Weed Control on Rights-of-Way

Extension Bulletin 0669
Cooperative Extension
College of Agriculture & Home Economics
Washington State University
Contents

Introduction .................................................................................................................. 3
Classification of Weeds ............................................................................................... 4
Methods of Control .................................................................................................... 6
Selective Vegetation Management ........................................................................... 6
Nonselective Vegetation Control ............................................................................. 9
Classification and Types of Herbicides ................................................................. 10
Herbicide Formulations ........................................................................................... 10
Timing of Herbicides Treatments and Rates ......................................................... 12
Factors Affecting Chemical Weed Control ............................................................ 12
Woody Plant Control ............................................................................................... 19
Drift ........................................................................................................................... 21
Herbicide Application Equipment ......................................................................... 21
Aquatic Vegetation Management on Rights-of-Way ........................................... 22
Operational Procedures and Administration ......................................................... 24
Bibliography ............................................................................................................... 26
Appendix Chart A ...................................................................................................... 26
Appendix Chart B ...................................................................................................... 27

Issued by Washington State University Cooperative Extension, F.L. Poston, Director, and the U.S. Department of Agriculture in furtherance of the Acts of May 8 and June 30, 1914. Extension programs are available to all persons without regard to race, color, or national origin. Revised January 1988. 50¢

Acknowledgment: This publication was developed under an U.S. Environmental Protection Agency contract (No. 68-01-2263). Appreciation is expressed to R.E. Higgins, University of Idaho, and R.J. Burr, Oregon State University, for some of the artwork used.
WEED CONTROL ON RIGHTS-OF-WAY

Introduction

This publication offers administrators, supervisors, and applicators information that can lead to safer use of herbicides and alternative control procedures.

Rights-of-way. Rights-of-way are the areas involved in common transport. They are necessary for the proper functioning and safety of transportation facilities and installations. 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 water ways
- Banks of public barge ways
- Bicycle, bridle, snowmobile, and other public paths or trails (outside established recreational areas)

Rights-of-way go everywhere, and their surfaces are as variable as the country. They encompass every soil type, climate, vegetation complex, land use area, and type of topography.

Vegetation to be controlled or managed. The vegetation management and control problem is diverse, with many regional and localized situations. Undesired vegetation is any plant that is:

- A safety hazard
- A nuisance
- Unnecessarily impedes operational and maintenance activities
- Causes injury to man or animal
- Has been legally declared "noxious"

Has a repressive effect on desired right-of-way vegetation
Causes damage to structures such as road surfaces and rail ballast
If allowed to persist or spread may be detrimental to adjacent crops

Planning requirements. A planned vegetation management program with stated goals and objectives provides a comprehensive, rational approach for control and management of the right-of-way environment. Nature often is capricious and goes off in undesirable directions. The encroachment of woodlands too near highways is an example. Animals crossing may not be seen by the motorist until too late to avoid an accident. Trees may become a visual hazard for drivers leaving or entering the surfaced area.

Another example is when desired vegetation fails to establish while weeds and fireprone species become established. Use of seeding mixtures that contain only grasses which tend to become nitrogen-deficient and weed infested rather than nitrogen-fixing legumes is another example.

Goals of right-of-way vegetation management program. The principal goal is to provide maintenance practices for the right-of-way vegetation that will economically insure the protection, operation, stability, continuance, and safety of the common transport involved.

Other goals of a well-planned vegetation management program are:

- Naturalize the right-of-way to the extent desirable with the adjacent land areas
- Encourage the regeneration of operationally acceptable natural vegetation indigenous to the area
- With the aid of the above two, make the right-of-way appear to be more of a natural entity blended into its landscape
- Reduce maintenance costs

Authors of this publication are D. G. Swan, Extension Weed Scientist, Washington State University; L. E. Foote, Director of Environmental Services, Department of Highways, State of Minnesota; T. M. Evans, Pesticide Sales—E. I. DuPont, Dunwoody, GA; R. L. Berger, Landscape Architect, Department of Highways, State of Washington; W. E. Currie, Training Branch, Environmental Protection Agency, Washington, D. C.
Improve the aesthetics of the facility for all who must view it.
Reduce erosion and water sedimentation.
Provide strips of natural area for wildlife (where the species of wildlife fostered are operationally acceptable).
Provide maintenance practices for:
  1. The right-of-way vegetation appropriate to the topography.
  2. The land use of the property adjacent to that specific portion of the right-of-way.
  3. The vegetation complexes of the regions traversed.

Benefits of a right-of-way management program. Following are some possible benefits:
- Increased public acceptance of the right-of-way facility.
- Less complaints about the right-of-way.
- Improved public relations.
- Reduced maintenance costs.
- Decreased damages to structures and facilities.
- Increased safety.
- Less interruptions to operations.
- Less legal trouble with noxious weed controllers, public action groups, and others.
- Reduced erosion and water pollution.
- Cost planning and control.
- Work load leveling.
- Better utilization of equipment.

Public relations. The shape of most rights-of-way is linear, maximizing the length of edge. The number of adjacent property owners and the probability of having neighbor problems is magnified. Vegetation control operations, if not well contained within the right-of-way property lines, can lead to public relation problems.

Vegetation control operators must know the vegetation management program, operation, goals, and how their work activities relate to the overall program. The what, why, how, where, and when need to be politely explained to the public whenever and wherever the opportunity arises.

Classification of Weeds

It is important to recognize grass and broadleaf plants because they differ in reaction to herbicides, cultural aspects, desirability, and method of control. For weed control purposes, plants are divided into three main categories—grass, broadleaf, and woody.

Grass

Grass plants have one seed leaf. They generally have narrow, upright, parallel veined leaves and fibrous root systems.

Broadleaf

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

Woody Plants

Woody plants include brush, shrubs, and trees. Brush and shrubs are regarded as woody plants that have several stems and are less than 10 feet tall. When trees are present, brush or shrubs may
be understory. Trees usually have a single stem (trunk) and are over 10 feet tall.

Growth Habits

*Annuals* complete their life cycle from seed in less than one year.

**Winter annuals** germinate in the fall, overwinter, mature, set seed, and die in the spring or early summer. For best results, control winter annuals in the seedling stage of growth in fall or early spring.

**Summer annuals** germinate in the spring, make growth, set seed, and die before fall. For best results, control summer annuals soon after germination in the seedling stage of growth.

Some weeds are specifically winter or summer annuals. Other species are adapted and can germinate and grow either in the fall or spring. Knowing the growth habits of annuals is important in planning how and when to control.
**Biennials** complete their life cycle within two years. The first year the plant forms basal leaves (rosette) and a tap root; the second year it flowers, matures, and dies. For best results, control biennial weeds in their first year of growth.

**Perennials** live more than two years and may live almost indefinitely. They reproduce by seed and many are able to spread and reproduce vegetatively. Perennials are difficult to control due to the persistent root system. Do not let seedling perennials become established.

For best results, adapt control of established perennials to the yearly growth cycle of the specific species. Control during the fast growth period prior to flowering or during the regrowth period after fruiting or cutting.

**Simple perennials** spread by seed, crown buds, and cut root segments. Most have large and fleshy tap roots.

**Creeping perennials** spread vegetatively as well as by seed. Grass plants generally have a shallow root system compared to the deep root system of broadleaf plants.

**Grass**

**Broadleaf**

**Bulbs and tubers** reproduce vegetatively from underground bulbs or tubers. Many also produce seed.

**Brush, shrubs, and trees** may spread vegetatively as well as by seed. Woody plants can be controlled at any time of year.

**Methods of Control**

**Biological**

Animals, birds, insects and competing plants are used for biological control. Plant competition is the most successful.

**Mechanical**

Mechanical is the oldest method of weed control. This includes hand-pulling, hoeing, blading, mowing, burning, flooding, cultivation, and other tillage operations. Woody plants may be mowed, chained, bulldozed, or sawed. All these methods are used.

**Chemical**

Herbicides are chemicals that control by changing normal growth or causing plant death.

**Selective Vegetation Management**

**Planned Management**

With stated goals and objectives, planned management provides a comprehensive rational approach to right-of-way vegetation management.

Facilities should be designed for the management of vegetation as well as transport. However, in most cases, transport employees must operate with varying existing right-of-way situations. In
many instances, personnel and nature, together or separately, have done a satisfactory job of managing right-of-way vegetation. In other instances, situations have been created that nature cannot handle in a desirable and timely manner without assistance. This assistance can be supplied by a program of vegetation management.

Principles

Rights-of-way are generally more suitable for management by ecological principles than for management by agronomic principles. Some understanding of the interrelationships of the climate-soil-plant-animal complex is needed.

The vegetation, potential or existing (if any vegetation is to be allowed), should be predominantly grasses, grass-like plants, legumes, forbs (including many wildflowers), or shrubs (including many wild berries or fruits). Rights-of-way include grasslands (native or introduced), savannas, shrublands, deserts, tundra, alpine communities, coastal marshes, wet meadows, and some non-productive areas such as barren rock. Also included is the transition area where forest and open areas meet.

Practices for Vegetation Management

- Right-of-way location
- Right-of-way design
- Erosion prevention and turf establishment
- Planned, controlled, and maintained right-of-way drainage
- Vegetation manipulation
- Fertilization and refertilization
- Mowing (frequency, timing, and type)
- Landscaping
- Selective weed control with the use of herbicides
- Equipment allocation
- Controlled burning

These practices have interrelating effects and have to be coordinated to achieve the goals and objectives of the vegetation management program.

Location and Design

In the development of new transport facilities, it is possible to "stack the deck in your favor," that is, to control the situation and vegetation so
as to obtain what you desire to manage. Directly affected are the costs and difficulties of the future vegetation management and control measures required.

It is possible, with sensitive alignment of the facility and better development practices, to blend the right-of-way with the natural land surface. Alignment should be as directional as possible, consistent with topography.

Corridor and site selection offer an opportunity to place the transport facility in a favorable relationship to topography, drainage ways, soils, other natural features, and present or anticipated man-made features.

Vegetation management and control may be minimized by choosing an alignment that will:

Minimize the number of cut, fill, and cut-fill required
Utilize natural stabilized waterways and channels to divert excess water from transport facility ditches
Conform to the contour and drainage patterns of the area
Make use of natural land barriers and contours to a) divert runoff b) confine erosion and sedimentation c) block views to the facility
Minimize the amount of total surface disturbance necessary
Make use of existing vegetation
Have sufficient right-of-way width to accommodate the necessary management practices
Avoid locations having severe erosion potential
Avoid seepage areas
Avoid areas of difficult vegetation management
Avoid areas of sensitive neighbors (vineyards for example)

By limiting the stripping, grubbing, and clearing during construction, more of the indigenous vegetation is conserved. When indigenous vegetation cover is removed, it is rarely replaced with the same kinds of plants. Disturbance of the habitat provides a different kind of seedbed and growing conditions for seedlings.

Save existing trees, shrubs, and turf wherever possible. On both old and new rights-of-way, encourage regeneration of the natural vegetation.

Erosion Prevention and Cover Establishment

New rights-of-way should be tilled, fertilized, seeded, and mulched. Select seeding mixtures so as to best suit local conditions. Special plants such as woody species, crownvetch or other perennial legumes, native grasses, or annual legumes may be introduced into certain selected areas at this time.

Different seeding mixtures may be necessary for various conditions within a state and for all the levels of maintenance required. On old rights-of-way, where the vegetation species composition is not that desired, efforts should be made to introduce more desirable species.

Drainage

Wherever possible, do not disturb existing drainage ways. Where required, surface drainage ways should be planned—and hydraulically adequate.

Naturally shaped channels of nonerosive soils, well-stabilized with vegetation should be developed. Provide extra protection such as rip-rap as needed. Where necessary, construct a closed drainage system. The drainage ways must be maintained.

Vegetation Management

Vegetation management is the selective stimulation of competition between desirable, less desirable, and undesirable vegetation. Reseeding operations, new species introduction, selective spraying, cutting frequencies, and fertilization are practices used to change the vegetation composition in a preplanned direction.

Fertilization and Refertilization

Appropriate fertilizer applied at the right time will stimulate desirable vegetation, resulting in a decrease in weeds and bare ground. Fertilization is an effective means of reducing weed species populations in a given area. Refertilization may be necessary periodically. Fertilization is a long-term cure, or a preventive measure, rather than a temporary control.

Mowing—Frequency, Timing, and Type

Reasons for mowing are:

Safety—includes mowing to remove tall-growing plants that restrict sight distance or hide hazards and constrict or produce a feeling of constriction to passage
Aesthetics—urban areas and approaches to towns may be mowed frequently to improve appearance and for conformance to adjacent land use.

Drainage—it may be necessary to mow ditches to maintain flow velocity.

Snow drift control—tall vegetation may be mowed in the fall to prevent snow drifts on travel areas.

Fire prevention
Vegetation management

Certain annual weeds may be partially controlled by mowing times to prevent seed formation. Mowing operations should be planned and monitored for effective results.

Increased frequency of grass mowing leads to fine-textured grasses. Decreased mowing results in tall, coarse-textured grasses and other plants. Mowing frequency for brush control varies with the species and climate. Timing is important for safety, appearance, weed control, and to cause vegetation changes. In type of equipment, reel mowers are used for a neat appearance, heavy rotary mowers for brush control.

Landscaping

Landscaping is the placement of selected plant materials to: (a) improve appearance, (b) block or direct views, (c) eliminate difficult areas from future maintenance.

Use of Selective Herbicides

Selective herbicides are used to control specific undesirable plants. Their removal improves the right-of-way environment and benefits the overall well-being of the transport facility, its uses, and adjacent property owners.

To be successful, the weed must be correctly identified and the right chemical correctly applied at the right time. Wherever possible, use a selective spot spraying program instead of a broadcast blanket spray operation.

Equipment Allocation

An adequate number of the correct equipment must be available at the time it is needed. Examples are the allocation of heavy rotary mowers for winter brush control, of reel mowers for frequent cuttings, and of invert sprayers for work requiring special targeting and drift control.

Controlled Burning

Burning, when applied to the appropriate vegetation complex, is an economical, rapid, and efficient way to decrease undesirable vegetation and promote desirable species.

Summary

The vegetation management approach provides an environmentally sound means for long-term improvement of rights-of-way. Vegetational stability is developed. Planning and scientific and managerial inputs are used to partially replace money, energy, and material inputs. The rapid occurrence of problem situations becomes less likely. A lower level of planned, continuing inputs is used to replace large, occasional, forced efforts.

Nonselective Vegetation Control

Nonselective vegetation 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. Vegetation in these areas could be a fire or safety hazard, restrict visibility, damage structures, provide a breeding area for rodents and other pests as well as reduce facility security.

Nonselective herbicides are chemicals which kill all vegetation and may leave the soil nonproductive (barren) for a year or more, depending on the chemical and the rate used. The material in most cases must have the ability to knock down existing vegetation and also prevent or inhibit regrowth and germination for a time.

The material or materials selected should not move laterally in the soil and the application should be in an even pattern at prescribed rates to prevent surface movement, damage to abutting areas, plant life, or soil erosion. Generally, such materials should not be applied to slopes greater than 6:1, horizontal to vertical, without a cap or other means of protection or containment.

Water movement over areas treated with a soil residual herbicide must be prevented, or contained on site, to avoid damage to other areas and soil erosion. The chemical (depending on what is used) may be capped with an asphalt, or mixed in with a cut-asphalt and sprayed over the surface. The barren surface may be protected from erosion with crushed stone. Railbed ballast and pavement cracks generally do not present chemical movement problems. A planned retreatment program is generally required.
Kill of established perennial vegetation by soil residual chemicals is slow and may impair the effectiveness of the treatment. To improve effectiveness, contact or translocated herbicides may be combined with soil residual herbicides. Vegetation on site may be mowed closely and removed before treating the area. Vegetation may be removed from around guardrail posts with a shovel. Blading can also be used.

In some situations, where a vegetation cover must be maintained and mowing is not practical, growth retardants may be used. They are safer from a movement and erosion prevention standpoint, but may result in an increase in undesirable vegetation.

Classification and Types of Herbicides

The most satisfactory classification of herbicides is based upon how they are used for weed control and how they work.

Classification by Use

Selective herbicide implies that certain weeds are killed but most desirable plants are not significantly injured.

Nonselective refers to chemicals that are generally toxic to plants without regard to species. Remember, plants differ in susceptibility to any specific chemical and the choice of herbicide and application rate depends on the species to be controlled. There are generally three classes of herbicides based upon activity (all may be selective or nonselective).

Classification by Mode of Activity

Contact herbicides—foliage applied—control weeds by direct contact with plant parts. They are referred to as chemical "mowers," as only the plant area contacted is controlled. Good coverage is necessary.

Translocated herbicides—foliage applied—products move through the entire plant system in both the water stream and the food stream. They accumulate in, and affect the active growth centers. In general, these compounds are selective. Some are effective in the soil and can be taken into the plant through the roots. However, they are most effective when applied to the plant foliage.

Root or emerging shoot-absorbed herbicides—soil applied—are referred to as the residual herbicides. The length of time the soil remains relatively weed-free depends upon the chemical used, amount applied, rainfall, soil type, and the plant species invading the treated area.

Compounds that can be used selectively in some situations may be used nonselectively by increasing the rate of application. Soil residual herbicides generally have little effect upon plants when sprayed on foliage. The main effect is when they are absorbed through the shoot or root and moved in the water stream of the plant to the leaves.

Herbicide Formulations

Most herbicides, as packaged, do not contain 100 per cent active ingredients. The portion that is not active herbicide is composed of inert chemicals. Here are the ways the various forms are marketed:

Dry Formulations

- Wettable powders (WP)
- Water dispersible granules or dry flowables (WDG-DF)
- Water soluble powders (SP)
- Granules (G)

Liquid Formulations

- Water soluble concentrate (WS). Like a water soluble powder, this forms a true solution in water, requiring little agitation.
- Emulsifiable concentrate (EC). The active ingredient is not soluble in water but is dissolved in a solvent along with emulsifiers. This mixture forms a milky-looking emulsion in water and requires moderate agitation.
- Liquid suspension (L). This is equivalent to a concentrated suspension of a wettable powder. Fine particles are suspended in a liquid concentrate which disperses readily in the spray tank. Constant agitation of the spray mix is required.

Special Formulations

- Oil solubles
- Invert emulsions

Special Agents

- Thickeners
- Foams
CONTACT HERBICIDES HALT VISIBLE PLANT GROWTH, AT LEAST FOR A SHORT TIME

Spraying of visible plant foliage initiates the action of a contact herbicide. A spray wand or spray boom is used to apply the compound, with application being made after growth has started.

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

Weed growth above ground is eliminated. Some weeds will not come back but many will reappear later in the season, since germinating seeds or perennial root systems are usually not affected by contact materials.

HOW A FOLIAGE TRANSLOCATED HERBICIDE WORKS

Spray growing vegetation to wet. Chemical translocated down to roots and growing points and throughout the plant. Susceptible plant then gradually dies.

HOW A NONSELECTIVE RESIDUAL WORKS

Apply to soil and young plants in early spring. Rain washes herbicide in the soil; it dissolves and is absorbed by shoots or roots. Herbicide is translocated to growing points, plant yellows and gradually dies. Plants die and bare ground occurs for a year or more.
Timing of Herbicide Treatments and Rates

The timing of herbicide treatments depends on the herbicide and its persistence, species, tolerance, characteristics of target species, cultural practices, climate, and soil conditions. Three categories of timing are recognized: preplanting (usually agricultural), preemergence, and postemergence. The herbicide rate is determined by label direction and use experience.

Factors Affecting Chemical Weed Control

Stages of Growth

Weeds go through four stages of growth: seedling, vegetative, flowering, and maturity. There is a best stage for weed control. If control is not obtained at the best stage of growth, the method of control may need to be changed.

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 succulent, therefore less energy is required for control at this stage of growth than any other. This is true whether the energy be mechanical, chemical, or management.

Vegetative (annuals). The vegetative stage of growth is when energy being produced by the plant is going into the production of stems, leaves, and roots. Control at this stage is still feasible but more difficult than at the seedling stage of growth.

Flowering (annuals). At a certain stage of growth and time of year, a chemical messenger formed by the plant tells it to change from the vegetative to the flowering stage of growth. At this time most of the weed's energy goes into the production of seed. Chemical control at this stage, for both grass and broadleaf, is not feasible because eliminating these older plants requires much more energy.

Maturity (annuals). Maturity and seed set of annuals completes the life cycle. Chemical control is not effective at this stage.

The chart shows the expected weed control of annuals from an herbicide application. Note that almost 100 per cent weed control is obtained when the herbicide is applied at the seedling stage of growth. When applied at the vege-
WEED CONTROL (ANNUALS)

<table>
<thead>
<tr>
<th>PERCENT CONTROL</th>
<th>100</th>
<th>50</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEEDLING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VEGETATIVE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FLOWERING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MATURE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stage when herbicide applied

MATURE (ANNUALS)

Vegetative stage, control drops to approximately 75 per cent; and when applied at the flowering stage, below 40 per cent. Virtually no control is obtained when the herbicide is applied at the mature stage.

Biennials. Biennials, in two years, go through the same stages as annuals.

Seedling (perennials). The seedling stage of growth and its control is the same as for annuals and biennials. However, the stages of growth from vegetative through maturity are different.

Vegetative (perennials). Part of the energy used in the production of stems and leaves for the vegetative stage of growth is derived from energy stored in the underground roots and stems. Other energy comes from production in the plant leaves. Chemical control is mediocre at this stage of growth.

Flowering (perennials). Again, as with the annuals, a messenger is manufactured by the plant at a certain time and stage of growth. The plant’s energy then goes into the production of flowers and seeds. Food storage in the roots is initiated and continues through maturity. Chemical control is effective just prior to flowering (bud stage).
Maturity (perennials). For these plants only the above-ground portions die each year. The underground roots and stems remain alive through the winter months and send up new plant growth the following spring. Chemical control is not feasible at this stage.

The chart shows the expected control of perennial weeds from an herbicide application at the various stages of growth. Best control is obtained by treating perennials at the bud or regrowth stage. This causes the greatest drain on the underground food reserves. Treatment at early flowering almost equals that obtained at the bud stage of growth. When perennials reach full flower, control drops off. It is also beneficial to treat the regrowth.

An important advantage of fall applications of herbicides is that of environmental safety. In the fall, desirable plants in cropland, gardens, etc., have completed their growth and escape the herbicide. Problems of drift onto soybean or tomato fields are eliminated since the growing season is over.

Additionally, fall is a time when herbicides will reach the underground plant parts through the natural translocation activity of the plant. In the fall, nutrients are moved from the aboveground parts of the plants in advance of the first killing frost to be stored over winter in the underground parts. Perennial weeds are most susceptible to herbicides in the fall. Underground parts must be killed to achieve control of these weeds.

Biennials, plants which develop from seed the first year, overwinter in a rosette stage, to flower and cause problems the following year, are also controlled by a fall application. The rosette stage is an ideal time to control biennial species.

Also controlled by a fall application are winter annuals which germinate in the fall, grow through the winter and flower in the spring or early summer.

With a fall application of an herbicide, the target plant has to survive three stresses in a row: (1) herbicidal effects, (2) winter effects, (3) effects of the heavy demand for nutrients caused by the rapid growth period in the spring. The chances of plant mortality are greatly increased.
Factors Affecting Foliage Application

Location of growing points. Growing points and regrowth of weeds are plant factors.

Grass. A seedling grass has its growing point below the soil surface. Control is more difficult when the growing point is protected in this manner. Neither herbicide nor cultivation may reach the growing point and the plant regenerates. Creeping perennial grasses have protected buds below the soil surface, as shown by the dots in the illustration.

Broadleaf. Growing points and regrowth of broadleaf plants are different from those of grass plants. Seedling broadleaf weeds, in contrast to grass weeds, have an exposed growing point at the top of the young plant. They also have growing points in the leaf axils. Herbicides can reach these points more readily and cultivation will control the plant easily. The perennial broadleaf plant is difficult to control because of the many buds on the creeping roots and stems, as shown by the dots in the illustration.

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

Herbicide entrance into the weed. Leaf shape and surface are factors in herbicide retention and penetration.

Leaf shape. Differential foliar wetting affects herbicide selectivity. Note the plant to the left in the illustration with its narrow vertical leaves; the herbicide spray solution tends to bounce or run-off. In contrast, the broadleaf plant on the right, with the flat, wide leaves, tends to retain the spray solution. Retention of spray solution is important.

Leaf surface (wax and cuticle). It is important for the chemical to penetrate the weed leaf surface. Thickness of wax and cuticle are factors partially governing entrance of an herbicide into a leaf.

The illustration shows a leaf on the left with a thin cuticle, and, in the magnified cross-section, note the spray solution is in good contact with the leaf surface, with some going through the breathing pore. In contrast, on the right, is a leaf with a thick, waxy surface; in the magnified cross-section
note the spray solution tends to stand up in droplets with 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.

*Leaf surface (hairs).* Other factors that tend to keep the spray solution from entering the leaf are important. Here is a weed leaf with hair on the surface, and, in the magnified cross-section, the droplets tend to stand up on the hair and are not in contact with the leaf surface.

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.

*Species and size are factors.* Species vary in growth habits and susceptibility to herbicides.

Seedling weeds require less energy for control than do established weeds.

---

**Soil Applied Factors**

*Herbicide characteristics and soil particle tie-up.* Herbicides have different properties. One of the properties is magnetism. These chemicals vary and have from none to strong magnetism. Those without a magnetic charge tend to leach through the soil profile more readily. Others, with magnetic charges, tend to tie-up on the negative charge sites of soil particles.

*Solubility.* Another property is solubility in water or the soil solution. Herbicides vary from insoluble to soluble. Solubility is somewhat related to movement in the soil.

*Leaching.* Leaching is related to herbicide characteristics and soil factors. Herbicides and soils vary from non-leachable to completely leachable.

*Persistence.* Persistence of an herbicide in the soil is governed mainly by the chemical's properties, rate of application, precipitation, temperature, and the soil's properties.

*Soil type.* Some herbicides are applied to the foliage of weeds. Other herbicides are soil-active and are applied to the soil surface. Soil type and herbicide movement are important considerations. Two factors are of importance in herbicide movement in the soil. The first is the texture of the soil (sand, silt, and clay). The second is organic matter in the soil.
Texture (sand). Sand is coarse and does not have many charge sites. The illustration shows a magnified sand particle in the soil. The magnet-shaped particles are herbicide molecules moving down through the soil profile. The magnified circle shows the herbicide particle moving on past the smooth sand surface, deeper into the soil profile. It does not tie up.

Texture (silt). Silt is intermediate in charge sites. It has more sites than sand but fewer than clay and organic matter.

Texture (clay). Clay is fine and has many charge sites. The illustration shows a magnified clay particle. Again, the herbicide molecules are moving through the soil profile. In the magnified circle, note that the plus-charged herbicide particle has fit into the negatively charged slots.
Factors that affect soil-applied herbicides:

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Soil type</th>
<th>Precipitation and soil moisture</th>
</tr>
</thead>
</table>

**Soil class and rights-of-way.** When you are doing soil residual work, it is essential to know the soil properties. Soil residual herbicides need to be activated, that is, they must be in the soil solution to be effective against weeds. There are two methods:

- Water—either precipitation or irrigation
- Mechanical incorporation—with tillage equipment

**Climatic Factors**

- **Temperature.** As temperature increases, the effect of the herbicide activity speeds up. Weed control results are the same, regardless of temperature. It is merely the number of days taken to see the full effect.

- **Humidity.** Approaching 100 per cent humidity, a foliar-applied herbicide will enter the leaf more easily and rapidly than at low humidity where penetration is slow. At high humidity, the weed leaf is more succulent, has less wax layer and a thinner cuticle.

- **Precipitation.** Rainfall is an important factor in right-of-way weed control. Precipitation, occurring after a foliar-applied herbicide treatment, may decrease effectiveness.

Rain will activate soil-applied herbicides. But it can also move the herbicide through or from the target area. It is difficult to hold the herbicide at the edge of paving due to flushing and leaching action of surface runoff water.

Herbicide characteristics, soil texture, organic matter, precipitation, and surface flow determine chemical persistence on rights-of-way. 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.

on the clay particle. Thus, it is tied up, like a magnet, and will not continue moving through the soil profile.

**Organic matter.** Organic matter has many, many times more negative charge sites to tie up plus-charged particles; many moving through the soil profile are tied up by both organic matter and clay. Note in the magnified circle there are different types of particles on the organic matter. These particles include water, herbicides, sodium, calcium, ammonia.

Remember, sandy soils have few charge sites to tie up herbicide molecules, and they tend to move on through the soil profile. Soils with clay and organic matter tend to tie up and hold herbicides and other charged particles.

Salt content of soils, increased by snow and ice control, increases activity of soil residual herbicides. In soils with high salt content, lower rates may give acceptable control.
Wind. Wind can cause spray drift as well as move dust-laden herbicide particles.

Wind and temperature. Wind and temperature can also affect the weed. A hot, dry wind will cause plant stomata to close, leaf surface to thicken, and wax layer to harden. These factors make foliar herbicide penetration more difficult.

Woody Plant Control

Woody plants can be controlled mechanically and chemically.

Control with Herbicides

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 crowns. For large stems, best results are obtained by cutting and treating the stump.

**Stump treatment.** Close cut stumps and root collars may be treated with basal spray mixtures. Best results are obtained by treating immediately after cutting. All sprouts must be treated.

**Soil treatment.** Applications are made to the base of plants. Generally, herbicides in the pellet form are used. These must be activated with precipitation for results to occur.
Drift

A principal concern in the use of herbicides is containment within the right-of-way. The operator must know what the target is, be able to identify it, get the material on target at the right time, and in the right amount. Drift may occur off the right-of-way or within the right-of-way target. However, damage has resulted from direct off-target hits (not drift), caused by operator carelessness, lack of knowledge or accidents or from the application of incorrect rates and chemicals. Steps must be taken to avoid misuse.

The term "drift" refers to the movement of herbicides through the air to off-target areas. It presents a potential hazard to sensitive vegetation (crops, gardens, ornamentals) adjacent to or on the right-of-way.

Drift Occurrence

*Particle drift*—at the time of application, small spray droplets can be carried by air movement from application areas to other areas. The distance a particle of herbicide spray can drift is determined by one or more factors: a) force of an existing crosswind, b) distance from the spray nozzle to the ground, c) size of the particle itself. Particles smaller than 150 microns (fog or mist) present the greatest drift hazard.

*Vapor drift*—this form of drift results from the tendency of chemicals to vaporize. The movement of such vapor with wind currents may cause injury to sensitive vegetation. Vapor drift has less likelihood of occurring than does particle drift, but if vapor drift does occur, it has more potential for distance.

Control Measures

Use as low pressures as possible
Leave an untreated edge
Angle nozzles toward the ground, slightly forward in the direction of travel

Use nozzles with as large orifices as possible for rate and pressure required
Use less volatile formulations of the chemicals
Spray at times wind speed is low
Do not spray during a temperature inversion
Spray when sensitive vegetation is mature or not present

Special Systems

Adjuvants and application systems have been developed which help overcome certain drift problems that exist in conventional spraying. Three of these systems are:

Foams
Invert emulsions
Spray additive stabilizers (thickeners)

Though different in method, there are similar advantages: invert and thickeners give better drift control (physical and volatile), and all three give more highly visible spray (better placement).

Herbicide Application Equipment

Types and Classes

The equipment used is of two general types, airborne and ground. The airborne equipment is either carried by fixed wing aircraft or helicopter. Each has special advantages for certain right-of-way jobs and should be selected accordingly. Speed, cost control and ease of access to difficult and remote areas are advantages of airborne equipment. Difficulties involve trouble getting the material on target, drift problems, flight obstacles, and safety.

Operational preplanning, including: application area mapping, sensitive area marking, flight obstacle identification, pre-application flyover and other information specific to the right-of-way being treated, is essential to the practical use of this equipment.
Ground equipment (including floating equipment on drainage, irrigation, and bargeways) is in general use on rights-of-way. Both airborne and ground equipment are classified according to the type of material used:

- Conventional (water in water, oil in water, and oil in oil)
- Invert (water in oil)
- Granular

**Special Considerations**

Because of their diverse physical nature, rights-of-way present many unique problems. Drift and application control must be definite "straight line." This has led to the development and use of such special equipment, formulations, and materials as the "inverts," "foams," and "thickeners."

Rights-of-way have many obstacles which make the use of conventional spray booms difficult or impossible. The "manifold" spray and the "hand-gun" sprayer nozzle are widely used. Special equipment for herbicide placement is also in use for airborne applications.

A considerable amount of "job specific" equipment has been developed to fit the specific requirements of the various right-of-way agencies. Included is truck, trailer, barge, rail, and all-terrain vehicle-mounted equipment. Right-of-way agencies have put together many herbicide sprayers to suit their individual needs. The lack of a full range of well-adapted, readily available equipment for right-of-way spraying is an added problem to success.

**Application**

Proper application is an absolute requirement in obtaining satisfactory results from any herbicide treatment. All treatments must be applied uniformly at the recommended rate over the area or onto the species to be treated in a timely manner.

A difficulty in right-of-way application is the maintenance of a support base. Due to the general long, narrow shape of rights-of-way, the operation continually moves away from its support base. Travel time is often excessive. Low application rates with minimum amounts of water or oil carrier result in operational efficiency and speed applications. Mobile support units are often needed. One unit, spray and support combined, may improve operational effectiveness.

---

**Aquatic Vegetation Management on Rights-of-Way**

The following information is directed to aquatic vegetation management on rights-of-way.

Aquatic weeds are those species of vegetation which interfere with the use or performance of the aquatic environment. The interference can range from degradation of aesthetics, interruption of water surface for recreational use, preventing the essential hydraulic performance of a ditch or canal, and harboring of insects or rodents.

Prior to developing a method of management, it is essential that the problems to be solved are adequately identified. An incomplete understanding of the problem and its effect on the environment will often result in failure of the control program.

As an example, total eradication of vegetation on a stream bank will often lead to erosion of the bank and downstream siltation and deposit. If brush species are blocking the movement of water, remove only the brush and leave the desirable grasses to maintain the stability of the bank.

Once the problem has been totally identified, it is necessary to identify the species to be controlled. Agricultural Extension personnel, written material, and manufacturers' representatives can aid in this task.

Basically, there are four approaches to aquatic weed control. They are: design and construction of the aquatic environment, operation and maintenance, mechanical manipulation, and chemical manipulation. The best method of control is that which controls the target vegetation with the least impact on the other elements of the environment in a practical and safe manner.

**Design/Construction**

The design and construction of the aquatic environment is best illustrated by the old axiom "an ounce of prevention is worth a pound of cure." By proper design and construction of the aquatic environment, subsequent removal or control of undesirable vegetation can be minimized or eliminated. Following is a list of design and construction considerations.

Make channels narrow and deep if they carry water throughout the year

Make channels wide and shallow if they become dry enough to allow movement of equipment for mowing or chemical application
Design for a larger carrying capacity than the expected maximum requirement

Aquatic weeds are more prevalent in low gradient ditches with slow moving water than in ditches with steeper grades and more rapid water flows

The ditchbottom should contain no water pockets or undrainable areas when channel is dewatered

Lining canals with concrete helps alleviate aquatic weed problems, but does not eliminate them

Smooth, level ditchbanks on both sides of the channel provide places for roads which are essential for proper inspection and transporting of weed control equipment

Keep roadways no higher than necessary to insure a safe freeboard—mowers and other equipment can then reach weed growth down to the waterline

Build slopes uniform and plant grasses to aid in the prevention and control of weeds along ditchbanks

The banks of lakes and ponds should be steep rather than sloping or saucer-shaped

In building ponds, leave no fertilizer, topsoil, or plant debris in the basin

Seed desirable, moisture-tolerant grasses along the pond and lake banks

Fence lakes and ponds to eliminate general access by livestock—for livestock watering, construct water gaps

Provide a facility for bypassing water around the pond. Do not permit flood, silty, or other undesirable waters to enter the pond

If possible, provide facilities for regulating the depth of water in the pond

Catch basins, traps, and screens help prevent the spread of weeds by fragments, tubers, seeds, and other propagules

Operation/Maintenance

Operation and maintenance of an aquatic environment can often eliminate the need for remedial programs. By eliminating the source of infestation it is possible to prevent development of a weed population. Consider the following in developing an operation and maintenance program:

Locate new or small infestations of weeds and eliminate
Never allow weeds to produce more seed
Fluctuate water level to control shoreline weeds
Drain and dry for control of submersed aquatic weeds
Avoid the drainage of highly nutritive waters into lakes, ponds, or irrigation systems

Mechanical Manipulation

Mechanical manipulation of vegetation ranges from physical removal by tillage or cutting to the use of burning.

Generally severing of the above-ground portions of a plant will only eliminate annual and biennial types of plants. Perennial plants are only eliminated when top removal reduces their ability to compete with adjacent plants. Competition is the key to a successful mechanical program if some vegetation is to be maintained.

Tillage is effective on all plants but often can’t be utilized due to increased erosion and sedimentation and high unit costs. Burning to control weeds in the aquatic environment should receive the same considerations as tillage and cutting.

Chemical Manipulation

Use of chemicals to control vegetation in an aquatic environment is often an effective solution to weed problems. Use the chemical in the prescribed manner to ensure that off-target effects will not occur.

Problem Analysis

The following procedure will assure safe and effective chemical manipulation of aquatic vegetation.

Biological aspects:
Identify the problem species
Identify other species present
Determine density, stand or scope, and stage of growth of the weeds
Determine what species of fish are present

Water use aspects:
Determine water use
Determine the length of time the water can be quarantined from each use
Determine the amount and destination of the outflow or tailwater

**Physical aspects:**
- Determine size of channel or impoundment to be treated
- Determine depth and movement of the water
- Note turbidity of the water
- Determine water temperature
- Determine water quality

Select the herbicide and use rate for effectiveness and safety. Apply the aquatic herbicide in the prescribed manner.

**Operational Procedures and Administration**

**Standards**

Standards are necessary to obtain a uniform vegetation management and manipulation program (including weed and brush control) on transport rights-of-way within any given administrative area. Standards are pre-set quantitative measurements of factors associated with the rights-of-way, its vegetation, and the needs of the transport it serves. They can be developed according to: regions (agriculture, forest, or range), development (rural, suburban or urban), or other factors.

Examples are: sight distance requirements; maximum height of brush which may be sprayed; lists of weeds which are to be controlled; per cent of vegetation in undesirables, singly or in combination, which will not be tolerated; wind speed, temperature, adjacent property use, or other conditions which stop spraying; clear zone requirements (under power lines, around substations, and other areas); persistence to be applied in control measures, per cent undesirable cover reduction or eradication; treatment patterns; and other standards specific for the particular right-of-way agency, its right-of-way, and its part of the country.

**Level of Service**

Level of service is the quality limit that should be set up with the standards. It determines the conditions that will be tolerated and the conditions that will cause action. Level of service will vary with a) needs of the transport agency, b) the vegetational zone of the region, c) the socio-political situation and d) economic value of adjacent lands. A determination of level of service plus the development of standards set finite limits on the vegetation management program for the administrators and the applicators. Based on these limits, needed measures are developed and taken by the administrator and/or supervisor.

**Procedures**

Procedures must be developed to implement the vegetation management program as defined by the goals, objectives, standards, and level of service.

**Right-of-Way Mapping**

Right-of-way mapping should be included for:
- Vegetation zones
- Special weed problems
- Special hazards
- Socio-economic conditions (example — rural, suburban, urban development)
- Landscaped areas
- Any other important mappable items

**Photo Logging**

Photo logging is the photographing of the right-of-way from either ground level or the air. Pictures may be taken at certain distances running in one or both directions. Rephotographing should be scheduled.

**Computer Data Banks**

A computer data bank is required for:
- Sign locations
- Culvert locations
- Bridge locations
- Ditch locations (whether with or without permanent flowing water should be noted)
- Mowable acres
- Forested acres
- Water surfaces
- Rock surfaces
- Weedy areas
- Guardrail locations
- Areas in substations
- Streams and river crossings
- Open water
- Sensitive areas
- Previous trouble spots
Key operational areas (example, main or minor switching yards)

**Record Keeping**

Records need to be kept on:
- Location of weed problems
- Areas sprayed, location limits, rate of application, materials used, concentration, manufacturer, time of day, wind speed and direction, temperature, relative humidity, rainfall, applicator, sprayer operator, operational problems, equipment unit, and species treated (year-by-year)
- Total materials used, pounds bought, pounds applied
- Fertilizer and lime applications

Location of sensitive vegetation on right-of-way (such as crownsvetch, other legumes)
Evaluation of spraying effectiveness
Damage claims
Rare and endangered plant species
Wild flower stands
Location of areas to be retreated (poison ivy, mature perennial weed stands mowed—regrowth to be sprayed, brush mowed—sprouts to be sprayed)

**Costs**

Monitoring reports as to general conditions, changing conditions, level of service actually supplied, conformance of applicators to standards, and other pertinent items
Seeding mixtures used to establish vegetation
Bibliography


APPENDIX

Chart A—Herbicide Classification

```
Herbicide
     | Nonselective
     | Soil Applied
     | Aquatic (diquat)
     | Soil Applied
     | Foliage Applied
     | Root-Absorbed—Residual (diuron, simazine)
     | Fumigants (methyl bromide)
     | Aquatic (diquat)
     | Soil Applied
     | Translocated (glyphosate)
     | Root- or Emerging Shoot-Absorbed Residual (diuron, simazine)
     | Soil Applied
     | Translocated—Systemic (2,4-D)
     | Selective
     | Aquatic (2,4-D)
     | Foliage Applied
     | Contact (paraquat)
     | Soil Applied
     | Root-Absorbed—Residual (diuron, simazine)
     | Contact (MSMA)
```

26