APPLY PESTICIDES CORRECTLY
A GUIDE FOR COMMERCIAL APPLICATORS

RIGHT-OF-WAY PEST CONTROL

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDE PROGRAMS
WASHINGTON, D.C. 20460

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1976

ACKNOWLEDGMENTS

This guide has been developed by Washington State University under U.S. Environmental Protection Agency (EPA) contract number 68–01–2263. This contract was issued by the Training Branch, Operations Division, Office of Pesticide Programs, EPA. The leader of this group effort was Dean G. Swan, Washington State University. Editors were Mary Ann Wamsley, EPA, and Donna M. Vermeire, North Carolina State University.

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PREFACE

Federal regulations establish general and specific standards that you must meet before you can use or supervise the use of certain pesticides. Your State will provide material which you may study to help you meet the *general* standards.

This guide contains basic information to help you meet the *specific* standards for applicators who are engaged in right-of-way weed control. Because the guide was prepared to cover the entire nation, some information important to your State may not be included. The State agency in charge of your training can provide the other materials you should study.

This guide will give you information about:

- types of weeds,
- methods of weed control,
- safe and effective use of herbicides, and
- application equipment.

INTRODUCTION

Rights-of-way are the areas involved in common transport. Included are:

- Federal, State, county, and township highways and roads,
- public airports,
- railroads,
- electric utilities (including transformer stations and substations),
- pipelines (including pumping stations),
- public surface drainage ways,
- public irrigation waterways,
- banks of public bargeways, and
- bicycle, bridle, snowmobile, and other public paths or trails (outside established recreational areas).

Plant growth along the right-of-way must be controlled to make sure that the right-of-way is:

- safe,
- usable,
- attractive,
- as inexpensive as possible to maintain, and
- not harmful to the environment of the surrounding area.

VEGETATION MANAGEMENT

Consider what vegetation already exists along the right-of-way and what may need to be added. Usually grasses should predominate, but some legumes may be desirable. For added beauty and variety, encourage some wildflowers Also consider shrubs with colorful fruit and berries.

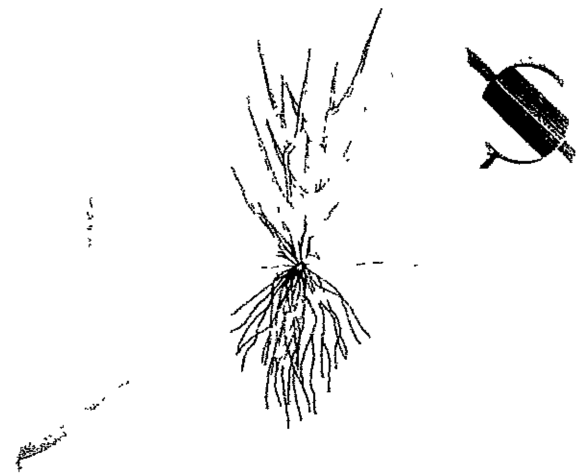
Plants along a right-of-way that can be considered weeds are those which:

- are a safety hazard,
- are a nuisance,
- are unsightly,
- impede the use and maintenance of the right-of-way,
- cause injury to man or animals,
- have been legally declared "noxious",
- crowd out desired plants,
- damage structures such as road surfaces and rail ballast, or
- could harm adjacent crops if allowed to spread.

For weed control purposes, plants may be classed as grasses, broadleafed, or woody plants.

GRASSES

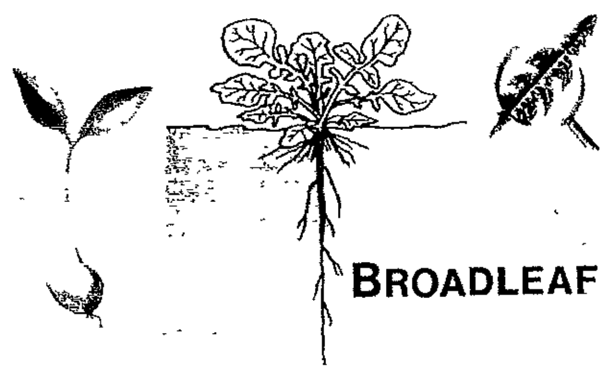
Young grass seedlings have one leaf coming from the seed. Grass leaves are generally narrow, upright, and have parallel veins. Many grasses have fibrous root systems.



GRASS

BROADLEAF PLANTS

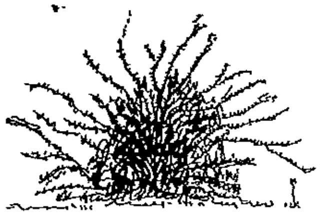
Broadleaf plants have two seed leaves. They generally have broad, net-veined leaves and tap roots or coarse root systems.



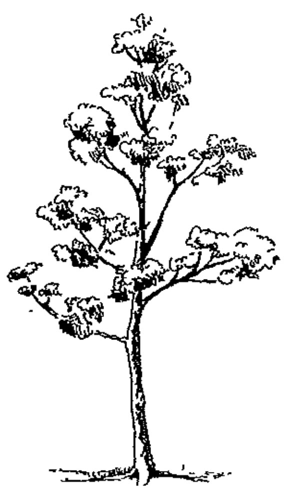
WOODY PLANTS

Woody plants are those that form wood. They include:

- Brush and Shrubs—woody plants that have several stems and are less than 10 feet tall. When trees are present, brush or shrubs may be called understory.



- Trees—woody plants which usually have a single stem (trunk) and are over 10 feet tall.



A plan for controlling plant growth along a right-of-way may include both nonchemical and chemical aspects. All the control methods must be coordinated, since each has an effect on the others.

NONCHEMICAL aspects of the plan might include:
- right-of-way location and design,
- erosion prevention and cover establishment,
- planting and encouraging desirable species,
- utilizing competitive characteristics of desirable plants,
- mowing,
- landscaping,
- equipment allocation, and
- controlled burning

CHEMICAL methods include.
- fertilization, and
- use of herbicides.

TYPES OF HERBICIDES

SELECTIVE HERBICIDES

Selective herbicides kill certain kinds of plants but do not significantly injure others. Weeds must be correctly identified, and the right chemical must be correctly applied at the right time. Use spot treatments wherever possible instead of broadcast applications.

NONSELECTIVE HERBICIDES

Nonselective herbicides kill almost all plants in the area of application. They may leave the soil nonproductive (barren) for a year or more, depending on the chemical and the rate at which it is used. Not all plants react the same way to any one herbicide. Your choice of herbicide and application rate depends on what plant you need to control.

Use nonselective herbicides in areas where bare ground is needed. This type of control may be necessary around substations, pole yards, pumping stations, storage areas, guardrails, signposts, runway lights, parking areas, railroad yards, in railroad ballast, in pavement cracks, and on highway shoulders.

Plants in these areas could be a fire or safety hazard, restrict sight, damage structures, provide a breeding area for rodents and other pests, or reduce security.

The herbicide must be able to:
- kill existing exposed plants, and
- keep others from growing during the desired period of time.

The application should be in a uniform pattern at rates recommended on the label.

Wind, water, and soil erosion can cause herbicides to move sideways after application and before the chemical is fixed in the soil. Be careful to prevent surface movement which could cause damage to desirable plants in adjacent areas. Herbicides seldom move off target when applied to ballast and pavement cracks.

Nonselective herbicides usually should not be applied to slopes greater than 6:1, horizontal to vertical, without protecting the ground from erosion.

The area can be protected by:

- covering it with asphalt or crushed stone, or
- mixing the herbicides with a cut-asphalt and spraying it over the surface.

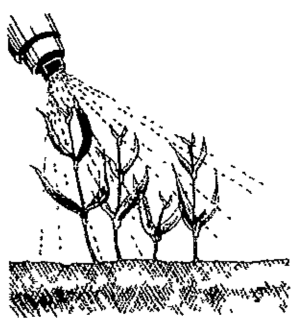
Nonselective soil-applied herbicides kill existing perennial plants slowly. To improve their effectiveness, combine them with contact and/or translocated herbicides. You can mow existing plants closely and remove them before treating the area. Remove plants from around guardrail posts with a shovel. Blading with a grader can also be used.

PLANT GROWTH REGULATORS

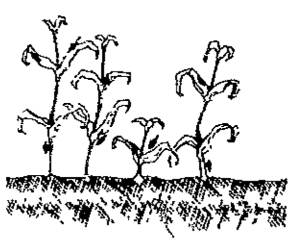
A vegetation cover is sometimes needed where mowing is not practical. In some of these places, you can use growth regulators to slow down plant growth. They act only on the leaves they contact, so they create no hazard from moving off target in the soil. Because they generally do not create bare ground, they help prevent erosion. Use of these chemicals may cause an increase in undesirable plants, however, because not all plants are equally susceptible to them.

CONTACT HERBICIDES

These are herbicides that control weeds by direct contact with plant parts. They must be applied to the leaves. They are sometimes referred to as chemical "mowers". Good coverage is necessary since *only the plant area contacted is controlled.* Most contact herbicides are nonselective.



Spraying of visible plant foliage starts the action of a contact herbicide. A sprayer is usually used to apply herbicide after growth has started

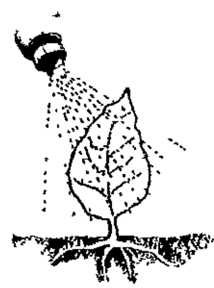


Herbicide is taken into the plant leaves where it interferes with growth The plant begins to curl, wither, and then turn brown.

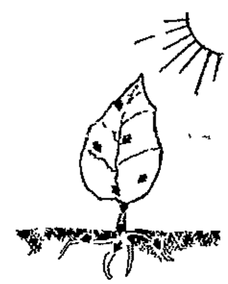
Weed growth above ground is eliminated. Some weeds will not come back. However, some weeds may regrow from roots New weeds may grow from seeds in the soil.

TRANSLOCATED HERBICIDES

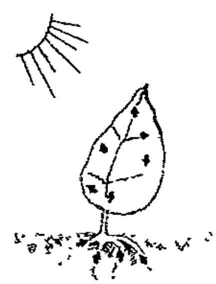
These herbicides move through the entire plant system. They may build up in the plant's active growth centers. Most of these herbicides are selective. Some of them are most effective when applied to the plant foliage.



Spray growing vegetation until wet.



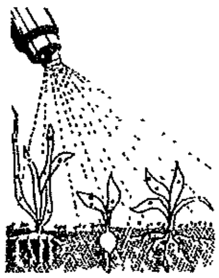
Chemical translocates to growing points and roots



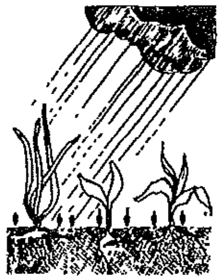
—and throughout the plant

Susceptible plant gradually dies.

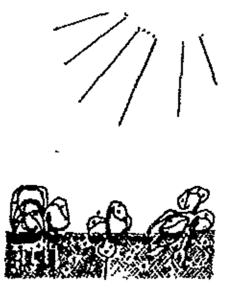
Other translocated herbicides must be applied to the soil. They are taken into the plant through the roots. These are called *soil residual* herbicides The length of time the soil remains relatively weedfree depends upon the chemical used, amount applied, rainfall, soil type, and the plant species in the treated area. Soil residual herbicides that are selective in some situations may be used nonselectively by increasing the rate of application.



Apply to soil and young plants in early spring.



Rain washes herbicide into the soil. It dissolves and is absorbed by the plant.



Herbicide is translocated to growing points. Plant yellows and gradually dies.

Plants die and ground may remain bare for a year or more.

FACTORS AFFECTING CHEMICAL WEED CONTROL

STAGES OF GROWTH

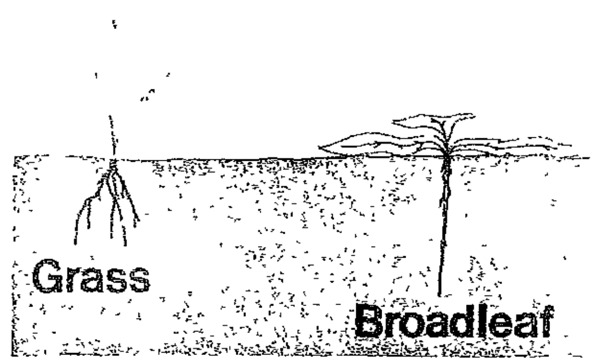
Grasses and broadleaf weeds go through four stages of growth:

- seedling,
- vegetative,
- bud and flowering, and
- maturity.

Seedling

The seedling stage of growth is the same for *annual, biennial, and perennial* weeds. They are all starting from seed. The weeds are small and tender, so less energy is required for control at this stage of growth than at any other stage. This is true whether mechanical or chemical control is used. Herbicides with foliar and/or soil activity are commonly used and usually effective at this stage.

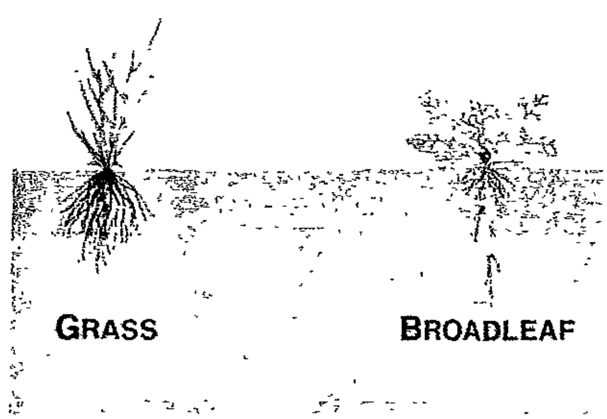
SEEDLING (All)



Vegetative (annuals)

During the vegetative stage of growth, energy produced by the plant goes into the production of stems, leaves, and roots. Control at this stage is still possible but sometimes more difficult than at the *seedling stage of growth. Cultivation, mowing, and* postemergence herbicides are effective controls.

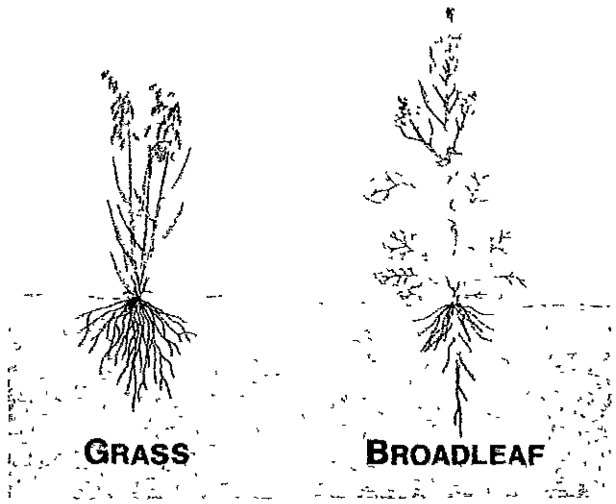
VEGETATIVE (ANNUALS)



Bud and Flowering (annuals)

When a plant changes from the vegetative to the flowering stage of growth, most of its energy goes into the production of seed. As plants reach this more mature stage, they are usually much harder to control by either mechanical or chemical methods.

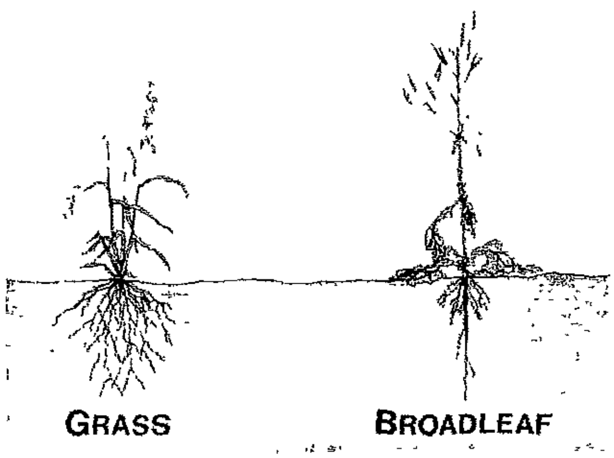
FLOWERING (ANNUALS)



Maturity (annuals)

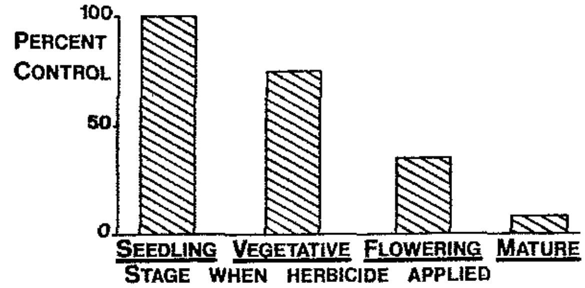
Maturity and seed set of annuals completes the life cycle. Chemical control is usually not effective at this stage since there is little or no movement of materials in the plant. Once the seeds are mature, neither mechanical nor chemical controls can harm them.

MATURITY (ANNUALS)



(Degree of control at any stage will vary according to the species of weed and the herbicide used.)

WEED CONTROL (ANNUALS)



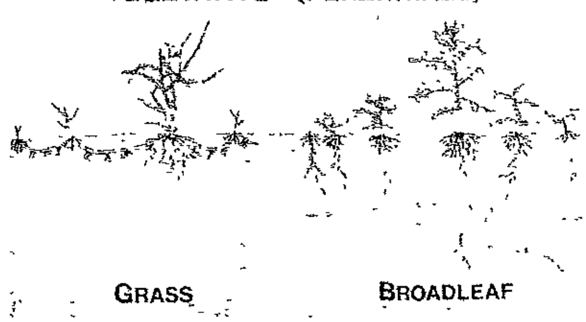
Biennials

Biennals, in two years, go through the same stages as annuals. Control is usually easiest during the seedling stage or when the weeds are still quite small.

Vegetative (perennials)

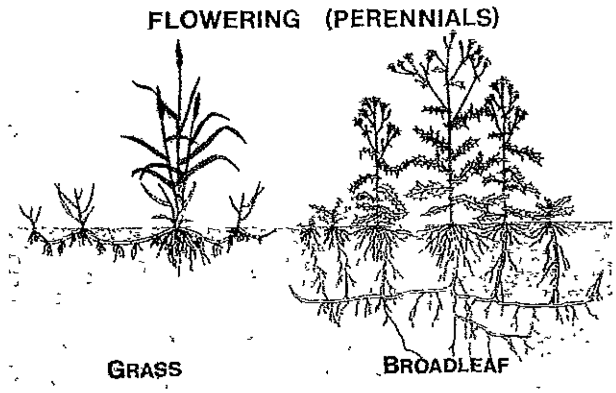
When the plant is small, part of the energy used to produce stems and leaves comes from energy stored in the underground roots and stems. As the plant grows, more energy is produced in the plant leaves. Some of this is moved to the underground parts for growth and storage. Herbicides provide some control at this stage.

VEGETATIVE (PERENNIALS)



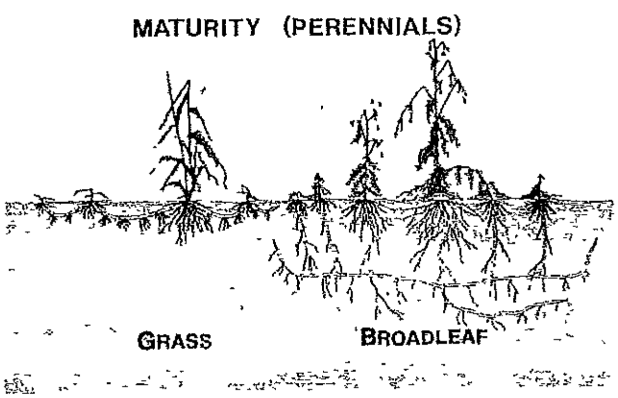
Bud and Flowering (perennials)

At this stage the plant's energy goes into the production of flowers and seeds. Food storage in the roots begins during these stages and continues through maturity. Chemical control is more effective at the bud stage (*just before flowering*).

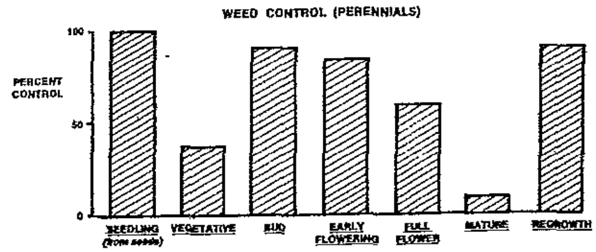


Maturity (perennials)

Only the above-ground portions of these plants die each year. The *underground roots and stems* remain alive through the winter and send up new plant growth the next spring. Chemical control is usually ineffective at this stage.



(Degree of control at any stage will vary according to the species of weed and the herbicide use.)



Woody Plants

Woody *plants go through the same four growth* stages as other perennial plants. They do not die back to the ground during the winter, but many kinds lose their foliage. Woody plants can be controlled with herbicides at any time, but control is easiest when the plants are small. Foliar treatments can be used at any time when the woody plants have actively growing leaves. They usually work best when the leaves are young.

TIME OF YEAR

With a fall application of an herbicide, the target plant must survive three stresses:

- the effects of the herbicide,
- the effects of winter, and
- the heavy demand for nutrients caused by the *rapid growth period in the spring.*

Fall treatments also may be safer for the environment, because many crops and other desirable plants have completed their growth.

Perennial weeds that have regrown after being controlled by chemical or mechanical methods should be treated in the fall At that time, herbicides reach underground plant parts through the natural translocation activity of the plant. Before the first killing frost, nutrients move from the above-ground parts of the plants to be stored over winter in the underground parts. Underground parts must be killed to control these weeds.

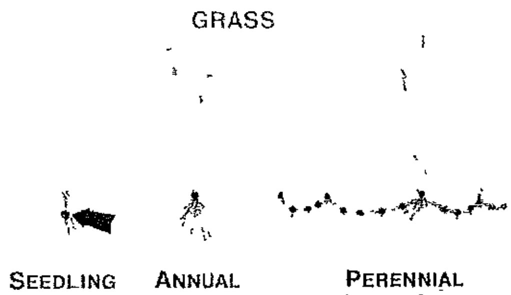
Winter annuals also can be more easily controlled by a fall application of herbicide, because they are seedlings at that time.

Spring treatments will control summer annuals and perennials while they are in the seedling stage. Fall and spring are ideal times to control biennials in the rosette stage. In the fall, translocation is occurring, and in the spring active growth begins again.

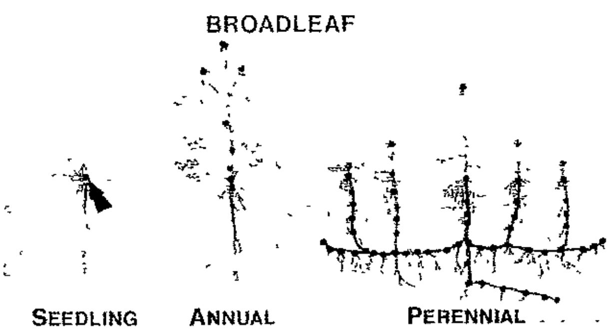
FACTORS AFFECTING FOLIAGE APPLICATION

Location of Growth Points

GRASS—The growing point of a seedling grass is protected below the soil surface. The plant will grow back if the herbicide or cultivation does not reach the growing point. Creeping perennial grasses have buds below the soil surface.



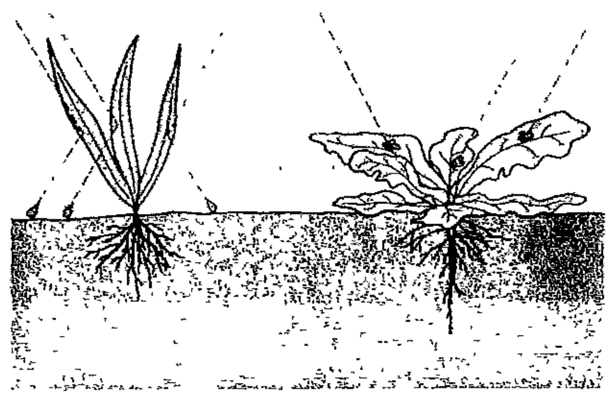
BROADLEAF—Seedling broadleaf weeds have an exposed growing point at the top of the young plant. They also have growing points in the leaf axils. Herbicides and cultivation can reach these points easily. The established perennial broadleaf plant is hard to control because of the many buds on the creeping roots and stems.



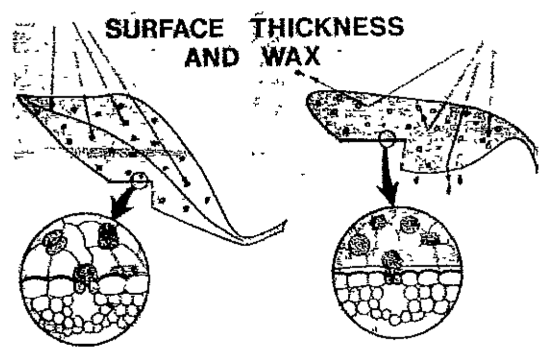
WOODY—Many woody plants, either cut or uncut, will sprout from the base or roots.

Herbicide Entrance Into the Weed

LEAF SHAPE—Herbicide sprays tend to bounce or run off of plants with narrow vertical leaves. Broadleaf plants tend to hold the spray. If recommended on the label, add an adjuvant to increase spray retention.

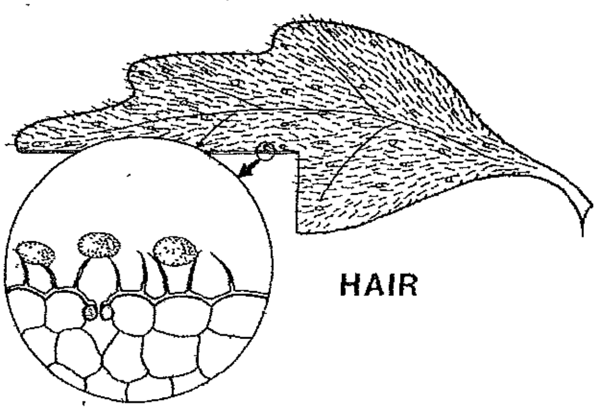


WAX AND CUTICLE—The herbicide must penetrate the leaf surface of the weeds. Thickness of wax and cuticle affect the entrance of an herbicide into a leaf. A leaf with a thin cuticle allows the spray solution good contact with the leaf surface. On a leaf with a thick waxy surface, the spray solution tends to stand up in droplets.



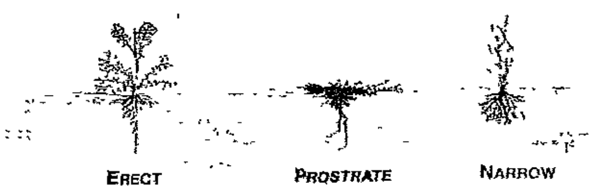
The wax and cuticle are thinner on young weeds. This is another reason for applying herbicides at the early growth stage.

HAIRS—Hairs on the leaf surface tend to keep the spray solution from entering. The droplets stand up on the hair and do not contact the leaf surface.

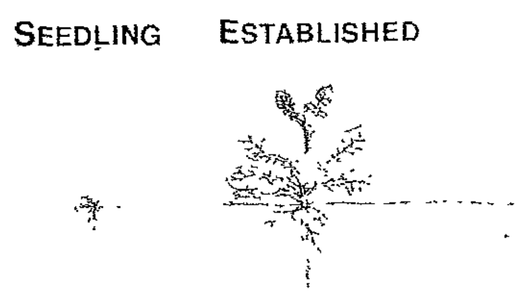


Seedling weeds usually have fewer and shorter hairs. This is another reason for early control.

SPECIES—Species vary in growth habits and susceptibility to herbicides.



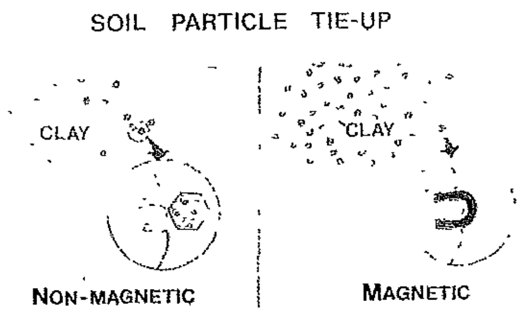
SIZE—Seedling weeds are easier to control than established weeds. Smaller plants, regardless of their stage of growth, are usually easier to control than larger plants.



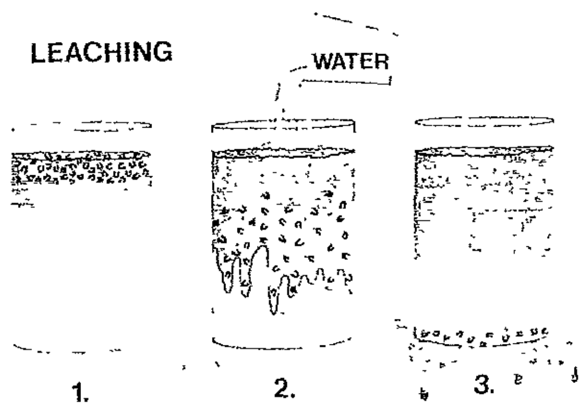
FACTORS AFFECTING SOIL-APPLIED HERBICIDES

Herbicide Characteristics

SOIL PARTICLE TIE-UP—One of the properties of herbicides is magnetism. Some are not magnetic at all; others have strong magnetism. Those without a magnetic charge move down through the soil quickly. Others, with positive magnetic charges, tend to tie-up on the negative charge sites of soil particles.



LEACHING—Leaching is related to herbicide *characteristics and soil factors. Herbicides and soils* vary from nonleachable to completely leachable.



PERSISTENCE—Persistence of an herbicide in the *soil depends on herbicide characteristics, rate of ap*plication, soil texture, organic matter, precipitation, temperature, and surface flow. Herbicides can:

- remain concentrated at the soil surface,
- partially leach (diluting effect), or

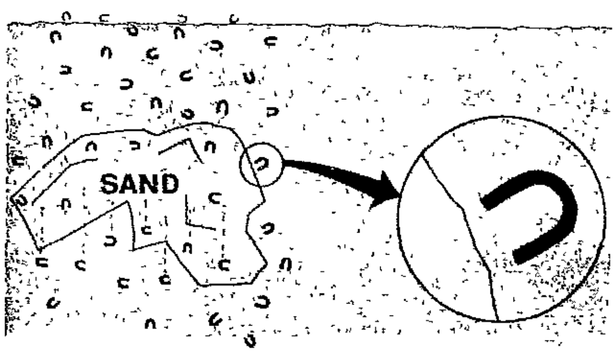
- move through the soil in a front, allowing new weeds to grow above.

Soil Type

Two factors affect the movement of herbicides that are applied to the soil:
- the texture of the soil—how much sand, silt, and clay the soil contains, and
- organic matter in the soil.

TEXTURE—Sand is coarse and does not have many charge sites. The drawing shows a magnified sand particle in the soil. The magnet-shaped particles are herbicide molecules moving down through the soil. The magnified circle shows the herbicide particle moving past the sand surface. It does not tie-up.

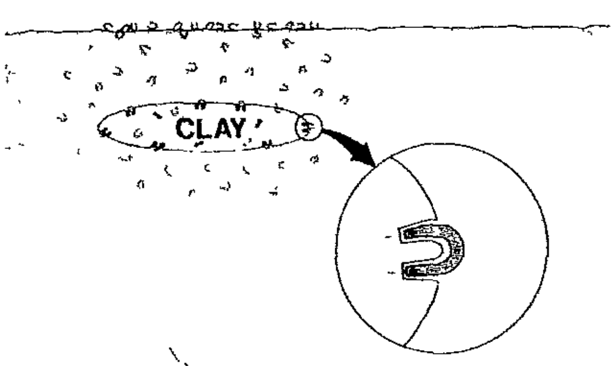
TEXTURE



Silt has more sites than sand, but fewer than clay and organic matter.

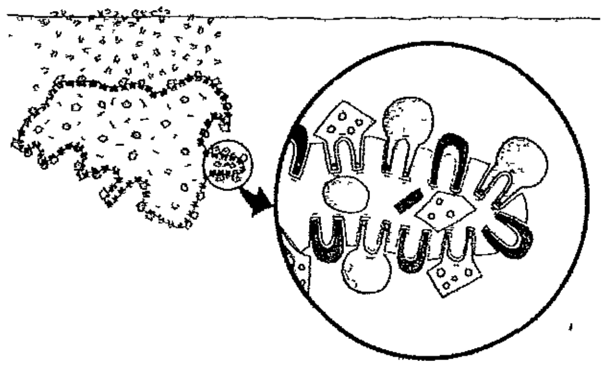
Clay is fine and has many charge sites. The drawing shows a magnified clay particle. The positively charged herbicide particle has fit into the negatively charged slots on the clay particle. It is tied up and will not continue moving through the soil.

TEXTURE



ORGANIC MATTER—Organic matter has many more negative charge sites than even the finest soil particles. The magnified circle in the illustration below shows not only herbicide particles tied up on the organic matter, but also particles of other materials such as water, sodium, calcium, and ammonia.

ORGANIC MATTER



OTHER FACTORS

Soil Moisture

Soil-applied herbicides must be in moist soil to be taken up by plant roots. This requires water in the form of precipitation or irrigation.

Temperature

Temperature generally does not affect weed control results. It may, however, affect the amount of time required for the herbicide to do its job. As temperature increases, the herbicide may work more quickly. In very cold weather, action of the herbicide may be slowed.

Humidity

A foliar-applied herbicide will enter the leaf more easily and rapidly at high humidity than at low humidity. At high humidity, the leaf is more tender and has a thinner layer of wax and cuticle.

Precipitation

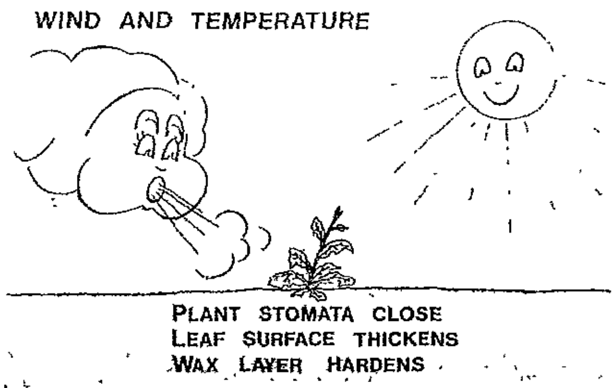
If rainfall occurs soon after a foliar-applied herbicide treatment, it may decrease effectiveness. Rain increases soil moisture so soil-applied herbicides can be more readily absorbed by the weeds. But too much rain may move the herbicide too deep, past the zone where the weeds are. A hard rain may move surface-applied herbicides out of the target area. This is especially true if the soil surface is packed or sloping.

Wind and Temperature

Wind and temperature can also affect the weed. A hot, dry wind will cause:

- the openings on the plant surface to close,
- the leaf surface to become thicker, and
- the wax layer to harden.

These factors make it harder for herbicides to penetrate the leaves.



WOODY PLANT CONTROL

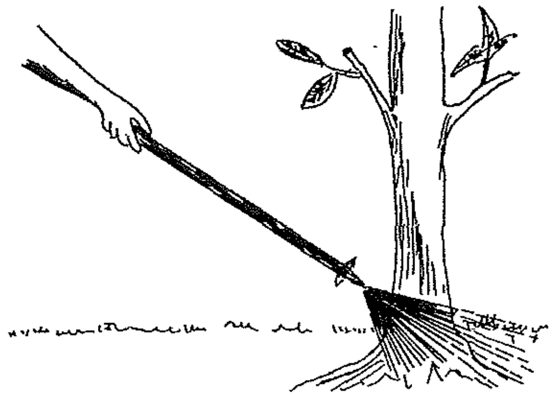
Woody plants may be controlled mechanically or chemically.

FOLIAR SPRAYING

Herbicides are applied to the foliage of woody plants. Spraying woody plants at a young stage of growth is best.

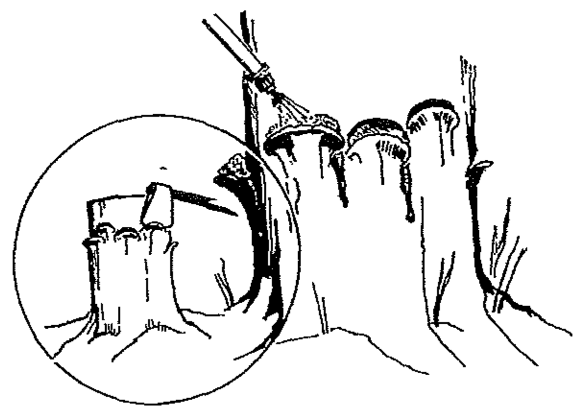
BASAL SPRAYING

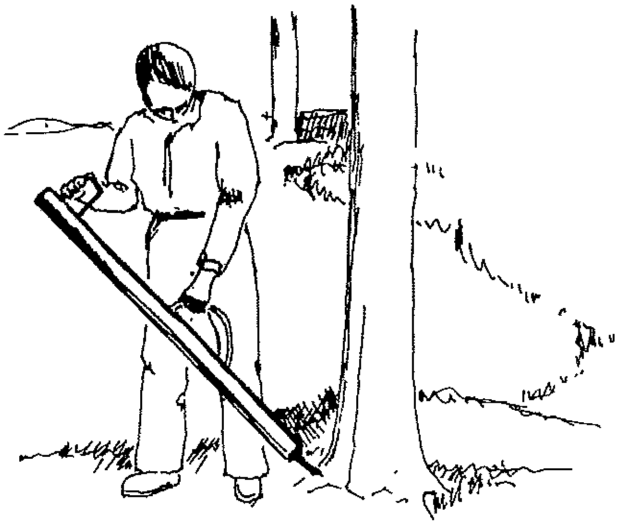
Herbicides are applied in oil to lower parts of stems and exposed roots. It is best to fell large trees and then treat the stumps.



CUT-SURFACE TREATMENT

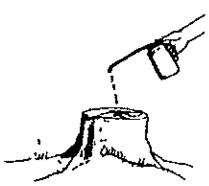
The herbicide can be applied to the sapwood through frill or notches. Another alternative is injection.





STUMP TREATMENT

Close-cut stumps and exposed roots also may be treated with herbicides in oil. It is best to treat immediately after cutting. All sprouts must be treated.



SOIL TREATMENT

Applications are made to the soil around the base of plants. Generally, granular herbicides are used. These must be in moist soil for results to occur.

DRIFT

Be sure that the herbicides you use do not drift to nontarget areas, either within the right-of-way or outside of it.

There are two kinds of drift:

PARTICLE DRIFT—spray droplets which are carried away from the application area by air movement. The distance a particle of herbicide spray can drift is determined by:

- the force of the wind,
- the distance from the spray nozzle to the ground, and
- the size of the particle. The smallest particles, such as those in fog or mist, present the greatest drift hazard.

VAPORIZATION—evaporation of an active ingredient during or after application. The movement of such vapor with wind currents may injure sensitive vegetation. Vaporization is not as common as particle drift, but it has more potential for moving a greater distance.

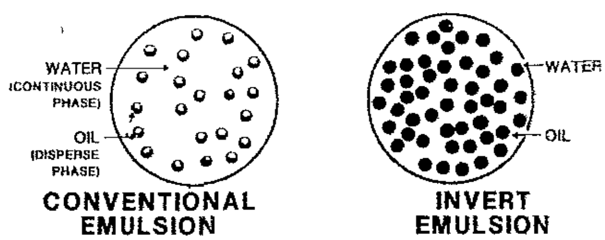
To reduce the chances for drift:

- Use the lowest practical pressures.
- Leave an untreated edge.
- Angle nozzles toward the ground, slightly forward in the direction of travel.
- Use nozzles with the largest practical openings.
- Use low-volatile formulations of the chemicals.
- Spray when wind speed is low.
- Do not spray during a temperature inversion (when air is coolest at ground level, gets warmer up to a certain height, and gets cooler from that point on up).
- Spray when sensitive vegetation is not actively growing.

DRIFT CONTROL AGENT

Special adjuvants and application systems have been developed to help overcome some drift problems. Three of these are:

- foams (tank mixed, conventional formulation with an additive),
- invert emulsions (three systems; mixed at nozzle, mixed at pump, or tank mixed), and



- spray additive stabilizers (thickeners in dry form mixed with conventional formulation in tank with agitation).

Though they differ in method, all three have similar advantages:
- better control of both particle drift and vaporization, and
- more highly visible spray, which allows you to see where you are placing it.

HERBICIDE APPLICATION EQUIPMENT

The equipment used is of two general types:
- airborne equipment, carried either by fixed wing aircraft or by helicopter, and
- ground equipment (including floating equipment on drainage ways, irrigation waterways, and barge-ways).

Both airborne and ground equipment are available for applying:
- conventional sprays (water, oil in water, and oil in oil),
- invert emulsions, and
- granular formulations.

Rights-of-way have many obstacles which make the use of conventional spray booms difficult or impossible. The "manifold" sprayer (usually six nozzles with individual on-off valves, each set for different distances but with adjacent swath patterns) and the "handgun" sprayer nozzle are widely used. You also can get special equipment for applying herbicides to rights-of-way from aircraft.

Much special equipment has been developed for specific right-of-way jobs. It includes equipment for mounting on trucks, trailers, barges, rail vehicles, and all-terrain vehicles. The lack of a full range of well-adapted, readily available equipment for right-of-way spraying is a problem Another difficulty in right-of-way application is the maintenance of a supply base. Because most rights-of-way are long and narrow, the operation continually moves away from its supply base. Return travel time is often excessive. Low application rates with minimum amounts of water or oil carrier make the job faster and more efficient since it reduces the supply runs. Mobile supply units are often needed. One unit, spray and supply combined, may be more efficient.

MANAGING AQUATIC PLANTS

Aquatic weeds are plants which interfere with the use or performance of water areas. They may:
- make the area less attractive,
- interfere with recreation,
- obstruct the flow of water in ditches or canals, and
- harbor insects or rodents.

The first step in control is to identify the general problem. Then you must identify the specific species to be controlled. Cooperative Extension Service personnel, written material, and herbicide manufacturers' representatives can help you.

The basic approaches to aquatic weed control are:
- design and construction of the water area,
- operation and maintenance,
- mechanical control, and
- chemical control.

The best control method is that which gives safe, effective weed control while causing the least harm to other parts of the environment.

CHEMICAL CONTROL

The use of herbicides to control weeds in water areas is often very effective. Use the herbicides as the label directs.

As you analyze any aquatic weed problem, consider the following:

BIOLOGICAL ASPECTS:
- Identify the problem species.
- Identify other species present.
- Determine the density and stage of growth of the weeds, and how much area they cover.
- Determine what species of fish are present.

WATER USE ASPECTS:
- Know the uses of the water in the treatment area.
- Find out how long the water can be quarantined from each use.
- Know how much water leaves the treatment area and what it will be used for.

PHYSICAL ASPECTS:
- Determine the size of the area to be treated.
- Determine the depth and movement of the water.
- Note the clarity of the water.
- Determine the water temperature.
- Determine the water quality.

RECORDKEEPING

Keep detailed records of control measures so that evaluations can be made of previous activity in order to improve future control and to be able to have accurate information in case of outside liability actions.

Such records may include:
- areas treated and date,
- material and rate applied,
- environmental conditions,
- equipment and crew,
- evaluation of effectiveness,
- problems encountered, and
- damage claims.

GPO 906-286

Table 1. General herbicide translocation patterns. (All can vary with species)

WHEN APPLIED TO FOLIAGE	WHEN APPLIED TO SOIL
1. Move in phloem and xylem	1. Move readily in xylem
amitrole	amitrole
asulam	asulam
chlorsulfuron	atrazine
2,4-D	bromacil
dalapon	chlorsulfuron
dicamba	dalapon
dichlorprop	dicamba
fluazifop-butyl	diuron
fosamine	hexazinone
glyphosate	picloram
MSMA	prometon
picloram	pronamide
sethoxydim	simazinee
sulfometuron-methyl	sulfometuron-methyl
triclopyr	tebuthiuron
	triclopyr
2. Move only in xylem	2. Movement in xylem restricted
atrazine	2,4-D
bromacil	
diuron	
hexazinone	
simazine	
sodium chlorate	
3. Little or no movement	3. Little or no movement
acifluorfen	bifenox
bifenox	DCPA
cacodylic acid	oryzalin
diquat	oxadiazon
oxadiazon	oxyfluorfen
oxyfluorfen	trifluralin
paraquat	

Factors Affecting Chemical Weed Control

PLANT FACTORS

PLANT TYPES

Most plants are either 1) grasses or 2) broadleaves. Broadleaf plants include herbaceous forbs and many woody plants. The sedges, such as the nutsedges, are neither grasses nor broadleaves. However, they have similar characteristics to grasses and are often listed under grasses on the herbicide label.

Grasses. Grass seedlings have only one leaf as they emerge from the [illegible]d. Their leaves are generally narrow and upright with parallel veins. Most grasses have fibrous root system. The growing point on seedling grasses is sheathed and located below the soil surface. The growing point gradually moves above the soil as the plant grows and matures. Examples: Bermudagrass, *foxtail, Johnsongrass, quackgrass.*

Broadleaves (Forbs). Herbaceous (plants that do not develop persistent woody tissue above ground) broadleaf seedlings have two leaves as they emerge from the seed. Their leaves are generally broad with net-like veins. Broadleaves usually have a taproot and a relatively coarse *root system. All actively growing broadleaf plants have exposed growing points at the end of* each stem and in each leaf axil. Examples: dandelion, mullein, pigweed, plantain, ragweed.

Woody Plants. Woody plants are those that form wood. They include brush and shrubs, and trees. Brush and shrubs are woody plants that have several stems and are less than 10 feet tall. When trees are present, brush or shrubs may be called understory. Trees are woody plants which usually have a single stem (trunk) and are over 10 feet tall. Examples: hickories, oaks, pines.

PLANT LIFE CYCLES

A plant's life cycle is either annual, biennial or perennial.

Annuals. Annuals complete all stages of development in less than 12 months. There are two distinct kinds of annuals: winter annuals and summer annuals.

Winter annuals germinate in the fall, overwinter, mature, set seed, and die in the spring. Examples: bedstraw, cheat, downy brome, henbit, little barley, pepperweed, wild mustard.

Summer annuals germinate in the spring, grow, set seed, and die in the fall. Examples: common ragweed, crabgrass, foxtail, giant ragweed, marijuana, partridge pea, pigweed.

Some weeds are specifically winter or summer annuals. Others can germinate and grow in either the fall or spring. Knowing the growth habits of annuals is important in planning how and when to control.

Biennials. Biennials complete their life cycle in two years. Biennial plants complete the seedling and vegetative (rosette) stages of growth the first year and the seed production and maturity stages in the second. Some herbicide labels identify biennials as annuals. Examples: bull thistle, common evening primrose, common burdock, common mullein, teasel, wild carrot, wild parsnip.

Perennials. Perennials may complete all four stages in the first year and then repeat the vegetative, seed production, and maturity stages for several years following, or the seed production and maturity sages may be delayed for several years. Some perennial plants die back in the maturity stage each winter; others, such as trees, may lose their leaves but do not die back to the ground. They all reproduce by seed but many are able to spread and reproduce vegetatively. *Perennials are difficult to control due to the persistent root system.*

Perennials can be divided into three general groups, depending upon how they reproduce.

Simple perennials spread by seed, crown buds, and cut root segments. Most have a large, *fleshy taproot. Examples: chicory, curly dock, dandelion, goldenrod,* buckhorn plantain, spiderwort, white heath aster, white oak.

Creeping perennials spread vegetatively with stolons (horizontal stems running on the soil surface; usually rooting at the joints) or rhizomes (underground horizontal stems modified for food storage and asexual reproduction) as well as by seed. Examples: Bermudagrass, Canada thistle, common milkweed, hemp dogbane, horsenettle, horsetail, Japanese honeysuckle, Johnsongrass, poison ivy, quackgrass, Virginia creeper, yellow toadflax.

Bulbous perennials reproduce vegetatively from underground bulbs or tubers, and also produce seed. Example: wild garlic.

DEVELOPMENTAL STAGES

All plants have four stages of development:

1) *Seedling* -- small, vulnerable plantlets; seed leaves still present; seed leaves lost, true leaves present

2) *Vegetative* -- rapid growth of stems, roots, and foliage; rapid uptake of water and nutrients

3) *Seed production* -- little or no growth; production of fruit; slow uptake and movement of water and nutrients directed mainly to reproductive parts -- flowers, fruits and seeds

4) *Maturity* -- little or no growth; slow movement of water and nutrients in plant

All weeds are most easily controlled at the seedling stage regardless of life cycle. As annual plants mature they tend to be more difficult to control. Biennials are best controlled at the seedling or rosette stage. Contact herbicides may not be effective at the rosette stage, but foliage-absorbed translocated herbicides should be effective. Many biennials become less sensitive to herbicides after they produce a flowering stalk. Perennial plants are also best controlled while seedlings. If a plant has become established and is truly perennial in nature, contact herbicides provide only temporary suppression. Phloem transported herbicides are most effective if applied when carbohydrate flow has been diverted from new vegetative growth to replenishing depleted root reserves.

LOCATION OF GROWING POINTS

Seedling grass has its growing point below the soil surface. Control is difficult when the growing point is protected in this manner and the herbicide does not move in the phloem. If a herbicide does not reach the growing point, the plant may regenerate. Creeping perennial grasses have protected buds below the soil surface.

Seedling broadleaf weeds have an exposed growing point at the top of the young plant. They also have growing points in the leaf axils. Perennial broadleaf plants are difficult to control because of the many protected buds on the creeping roots and stems.

LEAF SHAPE

The shape of the leaf can be important to the effectiveness of an herbicide. When applied to a plant with narrow vertical leaves, the herbicide spray solution tends to bounce or run off. On the other hand, a vertical leaf can direct the chemical downward into the growing point. A broadleaf plant with flat, wide leaves tends to retain the spray solution. Retention of spray solution is important if the herbicide is a contact or must be absorbed through the foliage.

LEAF SURFACE (WAX AND CUTICLE) AND HAIRS

It is important for foliage-absorbed (postemergence) herbicides to penetrate the leaf surface. Thickness of wax and cuticle affect the entrance of a herbicide into the leaf. When applied to a leaf with a thin cuticle, the spray solution makes good contact with the leaf surface. However, on a leaf with a thick, waxy surface, the spray solution tends to stand up in droplets, resulting in poor leaf contact. Wax and cuticle are less thick on young weeds. Best results are obtained by treating with herbicides at the early growth stage.

Some weeds are hairless; others have many and varied hairs. Generally, there are fewer and shorter hairs on seedling weeds compared with the older stages of growth, another reason for early control. When applied to a weed leaf with hair on the surface, spray droplets tend to stand up on the hair and do not contact the leaf surface. Sparse hairs tend to hold the herbicide in contact with the leaf surface for longer periods of time.

SPECIES

Species vary in growth habits and in susceptibility to herbicides. Generally, vegetation can be categorized as grasses, broadleaved weeds and woody vines or brush. Programming around such broad categories can be beneficial because the herbicides selected are those reasonably effective on the predominant species. Species resistant to the herbicide(s) being used become better established from continued use of the same treatment as the susceptible species are eliminated.

SIZE

Seedling weeds are easier to control than established weeds. Smaller plants, regardless of their stage of growth, are usually easier to control than larger plants.

CLIMATIC FACTORS

RELATIVE HUMIDITY

A foliar-applied herbicide will enter the leaf more easily and rapidly at high than at low relative humidity. At high relative humidity, the weed leaf is more succulent, perhaps has less of a wax layer and a thinner cuticle, and the cuticular components are hydrated with molecules of water. Herbicides work best when plants are actively growing. High relative humidity and optimum temperature usually enhance active growth.

LIGHT

Light is of obvious importance to the plant for photosynthesis. The seed of herbicide activity may be altered by presence or absence of light. However, operationally, light is an uncontrolled factor. Light may break down some herbicides if they remain on the soil or plant surface for a long time.

PRECIPITATION

Soil moisture and rain affect the way herbicides work. They also affect how long herbicides stay on soil and plants. Herbicides work best with moderate soil moisture. Soil moisture may keep the herbicide from contacting soil particles. Rain causes soluble herbicides to leach through the soil. Some rain can be beneficial after root-absorbed herbicides have been applied because it carries them down into the soil. Rain during or soon after foliar applications may wash herbicides off the leaves and reduce effectiveness.

During drought periods plants usually undergo growth stress conditions, causing most translocated herbicides to perform poorly. Contact herbicides usually do not perform well under drought conditions as the plants produce heavy wax or corky layers of tissue on leaves or stems to protect against excessive transpiration losses. During dry periods herbicides remain in the soil surface until moisture is received to dissolve and carry them into the root zone. Low water solubility compounds are usually used in heavy rainfall areas and higher water soluble materials in arid or semi-arid regions.

WIND

Wind can move spray solution off site as well as move soil-herbicide particles. However, application during a light wind is preferred over no wind. Very fine droplets can remain suspended to be moved off site in an unknown direction when the calm breaks. Applications made in a light wind permit the applicator to make adjustments and allowances for direction of movement. Hot, dry wind may make foliar herbicide penetration more difficult as well as slowing plant physiological processes resulting in less effective herbicide results.

TEMPERATURE

Temperature generally does not affect weed control results. It may, however, affect the amount of time required for the herbicide to do its job. As temperature increases, the herbicide may work more quickly. In very cold weather, action of the herbicide may be slowed. High temperatures enhance herbicide volatility. Warm temperatures create warmer soils with increased microbial activity which reduces the effectiveness of residual, soil-active herbicides.

LENGTH OF GROWING SEASON

Along with soil type and rainfall, length of growing season is an important factor in selecting residual soil active herbicides. Normally, the longer the growing season the more resistant is the vegetation. This necessitates higher rates to realize a given degree of control. Also, the combination of long growing season and high rainfall results in the leaching of residual chemicals below the root zone, requiring multiple applications.

SOIL FACTORS

SOIL TYPE

Two factors are important to herbicide movement in the soil: 1) texture of the soil (sand, silt, clay), and 2) soil organic matter. Herbicides tend to be adsorbed or tied up in clay soils or organic matter more than in sand or silt. Thus, the soil type and the presence of organic matter can influence the effectiveness of soil-applied herbicides.

Sand has very little ability to hold water or chemicals. Chemicals will leach readily in soils that are high in sand. Silt is comparable to sand in its adsorptive properties.

Clay soils are generally more impenetrable to water and chemicals. Also, because of the small size and high number of particles, they can tie up a sizable percentage of herbicide by adsorption. Usually, the rate of application of soil applied herbicides increases with increasing clay content. Clays vary in their adsorption characteristics. Expanding lattice clays are more adsorptive than nonexpanding clays.

Organic matter content is probably the most important to adsorptive characteristics of soil. It is more active than clay in its ability to tie up most herbicides. It is also a medium for microscopic life. If a herbicide is subject to microbial breakdown, its life in organic soils is usually shortened. Soils with high organic matter content often need higher rates of soil applied herbicides for good weed control.

LEACHING

Leaching is the movement of a herbicide downward or out of the soil as the result of water movement. The amount of leaching that occurs depends on herbicide characteristics and soil factors. Herbicides in soils vary from nonleachable to completely leachable. Herbicides which are water soluble tend to leach more readily. Insoluble herbicides tend to remain at or near the soil surface (Table 2). Herbicides can remain concentrated at the soil surface, partially leach (diluting effect), or move through the soil in a concentrated front. When the herbicide moves through as a concentrated front, new weeds may grow above.

Table 2. Relative movement of herbicides in soil.

1. High movement
   - dalapon
   - dicamba
2. Moderate to high movement
   - amitrole
   - bromacil
   - 2,4-D
   - diphenamid
   - picloram
3. Moderate movement
   - atrazine
   - DCPA
   - hexazinone
   - prometon
   - simazine
   - tebuthiuron
4. Low to moderate movement
   - bifenox
   - dichlobenil
   - diuron
   - napropamide
   - oxadiazon
   - oxyfluorfen
5. Little or no movement
   - diquat
   - glyphosate
   - MSMA
   - oryzalin
   - paraquat
   - trifluralin

PERSISTENCE

Soil persistence can be an important attribute when residual weed control is desired as in forest seedling establishment or industrial total vegetation control. Persistence can be undesirable when it hinders or delays desirable plan establishment. Herbicides vary greatly in their resistance to breakdown and leaching in the soil.

Important environmental factors include soil moisture, rainfall, soil temperature and pH. Soil moisture and temperature are important for microbial degradation. Optimum conditions for microbial activity reduces herbicide persistence. The amount and frequency of rainfall are important influences on leaching and decomposition. Cold, dry conditions increase soil persistence.

Because of the many factors involved, it is not possible to predict the exact time required for given level of herbicide degradation to occur. The following table suggests their relative persistence under similar conditions (Table 3).

Table 3. Relative persistence of herbicides in warm, moist soil at dosages used for selective weed control in crops.

LITTLE OR NO SOIL ACTIVITY
- diquat
- glyphosate
- MSMA
- paraquat

LESS THAN ONE MONTH
- acifluorfen
- 2,4-D
- dalapon
- fluazifop-butyl
- sethoxydim

ONE TO THREE MONTHS
- amitrole
- bifenox
- DCPA
- dicamba
- diuron
- oxadiazon
- oxyfluorfen
- pronamide

THREE TO SIX MONTHS
- atrazine
- dichlobenil
- orzyalin
- simazine
- trifluralin

MORE THAN SIX MONTHS
- bromacil
- hexazinone
- napropamide
- picloram
- prometon
- tebuthiuron

FOREST, RIGHTS-OF-WAY AND INDUSTRIAL HERBICIDES

(FNR-73)
(as of 11/11/87)

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Classification

The use and application of a herbicide depends on characteristics of the active ingredient, including: 1) foliage-absorbed and root-absorbed, 2) contact or translocated, 3) selective or nonselective, and 4) persistent or nonpersistent. Effective weed control can be accomplished by combining the desired characteristics of selected herbicides (assuming no incompatibility or label restrictions).

FOLIAGE-ABSORBED OR ROOT-ABSORBED

Foliage-absorbed herbicides enter the plant through the leaves (postemergence). Root-absorbed herbicides enter the plant through the roots. They are generally most effective when applied before the weeds emerge (preemergence). Root-absorbed herbicides are often applied in combination with a herbicide having postemergence activity. Some herbicides are absorbed by foliage and roots. Herbicide formulation or method of application influences sites of absorption. Examples: (foliage-absorbed) 2,4-D, dicamba, diquat, glyphosate, hexazinone, imazapyr, picloram, triclopyr; (root-absorbed) bromacil, diuron, hexazinone, imazapyr, picloram, prometon, simazine, tebuthiuron.

CONTACT OR TRANSLOCATED (SYSTEMIC)

Contact herbicides kill only the green portion of the plants which they contact. Good coverage is necessary because they do not translocate through the plants. Many contact herbicides are nonselective. They are effective in controlling annual weeds and provide temporary suppression of perennial vegetation. Translocated herbicides move throughout the plant, whether foliar- or root-absorbed. These herbicides are especially useful for controlling perennial weeds because they will move into the roots. Examples: (contact) cacodylic acid, diquat, oxyfluorfen, paraquat; (translocated) amitrole, 2,4-D, dicamba, dichlorprop, diuron, glyphosate, picloram, simazine, tebuthiuron, triclopyr.

SELECTIVE OR NONSELECTIVE

Selective herbicides control only certain types of plants. When applied to mixed vegetation some plant types (species) will be noticeably unaffected. Nonselective herbicides will generally control most weed species. Some herbicides have true physiological selectivity. However, selectivity is most frequently determined by rate of application. Timing and method of application, and herbicide placement can also accomplish selectivity. Examples: (selective) 2,4-D, dicamba, dichlorprop, picloram, triclopyr; (nonselective) amitrole, bromacil, paraquat, tebuthiuron.

PERSISTENT OR NONPERSISTENT

Persistent herbicides remain active in the environment for an extended period of time. Nonpersistent herbicides are relatively short-lived in the environment. The degree of persistence is greatly influenced by temperature, moisture, soil type and rate of application. Persistence is generally used in the context of residual soil activity. Examples: (persistent) bromacil, imazapyr, picloram, sulfometuron methyl, tebuthiuron; (nonpersistent) amitrole, cacodylic acid, 2,4-D, dalapon, diquat, glyphosate, paraquat.

Modes of Action

Growth regulator *– IAA mimic, cupped leaves – grasses are resistant*
- Phenoxy acetic acid
  - 2,4-D (several brand names)
- Phenoxy propionic acid
  - dichlorprop (Weedone 2,4-DP)
- Benzoic acid
  - dicamba (Banvel, Trooper)
- Picolinic acid and related compound
  - picloram (Tordon) *→ Access + Acclaim*
  - triclopyr (Garlon)

Premixes: 2-4D + Dichlorprop, Dicamba, Picloram

Photosynthetic inhibitor *– ~~activates IAA~~*
- Chloro-s-triazine
  - atrazine (AAtrex, Atratol)
  - simazine (Princep)
- Methoxy-s-triazine
  - prometon (Pramitol)
- Other triazine
  - hexazinone (Velpar, Pronone)
- Substituted urea
  - diuron (Karmex)
  - tebuthiuron (Spike)
- Uracil
  - bromacil (Hyvar)

Pigment inhibitor
- amitrole (several brand names)

Free radicals formed during photosynthesis *– contact*
- Bipyridylium compound
  - diquat (Ortho Diquat)
  - paraquat (Gramoxone Super)

Light activated by carotenoids
- Diphenyl ether
  - acifluorfen (Blazer, Tackle)
  - bifenox (Modown)
  - oxyfluorfen (Goal)
- Other
  - oxadiazon (Ronstar)

Mitotic disruptor
- Carbanilate
  - asulam (Asulox)
- Dinbitroaniline
  - oryzalin (Surflan)
  - trifluralin (Treflan)
- Other
  - DCPA (Dacthal)
  - pronamide (Kerb)

Inhibit root growth of germinating seedlings
- diphenamid (Enide)
- napropamide (Devrinol)

Inhibit aromatic amino acid synthesis
- glyphosate (Roundup, Rodeo, Accord)

Inhibit branch chain amino acid synthesis
- Sulfonyl urea
  - chlorsulfuron (Telar)
  - metsulfuron-methyl (Escort)
  - sulfometuron-methyl (Oust)
- Imidazolinone
  - imazapyr (Arsenal)

Inhibit bud development
- fosamine (Krenite)

Miscellaneous (modes of action not clear)
- dalapon (several brand names)
- dichlobenil (Casaron, Norasac)
- sodium borate (several brand names)
- sodium chlorate (several brand names)
- Organic Arsenicals
  - cacodylic acid (several brand names)
  - MSMA (several brand names)
- Grass specific herbicides
  - fluazifop-butyl (Fusilade)
  - sethoxydim (Poast)

Many more products are available. Most of these products are mixtures of the active ingredients above. Pre-mixed and tank mixed combinations offer convenience and utilize the desired characteristics of each component.

Characteristics

Growth regulators (2,4-D, dicamba, dichlorprop, picloram, triclopyr)

* Similarly affect plant growth and appear to act at the same site as the natural plant auxin IAA (indole acetic acid); however, much more active than IAA and applied at much higher rate than the amount of IAA present in the plant

* Distorted growth of plant parts results in disruption of vascular tissue; plant eventually dies, partly due to depletion of food reserve

* Translocated in both the phloem and xylem, therefore will control several perennial weeds; large differences in degree of translocation of different compounds in this group; also, varying translocation of the same compound in different species

* Because of translocation through the plant rather than contact, they are effective when only part of the plant is treated

* Low pressure and low volume sprays as well as wiping applications are possible because of translocation

* Effects on plant growth visible at doses far below the lethal dose; creates a potential problem with spray drift to susceptible crops (grapes, tomatoes, cotton, soybeans, tobacco)

* Quite mobile in soil

* Do not persist long in the soil, with the exception of picloram (low volatility, ... fish toxicity)

* These herbicides available in liquid forms as water soluble salts (amine and mineral salts) and emulsifiable concentrates (EC); influences rate, method and timing of application

* General resistance of grasses to these herbicides

* Low mammalian toxicity

* Some products containing picloram are classified as *Restricted Use* pesticides

Photosynthetic inhibitors (atrazine, bromacil, diuron, hexazinone, prometon, simazine, tebuthiuron)

* Stop photosynthesis rapidly in susceptible plants; in resistant plants, much less and temporary; after a few days cell membranes are damaged with leads to tissue death

* Have no direct effect on root growth

* Move primarily in the xylem; therefore, control perennial weeds only by root applications; atrazine - some foliage activity, surfactants or oils can be added to increase foliar activity; hexazinone has considerable root and foliage activity (except Hexazinone)
  Applied to soil absorbed through roots

* Moderately to highly resistant to movement in soil, but varies with the compound, soil and rainfall

* Varying persistence in the soil from a few weeks o more than two years, depending upon the herbicide, amount applied, climate and soil

* Repeated applications of these herbicides have not resulted in an increase in rate of breakdown in the soil

* Very low mammalian toxicity

Pigment inhibitor (amitrole)

* Very soluble in water
* Translocated in both xylem and phloem and moves throughout the plant
* Interferes with pigment formation in the leaves and new growth becomes almost white
* Persists for several months in some perennial plants and new buds produce white leaves
* Not very selective, all plant species are injured; perennial grasses may exhibit some resistance
* Rapidly inactivated in the soil; usually only as a foliage spray
* Often formulated with ammonium thiocyanate (Amitrol-T) which greatly increases the activity on several perennials due to better translocation
* Very low acute mammalian toxicity
* Classified as a *Restricted Use* pesticide

Free radicals formed during photosynthesis (diquat, paraquat)

* Very soluble in water
* Strong cations - bind in soil rapidly
* Enter the foliage very rapidly (rain after 30 minutes does not affect results)
* Quickly kill plants, usually within 1 or 2 days
* Damage to cell membranes allows cellular components to leak into the intecellular spaces; leaf tissue appears water soaked and tissue death results
* Nonselective, contact herbicides
* More rapid action in the light than in the dark
* Rapid plant death with very little translocation
* Strongly absorbed by soil colloids, especially expanding lattice clays; therefore, little or no activity in the soil
* Mammalian toxicity moderate for diquat and high for paraquat; low fish toxicity for both
* Paraquat is classified as a *Restricted Use* pesticide

Light activated by carotenoids
(acifluorfen, bifenox, oxadiazon, oxyfluorfen)

* Damage to cell membranes kills tissue; leaf tissue appears water-soaked; damage not as rapid as paraquat

[illegible]

* Enter the roots, stems or leaves of young plants
* Little or no translocation in the plant
* Strongly adsorbed by soil organic matter and highly resistant to leaching
* Mammalian toxicity is low

Mitotic disruptors (asulam, DCPA, oryzalin, pronamide, trifluralin)

* Stop the growth of roots and shoots of germinating seeds or small seedlings by disrupting the mitotic sequence
* Established annual and perennial weeds seldom killed
* Translocation occurs primarily in the xylem, if at all; asulam translocated in the phloem and xylem
* Often highly selective between species
* Moderately to highly resistant to leaching in soil
* Very low mammalian toxicity
* Pronamide is classified as a *Restricted Use* pesticide

Inhibit root growth of germinating seedlings
(diphenamid, napropamide)

* Enter the roots and stop root growth of susceptible species
* Roots not in direct contact with the herbicide not affected
* Most effective on annual grasses
* Established annual and perennial weeds not controlled
* Diphenamid moderately mobile in the soil; napropamide is very immobile
* Varying soil persistence from a few to several months
* Low mammalian toxicity

Inhibits aromatic amino acid synthesis (glyphosate) Round-up

* Inhibits synthesis of the amino acids phenylalanine, tyrosine, and tryptophane in plants
* Broad-spectrum, postemergence herbicide; some conifer species resistant while dormant
* Readily *translocated throughout plants*
* Requires a week or more to control annual plants and longer for perennials
* Low spray volumes more effective than higher volumes
* No rapid foliage injury from very *concentrated sprays*

* Increasing control of perennial weeds with age at treatment up to about the flowering stage; late summer to early fall application for woody plant control

* Wiping applications effective

* Essentially no soil activity at normal use rates due to rapid precipitation as iron and aluminum complexes

* Very low toxicity to mammals

Inhibit branch chain amino acid synthesis (chlorsulfuron, imazapyr, metsulfuron-methyl, sulfometuron methyl)

* Inhibit synthesis of the amino acids leucine, isoleucine and valine in plants

* Foliage and root absorbed; foliage application more effective

* Translocate in phloem and xylem

* Imazapyr and sulfometuron methyl provide broad-spectrum control of grass and herbaceous weeds; some grass species selectively at low rates of sulfometuron-methyl; many grasses resistant to chlorsulfuron

* Complete plant kill may take several weeks although plant growth stops soon after application

* All persist in soil with residual soil activity

* Low use rates

* Activity of the sulfonyl urea herbicides enhanced by addition of nonionic surfactant

* Low mammalian toxicity

Inhibits bud development (fosamine)

* Applied to woody plants during the two months before fall coloration

* Little or no apparent effect until the spring following application

* Failure of suspectible woody plants to refoliate; subsequent death

* Complete coverage of all parts of woody plants is necessary for effective control under practical use situations

* Rapidly decomposed by soil microorganisms

* No activity on grass species except at high rates

* Very low mammalian toxicity

Miscellaneous (modes of action not clear)

Grass specific herbicides (fluazifop-butyl, sethoxydim)

* Annual and perennial grasses are controlled with species varying in sensitivity
* Foliage absorbed; little soil activity
* Plants not in the grass family are tolerant
* Low use rates
* Use oil concentrate with these herbicides
* Low mammalian toxicity

dalapon

* Very soluble in water
* Enters plant through either the roots or foliage, but only active in the foliage
* Translocated in both the xylem and phloem
* Applied as foliage spray
* Used primarily to control grasses and cattails
* Not absorbed by soil colloids and leaches readily in all soils
* Normal soil life limited to a few weeks under warm, moist conditions due to leaching and rapid microbial degradation
* Very low mammalian toxicity

sodium borate

* Nonflammable, noncorrosive and nonvolatile
* Usually used in combination with sodium chlorate
* Causes plant desiccation
* Nonselective herbicide
* Used a high rates per acre
* Low mammalian toxicity

sodium chlorate

* Absorbed by roots and foliage
* Nonselective
* Translocates in xylem

* Treated plant foliage and contaminated clothing become highly flammable when spray solution dries
* Usually mixed with sodium borate to reduce fire hazard
* Low mammalian toxicity

organic arsenicals (cacodylic acid, MSMA)

* Both are highly water soluble
* Cacodylic acid is a contact herbicide; movement only in the xylem
* MSMA moves in xylem and phloem
* They inhibit growth in general, inhibit the sprouting of rhizome and tuber buds, and cause aberrant cell division
* Low mammalian toxicity

dichlobenil

* Inhibition of growth of apical growing points and root tips
* Inhibits seed germination of grass and broadleaf plants
* Does not control emerged weeds
* Volatile
* Soil applied; should be incorporated by rain or mechanically

Penetration and Translocation in Plants

To be effective, a herbicide must enter the plant and arrive at the site of action in an active form, in sufficient quantity, and be present long enough to produce its effect.

PENETRATION

Herbicides usually enter the plant through the leaves, the roots, or the seedling shoot before emergence. The above-ground stem may also be an important site of entry in certain cases (i.e., basal bark treatment of trees with herbicide in soil or injection of water soluble herbicides into the tree trunk).

LEAVES

The leaf surface presents many barriers to the entry of herbicides.

Cuticle. This is more easily penetrated by various oils and organic solvents than by water sprays. Water soluble sprays penetrate through aqueous routes thought to consist of pectin strands and hydrated cutin which are most available with adequate soil moisture and high humidity.

Wax. In addition to the wax in the cuticle, many plants have wax deposited on the leaf surfaces making them difficult to wet and reducing penetrability of water sprays. Spray additives and carriers greatly influenced penetration through this barrier.

Stomata. Penetration through stomata is probably of minor significance. Stomata are usually on the under surfaces of the leaves and the degree of opening varies greatly. Both factors reduce the importance of stomata as points of entry.

ROOTS

Entry of herbicides into roots is not as difficult as entry into foliage since no wax layer or well developed cuticle is present in the area of absorption. There may be resistance to absorptivity and differences between species many exist but little is known about this. The major problem with root uptake is getting the herbicide through the soil and into contact with the roots.

SEEDLING SHOOTS BEFORE EMERGENCE

This is an important site of entry for many volatile soil-applied herbicides that are active on germinating seeds or small seedlings. Before emergence, the shoot has a poorly developed cuticle and probably no wax layers, allowing he herbicide to penetrate the shoot more easily.

STEMS

Young stem tissue of herbaceous plants may be penetrated by herbicide solutions in much the same way as leaves. However, stems are not as important as leaves because they have a much smaller surface area. Older stems and even the bark of trees can be penetrated by herbicides applied in oil carriers.

TRANSLOCATION

Once a herbicide has penetrated the leaf cuticle or the root epidermis, there are still many barriers to its movement to the site of action. A number of herbicides are conjugated (chemically bound), absorbed or otherwise inactivated in the roots or leaves and do not move to other parts of the plant. Assuming the herbicide is not immobilized in the leaf or root, it moves in the plant primarily by one or both of two routes (Table 1).

XYLEM

Herbicides that enter the roots or foliage may move upward in the xylem with he transpiration stream. The pattern of xylem movement of a herbicide applied to a leaf is toward the leaf tip only if there is no phloem movement.

PHLOEM

Some herbicides move in the phloem. One of the important features of the growth regulators, as well as amitrole, dalapon and glyphosate, is their ability to be transported in phloem. Herbicides applied to the leaves can be translocated to the roots of perennial plants. Phloem movement is associated with sugar transport and light conditions. Also, it is very important not to kill the leaf and stem tissues rapidly since transport is via living tissue. Rapid foliage kill will result in poor transport and poor root kill. Sometimes repeated doses of a phloem transported herbicide will give better results than a single large dose that kills too rapidly.

Weed and Brush Control Guide
For Forages, Pastures and Noncropland

Kevin W. Bradley and J. Andrew Kendig
Extension Weed Management Specialists

University of Missouri Extension
and Commercial Agriculture Program
Plant Sciences Unit
University of Missouri-Columbia

Guide to brush and woody plant response to herbicides

Woody species \ Herbicide	2,4-D amine (FS)*	2,4-D amine (CS)*	2,4-D ester (FS)*	2, 4-D ester (BS)*	2, 4-D + dicamba (FS)*	Arsenal/Contain (FS)	Banvel (FS)	Crossbow (FS)	Escort /Cimarron (FS)	Garlon/Remedy (FS)	Garlon/Remedy (CS)	Garlon/Remedy (BS)	Glyphosate (FS)*	Glyphosate (CS)*	Hyvar X-L (FS)	Hyvar X-L (ST)	Krenite (FS)	Pathfinder/Remedy RTU(CS)	Pathway (CS)	Spike (ST)	Tordon K/Tordon 22K (FS)	Tordon 101 (FS)	Tordon 101 (CS)	Tordon RTU (CS)	Velpar (ST) + (BS)
Willow	F	G	F	F	F	G	F	G	G	F	F	F	F	F	F	F	F	F	P	F	-	F	F	G	F
Virginia creeper	F	P	P	P	F	G	G	P	G	F	G	P	P	-	G	F	P	-	F	F	F	F	-	F	F
Trumpetcreeper	P	F	P	P	F	G	F	P	P	P	P	P	F	P	P	P	F	P	P	F	P	P	F	F	P
Tree-of-heaven	F	F	F	F	F	P	P	F	P	G	G	G	F	-	F	F	F	G	G	G	G	F	F	F	F
Sweetgum	P	F	P	F	P	G	F	F	P	G	G	G	F	G	F	F	G	G	F	F	P	F	G	-	F
Sumac	F	F	F	F	G	G	F	G	P	G	G	G	F	F	F	F	G	G	P	G	F	F	F	F	F
Sassafras	P	G	P	F	F	G	F	F	P	F	F	F	P	F	P	P	P	F	P	P	F	F	F	F	P
Poplar	F	G	-	F	F	F	-	F	P	F	F	F	F	F	F	F	F	F	P	F	P	F	F	-	F
Poison ivy	P	F	P	F	F	G	F	G	P	G	G	P	F	G	F	F	P	F	P	P	P	P	P	P	F
Pines	P	F	P	F	F	P	G	F	P	G	F	G	P	G	G	G	G	G	G	F	-	G	G	-	P
Persimmon	P	F	P	P	F	F	F	F	P	F	F	F	F	F	P	P	F	F	F	P	G	G	F	G	P
Oaks	P	P	P	P	F	G	F	F	F	G	G	G	G	G	F	F	G	F	F	G	F	F	G	G	G
Multiflora rose	F	F	F	F	G	G	G	F	G	F	F	F	F	P	F	F	F	F	P	G	G	F	F	F	G
Mulberry	P	F	P	P	P	G	P	P	P	F	F	F	P	F	F	F	F	F	P	F	F	F	G	F	F
Maple	P	P	P	P	P	G	P	G	G	F	G	G	F	F	F	F	F	F	F	F	F	F	F	G	F
Locust, black	F	G	F	F	G	P	P	G	F	G	G	F	F	-	P	G	G	-	G	F	G	G	-	F	G
Honeysuckle	P	P	P	G	F	G	F	P	P	F	P	P	F	F	F	P	F	P	F	G	-	G	G	G	P
Honeylocust	P	F	P	P	P	G	P	F	P	F	F	F	P	F	F	F	F	F	F	G	F	G	G	G	G
Hickory	F	F	P	G	P	G	P	F	P	F	F	G	P	F	F	F	P	F	F	F	P	F	G	-	P
Hedge/ Osage orange	P	F	P	F	P	P	P	F	P	F	F	P	P	F	F	F	F	P	P	P	F	F	P	F	F
Hawthorn	F	F	-	F	F	G	F	F	G	F	F	F	F	F	F	F	P	F	F	P	-	P	F	F	P
Greenbrier	P	P	P	F	F	G	P	P	P	P	P	P	P	P	P	P	P	P	P	F	P	F	P	P	P
Elm	F	G	F	F	P	P	F	F	G	F	F	F	F	F	F	F	F	F	F	G	F	F	F	F	F
Eastern red cedar	P	P	P	P	P	P	F	P	P	P	F	F	P	F	F	F	P	P	F	P	P	F	F	G	F
Cherry, black	F	G	F	F	G	G	G	F	G	F	F	G	G	-	G	F	F	F	G	F	F	F	G	G	F
Buckbrush	G	P	G	F	G	P	F	F	F	P	P	P	F	P	F	F	F	P	P	F	P	P	P	P	F
Brambles/blackberry	P	P	P	F	F	P	F	G	G	G	P	G	F	F	F	F	G	G	P	F	F	F	F	F	G
Birch	F	F	-	F	F	P	G	F	P	F	F	G	F	F	F	F	G	F	F	F	-	F	F	G	F
Autumn olive	F	F	F	F	F	G	F	F	P	F	G	G	F	-	-	F	F	G	G	G	G	G	-	-	F
Ash	P	P	P	P	P	G	P	F	G	F	F	G	F	F	F	F	F	F	F	F	P	P	F	F	F

Weed control: G = Good, 80-90%; F = Fair, 60-80%, P = Poor, <60%
* A variety of trade names exist.
FS = foliar spray; CS = cut stump; BS = basal spray; ST = soil treatment

PESTICIDE FACTS

Fact Sheet No. 1

Laundering Pesticide Contaminated Clothing

By Candace L. Bartholomew Extension Agent, Pesticides*

The problem of how to launder pesticide contaminated clothing has puzzled many as pesticide use has become widespread. What is the *best method? What water temperature should be used? Is there a difference in detergent performance? Must you be careful about washing contaminated clothes with other clothing?*

Use the pesticide label as a guide for knowing which chemicals are more toxic. Key words on all pesticide labels identify the toxicity of the product *(Figure 1).*

Key Word	Toxicity	Examples*
DANGER POISON	Highly toxic/ concentrated	Counter Disyston Parathion Furadan Dyfonate Lasso
WARNING	Moderately toxic	Diazinon Glyphosate Phosmet Dicamba
CAUTION	Slightly toxic	Ammate Sevin Atrazine Malathion

*Toxicity of the pesticide may vary depending upon the formulated product. Use the key word as an indication of the toxicity level.

Figure 1

Clothing contaminated with highly toxic and concentrated pesticides must be handled most carefully, as these pesticides are easily absorbed through the skin. If the clothes have been completely saturated with concentrated pesticides, discard them. Clothing contaminated by moderately toxic pesticides *do not warrant such drastic measures.* Hazards are less pronounced in handling clothing exposed to low toxicity pesticides. But...the ease of pesticide removal through laundering does *not* depend on toxicity *level—it depends on the formulation* of the pesticide. For example, 2,4-D amine is easily removed through laundering because it is soluble in water; 2,4-D ester is much more difficult to remove *through laundering.*

Disposable clothing helps limit contamination of clothes because the disposable garments add an extra layer of protection. This is especially important when you are in direct contact with pesticides, such as when mixing and loading pesticides for application.

Laundering Recommendations

Wash contaminated clothing separately from the family wash. Research has shown that pesticide residues are transferred from contaminated clothing to other clothing when they are laundered together. Know when pesticides have been used so all clothing can be properly laundered.

Prerinsing contaminated clothing before washing will help remove pesticide particles from the fabric. Prerinsing can be done by:

1. presoaking in a suitable container prior to washing;
2. prerinsing with agitation in *an automatic washing machine;*
3. spraying/hosing garment(s) outdoors.

Prerinsing is especially effective in dislodging the particles from clothing when a wettable powder pesticide formulation has been used.

Clothing worn while using slightly toxic pesticides may be effectively laundered in one to three machine washings. It is strongly recommended that *multiple* washings be used on clothing contaminated with more toxic or more concentrated pesticides to draw out excess residues. Burn or bury clothing contaminated with concentrated, highly toxic pesticides. Always wear rubber gloves when handling highly contaminated clothing to prevent pesticide absorption into the body.

Washing in hot water removes more pesticide from the clothing than *washing in other water* temperatures. Remember...the hotter, the better. Avoid cold water washing! Although cold water washing might save energy, cold water temperatures are relatively ineffective *in removing pesticides from clothing.*

Laundry detergents, whether phosphate, carbonate, or heavy duty liquids, are similarly effective in removing pesticides from fabric. However, research has shown that

Reviewed by Anita Malone, home economist for New Haven County, and slightly revised by Candace Bartholomew, Agricultural Agent for Tolland County, with permission from The University of Nebraska at Lincoln. The original authors of this fact sheet are: Carol Bryan Easley, Instructor: Textiles, Clothing and Design, John Laughlin, Professor of Textiles, Clothing and Design; Roger Gold, Extension Specialist: Environmental Programs; University of Nebraska at Lincoln.

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heavy duty liquid detergents are more effective than other detergents in removing emulsifiable concentrate pesticide formulations. Emulsifiable concentrate formulations are oil-based and heavy duty liquid detergents are known for oil-removing ability.

Laundry additives, such as bleach or ammonia, do not contribute to removing pesticide residues. Either of these additives may be used, if desired, but caution must be used. *Bleach should never be added to or mixed with ammonia,* because they react together to form a fatal chlorine gas. Be careful—*don't mix ammonia and bleach!*

If several garments have become contaminated, wash only one or two garments in a single load. Wash garments contaminated by the same pesticide(s) together. Launder, using a full water level to allow the water to thoroughly flush the fabric.

During seasons when pesticides are being used daily, clothing exposed to pesticides should be laundered daily. This is especially true with highly toxic or concentrated pesticides. It is much easier to remove pesticides from clothing by daily laundering than attempting to remove residues that have accumulated over a period of time.

Pesticide carry-over to subsequent laundry loads is possible because the washing machine is likely to retain residues which are then released in following laundry loads. It is important to rinse the washing machine with an *empty load*, using hot water and the same detergent, machine settings and cycles used for laundering the contaminated clothing.

Line drying is recommended for these items. Although heat from an automatic dryer might create additional chemical breakdown of pesticide residues, many pesticides break down when exposed to sunlight. This also eliminates the possibility of residues collecting in the dryer.

When Laundering Pesticide Contaminated Clothing...REMEMBER

READ the pesticide *LABEL* for information.

DISPOSABLE PESTICIDE CLOTHING provides extra protection.

PRERINSE clothing by:
- *presoaking in a suitable container;
- *agitating in an atuomatic washing machine;
- *spraying/hosing the garment(s) outdoors.

WASHING machine settings:
Hot water temperature (140o F/60° C), Full water level, Normal (12 minutes) wash cycle.

REWASH the contaminated clothing two or three times, if necessary.

Wash *A FEW* contaminated garments at a time using lots of water.

Wash *SEPARATELY* from *FAMILY* laundry.

DISCARD (bum or bury) clothing if thoroughly saturated or contaminated with highly toxic pesticides.

LAUNDER CLOTHING DAILY when applying pesticide daily.

RINSE MACHINE thoroughly after laundering contaminated clothing.

LINE DRY to avoid contaminating the automatic dryer.

BE AWARE of when pesticides are being used so that clothing can be appropriately laundered.

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PESTICIDE FACTS

Fact Sheet No. 2

Protecting Groundwater From Pesticide Contamination

By Candace L. Bartholomew Extension Agent, Pesticides*

Groundwater is the source of water for wells and springs. It is widely used for household and other water supplies. About half the people in the United States depend on groundwater as a source of drinking water. Ninety percent of them are rural residents.

Groundwater forms when water moves below the earth's surface and fills in empty spaces in and around rocks and soil. In the past few years contamination of groundwater with pesticides has featured prominently in the news media. As a pesticide user it is your responsibility to take any and all precautions necessary to protect groundwater from contamination by pesticides.

Pesticides are usually applied to or near the surface of the ground. Five major factors determine whether they will reach groundwater:

- — the practices followed by the pesticide applicator,
- — the presence (or absence) of surface water from rain or irrigation,
- — the characteristics of the pesticide being used,
- — the type of soil in the area of application,
- — the location of the groundwater
- — the distance from the surface and the type of geological formations above it.

Good application practices include careful attention to the pesticide label. Pesticide labels have been developed to provide instruction on how to use the material for the best control of pests with the least risk of environmental contamination. The proper timing and placement of pesticides are very important.

Mix and calibrate accurately. Avoid the temptation to use more product than the label directs. Overdosing will not do a better job of controlling the pests, it will only increase both the cost of pest control and the chance that the material may reach groundwater. Calibrate equipment carefully and recheck it often. Measure chemical concentrates and diluents accurately.

Avoid spills when mixing and loading. Use a backflow preventer or back-siphoning preventer when drawing mix water directly from a well or a pond.

Dispose of wastes properly. Improper disposal of empty containers, equipment rinse water, or unused chemical can cause localized groundwater problems. Triple-rinse or pressure-rinse containers and pour the rinse water into the spray tank. Leftover product in your spray tank must be disposed of in a manner consistent with the product label. Avoid having leftover tankmix in the first place by mixing only the quantities you need. Do not drain rinse water from equipment into ditches, streams, ponds, lakes or other water sources.

Prolonged heavy rain or excessive irrigation will produce excess surface water. If there is more water on the soil than the soil can hold, the water with pesticides in it is likely to move downward to the groundwater. Use weather forecasts, personal observations and irrigation scheduling to predict when excess surface water may be a problem.

Consider using Integrated Pest Management practices to reduce the amount of pesticides necessary to achieve pest contol.

Agricultural chemicals vary in the potential for moving to groundwater. Three properties of pesticides which may influence such movement are:

Solubility. Chemicals vary greatly in water solubility; the greater the water solubility, the more potential for movement of the product to groundwater.

Soil adsorption. Some chemicals become tightly bound to soil particles and do not move in the soil, some are not so strongly adsorbed, and are more likely to move.

Persistence. Some chemicals break down quickly; other, persistent materials take a long time to break down. The more persistent ones are more likely to reach groundwater over time.

Three major soil characteristics affect chemical movement:

Soil Texture. This is an indication of the proportions of sand, silt, and clay in the soil. Pest control products tend to be adsorbed mostly on clay and organic matter. Coarse, sandy soils generally allow water to move rapidly downward and offer few opportunities for adsorption. Finer textured soils generally allow water to move at much slower rates, and they contain more silt and organic matter to which pesticides and other chemicals may be adsorbed.

Soil Permeability. This is a general measure of how fast water can move downward in a particular soil. The more permeable soils must be carefully managed to prevent any form of chemical from reaching groundwater.

Soil Organic Matter. This influences how much water the soil can hold before movement occurs. Increasing organic matter will increase *the water-holding capacity of the soil.* Some pesticides may also be adsorbed into organic matter.

The distance of groundwater from the surface and permeability of

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geologic layers is another important factor. If the groundwater is within a few feet of the soil surface, and geologic layers are highly permeable, groundwater contamination is more likely to occur than if groundwater occurs at greater depths and below impervious geologic layers.

For more information on Integrated Pest Management Practices contact your local Extension Service. For information on soil types contact your local Soil Conservation Service.

*This information adapted from *Protecting Our Groundwater A Growers Guide*. 1987. American Farm Bureau Federation, National Agricultural Aviation Association, National Agricultural Chemicals Association, U.S. Department of Agriculture, Extension Service.

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