rapidly on clear, sunny days and more slowly on cloudy days.

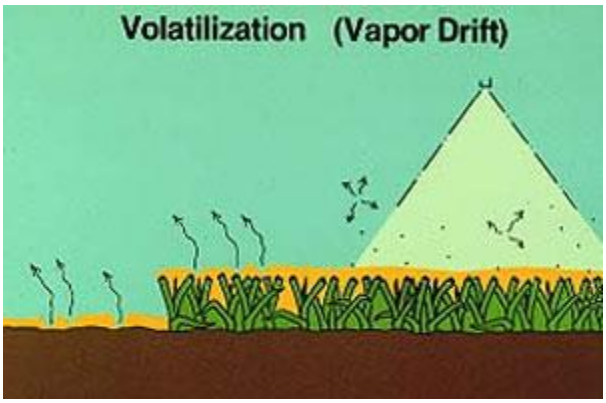
Drift



Off target movement of pesticide spray particles (personal.psu.edu)

Drift is the movement of spray particles or vapors through the air to areas not intended for treatment. The amount of drift depends on the particle or droplet size and the amount of air movement at the time of spraying. **Herbicide spraying should not be done if the wind speed is greater than 5 miles per hour.** Spray particles the size of fog or mist size present the greatest possibility for drift. These size particles are generated readily by high pressure spraying equipment and certain types of nozzles.

Volatilization



Off-target movement of pesticide vapors (personal.psu.edu)

Volatilization of herbicides is a chemical process whereby the herbicides change from a liquid to a gas. The herbicide, in the form of a gas or vapor, can move with the air currents for a mile or more to injure sensitive crops. **Drift and volatilization represent potential hazards to sensitive crops, gardens and ornamentals, and may have harmful effects on wildlife, people, livestock and aquatic areas near application sites.** In many cases, movement of herbicides off target results in complaints from the public or property owners. Complaints arising from herbicide application should be answered quickly and settled fairly.

Definitions

- **Basal bark treatment** — An application to the woody stems of plants at and just above the ground line and including the root crown.
- **Frill and squirt** — An individual tree application method where a hatchet or chainsaw is used to make a cut through the bark where the chemical is applied.
- **Hypo-Hatchet®** — An instrument used to inject a pre-measured amount of herbicide directly into the growing woody stem. Same as **Silvax®**.
- **Soil sterilant** — A chemical that prevents the growth of any organism in the soil—plants, animals or microorganisms; the effect may be temporary or long-lasting, depending on the chemical.
- **Tree Growth Regulator (TGR)** — A chemical which in small amounts alters the growth habits of trees.
- **Tree injection** — An application tool for injecting a herbicide directly through the bark of woody plants.
- **Woody plants** — Plants that live longer than two years and have a thick, tough stem or trunk covered with cork.

Environmental Concerns

Groundwater Advisories

The **potential for contamination of groundwater must be considered when choosing pesticides.** Several products have groundwater advisory statements on their label. Such statements advise not to apply these products where the water table (groundwater) is close to the surface and where the soils are very permeable (well-drained soils such as loamy sands). Refer to these statements and observe all precautions on the label when using these products.

Endangered Species

The Fish and Wildlife Service administers the Endangered Species Act

The Endangered Species Act (ESA) protects and promotes recovery of animals and plants that are in danger of becoming extinct due to the activities of people. Under the Act, the Environmental Protection Agency (EPA) must ensure that the use of pesticides it registers will not result in harm to the species listed by the U. S. Fish and Wildlife Service as endangered or threatened, or to habitats critical to the survival of those species. The EPA has implemented "Interim Measures," including county bulletins showing the area(s) within the county where pesticide use should be limited to protect listed species. Pesticide active ingredients for which there are limitations are listed in table form in the bulletins. The limitations on pesticide use are not law at this time, but are being provided for use in voluntarily protecting endangered and threatened species from harm due to pesticide use.

References

Brooks, R. Forest Herbicides and their mode of action. U of Idaho CES Tree Planting and Care No. 15. Forest pest control. U Georgia Special Bulletin 16 http://www.bugwood.org/pestcontrol/ Invasive plants of the eastern United States: Identification and Control. http://www.invasive.org/eastern Kentucky Woodlands Magazine Vol 1. SAF.

Herbicide use in forest management – a position of the Society of American Foresters. This publication, originally prepared by Jim Newman, Extension Forestry Specialist, is provided by the Pesticide Safety Education Program of the UK College of Agriculture. This version has been updated by Jeff Stringer, Extension Forestry Specialist, and Lee Townsend, Extension Entomologist.

http://www.ext.colostate.edu/mg/Gardennotes/331.pdf

Forest Pest Control - Insects

originally prepared by Jim Newman, Extension Forestry Specialist
updated by Jeff Stringer, Extension Forestry Specialist, and Lee Townsend, Extension Entomologist, University of Kentucky

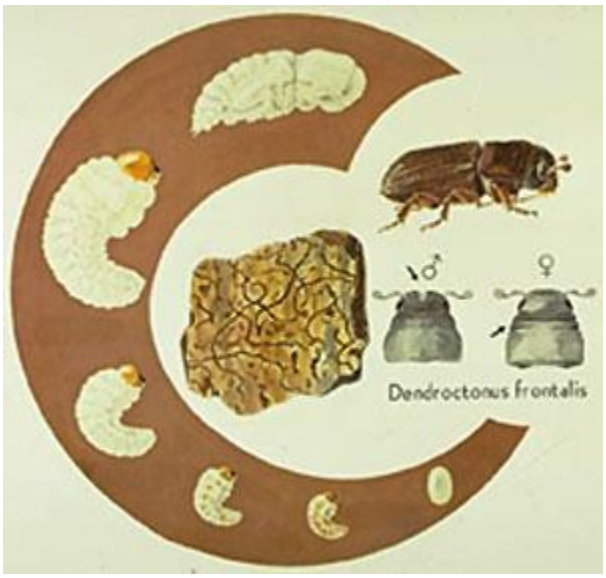
Wood Boring Insects

Bark Beetles

Bark beetles use trees as breeding sites and have an important natural role in killing weak or old trees or aiding the decomposition of dead wood. Odors from damaged trees attract bark beetles so initial attacks in an area often occur on stressed or injured trees. Beetles that develop in these trees emerge through small round holes in the trunk and move to other trees in the area.

Trees typically die in a directional pattern from southern pine beetle attack
(Ronald F. Billings, Texas A&M Forest Service, Bugwood.org)

Adults enter trees to lay their eggs, often creating distinctive tunnels or brood chambers. The grub-like larvae bore extensively into the wood feeding on tree tissue or fungi brought to the tree by colonizing individuals. Most bark beetle species in Kentucky attack trees that have been significantly weakened by disease, smog, competition, or physical damage. Extensive tunneling by the larvae can girdle and weaken or eventually kill the tree. Healthy trees have defensive compounds that can kill or injure attacking insects, or simply immobilize and suffocate them with the sticky fluid. However, under outbreak conditions, large numbers of beetles can successfully attack healthy trees with disastrous results for the lumber industry.



Pine bark beetle life cycle (barkbeetles.org)

Some bark beetles (ambrosia beetles) carry a fungus with them that grows within their galleries in the tree. These bark beetle larvae bore in the tree but feed on the fungal growth. The fungal growth clogs the vascular system of the tree and causes death.

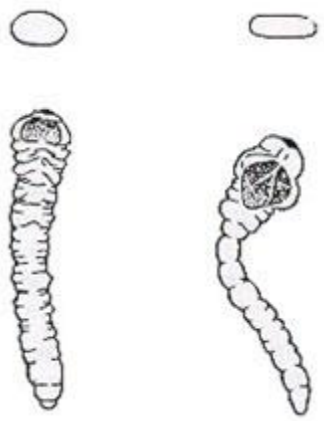

Stained sapwood is an indication of ambrosia beetle attack (entne.dept.ufl.edu)

Good silvicultural practices reduce the potential for bark beetle attack by reducing stress and keeping trees actively growing. When feasible, prompt removal of damaged trees significantly reduces the likelihood of successful bark beetle attacks.

Preventive truck spray to protect against attack by wood boring insects (klyq.com)

Insecticides used in bark beetle control do not penetrate the tree and kill the developing larvae so trees that have been successfully attacked by bark beetles cannot be saved by insecticide applications. However, uninfested high value trees, judged to be at high risk, can be sprayed with an insecticide as a preventative measure against attack. The area of the tree requiring insecticide treatment depends upon the insect species for which the application is being made. The appropriate area of the tree should be thoroughly wetted with the insecticide spray mixture.

Wood Borers



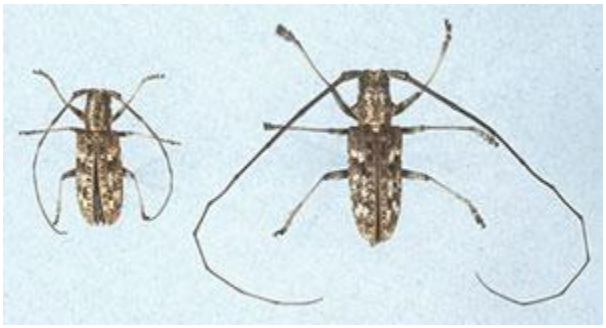
Round headed (left) and flat headed (right) wood borer larvae (extentopubs.tamu.edu)

Roundheaded and flat headed wood borers are mostly beetles, and a few caterpillars, that infest terminals, shoots, twigs and roots of living trees. Terminal and shoot insects are of particular importance in the initial stages of forest regeneration and early stand growth. These insects are very importance in forest nurseries and ornamental trees. Other species in this category damage or destroy trees that would otherwise produce quality lumber or other wood products. Most insects that cause this damage are borers as adults, larvae, or both.

Attack by a carpenterworm, the larva of a moth, typically begins near a wound. (James Solomon, USDA Forest Service, Bugwood.org)

As with bark beetles, most borers are secondary invaders that attack bark and wood of trees that are seriously weakened, dying, or recently cut. Examples include carpenterworms, oak clearwing borers, metallic wood borers, and pine sawyers. Trees attacked by these pests are usually scattered so that most control measures are difficult and not economically feasible. Prevention is the best management practice to reduce losses to wood borers. Keeping trees healthy and vigorous will allow them to fight off invading borers.

Pine Sawyer



Adult male (left) and female (right) of the pine sawyer, a round headed wood borer (www.apsnet.org)

Pine sawyer larva – a round headed borer (northernwoodlands.org)

Pine sawyers develop in fresh cut, felled, dying, or recently dead pines. Young larvae feed on the inner bark, cambium and outer sapwood, forming shallow excavations called surface galleries that they fill with coarse, fibrous borings and frass (insect excrement). They are called "sawyers" because of the noise made while feeding. The beetles can carry the pine wilt nematode.

Two-lined Chestnut Borer

Two-lined chestnut borer adult
(Robert A. Haack, USDA Forest Service, Bugwood.org)

The two-lined chestnut borer is a native insect that attacks stressed trees and can hasten their decline and death. Primary hosts are oaks, chestnuts, and beech. When trees and stands are healthy, it attacks low-vigor trees or broken branches. Drought stress and/or defoliation predisposes trees to attack. Outbreaks can occur following severe stress conditions.

Emerald Ash Borer

Emerald ash borer adult (www2.ca.uky.edu)

Distinctive serpentine gallery of the emerald ash borer (David Cappaert, Bugwood.org)

The emerald ash borer is a dark metallic green beetle about in color, 1/2 inch in length and 1/16 inch wide, that is May until late July. Larvae are creamy white in color and are found under the bark. The borer's host range is limited to species of ash trees. Usually, they go undetected until the trees show symptoms of infestation – typically the upper third of a tree will die back first, followed by the rest the next year. This is often followed by a large number of shoots or sprouts arising below the dead portions of the trunk. The adult beetles typically make a D-shaped exit hole when they emerge. Tissue produced by the tree in response to larval feeding may also cause vertical splits to occur in the bark. Distinct S-shaped tunnels may also be apparent under the bark.

Leaf Feeders or Defoliators

This diverse group of insects, which includes many species of caterpillars, sawflies, and beetles, eats leaves and needles. Trees attacked by defoliators can be recognized by missing foliage and uneaten leaf parts such as veins and petioles. Some members of this group feed within a leaf, mining between the upper and lower epidermis. Correct identification of the leaf feeders gives information needed to assess the problem.

Defoliation reduces photosynthesis, interferes with transpiration and translocation within the tree. Light defoliation normally has little effect on the tree but moderate-to-heavy or repeated defoliation can reduce tree vigor. The impact on a tree varies with time of attack, tree species and health, and single or repeated defoliations.

Sawflies

Several species feed on conifers or deciduous trees in forest and plantation stands. The adults are small broad-waisted wasps. Larvae resemble caterpillars but are usually without hairs and have pairs of fleshy prolegs on the underside of every segment on their abdomen (caterpillars normally have four or fewer pairs). Larvae of the more commonly found sawflies vary from 2/3 to 1 ¼ inches long, are usually greenish to dusky gray, and have conspicuous stripes or spots. Outbreaks occur periodically, sometimes over large areas, and can result in loss of tree growth and sometimes tree mortality.

Redheaded Pine Sawfly

Redheaded pine sawfly larvae (msue.ane.edu)

Redheaded pine sawfly has a red head and a yellow-white body marked with six rows of black spots. The larvae are usually found on trees from 1-15 feet tall, where they feed gregariously on old and new needles and on tender shoots of these young trees.

Introduced Pine Sawfly

Introduced pine sawfly larva
(Steven Katovich, USDA Forest Service, Bugwood.org)

Introduced pine sawfly has a black head and black body covered with yellow and white spots. The larvae prefer to feed on the needles of eastern white pine but also will eat Scotch, red, Austrian, jack, and Swiss mountain pine. Short leaf and Virginia pines have been attacked but usually are not heavily damaged.

Defoliation is most severe in the crown to upper half of the tree but heavily infested trees can be completely defoliated. If this occurs after the winter buds have formed, many branches or even the entire tree can be killed.

There are two generations each year. Larvae of the first generation feed on needles from the previous year. Young sawflies eat the more tender outer parts of the needles while older larvae consume them entirely. They are full-grown (about inch long) in July. The second generation of this sawfly feeds on both old and new needles during August and September. European pine sawfly is a green and black striped larva with a black head. A full grown larva is about 1 inch long. This species can feed on many hosts including Scotch, Eastern white, and Austrian pine. It feeds on the previous year's needles and does not damage new needles.

Caterpillars

Many species of caterpillars feed on deciduous trees in forest and a few feed on conifers. Adults are usually moths but a few are butterflies. Most caterpillars have five pairs of fleshy prolegs – four along the abdomen and one pair at the end. Full grown larvae of the more common caterpillars range from 3/4 inch-long to more than 3 inches. Color and markings are variable. Outbreaks occur periodically, sometimes over large areas, and can result in loss of tree growth and sometimes tree mortality.

Common Oak Moth

Common oak moth caterpillar
(M. J. Hatfield, bugguide.net)

The Common oak moth caterpillar is brown with tan to black blotches on the sides; there are diamond-shaped markings and slanted lines on its back. This caterpillar moves in a looping manner and is about 1¼ inches long when mature. There is one generation each year with the caterpillars active from May to June. Common oak caterpillars seem to be able to feed on many kinds of oaks but prefer white oaks. In many cases, trees can be severely or completely defoliated. While a single defoliation should not adversely affect established, healthy trees, previous droughts or other stresses can increase the impact of this damage.

Eastern Tent Caterpillar

Eastern tent caterpillars
(P. Shrewsbury, University of Maryland, extension.umd.edu)

The Eastern tent caterpillar feeds on trees in the genus *Prunus;* black cherry is the preferred host. The hairy larvae are black with a white stripe down the center of the back. A row of pale blue spots along each side is bordered by yellowish orange lines. Full-grown larvae are about 2 ½ inches long. Defoliated trees normally leaf back out and suffer only minor growth loss.

Forest Tent Caterpillar

Forest tent caterpillars
(James Solomon, USDA Forest Service, Bugwood.org)

Forest tent caterpillars are very similar to eastern tent caterpillars but have a row of light keyhole-shaped spots down the center of the back rather than a stripe. They feed on a wide range of trees including sweetgum, oak, birch, ash, maple, elm and basswood. Like the eastern tent caterpillar, there is one generation in the spring.

Fall Webworm

Fall webworm (waldeneffect.org)

Fall webworm is a hairy pale green to yellow caterpillar that is about one inch long when full grown. There are two or generations per year. Webworms enclose leaves and small branches in light gray, silken webs. They feed on more than 100 tree species.

Orangestriped Oakworm

Orangestriped oakworm
(USDA Forest Service-Region8-Southern, USDA Forest Service, Bugwood.org)

Orangestriped oakworm is black with eight narrow yellow stripes along the length of the body. They have a distinctive pair of long, curved "horns" behind the head. They can rapidly strip leaves from small trees but the defoliation usually occurs late in the summer or into the fall, their economic impact is relatively minor.

Pine Webworm

Pine webworm damage
(Robert L. Anderson, USDA Forest Service, Bugwood.org)

Pine webworm larvae are yellowish brown with two dark brown longitudinal stripes on each side. Young 12 larvae mine needles, while older larvae live in silken tubes that extend through webs of globular masses of

brown, coarse frass. These webbing masses enclose the needles upon which the larvae feed. At first, the webbing masses may be only one or two inches long. The webbing mass may contain several larvae and increases in size as the larvae mature. Seedlings up to two feet tall can be completely defoliated. Infestations on larger trees can cause partial defoliation resulting in loss of growth and poor tree appearance.

Potential Problem Species

Gypsy Moth

Gypsy moth larva
(Jon Yuschock, Bugwood.org)

Gypsy moth female with egg mass
(William M. Ciesla, Forest Health Management International, Bugwood.org)

The gypsy moth is established in Ohio, West Virginia, Virginia, and Tennessee. Older larvae have yellow markings on the head, a brownish-gray body with tufts of hair on each segment, and a double row of five pairs of blue spots followed by a double row of six pairs of red spots on the back. Moths are harmless, but the caterpillars from which they develop are voracious leaf feeders of forest, shade, ornamental and fruit trees and shrubs. Large numbers of caterpillars can completely defoliate an area. A single defoliation can kill some softwoods, but it usually takes two or more defoliations to kill hardwoods.

Hemlock Woolly Adelgid

Hemlock woolly adelgid cottony egg sacs (nps.gov)

Established infestations of the hemlock woolly adelgid (HWA) were discovered at specific locations in Harlan, Letcher, and Bell counties in 2006. This native of Asia is a 1/32 inch long reddish purple insect that lives within its own protective coating. White, woolly masses that shelter these sap-feeding insects are at the bases of hemlock needles along infested branches. The presence of these white sacs, which resemble tiny cotton balls, indicate that a tree is infested.

HWA is a threat to eastern hemlock forests, and eastern and Carolina hemlock of all sizes are susceptible. Kentucky has a significant hemlock component throughout its eastern forests, all of which could become infested. In addition, ornamental plantings in urban settings are equally susceptible. HWA feeding reduces new shoot growth, and causes grayish-green foliage, premature needle drop, thinned crowns, branch tip dieback, and eventual tree death.

Asian Longhorned Beetle

Asian longhorned beetle (J. Boggs, The Ohio State University)

If a pencil can be inserted into an exit hole, it is a good indication that the hole was made by a cerambycid beetle (like the ALB) because the larvae feed deep in the xylem. (J. Boggs, The Ohio State University)

Asian longhorned beetle (ALB) is an invasive insect that feeds on a wide variety of trees in the US, eventually killing them. The beetle is native to China and the Korean Peninsula and is in the wood-boring beetle was discovered in Ohio in June 2011. Known hosts include trees in the following genera Ash (*Fraxinus*), Birch *(Betula*), Elm (*Ulmus*), Golden raintree *(Koelreuteria*), London planetree/ sycamore (*Platanus*), Maple (*Acer*), Horsechestnut/buckeye (*Aesculus*), Katsura (*Cercidiphyllum*), Mimosa (*Albizia*), Mountain ash (*Sorbus*), Poplar (*Populus*), and Willow (*Salix*).

Insecticides for Forest Pest Control

Insecticide applications are rarely practical against forest insect pests. However, they may be useful in specific situations, such as limited infestations of an invasive species. Insecticidal soaps, horticultural oils, Bt-insecticides, and systemics are common choices because they have very low potential to harm the environment, non-target species, and applicators.

Insecticidal soaps are made from of salts of fatty acids. When sprayed directly on vulnerable stages of softbodied insects, such as aphids and adelgids, they kill by damaging individual cells. However, they are not very effective against stages of the life cycle that are inactive or hidden, or against larger insects such as caterpillars and beetles.

Spraying insecticidal soap to control hemlock woolly adelgid (archive.knoxnews.com)

Insecticidal soap sprays must come into direct contact with the target pest and often results are best against specific life stages. Timing and thorough spray coverage are essential for best results. If the vulnerable stage is active over a long period of time, several applications are needed to control most insects.

Do not apply insecticidal soaps directly to water or use near a water source. **Hard water is not effective for mixing soap sprays, so use softened or distilled water for best results.** Tender young growth of evergreens and shrubs in the spring can be sensitive to insecticidal soaps. Insecticide applications are rarely practical against forest insect pests. However, they may be useful in specific situations, such as limited infestations of an invasive species. Insecticidal soaps, horticultural oils, Bt-insecticides, and systemics are common choices because they have very low potential to harm the environment, non-target species, and applicators.

Bt insecticides (*Bacillus thuringiensis*) are protein toxins that are produced by a common soil bacterium. Many provide specific control of caterpillars without affecting other types of insects (beetles, sawflies, etc.). Bt insecticides disrupt the gut wall cells in the caterpillar digestive tract so a formulation of the insecticide must be sprayed on foliage that will be eaten by the caterpillars. Caterpillars stop feeding soon after eating the insecticide but usually do not die for several days. Bt insecticides work best against young caterpillars that are less than half-grown. These insecticides are relatively non-toxic to mammals and other animals.

Imidacloprid is the common name of a systemic insecticide that is used to control sap-feeding insects, such as the hemlock woolly adelgid. It is a nerve poison but it is much more toxic to insects than to warm-blooded animals. Imidacloprid can be diluted in water and applied as a drench poured around the base of a tree, or injected into the soil. The insecticide is taken up by the roots and moved throughout the tree.

References

Brooks, R. Forest Herbicides and their mode of action. U of Idaho CES Tree Planting and Care No. 15. Forest pest control. U Georgia Special Bulletin 16 http://www.bugwood.org/pestcontrol/ Invasive plants of the eastern United States: Identification and Control. http://www.invasive.org/eastern Kentucky Woodlands Magazine Vol 1. SAF.

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Forest Pest Control – Diseases

originally prepared by Jim Newman, Extension Forestry Specialist
updated by Jeff Stringer, Extension Forestry Specialist, and Lee Townsend, Extension Entomologist, University of Kentucky

Diseases

A plant disease usually results in abnormal growth and/or dysfunction of a plant. Living (pathogens) and non-living (environmental) factors are the main reasons that plants cannot function normally. Plant pathogens include fungi, bacteria, and occasionally viruses. Fungal pathogens are most common. They cause seed rots, seedling damping-off, root rots, foliage diseases, cankers, vascular wilts, diebacks, galls and tumors, trunk rots, and decays of aging trees. Abiotic factors, such as unfavorable weather, temperature and moisture extremes, high winds, or ice can damage trees directly and predispose them trees to pest attack.

Common Symptoms

Symptoms are the plant's reaction to the causal agent. Common symptoms include:

- **Blight** – a rapid discoloration and death of twigs, foliage, or flowers.
- **Canker** – Cankers are localized dead areas on the branches, twigs, or trunk of a tree. They can be caused by mechanical damage (especially weed whips and lawn mowers), environmental conditions (frost cracks, sunscald etc.), chemical injury, insects, or microorganisms (fungi and bacteria).

Canker on maple tree (Photo by C. Behrendt, University of Minnesota)

- **Chlorosis or yellowing** – abnormal reduction or loss of the normal green color of leaves. Chlorosis is so generic that diagnosis is impossible without additional details.

Chlorosis (missouribotanicalgarden.org)

- **Decline** – Progressive decrease in plant vigor.
- **Dieback** – Progressive death of shoot, branch, or root starting at the tip.
- **Distortion** – Malformed plant tissue
- **Gall** – Abnormal localized swelling or enlargement of plant part. It could be caused by insects, mites, diseases, or abiotic disorders.
- **Gummosis** – Exudation of gum or sap.

Gummosis is a sticky amber ooze or "gum" (ipm.iastate.edu)

- **Leaf distortion** – The leaf could be twisted, cupped, rolled, or otherwise deformed.
- **Leaf scorch** – Burning along the leaf margin and into the leaf from the margin.

Bacterial leaf scorch (N. Gregory, University of Delaware)

- **Leaf spot** – A spot or lesion on the leaf.
- **Necrosis** – dead tissue – Necrotic areas are also so generic that without additional details diagnosis is impossible.
- **Stunting** – Lack of growth
- **Wilt** – General wilting of the plant or plant part.
- **Witches broom** – Abnormal broom-like growth of many weak shoots.

Witches broom (Whitney Cranshaw, Colorado State University, Bugwood.org)

Signs of Disease

Signs are the actual organisms causing the disease. Signs include:

- **Conks** – Woody reproductive structures of fungi that grow from the trunk or base of a tree.

Artist's Conk (Becca MacDonald, Sault College, Bugwood.org)

- **Fruiting bodies** – Reproductive structures of fungi - mushrooms, puffballs, pycnidia, rusts, or conks.

Black pycnidia of Diplopoda pinea from base of red pine needle (Photo by G. R. Stanosz)

- **Mildew**– Whitish growth produced by fungi composed of mycelium.

Powdery mildew
(Photo by Yuan-Min Sen, Taichung District Agricultural Research and Extension Station, Bugwood.org)

- **Mushrooms** – Fleshy reproductive structures of fungi.
- **Mycelium** – Thread-like vegetative growth of fungi.

Mycelial mats of Armillaria root rot under the bark
(Joseph O'Brian, USDA Forest Service, Bugwood.org)

- **Rhizomorphs** – Shoestring-like fungal threads found under the bark of stressed and dying trees caused by the Armillaria fungi.

Rhizomorphs (atrium.lib.uogurlph.ca)

- **Slime flux or ooze** – A bacterial discharge that oozes out of the plant tissues, may be gooey or a dried mass.

Slime flux on ash (extension.colostate.edu)

- **Spore masses** – Masses of spores, the "seeds" of a fungus.

Fungi

Fungi are **organisms that lack chlorophyll** so they cannot produce their own food. They must obtain it from another source: decaying organic matter or from living plants. **Parasitic fungi are the most common causes of plant diseases.**

A fungus "body" is a branched filamentous structure known as mycelium. One single thread is called a hypha (hyphae, plural). Most fungi reproduce by spores, which are structures that contain little stored food (unlike seed). Spores are the main dispersal mechanism of fungi and can remain dormant until germination conditions are appropriate. Many fungi over-winter as fruiting structures embedded in dead plant tissue.

When a spore comes into contact with a susceptible plant, it will germinate and enter the host if the proper environmental conditions are present. Hyphae develop from the germinated spore and begin to take nutrients

from host plant cells. The hyphae secrete enzymes to aid in the breakdown of organic materials that are ultimately absorbed through their cell walls. Fungi damage plants by killing cells and/or causing plant stress.

Fungi are spread by wind, water, soil, animals, equipment, and in plant material. They enter plants through natural openings such as stomata and lenticels and through wounds from pruning, hail, and other mechanical damage. Fungi can also produce enzymes that break down the cuticle (the outer protective covering of plants). They cause a variety of symptoms including leaf spots, leaf curling, galls, rots, wilts, cankers, and stem and root rots. Fungi are responsible for "damping off" symptoms associated with seedlings.

Bacteria

Bacteria are **single-celled microorganisms that reproduce by dividing into two equal parts. As a result, they multiply and mutate rapidly.** Like fungi, bacteria function as either parasites or saprophytes. Bacteria can infect all plant parts. **Unlike fungi, bacteria must find a natural opening for entry**. Bacterial cells can move from one plant to another in water, soil, and plant material, just as fungi do. However, **bacterial pathogens are more dependent on water. Conditions must be very wet and/or humid for them to cause significant and widespread damage.**

Bacteria move between plant cells and secrete substances that degrade cell walls. Some produce enzymes that break down plant tissue, creating soft rots or water-soaking. Like the fungi, bacteria cause symptoms such as leaf blights and spots, galls, cankers, wilts, and stem rots. Bacterial leaf spots appear different from fungal leaf spots due to their intercellular movement. Veins often limit the development of a lesion, so they appear angular or irregular, not round.

Comparison of Fungal and Bacterial Leaf Spots

		
Symptom Description	**Fungus**	**Bacterium**
Appear water-soaked	No	Yes
Texture	Dry, papery	Slimy, sticky
Smell	No	Yes
Pattern	Circular, target like	Irregular, angular
Color changes	Red, yellow, purple halos	No
Structures	Mycelia, spores, fruiting structures	No

Abiotic Disorders

Abiotic agents of disease are non-living factors such as soil compaction, spring frosts, hail, and mechanical damage to tree trunks. Abiotic agents are noninfectious and non-transmissible. Plant diseases deriving from these agents have been referred to as physiological diseases or environmental diseases.

Water Management

One of the major causes of abiotic plant disorders is **improper water application**. Too much water can be just as damaging as not enough water, as both kill roots. Examples of abiotic disorders related to water are leaf scorch, winter desiccation, and oxygen starvation.

Water stress on trees often shows from the top down.

Leaf Scorch

Symptoms of leaf scorch include **necrosis (browning) of leaf edges and/or between the veins**. These are naturally the least hydrated areas of a deciduous leaf, so when moisture is lost, symptoms appear there first. Scorch symptoms on needled evergreens appear as necrosis from the needle tips downward in a uniform pattern. The initial reaction to these symptoms is to provide more water, but that may only make the problem worse depending on what is causing the scorch.

There are **several causes of leaf scorch**. There may not be enough water in the soil for root absorption. Water may be lost faster than it can be replaced. Warm, windy, and sunny weather during winter months causes rapid transpiration at a time when soil moisture may be frozen. During summer, sunny, hot, and windy weather causes such rapid transpiration that roots cannot physically keep up with the water loss. Soil water may be available but roots may not be functioning properly to absorb it.

What causes roots to function poorly? Soil may be so compacted that roots cannot adequately explore soil for nutrients and moisture. Roots may be severed or otherwise damaged from attack by animal chewing or boring insects. A number of factors can result in more water is lost than can easily be replaced.

Oxygen Starvation

Oxygen starvation occurs when **excess water in the soil drives out oxygen, in effect "suffocating" roots**. Plants respond by dropping the lower leaves that are usually yellowed or necrotic. Leaf loss is most noticeable from the inside of the plant out and the bottom up. In addition, leaves may be smaller than normal, growth increments may be small, and the plant may have an overall unthrifty appearance.

While oxygen starvation causes root damage, the first clue that something is wrong appears on the canopy, stems, and branches. These parts are the furthest from the water source, so the symptoms appear there first. To control problems caused by water management issues, identify the likely causes and correct them if possible. This will require some detective work to determine which factor or (usually) combination of factors is causing the problem.

Weather

Winter desiccation is **caused by dry winter winds that result in leaf water loss**. Water cannot be replaced in the plant because the soil is too cold and roots cannot absorb it. Symptoms of winter desiccation include necrotic leaf or needle tissue (typically from the tips inward), discoloration of needle or leaf tissue, and patchy damage distribution on individual plants in windy locations. Plants may not exhibit symptoms until the following summer when droughty summer conditions ensue.

Winter dehydration on pine shows at needle tips. Roots are still active and can absorb water until soil temperatures drop below 40°F.

Temperature

Temperatures below optimal plant growth cause plant damage. The **amount and type of damage depends on how quickly temperatures drop, the lowest temperature reached, and how long cold temperatures are sustained**. Freeze injury may be caused by frost crystals that form in the freezing water outside of plant tissues or by freezing water inside plant cells. Damage from the latter is much more severe and resembles herbicide phytotoxicity, bacterial blight, and branch flagging due to insect borer activity.

Southwest bark injury on trees is a combination of rapid winter temperature change coupled with winter drought Spring freezes damage exterior buds first, as these are the first to de-harden. Fall freezes affect interior buds first as these are the last to harden. Damage of tissues is uniform. For example, newly developing conifer needles may be killed completely or from the tips inward. Temperatures above optimal growth cause plant damage, as well. The most severe injury occurs on leaves that are exposed to the sun and tissue that is furthest away from water such as outer branch tips, leaf margins, and between leaf veins.

Chemical Injury

Chemical injury is **plant damage caused by pesticides, fertilizers, de-icing salts, and other products**.

Herbicides

Herbicides (weed killers) damage plant tissues by **causing symptoms such as chlorosis, necrosis, distortion, and elongated growth**. Glyphosate, dicamba, and 2,4-D are examples of common herbicides that cause chemical injury to desirable plants when used incorrectly. Herbicides that behave like PGRs (plant growth regulators), such as dicamba and 2,4-D translocate through both the xylem and phloem. They stimulate growth such as cell division, elongation, and fruit and flower production.

Excessive concentrations of these chemicals cause twisting and curling of stems, stem swelling, weakened cell walls, rapid cell growth, and cellular and vascular damage and death. Grasses are not affected by plant growth regulators apparently due to a different arrangement of vascular bundles (xylem and phloem). Glyphosate is an amino acid inhibitor that interferes with synthesis of certain amino acids needed to build proteins. Glyphosate moves through the phloem to the new growth of shoots and roots. Injury symptoms include chlorosis, shortened internodes (compact growth or stunting), stem proliferation, and mimics damage caused by 2,4-D and other plant growth regulators, viruses, phytoplasmas, eriophyid mites, and environmental factors.

Fertilizers

An **excess or shortage of the 17 essential elements required for plant growth and development** may cause plant damage. Excess amounts of fertilizers can "burn" plants due to the level of salts in fertilizers. Symptoms of fertilizer damage include leaf margin necrosis (similar to drought stress in appearance), leaf discoloration, soft rapid growth, and vegetative growth at the expense of flower and fruit production. Nutrient deficiencies include chlorosis, interveinal chlorosis, blossom-end rot, stunting, and purpling.

Symptoms of nutrient excesses and deficiencies may be confused with disease, insect, mite, or other environmental problems. If a soil nutritional problem or salt injury is suspected, have the soil tested. When excess fertilizer has been applied, apply water in an effort to leach salts from the root zone. **Quick release fertilizers are more prone to "burn" plants. Follow label directions when applying fertilizers to avoid plant damage.**

References

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http://www.ext.colostate.edu/mg/Gardennotes/331.pdf