# Chemical Control of Weeds and Brush Along Roadsides

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Photo credits: Figure 1, U.S. Rubber Co., Figure 2, Connecticut State Highway Department.

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## INTRODUCTION

Herbicides — chemicals that kill plants — have long been known. Until the '40's, however, most of these herbicides were non-selective and of limited value. The discovery of growth regulating properties of 2,4-D marked the beginning of a new era in control of plants commonly called weeds. Other selective herbicides have vastly expanded the list of situations in which chemical control of weeds is considered economical and desirable. This Station and many others have reported on weed control research, and producers of food plants and other valuable species have been quick to adopt the use of herbicides.

With steadily higher costs of labor, increasing appreciation of the functional and esthetic importance of roadsides, and a rapid expansion of divided-lane highway mileage, it is inevitable that herbicides are now at work on the median strips and borders of travelled ways.

The use of herbicides along roadsides is controversial. Herbicides can unquestionably cut maintenance costs. These chemicals, carelessly used, may also destroy desirable plants. Without question, herbicides reduce the variety of the roadside flora. In this selective action lies the value and the peril of these materials.

Whether chemical control of plants along highways is esthetically desirable is a perplexing question, a question not to be answered in the laboratory or on field plots. Our research staff shares responsibility, however, for evaluating herbicides in Connecticut and for publication of our findings. The information we present is intended to be useful to those officials of the town or state who must decide whether to use herbicides and how the materials should be applied. At the same time, this review of our observations and experience, with that of others, may be helpful to all who are concerned with the financial, esthetic, and other considerations in control of weeds and brush along roadsides.

### Objectives of Roadside Weed and Brush Spraying

Herbicides assist in achieving the primary objectives of roadside weed and brush control (30, 34, 61). These objectives are the attainment of safety, health, beauty, and economy. Elimination of weeds and brush improves the safety of travel along roads in several ways. It permits better visibility along roads and keeps highway shoulders clear for motorists to use in emergencies. It may provide a walkway for pedestrians. It reduces





the fire hazard along roadsides, resulting from unchecked growth of weeds and brush. Elimination of noxious weeds such as poison ivy, poison sumac, and ragweed reduces the hazard to motorists using the roadside for repairs and to maintenance crews. At the same time the elimination of weeds and brush improves the appearance of the roadside.

There are real economies in using herbicides. Their use cuts maintenance costs by reducing mowing requirements when broadleafed weeds are eliminated and makes handmowing almost unnecessary in places. Continual, expensive recutting of brush is replaced by chemical treatments at lower cost.

## BACKGROUND INFORMATION

Weeds or brush can be controlled with herbicides by an operator who understands little about what is going on and why. Success is more likely, however, if one has some understanding of the factors involved and the underlying principles of herbicide application.

### Types of Weeds Encountered

A weed is a plant growing where it is not wanted. On the basis of their response to chemical treatment, weeds have been divided into broadleafed weeds and narrow-leafed weeds or grasses. On the basis of their growing habits weeds are also classified as annuals, biennials, or perennials (1). Annuals and winter annuals reproduce from seed alone and require a single growing season to complete their life cycle. Examples are ragweed, lambsquarters, common chickweed, and wild mustard. Biennials require two years to complete their cycle, usually storing food in their fleshy roots the first season and flowering the second. Examples of biennial weeds are wild carrot, bull thistle, mullen, and burdock. Perennials live over from year to year, and reproduce by seed, rhizomes (rootstocks) or stolons (creeping stems). Examples of perennials are dandelion, Canada thistle, poison ivy, and all woody species.

Perennials are often difficult to control because of their extensive root systems. Merely killing the foliage will not kill the roots of a perennial plant. Repeated chemical treatments are often required.

A list of weed species and other plants of both herbaceous and woody types is given in the Appendix, with the relative susceptibilities of these plants to our most common herbicides, 2,4-D and 2,4,5-T. Several aids to weed identification are available. (6,20,47).

### Components of Spray Mixtures

Sprays for weed control contain (a) the active herbicide, (b) spray additive or ingredients that aid the action of the herbicide, and (c) a carrier of water or oil or a mixture of the two. Commercial formulations of herbicides often include filler material which is inactive and serves merely as a diluent.

Spray additives including wetting agents are of several types but have in common the action of making the spray wet the waxy leaf surface more readily and spread over that surface more uniformly. Such materials are often included in commercial herbicide formulations.

Additional wetting agent sometimes is added to spray mixtures. Household detergents and many commercial wetting agents are obtainable for this purpose.

### Herbicides Available For Roadside Use

The list below includes the properties of chemicals which have proven satisfactory for the control of weeds and brush along rights-of-way in the Northeast. Each of these herbicides may be obtained under one or more trade names (27). The uses of these herbicides are discussed more fully in following sections.

A. Common name: **Amitrol (amino triazole)**
Chemical name: 3-amino-1,2,4-triazole

Properties: Amitrol is a crystalline water-soluble powder. It is readily absorbed by foliage and is translocated throughout the plant causing chlorosis and inhibition of new growth (41). Because amitrol is not obsorbed through bark, it has been used effectively to kill poison ivy and other vine growth on trees without affecting the tree itself. It is rapidly inactivated in most soils and therefore has proven useful in controlling weeds in certain shrub plantings. Amitrol has proven useful for the control of plant pests such as milkweed and Canada thistle. Amitrol is non-volatile in solution and relatively non-toxic to mammals. Addition of wetting agents to the spray mixture may increase wetting and subsequent kill of some weeds. Concentrations are expressed in terms of the active ingredient only, amino triazole.

B. Common name: **Ammonium sulfamate**
Chemical name: Ammonium sulfamate

Properties: Ammonium sulfamate is a yellow, crystalline, water-soluble powder. In solution it kills plants on contact, and is translocated under some conditions (1). Ammonium sulfamate will kill most herbaceous and many woody plants and is used primarily for non-selective brush and weed control and to kill stumps and standing trees. The solution is corrosive to metals including brass, relatively non-toxic to mammals, and non-volatile. Addition of a spreader-sticker is required. Concentrations are expressed in terms of the active ingredient, ammonium sulfamate.

C. Common name: **Dalapon**
Chemical name: 2,2-dichloropropionic acid

Properties: Dalapon is obtainable as a water-soluble, crystalline, sodium salt. It is a very effective grass killer and is absorbed and translocated readily by plant foliage and roots (41). While generally applied to foliage it has limited residual activity in the soil. It is used along roadsides to kill grass under guide rails, around structures, and around planted shrubs (3,32). Dalapon sodium-salt is non-toxic to mammals, is non-volatile and non-corrosive. A wetting agent often aids absorption in



hard-to-wet leaves. Concentrations are expressed in terms of the acid equivalent.

D. Common name: **DNBP**
Chemical name: 4,6-dinitro ortho secondary butyl phenol

Properties: DNBP is one of the dinitro phenols, insoluble in water and soluble in oil (41). The compounds of DNBP of principal interest in roadside weed control are water soluble amine-salt formulations. DNBP kills weeds by contact action on roots or foliage and is not translocated in the plant. It can be used along roadsides primarily as a means of pre-emergence weed control in functional plantings (2,16).

Although very toxic to mammals, DNBP is quite safe to use in pre-emergence weed control as long as care is taken to avoid inhalation of vapors or contact with the skin. The compound imparts a yellow color to skin and clothing upon contact. It is non-corrosive and although somewhat volatile the danger of injury due to drift of the compound is slight. Concentrations are expressed in terms of the active ingredient.

E. Common name: **Erbon**
Chemical name: 2-(2,4,5-trichlorophenoxy)-ethyl-2,2 dichloropropionate

Properties: Erbon is formulated as a greenish, viscous liquid which is oil soluble and forms oil-water emulsions. It is absorbed by both foliage and roots and is translocated to the growing points (4). It has residual activity in the soil and is effective in killing existing plants and germinating seeds. Erbon has been used as a soil sterilant under guide rails, around structures and sign post delineators, and has given effective chemical control of Japanese fleeceflower in Connecticut. It is relatively non-corrosive to spray equipment and presents less of a drift hazard than the phenoxy compounds because of its lower activity on foliage of susceptible plants (56). Although relatively non-toxic to mammals, it may irritate the skin and eyes. Therefore contact with the spray should be avoided. Similar to other soil sterilants it requires ample moisture for best activity but may be leached with excessive rainfall. Concentrations are expressed in terms of the active ingredient.

F. **The phenoxy herbicides**

| | | | |
|---|---|---|---|
| Common names: | **2,4-D** | **2,4,5-T** | **Silvex (2,4,5-TP)** |
| Chemical names: | 2,4,dichloro-phenoxyacetic acid | 2,4,5-trichloro-phenoxyacetic acid | 2-(2,4,5-trichloro-phenoxy) propionic acid |

Properties: The above compounds are a few of the phenoxy herbicides. Their chemical properties are similar, but they differ in selectivity, i.e., the weeds they will kill (1, 19). The phenoxy herbicides are commonly available either as salts or as esters.

Amine salts. — Among the most phytotoxic and most useful salt formulations are the alkanolamine, dimethylamine, triethylamine and isopropylamine salts of the phenoxy acetic acids. Because they are practically non-volatile the amine salts are especially useful for weed control in areas adjacent to susceptible crops and shrubs. Also, they are water soluble and cannot be used in emulsions or solutions in oil. Thus they are not adapted to use on stems or stumps where oil carriers are often used. Wetting agents improve their penetration and absorption into plants.

Esters. – Some ester formulations have relatively high volatility and others relatively low (65). High-volatile esters include the methyl, ethyl, isopropyl, butyl, amyl, and other formulations. Only the relatively low-volatile esters are suitable for use along roadsides. The esters of low volatility include the butoxy ethanol, butoxy ethoxy propanol, capryl, ethoxy ethoxy propanol, isooctyl, and propylene glycol butyl ether esters. Even low-volatile esters vaporize somewhat at temperatures above 85°F. and may injure adjacent susceptible plants under these conditions.

Unlike the amine salts, the esters are soluble in oil and insoluble in water and are used as emulsions. Generally the esters are more toxic to plants per pound of acid equivalent than the amine salts. When formulated the esters contain enough emulsifying agent so that additional wetting agent is not ordinarily required. Adding wetting agent to ester emulsions may actually decrease plant kill because of increased leaf surface runoff (60).

The phenoxy compounds are absorbed quite readily by foliage and are translocated most rapidly when plants are actively growing and soil moisture is adequate (44). Grasses in general are not affected seriously by these compounds while most broadleafed weed species are (36). The phenoxy herbicides also possess limited residual activity in the soil where they inhibit germination of seeds of both grasses and broadleafed weeds. All three compounds mentioned above (2,4-D, 2,4,5-T, and silvex) are commonly used for control of weeds and brush. Applications of the esters in oil or oil emulsions are frequently used for foliage, stem, or stump applications in killing brush and trees, while the amine salts are restricted to foliage applications.

The herbicide 2,4-D is both inexpensive and effective in controlling most broadleafed weeds (1). While 2,4-D can also be used to control certain woody plants, 2,4,5-T is generally more effective for most woody species. Therefore, mixtures of the two herbicides are commonly employed in weed and brush control. Silvex is of primary value along roadsides in the control of weed species resistant to 2,4-D. However, silvex is about equal to 2,4,5-T in the control of oak, maple, and sassafras and could substitute for 2,4,5-T in many areas of brush control (19).

The phenoxy compounds are relatively non-toxic to mammals. Concentrations are expressed in terms of the acid equivalent, regardless of the formulation used.

G. Common name: **Simazin**
Chemical name: 2-chloro-4,6-bis(ethyl amino)-s-triazine

Properties: Simazin is very slightly soluble in water and is formulated as a wettable powder or in granular form. It is absorbed mainly through plant roots, not foliage, and is non-toxic to foliage of most plants (5). It is used primarily for soil sterilization under guide rails and around structures and at lower rates of application for pre-emergence weed control in functional plantings (2,3,52). Because of its low water solubility simazin is not easily leached or moved horizontally in the soil. It presents no drift hazard, is non-corrosive to metals, and is extremely non-toxic to mammals. Concentrations of simazin are expressed in terms of the active ingredient.



## H. The Substituted Urea Herbicides

| | | | |
|---|---|---|---|
| Common names: | **Monuron** | **Diuron** | **Neburon** |
| Chemical names: | 3-(p-chlorophenyl)-1,1-dimethyl urea | 3-(3,4 dichlorophenyl)-1,1-dimethyl urea | 1-n-butyl-3-(3,4 dichlorophenyl)-1-methyl urea |

Properties: These three compounds represent the substituted ureas. They are all only slightly soluble in water, solubility decreasing in the order of monuron>diuron>neburon. All are formulated as wettable powders that make suspensions in water. Mechanical agitation is necessary to keep them in suspension and relatively high volumes of water should be used in their application (50-100 gals. to the acre).

The substituted urea herbicides are absorbed chiefly through the roots and possess residual properties in the soil (54). Because of their lack of effect on foliage they present no drift hazard. They are relatively non-toxic to mammals.

Monuron and diuron have found extended use as soil sterilants along highways. In the humid Northeast, however, rain may wash the chemical to adjacent areas and cause damage. This possibility has limited their use to areas where protective coverings are present, such as bitumen or tar. Neburon and diuron are useful in shrub plantings where they are effective at low rates of application primarily as pre-emergence treatments (2,3,58). Thus they are applied to weed-free soil to kill germinating weed seeds. Concentrations are expressed in terms of the active ingredient.

### Volatility and Drift

Volatility refers to the vaporization of a compound whereas drift refers to the movement of spray droplets or vapor from one area to another (1, 41, 42). Injury to plants near treated areas can arise from either cause.

Drift is responsible for most plant damage and includes the movement of either droplets or vapors by wind. Injury due to drift can be caused with any compound that affects plant foliage. With relatively volatile forms of 2,4-D, for example, a wind might cause vapor to travel considerable distances and injure susceptible plants.

Drift can be avoided by following certain precautions (1, 6, 42, 43). (a) Drift is avoided if roadside spraying is stopped when there is wind. When volatile materials, such as phenoxy herbicides are used, spraying should cease when a wind is blowing toward sensitive plants. (b) Using low pressures with large nozzles results in coarse spray droplets, less likely to drift than those of mist-like spray. Pressures of 30-60 p.s.i. are sufficient for most roadside spraying. (c) Application at slow speeds reduces drift from turbulence.

Danger from volatility of the phenoxy herbicides, (2,4-D, 2,4,5-T, silvex) can be reduced by using the low volatile esters or amine salts. Even with low-volatile esters damage from volatility may result when air temperatures exceed 85°F. (7).

### Effects of Weather on Herbicide Action

Weather conditions cannot be ignored in the application of roadside herbicides. Soil sterilants and pre-emergence herbicides are usually more effective when applied on moist soil (1, 41). Moisture following application carries them into the root zones, where they are active. Moisture also encourages weed seed germination and enables chemicals to kill seedlings before they emerge. Rainfall immediately following application is therefore beneficial unless the rain washes the compounds away.

The opposite is true of foliar herbicides such as the phenoxy compounds, dalapon, amitrol, and others. If foliage is wet before application, runoff of the chemical results in poorer weed or brush kill. Rainfall within a few hours of application of these herbicides also decreases their absorption into the plant (41). Ester formulations of the phenoxy herbicides are absorbed more rapidly than amine-salts. Therefore, they are less affected by rainfall following application.

Adequate soil moisture is necessary for greatest effectiveness of the foliar herbicides. Translocation of the phenoxy compounds in particular is greatest when root activity is high and the plants are actively growing (44). Application during a drought is less effective against weeds and brush than when moisture is adequate.

Temperature affects the volatility of herbicides and also affects plant growth. Low temperatures slow plant growth and often retard herbicidal activity. Moderate temperatures ranging from 70 to 85°F. are considered best for spraying operations (41). At temperatures over 85°F. damage is likely to occur to desirable plants because of increased volatility of some herbicides.

A high humidity when foliage sprays are applied increases absorption of the herbicide and decreases evaporation of the carrier. These result in increased weed or brush kill. Because humidity is usually high when temperature is low, conditions favor effective foliar application in the morning or late afternoon. Also the wind is usually least in the morning and this minimizes the hazard of injury due to drift.

### Effects of Herbicides on Livestock

The likelihood of livestock poisoning from any of the herbicide treatments discussed here is very small indeed. With the exception of DNBP all of these herbicides are relatively non-poisonous to livestock. None of them would be expected to poison stock in the quantities that could be eaten on treated vegetation. The possibility exists that animals



eat toxic quantities of certain poisonous plants made palatable by spraying, but experiments have not determined this conclusively. Reports from New York State indicate that livestock poisoning as a direct result of roadside spraying often has been "grossly exaggerated" (25).

### The Value of Shrubs

Removal of all plants from the roadside other than grasses is not an objective of roadside spraying. Rather the objective is to eliminate only the growth that creates a hazard. Which plants are desirable and which are not?

Desirable shrubs are by nature relatively low-growing woody plants; whereas undesirable brush usually consists of scrubby trees or sprouts from trees or stumps which nevertheless grow exceedingly tall and are more apt to create a hazard. Shrubs tend to crowd out both tree seedlings and weeds and can produce a somewhat stable low-growing community (12, 23, 24). Such plants are usually picturesque as well as functional. They absorb traffic noise, reduce headlight glare, and may serve as safety buffers in accidents. They also help to decrease driver eye-fatigue by breaking up the monotony of the landscape.

#### *Desirable Shrubs of Connecticut**

Shrubs of the kind listed below are found in Connecticut and are desirable in many areas along roadsides. Selective chemical treatment of brush will permit desirable shrubs to remain undisturbed (31, 35, 49). The shrubs designated as low generally grow less than 3 feet high, while those designated as tall grow over 3 feet high.

| *Common Name* | *Scientific Name* | *Tall* | *Short* |
|---|---|---|---|
| Yew | *Taxus canadensis* | | X |
| Low juniper | *Juniperus communis* | | X |
| Red cedar | *Juniperus virginiana* | X | |
| Heart-leafed willow | *Salix cordata* | X | |
| Pussy willow | *Salix discolor* | X | |
| Long beaked willow | *Salix bebbiana* | X | |
| Sweetfern | *Myrica asplenifolia* | | X |
| Bayberry | *Myrica carolinensis* | X | |
| Flowering dogwood | *Cornus florida* | X | |
| Southern hazel | *Corylus americana* | X | |
| Beaked hazel | *Corylus cornuta* | X | |
| Bluebeech — small tree | *Carpinus caroliniana* | X | |
| Northern alder | *Alnus rugosa* | X | |
| Southern alder | *Alnus serrulata* | X | |
| Barberry | *Berberis thunbergii* | X | |
| Barberry | *Berberis vulgaris* | X | |
| Spicebush | *Lindera benzoin* | X | |
| Witchhazel | *Hamamelis virginiana* | X | |
| Nine-bark | *Physocarpus opulifolius* | X | |
| Meadow-sweet | *Spiraea latifolia* | | X |
| Hardhack | *Spiraea tomentosa* | | X |
| Shrubby cinquefoil | *Potentilla fruticosa* | X | |
| Blackberry and raspberry | *Rubus* spp. | X | |
| Wild rose | *Rosa carolina* | X | |
| Choke cherry | *Prunus virginiana* | X | |
| Sand cherry | *Prunus pumila* | | X |
| Beach plum | *Prunus maritima* | X | |
| Chokeberry | *Aronia arbutifolia* | X | |

| Common Name | Scientific Name | Tall | Short |
|---|---|---|---|
| Chokeberry | *Aronia melanocarpa* | X | |
| Hawthorns — small trees | *Crataegus* spp. | X | |
| Bristly locust | *Robinia hispida* | X | |
| Winged sumach | *Rhus copallina* | X | |
| Smooth sumach | *Rhus glabra* | X | |
| Staghorn sumach | *Rhus typhina* | X | |
| Black alder | *Ilex verticillata* | X | |
| Mountain holly | *Nemopanthus mucronata* | X | |
| New Jersey tea | *Ceanothus americanus* | | X |
| Buckthorn | *Rhamnus cathartica* | X | |
| Leatherwood | *Dirca palustris* | X | |
| Pepperbush | *Clethra alnifolia* | X | |
| Pinkster-flower | *Rhododendron nudiflorum* | X | |
| Mountain azalea | *Rhododendron roseum* | X | |
| Swamp honeysuckle | *Rhododendron viscosum* | X | |
| Mountain laurel | *Kalmia latifolia* | X | |
| Sheep laurel | *Kalmia angustifolia* | | X |
| Male-berry | *Lyonia ligustrina* | X | |
| Leather-leaf | *Chamaedaphne calyculata* | X | |
| Dangleberry | *Gaylussacia frondosa* | | X |
| Huckleberry | *Gaylussacia baccata* | | X |
| Low blueberry | *Vaccinium vacillans* | | X |
| Low blueberry | *Vaccinium angustifolium* | | X |
| High blueberry | *Vaccinium atrococcum* | X | |
| High blueberry | *Vaccinium corymbosum* | X | |
| Buttonbush | *Cephalanthus occidentalis* | X | |
| Highbush cranberry | *Viburnum opulus* | X | |
| Hobblebush | *Viburnum alnifolium* | X | |
| Maple-leaved viburnum | *Viburnum acerifolium* | | X |
| Withe-rod | *Viburnum cassinoides* | X | |
| Sheepberry | *Viburnum lentago* | X | |
| Arrow-wood | *Viburnum dentatum* | X | |
| Elder | *Sambucus canadensis* | X | |
| Red-berried elder | *Sambucus pubens* | X | |
| Bush honeysuckle | *Diervilla lonicera* | | X |
| Japanese honeysuckle | *Lonicera japonica* | | X |
| Honeysuckle | *Lonicera morrowi* | X | |

*A list of shrubs abbreviated from a report of the Right of Way Vegetation Committee of the Connecticut Botanical Society, Paper No. 3, Dec. 1956.

## Use and Calibration of Spray Equipment

The proper use and calibration of spray equipment determines the success of a spraying operation to a very large extent. Ahlgren *et al.* (1), Conley (17), and others (6,41, 42, 43) have contributed useful information on this subject. Sprays should be applied accurately, uniformly, and in a sufficient volume of carrier to cover the area adequately. In addition the droplet size should be large enough to prevent drift. Proper application also involves care in keeping nozzles clean and in spraying a constant volume per acre.

### Adjusting the volume of spray

Volume of spray per acre is adjusted by varying the pressure, the speed of travel, or the nozzle size.

Pressure: Adjustment of pressure can be used to make only small changes in volume of output. This is so because to double the volume of output by changing the pressure alone requires increasing the pressure



fourfold. Pressures of between 30 and 60 p.s.i. are sufficient for most roadside spraying. In order to keep the spray droplets large higher pressure should be used only in conjunction with large nozzle sizes.

Speed of travel: The range of speeds satisfactory for roadside spraying is generally from 5 to 10 m.p.h. The range of speeds for hand sprayers is even smaller, from 1 to 3 m.p.h. When the speed is doubled the volume of spray applied per acre is reduced by one half. Speeds can ordinarily be determined accurately only to the nearest mile per hour. Therefore adjusting the speed is usually a poor way to make small changes in volume of spray applied.

Nozzle size: Changing the nozzle size is the most convenient way to make a large volume change (17). The amount of spray delivered is directly proportional to the square of the diameter of the nozzle opening. Therefore, if the diameter of the opening is doubled the volume is increased four times.

Charts are available from spray equipment companies, showing the capacities of nozzle sizes in gallons per minute at different pressures. Some charts also convert this to gallons per acre at different speeds. From such charts the proper nozzle sizes for a particular job are selected. Having selected a nozzle size that will discharge the desired amount of spray per acre at a given speed and pressure, one must still calibrate the sprayer, because the actual output of a nozzle on a particular piece of a spray equipment may differ slightly from its charted capacities. Calibration may not be necessary where rates of application are given in terms of pounds of herbicide per 100 gallons of spray and the amount applied depends on density of foliage or stems, as in brush spraying with hand booms.

### Calibration of power sprayers

There are several ways to calibrate power sprayers (16, 17, 42). One of the simplest methods of calibration is to determine the nozzle output in gallons per minute and then to compute the speed required to apply the desired number of gallons per acre at constant pressure (32). The tank is partially filled with water, the sprayer is turned on and set to the desired pressure and the nozzles are inspected to see if they are working properly. The spray is then caught in a container for several minutes. The number of gallons of liquid collected is divided by the number of minutes to give the pump output in gallons per minute at the selected pressure. The speed of travel is then calculated by the following formula:

$$\text{speed of travel in miles per hour} = \frac{60 \text{ minutes/hour} \times 43{,}560 \text{ sq.ft./acre} \times \text{gal./min.}}{\text{gal./acre} \times \text{spray width in ft.} \times 5{,}280 \text{ ft./mile}}$$

$$\text{therefore, m.p.h.} = \frac{495 \times \text{gal./min.}}{\text{gal./acre} \times \text{spray width in ft.}}$$

Example: Suppose the nozzle output was 2 gals. a minute, the volume of application desired was 50 gals. to the acre and the spray width was 3 ft.

The speed of travel in m.p.h. would be $\frac{495 \times 2}{50 \times 3} = 6.6$ or 7 m.p.h.

If the calculated speed of travel is not suitable a small adjustment can be made in pressure and the new speed of travel is determined as before. Occasional checking of nozzles and nozzle capacities is necessary to maintain accurate application rates.

This method assumes that accurate speed adjustment is available. Speedometers should therefore be checked in the range of use.

### Calibration of hand sprayers

In using a hand sprayer the operator must maintain a constant walking speed and hold the nozzle or boom at a constant height above the ground. To calibrate a hand sprayer, one marks off an area 5 x 20 feet (100 sq. ft.), fills the sprayer with water and sprays the area at the same speeds and pressures that will be used in actual practice. Then the amount of water to refill the tank to the original level is measured accurately. The following table converts the discharge rate per 100 sq. ft. to gallons per acre (6, 41).

| *Nozzle or boom discharge per 100 sq. ft.* | *Equivalent discharge per acre, gallons* |
|---|---|
| ¼ pint | 14 |
| ½ pint | 27 |
| 1 pint | 55 |
| 1½ pints | 82 |
| 1 quart | 110 |
| 2 quarts | 220 |

### Mixing the spray materials

The volume of spray to be mixed must be adequate to cover the area to be sprayed. Thus:

$$\frac{\text{spray in tank (gals.)}}{\text{volume of spray to be applied (gals./acre)}} = \text{Acres to be sprayed}$$

and the amount of formulated herbicide to be added to the tank is equal to:

$$\text{(a) lbs./tank} = \text{acres to be sprayed} \times \text{lbs. of active herbicide per acre} \times \frac{100}{\text{percentage active herbicide in formulation}}$$

or

$$\text{(b) gallons/tank} = \frac{\text{acres to be sprayed} \times \text{lbs. of active herbicide or acid equivalent per acre}}{\text{lbs. of active herbicide or acid equivalent per gallon}}$$

Example 1: The sprayer will apply 75 gals. per acre; the herbicide rate is 10 lbs. of simazin per acre; the formulation is 50% active simazin; the tank holds 300 gallons.

The acres to be sprayed: $\frac{\text{300 gals.}}{\text{75 gals./acre}} = 4$ acres



The amount of simazin (50%) to add is:

$$4 \text{ acres} \times 10 \text{ lbs./acre} \times \frac{100}{50} = 80 \text{ lbs.}$$

Example 2: The sprayer will apply 100 gals. per acre; the rate of herbicide application is 2 lbs. of 2,4-D acid equivalent per acre; the concentration of 2,4-D is 4 lbs. of acid equivalent per gallon; the tank holds 500 gallons.

$$\text{Thus } \frac{\text{500 gals.}}{\text{100 gals./acre}} = 5 \text{ acres the sprayer will cover when full}$$

To cover this area at the indicated rate, the amount of 2,4-D (formulated) required is:

$$\frac{5 \text{ acres} \times 2 \text{ lbs./acre}}{4 \text{ lbs./gals.}} = 2.5 \text{ gallons}$$

The herbicide is never added to an empty tank, but rather is added to a partially filled tank. Then the rest of the water required is added.

In mixing oil-water emulsions, the herbicide and the oil are mixed before adding them to the partially filled tank. If the oil and herbicide are added to the water separately a poor emulsion will be obtained (60). Adding the herbicide to the tank filled with water (or oil) is also incorrect because the spray is then too dilute. After filling the tank, the pump should be run for a short period with the nozzles turned off to mix the spray thoroughly.

### Cleaning the sprayer

Sprayers used for the phenoxy herbicides (2,4-D, 2,4,5-T, silvex, etc.) should not be used for other sprays because these materials are difficult to remove completely from a sprayer (41). Even traces of these herbicides may damage susceptible plants.

To remove phenoxy herbicides from a sprayer requires thorough cleaning, which consists of first washing the tank with warm water and a detergent (6, 41). Then the tank is filled with dilute ammonia at the rate of 1 gallon of household ammonia per 100 gallons of water. Some of this solution is run through the nozzles and the sprayer is allowed to stand overnight with the solution in the sprayer. Then the solution is removed and the sprayer is rinsed with water.

Activated charcoal can substitute for household ammonia in removing phenoxy herbicides from a sprayer (41). Charcoal absorbs the herbicides in a very short time. The sprayer is rinsed for about 2 minutes with a 0.25 percent suspension of activated charcoal (1 lb. activated charcoal in 8 gallons of water containing a detergent) and is then rinsed with water. This procedure will remove most formulations of 2,4-D and similar herbicides from spray equipment. If in doubt a test can be run by spraying water from the cleaned tank on plants of tomato or bean. If no harmful effects are noted within 48 hours, the sprayer can be assumed to be clean.

Many herbicides, other than the phenoxy herbicides, are fairly easy to remove from spray equipment by water and detergent rinses. Daily care of a sprayer should include flushing out the sprayer with water at the end of spraying operations.

### General Precautions for Herbicide Use

Whenever suggested rates of herbicide application are given in terms of pounds per acre, it is necessary to calibrate equipment before use to insure accurate application. Care should then be taken to apply the sprays with the greatest precision. An overdose of an herbicide may be harmful and wasteful while an insufficient dose will result in poor control of weeds or brush.

The label on the herbicide container gives directions for handling and use. Following these directions carefully will avoid possible injury to spray operators or damage to neighboring property and will give maximum results with the herbicide.

Foliage spraying is hazardous in a wind, or when air temperatures at the time of application exceed 85°F. Damage to nearby susceptible plants will be a minimum when low-volatile ester or amine-salt formulations of the phenoxy compounds are used. Roadside sprays applied at low pressures with large nozzles are not prone to drift.

The selective application of herbicides along roadsides permits survival of desirable shrubs and trees that do not interfere with roadside safety. Foliar sprays applied to brush just before natural leaf coloring starts in the late summer avoids an unsightly brown-out. Foliar sprays applied to brush over 3 to 4 feet high will usually make the roadside unsightly.

Needless injury can be avoided by storing herbicides away from insecticides and fungicides, and by using herbicide spraying equipment for other uses only after thorough cleaning, as mentioned under "Use and Calibration of Equipment."

## SITUATIONS ENCOUNTERED IN ROADSIDE SPRAYING

No single herbicide will control all types of weeds and brush in all situations. However, the most common situations encountered are discussed below, along with treatments that have proven to be effective.

### The Control of Broadleafed Weeds in Established Turf

Experience has shown that herbicide spraying to control broadleafed weeds in turf materially decreases the number of mowings required (8, 21, 22, 30, 34). This is especially true during drier parts of the summer, when grass growth slows but weed growth continues (34).

#### Treatments

The low-volatile esters and amine salts of 2,4-D and 2,4,5-T have been used almost entirely for this purpose (30). 2,4-D alone at rates of 3/4 to 2 pounds acid equivalent per acre in 15 to 50 gallons of water gives effective control of most weeds at low cost. The addition of an



equal or slightly smaller amount of 2,4,5-T to the mixture increases its effectiveness over a wide range of weeds.

Treatments must be applied before the weeds have grown above the grasses if a reduction in the number of mowings is to be expected. Where several sprays are applied during the season, a common practice is to apply 3/4 to 2 pounds per acre of 2,4-D low-volatile ester or amine salt in the early spring for the control of the plantains, mustard, dandelions, and the like. This treatment can be combined with a liquid fertilizer application (33).

In Connecticut a second application in May is made consisting of 1½ pounds 2,4-D amine salt plus 1 cup of wetting agent per 50 gallons of water per acre (33). In Ohio the second application is delayed until July 1st when a mixture of 2 parts 2,4-D plus 1 part 2,4,5-T or a total acid equivalent of 1 pound per acre is applied (30). A third application may be required to control some weeds.

When the second or third application is applied depends upon the success of the previous spraying, the types of weeds present, and growth rates of new weed seedlings which have started after the previous application. Actually 2,4-D and 2,4,5-T may be applied throughout the growing season with no detrimental effects on established turf but weed kill is apt to be greatest when the weeds are immature, soil moisture is adequate and weed growth is normal (6, 41). In areas where the weed populations have been decreased by spraying in previous years it has been possible to decrease the number of treatments applied in a given season (30).

Spraying of ragweed to prevent pollen dispersion must be done before flowering has started (28). In our area ragweed starts to flower about the middle of August (10). Although early spring treatment with 2,4-D will kill the plants existing at that time, the germination of common ragweed takes place during the whole summer and a second spray application will be necessary to kill these new seedlings and thus prevent their flowering (10).

#### Methods of application

Spraying for weed control in turf can be done with various types of equipment. When the turf area adjacent to the road is relatively narrow, the entire application may be made from a truck-mounted boom. A view of one type of such equipment used successfully by the Connecticut State Highway Department is shown in Figure 1. Regardless of the equipment used, to obtain uniform coverage on the treated areas and to avoid drift, volumes of at least 50 gallons per acre are advisable.

#### Precautions in Broadleafed Weed Spraying

Although 2,4-D and 2,4,5-T formulations used at recommended rates do not seriously affect the more important turf grasses, it is advisable to delay treatment of new seedings until they have become well established. This is especially true on slopes and other areas subject to erosion. Weeds can be of great value in preventing erosion on newly seeded areas.

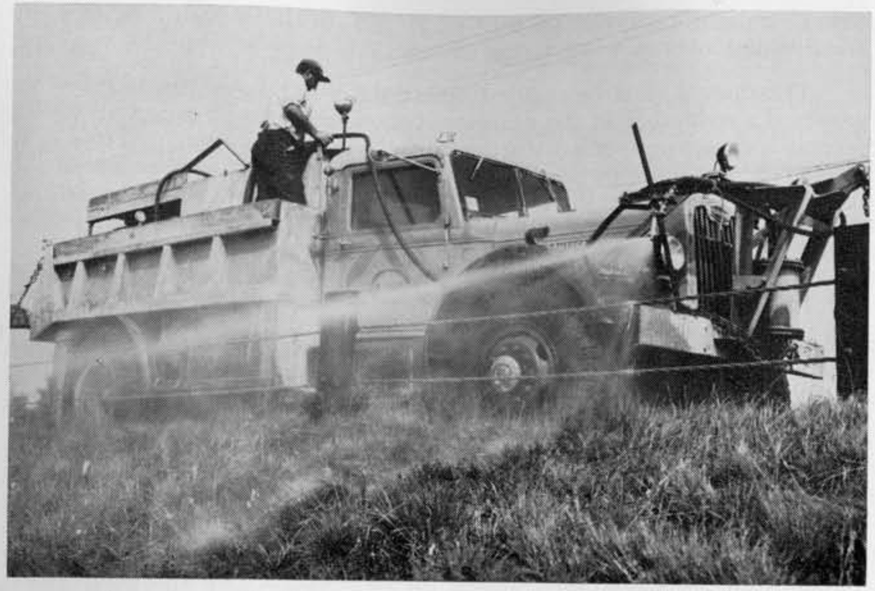

Figure 1. Application equipment shown above is one of the types used for control of broadleafed weeds in roadside turf and for the control of low brush with foliage sprays.

Skilled spray operators carefully avoid the spraying of desirable shrubs or trees. Spraying in a wind is avoided and special precautions are taken when spraying near 2,4-D sensitive crops or plantings. (See Volatility and Drift)

## The Control of Weeds Under Guide Rails and Around Structures (Soil Sterilization)

Hand methods are the most expensive operations in maintenance work. At one time all weed control under guide rails and around structures was done by hand. Now, such areas can be kept weed-free by chemical methods, which may save up to $43 per mile (32).

### Treatments

Soil sterilization is at best temporary in the humid Northeast when soil is chemically treated and left uncovered. Placing a layer of tar or bitumen over the treated area, especially under guide rails, prolongs the life of the treatment (33, 34). Monuron and diuron at 16 to 32 pounds per acre have proven effective for this use. Either compound at 16 pounds per acre has given successful weed control for at least 3 years along Connecticut state highways (33). Treatment is most effective if applied when soil moisture is adequate.

Without the protective cover of tar or bitumen, treatments for soil sterilization in the Northeast generally will control weeds for 1 to 2 years. Monuron or diuron, at 10 to 16 pounds per acre will hold treated areas weed-free for 1 to 2 years if applied before growth starts in the spring



and when soil moisture is adequate (54). If weeds are well established, higher rates are required for adequate kill. These compounds when used without a cover are easily leached or washed onto turf and other planted areas and must be used with extreme caution because of this characteristic (48). Trees with roots growing into treated areas may also be injured. Monuron is more hazardous in these respects than diuron.

Simazin on the other hand, is not easily moved in soil and has not damaged grassy areas downhill from the treated area except at very high rates of application. It acts most effectively on germinating seeds but has been used for seasonal weed control at 10 pounds per acre applied early in the spring before growth has started (5). Higher rates may be required to kill established herbaceous plants.

Simazin has been very effective at lower rates of application when used in combination with amitrol (40). Amitrol has the effect of killing the existing grasses and broadleafed weeds which include some of the hard-to-kill species such as milkweed and Canada thistle. Simazin then prevents development of new seedlings and effective seasonal weed control is obtained. Combinations of 2 to 5 pounds per acre of amitrol plus 5 to 10 pounds of simazin have been effective. Applications are delayed until some growth has been made but before mowing is required.

Combinations of 2,4-D low volatile esters or amine salt and dalapon, sodium salt, also have been very effective for control of plant growth under guide rails (21, 22, 33, 62). Dalapon is a very effective grass killer and has a limited residual effect in the soil, while 2,4-D controls the

Figure 2. Hand booms from truck-mounted power spray equipment, as shown above, are often used for applying herbicides in functional plantings. They can also be used for application of basal sprays and stump treatments for brush control, and spot treatments for the control of poison ivy and other plant pests.

broadleafed weeds (6). Sprays containing 16 to 20 pounds of dalapon acid equivalent plus 2 pounds of 2,4-D amine-salt acid equivalent plus 1 cup of wetting agent in 50 gallons of water per acre are used in Connecticut for this purpose (34). The treatment is made in early spring after growth has started but before mowing is required.

Repeat applications may be required in some years when rainfall is heavy and there is a lush regrowth of new weed seedlings. Retreatment with dalapon plus 2,4-D will generally be less expensive than the hand mowing required. This combination has only a limited effect on certain broadleafed weeds that are resistant to 2,4-D (milkweed and Canada thistle, for example). Where the problem is localized, these weeds may be spot-treated with amitrol as mentioned in the section "The Control of Special Plant Pests."

A combination of dalapon, 20 to 24 pounds per acre plus silvex, low-volatile ester, 3 pounds per acre, has also been used effectively for certain weeds. Silvex is notably more effective than 2,4-D on some weeds including bedstraw (*Gallium* sp.) (26) and chickweed (29). Applications are made on active weed growth during the spring.

### Methods of application

Applications around structures and sign-post delineators or other similar inaccessible areas can be made with either a knapsack sprayer or a hand boom off a power sprayer which remains on the roadside (Figure 2). Applications under guide rails are generally made with a truck-mounted boom as shown in Figure 3. Usually a strip about 2 feet wide under the

Figure 3. Application of guide rail sprays to eliminate costly hand mowing involves treating a narrow band with a minimum of herbicide hitting the pavement.



guide rails is treated. Application is made from behind and under the guide rails with the spray directed towards and overlapping slightly the pavement or shoulder. Spraying from behind the rails maintains a neat, even line of kill.

### Precautions in soil sterilization

Monuron or diuron may damage desirable plants unless they are used under a protective covering or in areas not subject to wash or serious leaching. Precautions for use of 2,4-D have already been given. Use of amine-salt formulations reduces the hazard to valued plants nearby. See "Volatility and Drift."

Careless application of guide rail sprays may leave too much herbicide on the pavement. The first rain will wash the chemical to areas where it can injure turf or other plantings.

## The Control of Woody Plants

Along narrow roads brush and trees readily create a hazard. The problem, then, is to remove them at a minimum cost and with minimum labor, while preserving roadside beauty to the maximum degree. Chemical techniques allow variations in types of control but all are decidedly less expensive than continued periodic cutting.

Three techniques are generally adaptable for the chemical control of brush and trees along roadsides: (a) stump treatment—cutting the growth and treating the stumps to prevent sprouting; (b) basal treatment—treating standing brush with materials in sprays directed at the bases of stems; (c) foliage treatment—treating the foliage and stems with a spray. The technique used depends upon previous brush control practice, size and density of existing growth, nearness to susceptible crops or plantings, the principal species to be controlled, nearness of the brush to the roadside, and the time and labor available for brush control practices.

### Stump treatments

Where adequate labor is available, cutting the undesirable growth and treating the stumps to prevent regrowth is often the most satisfactory method of woody plant control, although initially the most costly (23, 49). It is the only satisfactory method of killing trees along roadsides and is also the most suitable method for controlling undesirable brush over 3 to 4 feet high. Although standing trees of almost any size may be killed by other mechanical and chemical methods (girdling and frilling), these methods are undesirable along roadsides because of danger from falling limbs and unsightliness of standing dead trees.

Stump treatment involves the application of one of the following treatments after cutting the woody plant growth:

a) 2,4,5-T low volatile esters at 8 to 16 pounds acid equivalent per 100 gallons of spray in fuel oil, diesel oil, or kerosene.
b) 2,4-D plus 2,4,5-T low volatile esters at a combined acid equivalent of 12 to 16 pounds per 100 gallons of spray in oil.

c) Ammonium sulfamate at 4 to 6 pounds per gallon of water.

The spray is directed at the cut surface of stumps, on all sides and at the root collar, which lies at or just below the ground line, so as to drench the stump with rundown. Sufficient volume should be applied to soak the area thoroughly at the base of the stump as well, because contact of the herbicide with root collars and lateral roots is very important in obtaining root kill (65.) When large volumes of spray are used the concentration of herbicide is decreased. For this use a large volume is more important than high concentration (59). Scraping the leaf litter away from the base of the stump increases effectiveness (18).

Fuel oil, diesel oil, kerosene, and similar oils have some toxic effects in themselves when used for stump treatments (59). They are used without exception as carriers for 2,4-D or 2,4,5-T. Water has proven to be a poor carrier for these compounds in stump treatments (39).

Stump and stubble treatments with the phenoxy herbicides have been applied successfully during every month of the year (18). However, there are important considerations in timing other than the availability of labor. Ammonium sulphamate has been most effective during growing season applications (48). Treatment of stumps should be carried out as soon after cutting as possible because a newly cut surface allows more penetration of herbicide than a healed surface does (26). Cutting during the growing season (May-July) results in fewer surviving stumps of some species, probably because root reserves are low at this time (48). Also, frozen ground prevents saturation of the soil with herbicide, thus reducing the contact effect necessary for good kill.

The frill method yields good results on larger stumps that continue to produce sprouts (46, 48). A series of overlapping axe cuts are made completely around the stump. The same herbicide treatments used for stump and stubble treatment are then sprayed into the newly cut frills until they overrun.

Erratic results sometimes have been obtained with treatments on stubble of small brush, and especially on those species that sprout readily from roots (for example, willows, sumac, and sassafras) (18, 48). Because of their small size these stubs are often missed in applying the treatments and even when treated may produce root sprouts because the untreated root area is much greater than the small treated area. It is therefore sound practice to attempt to treat after cutting only stubs with diameters larger than 2 inches or so and to plan on treating the sprouts after one or two seasons regrowth by the basal or foliage techniques discussed below. Some follow-up spraying will be necessary within the next two seasons whether stumps are treated or not (15, 48).

Some of the ground cover, including grasses, will be destroyed in treated areas. With the chemicals mentioned, however, (15, 36) rapid regrowth of ground cover can be expected. Other treatments, which are equally effective in preventing stump sprouting, are unsatisfactory along roadsides because the soil is sterilized for a long time and because damage to the roots of desirable plants may occur (39, 48).



### Basal treatments

When it is not necessary to cut brush or where regrowth from cut brush or trees must be controlled, the most effective technique for roadside applications is a basal treatment with 2,4,5-T alone or in combination with 2,4-D in fuel oil, kerosene, or diesel oil (18, 49). This technique is well adapted to selective treatment and may be applied at any time of the year for many species (23, 49). It is generally more effective than foliar sprays for such hard-to-kill species as oak and maple but is often less effective for root suckering species (sumac, sassafras, and others) (11, 12, 15). Basal sprays have been relatively ineffective on trees over 3 to 4 inches in diameter (48, 49). Costs of materials and application are usually higher for basal treatments than foliar sprays and the application is difficult in dense brush (21, 63).

With basal treatments the brush is left standing. Otherwise basal and stump treatments are similar. Sprays of 2,4,5-T low-volatile esters at 8 to 16 pounds acid equivalent per 100 gallons in oil or combinations of 2,4-D plus 2,4,5-T in oil at 12 to 16 pounds combined acid equivalent per 100 gallons are effective for basal treatments. The spray is directed at the sides of the stems to a height of 15 to 20 inches and at the base of the plant (18). As with stump treatments sufficient volume should be applied to drench the root collar and when high volumes are used, low concentrations of herbicide are employed (13, 64).

Basal sprays are generally more effective on root-suckering species if applied during the summer (11, 12, 15, 48). With other species dormant treatments often are more effective (18, 65), although good control has been obtained with treatments in every season (15, 48, 49, 50, 51, 64). Desirable deciduous species are more easily recognized when the foliage is present. Therefore, early fall or late summer treatments are most practical. However, when the basal treatments are follow-up procedures to control sprouting from previous cutting, the desirable species are distinguished easily even in the winter. Advantages of dormant basal sprays include less danger of injury from volatility because of lower temperature, less danger of crop injury because the growing season is past, the use of labor during slack periods and the elimination of brown-out (51).

Basal sprays result in good stem kill and moderate root kill but some sprouting may occur. Then follow-up sprays are applied during the next growing season using basal or foliar sprays (11, 12, 15, 21, 22).

### Foliage treatments

Foliar sprays are generally the least expensive and are often considered the least effective of herbicide applications (49). When used improperly they cause severe brown-out with poor killing of plants (18, 63). When low volumes are applied mainly to leaves, foliar sprays are not as effective as basal sprays, especially on resistant species (13). Sprays in which only leaves are treated have been largely discontinued and specialists now recognize the superiority of stem-foliage application in which stems as well as foliage are saturated (13, 18, 63). Stem-foliage applications are often more effective than basal sprays on root-suckering species (11, 15). However, with foliar sprays there is greater danger of injuring desirable plants and of drift and subsequent injury to neighboring plants. Also, if used too early in the season, the period of undesirable brown-out is long (21, 33).

The most common foliar treatments have been the low-volatile ester or amine-salt formulations of 2,4-D plus 2,4,5-T at 6 to 8 pounds combined acid equivalent per 100 gallons of spray in water, or 2,4,5-T alone at 4 to 6 pounds acid equivalent per 100 gallons of spray in water. Silvex at 4 to 6 pounds per 100 gallons in water also is quite effective on resistant oaks, maples, and sassafras (14, 19, 50).

Sprays are applied to the stem and foliage to runoff. Merely wetting the foliage without wetting the stems thoroughly produces poorer root kill (18).

The use of amine-salt formulations has increased because they are less expensive and are non-volatile. The amine salt of 2,4,5-T is very effective and is preferred by some specialists (63).

Foliar sprays are most effective when plants are in full leaf and actively growing, usually during early summer (18, 44). However, early summer applications are feasible only where brown-out is not troublesome and possibilities of drift damage to crops or plantings are small. More commonly, foliar sprays are applied during late summer, usually from August 1 to September 15. At this time the danger of injury due to drift is a minimum and the time of brown-out before fall coloring is greatly shortened (33).

Effectiveness of late summer sprays is often less than that of earlier sprays. At this time leaves are hard to wet, penetration with herbicide is less, and dry soil conditions do not favor movement of herbicide down the plant (38, 44). To maintain good kill with late summer foliar sprays, one may add 1 to 5 gallons of No. 2 fuel oil to low-volatile ester formulations per 100 gallons of spray, or use 2,4,5-T or a combination of 2,4,5-T plus 2,4-D amine salts or esters at concentrations of 8 to 12 lbs. acid equivalent per 100 gallons of spray in water instead of the usual 6 to 8 lbs. Both procedures give better kill in late summer than the standard early summer foliage spray concentrations (38, 63). The small amount of oil may cause some browning of the grasses but this has not been too severe or objectionable.

Adding oil to herbicide mixtures for early summer (May-June) foliar sprays hastens brown-out and while leaf kill is good, excessive root collar and stem sprouting occur (50, 63). Rapid brown-out is an indication of poor, not good, plant kill. Once the leaves are killed (50) the herbicide cannot be translocated to the roots.

Foliar sprays applied during advanced leaf coloration or after frost are apt to provide very poor brush control (18). Spraying tall brush or trees causes excessive brown-out and is therefore unsuitable in most areas.

Follow-up treatments are required and are most effective when repeat foliage sprays are applied to root-suckering species and when basal sprays are used on predominantly oak-maple brush. Scattered regrowth can be treated more effectively by basal techniques while foliage sprays are more feasible in areas of dense regrowth.



### Methods of application

Stump and basal treatments may be applied with knapsack sprayers (Figure 4) or with hoses from power sprayers (Figure 2). Low pressures of 25 to 80 p.s.i. are generally used and volumes range from 50 to 150 gallons per acre or more, depending upon the number of stems per acre.

Selective foliar treatments are most conveniently applied with a hand boom from a power sprayer or suitable truck-mounted equipment. In dense brush or in areas immediately adjacent to the road, equipment similar to that used for weed control may be used (Figure 1).

Figure 4. The most satisfactory method of preventing sprouting of freshly cut trees along roadsides is to treat the stumps with ammonium sulfamate, 2,4,5-T, or mixtures of 2,4-D and 2,4,5-T.

### Precautions in woody plant control

To avoid excessive unsightly brown-out, foliage more than 3 to 4 feet above the ground is not sprayed. For the same reason foliage or basal sprays are not applied early in the season in many areas. Adding oil to early summer foliar spray mixtures gives undesired results. When oil is added to late summer foliar sprays, oil-soluble ester formulations and not the water-soluble amine salts are indicated. One must learn to distinguish desirable shrub species and treat selectively whenever possible. One should also observe the necessary precautions to prevent volatility and drift and if possible avoid using foliar sprays near susceptible plantings.

## The Control of Weeds in Functional Plantings

Along highways, shrubs or trees are frequently planted to reduce glare, create a buffer zone, or merely to hide something distracting. While these plantings are becoming established they are often hand-cultivated or hand-mowed. A good deal of this hand labor can be eliminated by proper use of herbicides.

### Treatments

Two types of herbicides may be used in this way. Pre-emergence herbicides are applied before weeds emerge, whereas post-emergence herbicides are applied after weed emergence. Pre-emergence herbicides are effective primarily on germinating seeds and seedlings while post-emergence herbicides act on existing plants and mainly on foliage. To use a pre-emergence herbicide effectively the soil must be free of growing weeds and preferably just cultivated (41). The herbicide is then applied as a spray or granular powder around the base of the plants. Sprays are directed so as not to hit foliage while granular materials may be applied overhead as long as the foliage is dry. The pre-emergence herbicide prevents development of weed seedlings but does not control most growing weeds. The following have been most successful for this type of application (2, 3, 6, 9, 16, 41, 52, 58):

a) neburon at 3 to 6 lbs. per acre.
b) diuron at 1 to 2 lbs. per acre.
c) simazin at 2 to 4 lbs. per acre.
d) DNBP at 9 to 12 lbs. per acre.

Pre-emergence applications are made early in the season, when soil moisture is adequate, and are applied to well rooted plantings which have been growing in their present location for at least 1 year. If necessary, a second application may be made the same year after removing the existing weed growth.

The post-emergence herbicides acceptable for use in plantings are dalapon at 5 to 10 pounds per acre and amitrol at 4 to 6 pounds per acre. These compounds are applied to weeds growing at the base of established plantings, preferably while the weeds are relatively immature (3, 40). Dalapon is mainly a grass killer while amitrol will kill both grasses and broadleafed weeds. A sufficient volume of water is necessary to wet the weed foliage thoroughly; usually 40 to 50 gallons per acre, but valued foliage must not be sprayed. Repeat applications can be made through the season if necessary.

Combinations of post- and pre-emergence herbicides kill existing weeds and maintain long residual weed control without initial mechanical weed removal. Promising combinations are amitrol at 2 to 4 pounds per acre plus simazin at 2 to 4 pounds per acre, or dalapon at 5 to 10 pounds per acre plus DNBP at 3 to 6 pounds per acre (3, 40, 52). Directional applications are made in a sufficient volume of water to wet the weed foliage at a time when the weeds are immature, well before mechanical weed removal or hand mowing is necessary.

### Methods of application

Knapsack sprayers are efficient for "chemical hoeing" operations because the areas to be treated are usually small. Hand booms off power sprayers also have been used. Hand dusters may be used to apply granular formulations of pre-emergence herbicides. Granular formulations are less likely to injure shrubs than sprays and are equally effective for weed control (2).



### Precautions in the use of chemicals in functional plantings

Spray formulations are always applied directionally to weeds only. Spraying the foliage of the plantings should be avoided. If granular materials are applied on wet foliage, some injury to the planting may result. Only well established plants, in location for a year, can be treated safely. Higher rates of application than are suggested may sterilize the soil, killing the foundation plants as well as the weeds.

## The Control of Special Plant Pests

Certain noxious plants and some plants resistant to the usual herbicides occur frequently in Connecticut and deserve special attention.

### Poison ivy (Rhus radicans) and Poison Sumac (Rhus vernix)

Both of these plants are woody perennials of noxious habit. Poison ivy is controlled chemically by spraying the entire foliage and stems when plants are in full leaf and actively growing (20, 21, 22, 53). The following materials are all effective.

a) amitrol at 2 to 6 lbs. per 100 gallons in water.
b) amine salts or low-volatile esters of 2,4-D at 2 lbs. acid equivalent plus 2,4,5-T at 1 to 2 lbs. acid equivalent per 100 gallons in water.
c) 2,4,5-T low-volatile ester or amine salt at 1 to 3 lbs. acid equivalent per 100 gallons in water.
d) Ammonium sulfamate at 3/4 to 1 lb. plus sticker-spreader per gallon in water.

Complete kill is seldom attained by a single treatment and repeated treatments the same season or the following season are necessary (20). All of the above compounds may be applied to poison ivy growing on tree trunks without harming the tree if great care is used to avoid spraying the tree foliage. Ammonium sulfamate and amitrol injure grasses and therefore care in application is necessary when poison ivy is growing in turf. Depending upon where the poison ivy or poison sumac is and the extent of infestation, either hand booms, knapsack sprayers or truck-mounted booms (Fig. 1) may be used for applying these treatments.

### Milkweed (Ascelepias spp.)

Milkweed is a perennial, reproducing by seeds and rootstocks (47). Dalapon, monuron, 2,4-D, and 2,4,5-T sprays are ineffective against it (55).

Spot treatments with amitrol are effective at 4 to 5 pounds per 100 gallons in water, when applied during early summer or before the milkweed plant flowers (26, 40). Repeated applications may be necessary. These can best be made with knapsack sprayers or hand booms off a power sprayer, again depending upon the degree of infestation.

### Canada thistle (Cirsium arvense)

Canada thistle is another long-lived perennial weed that reproduces by creeping roots as well as seeds (47). It is persistent in turf and pastured lands and thus is a threat to nearby agricultural land. Sprays of 2,4-D are effective only if applied at bud stage. Amitrol at 2 to 4 pounds per 100 gallons in water is effective if applied when the plants are at least 4 inches tall and before flower buds are formed (26). Applications can be made with a knapsack sprayer or a hand boom.

### Japanese honeysuckle (Lonicera japonica)

Japanese honeysuckle is often cherished along roadsides as a stable ground cover and long-lived perennial. These same qualities make it difficult to control in areas where it tends to displace desirable shrubs and trees.

No single chemical application will kill Japanese honeysuckle (45). Repeat treatments are necessary to kill new sprouts as they appear. Amitrol at 4 to 6 pounds per 100 gallons or 2,4-D amine salt or low-volatile ester at 2 pounds acid equivalent per 100 gallons in water have been fairly effective. Sprays are applied to the stems and foliage when the plants are in full leaf and actively growing, usually June to July. Sprays may be applied with a hand boom off a power sprayer.

### Japanese fleeceflower, Japanese bamboo (Polygonum cuspidatum)

Although not native to Connecticut, this weed is a serious pest along roadsides in some areas of the state. It is a perennial and grows to a height of 8 feet, often creating a fire hazard and interferring with the sight-line along the road. One part of erbon plus 13 parts of water is used to wet the foliage and stems to rundown when in full leaf, usually in late spring. The foliage is cut back later and the regrowth is treated. Two to several treatments may be necessary to kill this pest.

Applications can be made with a hand sprayer or truck mounted boom, if the stand of this weed is dense. Non-selective spraying is to be avoided since this herbicide has soil sterilizing effects and other ground cover will be injured (56, 57).

### Common chickweed (Stellaria media)
### Mouse-eared chickweed (Cerastium arvense)
### Bedstraw (Gallium species)

Common chickweed is an annual or winter annual, while mouse-eared chickweed and most bedstraws are perennial in habit (47). All three occasionally become problems in turf. They may be controlled with silvex at 1 to 2 pounds acid equivalent per acre, applied in early spring before flowering (26, 29). Repeat treatments may be required on mouse-eared chickweed and bedstraw. The silvex treatment can be substituted for the 2,4-D spring application on turf or may be applied as a spot treatment in areas where infestation is great enough to threaten the stand of turf grasses or cause more frequent mowings. Silvex may be applied under guide rails, in combination with dalapon, where necessary. Applications are made with hand sprayers or truck-mounted booms, depending upon the extent of infestation.



## APPENDIX

### Susceptibility of Plants to Foliar Sprays of 2,4-D and 2,4,5-T*

The following table lists certain plants, their habits of growth and reaction to foliar sprays of 2,4-D and 2,4,5-T. Habits of growth are indicated as: A — annual, B — biennial, P — perennial or W — woody. Reactions to foliar sprays of 2,4-D and 2,4,5-T are indicated as S, I, or R. S — susceptible; plants are killed or controlled usually with one moderate rate of application under optimum conditions but may require higher rates or repeat applications under adverse conditions. I — intermediate; plants are killed or controlled with moderate to high rates of application under optimum conditions but often require repeated applications. Often tops are killed but roots remain alive with single applications. R — resistant; plants are not killed or controlled by the chemical under most conditions. The susceptibilities of some cultivated plants are also given so that the hazard to crop plants near a site of application can be estimated.

| *Common Name* | *Scientific Name* | *Habit of Growth* | *Reaction to 2,4-D* | *Reaction to 2,4,5-T* |
|---|---|---|---|---|
| Alder | *Alnus rugosa* | W | S | S |
| Alfalfa | *Medicago sativa* | P | S | S |
| Apple | *Malus* spp. | W | I | S |
| Arbor vitae | *Thuja* spp. | W | R | |
| Ash | *Fraxinus* spp. | W | R | S-1 |
| Asparagus | *Asparagus* spp. | P | I | |
| Aspen | *Populus* spp. | W | S | S |
| Asters | *Aster* spp. | P | I-R | |
| Barberry, common | *Berberis* spp. | W | R | S |
| Bedstraw | *Galium* spp. | P or A | I-R | |
| Bindweed | *Convolvulus* spp. | P | S-I | |
| Birch | *Betula* spp | W | S-I | S |
| Blackberries & raspberries | *Rubus* spp. | W | I-R | S |
| Bitterweed | *Helenium tenuifolum* | A | S-I | |
| Blueberry | *Vaccinium* spp. | W | S | S |
| Bluegrasses | *Poa* spp. | A | R | |
| Bouncing-Bet | *Saponaria officinalis* | P | I-R | |
| Box elder maple | *Acer negundo* | W | S | |
| Bracken fern | *Pteridium* spp. | P | R | |
| Brier, common green | *Smilax* spp. | W | R | S |
| Burdocks | *Arctium* spp. | B | S | |
| Buttercups | *Ranunculus* spp. | A or P | S-I | |
| Buttonweed | *Diodia teres* | A | S | |
| Canada thistle | *Cirsium arvense* | P | I | |
| Carrot, wild | *Daucus carota* | B | S-I | |
| Cherry, wild | *Prunus* spp. | W | S | S |
| Chickweed, common | *Stellaria media* | A | I | |
| Chickweed, mouse-eared | *Cerastium vulgatum* | P | I | |
| Chicory | *Cichorium intybus* | P | S | |
| Cinquefoils | *Potentilla* spp. | A or P | S-I | |
| Clovers | *Trifolium and Melilotus* spp. | B or P | S-I | |
| Cockleburs | *Xanthium* spp. | A | S | |
| Corn | *Zea mays* | A | I | |
| Creeper, Virginia | *Parthenocissum quinquefolia* | W | S | |
| Dandelion | *Taraxacum* spp. | P | S | |
| Docks & sheep sorrel | *Rumex* spp. | P | I | |
| Dog fennel (mayweed) | *Anthemis cotula* | A | I-R | |
| Dogwoods | *Cornus* spp. | W | I-R | S-I |
| Elderberry | *Sambucus canadensis* | W | S-I | S |
| Elms | *Ulmus* spp. | W | S-I | S |
| Galinsoga | *Galinsoga* spp. | A | S | |
| Garlic, wild | *Allium vineale* | P | I | |
| Goldenrods | *Solidago* spp. | P | I | |
| Goosefoot, oak-leaved | *Chenopdium glaucum* | A | I | |

| Common Name | Scientific Name | Habit of Growth | Reaction to 2,4-D | Reaction to 2,4,5-T |
|---|---|---|---|---|
| Grapes, wild & cultivated | *Vitis* spp. | W | S | S |
| Grasses | *Gramineae* | A or P | R | |
| Ground cherry | *Physalis heterophylla* | P | R | |
| Hawthorns | *Crataegus* spp. | W | I | S |
| Henbit | *Lamium amplexcaule* | A | S-I | |
| Hickory | *Carya* spp. | W | I-R | S-I |
| Honeysuckle, bush | *Diervilla lonicera* | W | S-I | S |
| Honeysuckle, Japanese | *Lonicera japonica* | W | S | S |
| Ivy, poison | *Rhus radicans* | W | I | S |
| Juniper | *Juniperus* spp. | W | R | S-R |
| Knotweeds | *Polygonum* spp. | A | I-R | |
| Lambkill | *Kalmia angustifolia* | W | S-I | |
| Lambsquarters | *Chenopodium album* | A | S-I | |
| Laurel, mountain | *Kalmia latifolia* | W | I-R | |
| Locust, black | *Robinia pseudoacacia* | W | S-I | S |
| Locust, honey | *Gleditsia triancanthos* | W | I-R | S |
| Maples | *Acer* spp. | W | I-R | S-R |
| Milkweeds | *Asclepias* spp. | P | I-R | |
| Mullein | *Verbascum thapsus* | B | I-R | |
| Mustards | *Brassica* & other spp. | A | S | |
| Nightshade, black | *Solanun nigrum* | A | I-R | |
| Oaks | *Quercus* spp. | W | I-R | S |
| Peach | *Prunus persica* | W | S | S |
| Pear | *Pyrus* spp. | W | S | S |
| Parsnip, wild | *Pastinaca sativa* | B | S | |
| Peppergrass | *Lepidium virginicum* & *L. campestre* | A | S | |
| Pigweeds | *Amaranthus* spp. | A | S | |
| Pines | *Pinus* spp. | W | I-R | I |
| Pineapple weed | *Matricaria suaveolens* | A | S-I | |
| Plantains | *Plantago* spp. | P | S | |
| Potato | *Solanum tuberosum* | A | I | |
| Radish, wild | *Raphanus* spp. | A | S | |
| Ragweed, common | *Ambrosia artemisifolia* | A | S | |
| Ragweed, giant | *Ambrosia trifida* | A | S | |
| Rhododendron | *Rhododendron* spp. | W | I | S |
| Roses | *Rosa* spp. | W | S-R | S |
| Salmonberry | *Rubus spectabilis* | W | R | I |
| Sassafras | *Sassafras varifolium* | W | S | |
| Sedges | *Cyperus* spp. | P | R | |
| Shepherds-purse | *Capsella bursa-pastoris* | A | S-I | |
| Smartweeds | *Polygonum* spp. | A | I | |
| Sow thistles | *Sonchus* spp. | A or P | S-I | |
| Strawberry | *Fragaria* spp. | P | I | |
| Sumac | *Rhus* spp. | W | S-I | S |
| Tobacco | *Nicotiana* spp. | A | S | |
| Tomatoes | *Lycopersicon* spp. | A | S | |
| Tree of Heaven | *Ailanthus glandulosa* | W | S-I | S |
| Vetches | *Vicia* spp. | A or P | S | |
| Violets | *Viola* spp. | B or P | R | |
| Walnut, black | *Juglans nigra* | W | I-R | S-I |
| Walnut | *Juglans cinerea* | W | S-I | S |
| Willows | *Salix* spp. | W | S-I | S |
| Yellow rocket | *Barbarea vulgaris* | B or P | S-I | |

*Adapted in part from Ahlgren, Klingman and Wolf, Principles of Weed Control, 1951, John Wiley and Sons, Inc.; Skaptason, Reactions of Plants to Herbicides, 1958, Chemagro Corporation. Used by permission.



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