CHEMICAL WEED CONTROL IN HORTICULTURAL CROPS

D. D. Hemphill, A. E. Murneek and J. E. Smith, Jr.

This area was cleared by chemical spraying

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE AGRICULTURAL EXPERIMENT STATION J. H. Longwell, Director APRIL, 1951 COLUMBIA, MO. BULLETIN 549
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CHEMICAL WEED CONTROL IN HORTICULTURAL CROPS

D. D. Hemphill, A. E. Murneek and J. E. Smith, Jr.

INTRODUCTION

Weed control is very expensive and tedious in most horticultural crops due to the large amount of hand labor required. Every possible effort is being made to find desirable herbicides and the proper methods of using them. However, the use of chemicals to control weeds in horticultural crops is, for the most part, still “on trial”.

Chemical weed control is not a new practice, however, it has received widespread attention and made important advances only in the past few years. Sulfuric acid was used for killing mustard in small grain as early as 1890, and the weed-killing properties of sodium chlorate were discovered in 1926, but important advances were made in this field only after the discovery in 1942 of the remarkable herbicidal value of 2,4-D.

Even though 2,4-D is a very effective weed-killer, it can be used in only a few horticultural crops. Large scale search for new chemicals that can be used in growing various crops is in progress at present. Numerous difficulties are encountered in this work but progress is being made quite rapidly. It is the purpose of this publication to present the available information and to make suggestions for use of chemicals that have been found to be of value in horticultural practice.

It should be pointed out that chemical weed control must not be considered as a substitute for cultivation nor the sole means of controlling weeds. At best, chemicals are only another method to be used along with presently used practices.

In most cases weeds are better adapted to the soil on which they are found than is the domesticated crop. Weeds usually require a smaller supply of mineral elements than our cultivated crops, and will choke out the less hardy domesticated plants unless we make conditions ideal for their growth. Cultivated plants should be grown on soils best adapted to their culture; an abundant supply of nutrient elements should be provided, and the seed bed should be well prepared.

First use all cultural practices economically feasible to encourage the growth of the crop plants. After this has been done, consider the use of chemicals in your fight against weeds.

PRECAUTIONS

1. Don’t throw away your cultivator.
2. There is no chemical that will kill all undesirable plants and leave all desirable ones. Be reasonable in your expectations.
3. Try chemicals on a small scale until you learn how to use them.
4. Do not use 2,4-D or 2,4,5-T in gardens or vineyards.
5. Don't spray 2,4-D or other herbicides when wind will carry spray to susceptible crops.
6. Don't use esters of 2,4-D and 2,4,5-T in areas where vapors may drift to susceptible plants.
7. Avoid possible drift of 2,4-D to susceptible flowers and shrubs when spraying the lawn.
8. Don’t use the same sprayer for applying 2,4-D and insecticides and fungicides, unless very special precautions are taken in cleaning it.
10. Read directions on container before using. There are numerous formulations and concentrations of the same material on the market.
11. Apply chemical uniformly and at the correct rate.
12. Remember that chemicals at the best are only another tool to be used along with the tools and practices commonly used in battle against weeds.

TERMS AND ABBREVIATIONS

Herbicide—Any substance used to kill weeds.
Contact weed killer—A chemical that kills only the parts of a plant with which it comes in contact.
Translocated herbicide—A substance which is moved within the plant and exerts a toxic effect throughout the plant.
Hormone weed killer—A chemical that causes death of plants by altering the growth processes that occur in the living plant. It is a translocated herbicide.
Selective herbicide—A material which kills certain plants and does not seriously injure others.
Non-selective herbicide—A substance which tends to kill all plants.
Pre-planting treatment—Application of the chemical on the soil after it has been prepared for planting, but before the crop is planted.
Pre-emergence treatment—Application of the herbicide after seeding the crop but before it appears above the ground.
Post-emergence treatment—Treatments made after the crop plants have emerged.
Soil sterilant—A material which renders the soil toxic to all plant life for a period from a few weeks to several years.

2,4-D—2,4-dichlorophenoxyacetic acid or its salts and esters.
2,4,5-T—2,4,5-trichlorophenoxyacetic acid or its salts and esters.
IPC— Iso-propyl N-phenyl carbamate.
PMAC—Phenyl mercuric acetate.
TCA—Trichloroacetic acid or its salts.
Methods of Applying Chemicals

The method and/or times of application of chemicals for horticultural crops are, in general, the same as those for other crops. Following is a description of methods used:

(1) *Pre-planting treatment*; the application of herbicides, usually of the contact type, before seeding with no reworking of the soil. This method has proved useful with fast-germinating crops that will not tolerate residual dosages. The soil should be disturbed as little as possible after planting. A pre-planting treatment is also used for strawberries, but in this case, a residual dosage is used. The use of soil fumigants to kill weed seeds is another example of a pre-planting treatment.

![Figure 1.—A knapsack type of sprayer with featherweight covered boom is recommended for use near sensitive plants.](image)

(2) *Contact pre-emergence*; the use of non-residual dosages of contact type chemicals for killing tiny weeds that emerge before the crop. The term emergence refers to the crop. The herbicide is applied after seeding but before crop emergence. In the case of contact pre-emergence a heavy stand of weeds must have germinated ahead of the crop to make it profitable to spray. This method has proved valuable with certain slow-germinating small seeded crops that will not tolerate residual dosages. Aromatic oils such as Stoddard Solvent and potassium cyanate are two materials that can be used for this type of treatment.
(3) Residual pre-emergence; the killing of weed seeds and germinating seedlings with dosages that result in toxic concentrations in the surface soil. This treatment can be applied at the same time the crop is seeded or it can be delayed until just before the crop emerges. Usually weeds, both broad and narrow leaf types, can be controlled for three weeks or more by this method. At the present time, this method appears to be the most promising for flower and vegetable crops. Serious injury, however, can result to the crop if heavy rains wash the toxic chemical down to the level of the germinating seed.

(4) Post-emergence treatment; application of herbicides after emergence of the crop. Successful use of this method depends upon the employment of a selective herbicide that will kill or severely stunt the weed population without serious damage to the particular crop. The use of aromatic oils in carrots is a case where this method is used very satisfactorily, however, there is a dire need for effective selective herbicides that can be used in flower and vegetable crops.

Equipment for Applying Herbicides

Practically every type of spraying and dusting equipment has been used in applying herbicides. The type of equipment that is needed depends upon the acreage and type of crops grown. For small scale operation such as spraying the lawn, the knapsack type sprayer may be successfully used, but one man

Figure 2.—An inexpensive low-pressure sprayer operated by the power take-off of a tractor. Excellent for use in orchards, lawns and strawberry plantings. (Courtesy Evans Orchard Supply Company.)
with a knapsack type sprayer can spray only about one acre per day of row crops.

Power sprayers can be used on most farms for a number of jobs in addition to application of herbicides. Sprayers are available with gasoline motors or without motors for use on the power take-off or pulley of most farm tractors.

Satisfactory sprayers may be built at home if the necessary skill and tools are available. Special spray booms, designed for weed control work, have been developed and may be constructed at home or obtained from many sources. Large acreages can be covered in one day with such equipment.

![Figure 3.—A self-powered sprayer designed to cover large acreages of row crops such as corn and vegetables. (Courtesy Hardie Manufacturing Company.)](image)

Dusting is not recommended because of the danger of drifting to susceptible crops.

Low-pressure nozzles designed to give a flat, fan-shaped spray pattern have been found more satisfactory for weed control than those that deliver a cone-shaped pattern. These nozzles are available in sizes that will deliver from 5 gallons to more than 100 gallons per acre.

A weed-sprayer should have a pressure gauge, a pressure regulator and a quick-acting shut-off valve. There should be a screen on the intake side of the pump, as well as screens on the pressure side between the pump and the nozzles.

In chemical weed control, especially in growing crops, it is a "must" that the amount of chemical applied be accurately regulated. This is usually accomplished by controlling the volume of spray applied. Nozzle opening, trac-
tor speed, and pump pressure all affect volume of spray applied, and therefore must be regulated.

Figure 4.—Nozzles which produce a flat-fan pattern. Available with male and female bodies and different size orifices. Left: Nozzle dismantled to show separate parts. Top to bottom: tip, holding nut, screen, and female body.

One method of checking the rate of application is to operate the sprayer for 660 feet (40 rods) and refill the tank to determine the gallons used. Measure the width of the area sprayed and use the following formula:

\[
\text{Gallons used} \times \frac{66}{\text{Width of area sprayed in feet}} = \text{gallons per acre.}
\]

Example:

\[
\frac{4 \times (\text{gallons used in spraying 660 ft.} \times 66)}{20 \text{ feet (width sprayed)}} = 13.2 \text{ gallons per acre.}
\]

How Chemicals Kill

The successful use of herbicides requires some knowledge of their killing action. Chemicals kill plants due to the caustic (burning) action of the ma-
material on the leaves, roots and other tender parts of the plant or due to the effect of the material on the growth processes of the plant. Sulfuric acid kills by a caustic effect while 2,4-D brings about death by altering the growth processes. The caustic action of sulfuric acid is limited to the parts of the plants which it contacts. It is effective against annual weeds and grasses but not against perennial weeds because it kills only the above ground parts. 2,4-D is absorbed through the leaves and stem and is moved within the plant to all parts and therefore it is effective against most deep-rooted perennials. Sulfuric acid acts as a contact herbicide while 2,4-D is a translocated material.

Why Chemicals May be Used in Growing Crops

Many factors must be considered to explain why a certain chemical may kill some kinds of plants without seriously injuring others. Plants differ in many ways; their surfaces vary in form and composition; some are easily wet by water solutions while others are difficult to wet, the growing point of some plants is terminal and exposed while in others it is protected by older leaves.

Chemicals are able to enter the leaves and stems of some plants more readily than others, and the living tissues of the plants respond differently to different chemicals. Moreover, young actively-growing plants are more susceptible to injury than older plants.

Dinitros may be used in peas to kill weeds because the waxy coating of the pea plant protects it. Certain herbicides may be used in onions because the growing point is at the base of the plant and protected by the older leaves while the growing point of broad-leaved weeds are terminal and more exposed. Certain oils may be used for weeding carrots and celery because the tissues of these plants are tolerant to these herbicides, even though they enter the plant.

2,4-D may be used to kill broad-leaved weeds in lawn and fields of small grain without seriously injuring the grass or grain. In plants susceptible to 2,4-D, certain reactions result which bring about death of the plant whereas in 2,4-D tolerant plants these reactions do not take place or they occur to a lesser degree.

Selectivity is relative. Most herbicides will kill all types of plants if brought into intimate contact with the plants in sufficient concentration. Even in the case of weeding carrots with certain oils, it is a matter of degree of injury. Most weeds are injured so seriously that they die whereas the injury to the carrots is not as severe and they live.

Factors Determining Successful Use of Herbicides

Successful use of chemicals in the fight against weeds is dependent upon a large number of factors. In pre-emergence treatments considerably more injury results in sandy soils than in silt, clay or muck soils. Moisture content of the soil should be neither too high nor low. The seedbed should be in good condition to permit uniform coverage and penetration of the chemical. The amount and time of rainfall is very important in determining success of pre-emergence treatments.
In the use of selective herbicides in growing crops, temperature at time of and following treatment determines amount of injury to the crop and the kill of weeds. The stage of development of the cultivated plants and the weeds is of great importance. Varieties respond differently to chemical treatment and a tolerant variety should be used.

Successful kill of perennial weeds and woody plants such as poison ivy, with 2,4-D and 2,4,5-T depends upon the movement of the chemical into the roots of these plants. First the chemical must be absorbed through the leaves and stem. Ester forms of these herbicides penetrate leaves and stems more readily than salt forms and, therefore, are more effective as herbicides.

Movement of 2,4-D from leaves to stems and roots is associated with the movement of food materials within the plant. For best results with woody plants and perennial weeds these herbicides should be applied when the stored food in the roots has been depleted and the plant has completed its terminal growth for the season. At this time the plant begins to store food in the root system and there is excellent movement of the 2,4-D to all parts of the root system.

**Description of Herbicides Used in Horticultural Crops**

It is of utmost importance that anyone using chemicals for the control of weeds in growing crops have some knowledge of the chemical they are using. Some chemicals are very caustic and should not come in contact with the skin or clothing of the user. Other chemicals give off poisonous vapors which must not be inhaled.

A given chemical may appear on the market under several trade names. Different formulations of the material may contain different amounts of active ingredients. Recommendations are usually made on the basis of active ingredient or acid equivalent of the materials. Read the label on the container and learn as much as possible about the chemical before you use it.

**Ammonium Sulfamate**—This chemical commonly known as Ammate is a yellow granular material. It is a water soluble translocated herbicide, non-selective in action, and especially effective on many types of woody plants. It is generally useful for the control of woody plants in those areas where the vapors of 2,4-D and 2,4,5-T may injure susceptible crops. Ammate is non-poisonous but is corrosive to metals.

**Cyanamid**—Calcium Cyanamid, a nitrogen fertilizer, has contact weed killing properties. It is available in granular and powdered forms. The granular form, applied to the soil before seeding, has been used in tobacco seedbeds while both forms are used in asparagus beds. The granular material is applied when the weed seeds are germinating while the powdered form is applied with a duster to the weeds when they are small and covered with dew.

**Dichloral Urea**—An insoluble microfine powder that is applied as a suspension in water. Shows promise as a selective herbicide for grasses in strawberries and certain truck crops.
2,4-Dichlorophenoxyacetic Acid (2,4-D)—A selective hormone weed killer which is available in salt (sodium, ammonium, amine) and ester formulations. Ester formulations are more toxic than salt forms and except for recently introduced low volatile types are very volatile. Vapors may drift for considerable distance and still cause serious damage to very susceptible crops such as tomatoes, grapes, cotton, roses, zinnias, etc.

2,4-D is generally considered to be much more toxic to broad-leaved weeds than to grasses, however, there are some species of broad-leaved plants which are as resistant as grasses.

This chemical is one of the most effective herbicides and exhibits as much selectivity as most so-called selective herbicides. It is effective at very low concentrations and its action is systemic because it is translocated to all parts of the plant.

None of the 2,4-D formulations are corrosive to spray equipment but it is very difficult to clean all the material from the sprayer. Vineyards, truck crops and ornamentals should not be sprayed with a sprayer in which 2,4-D has been used.

2,4-D has been shown to be non-toxic to man or livestock, even when consumed directly in large quantities, however, it is advisable to keep livestock out of treated areas for about one week after spraying. It has been reported that animals and bees sometimes feed on poisonous weeds after they are sprayed, and nitrates which are converted to toxic nitrites in the stomachs of ruminants are known to accumulate in some plants after treatment.

Sodium 2,4-Dichlorophenyl “Cellosolve” Sulfate—A water soluble powder that exhibits selective herbicidal properties. It is found to be effective against certain weeds and grasses in strawberries without seriously injuring the strawberries. It may have use in certain vegetable crops.

Dinitros—Dinitro-ortho-secondary-butyl-phenol (DNOSBP) and various salts of this compound are effective herbicides. Certain formulations have excellent residual properties and are effective pre-emergence treatments for large seeded crops and those propagated by roots, bulbs, corms and tubers. Dinitros may be selective or non-selective, depending upon the type of carrier, the quantity of effective ingredient and the crop plant being treated. The waxy nature of the leaves and stem of peas which prevents thorough wetting of the plant permits the use of a water solution of NH₄-DNOSBP as a selective post-emergence spray for weeds.

Ethyl Xanthogen Disulfide—The commercial formulation of this organic sulfur compound contains 5 pounds of active material in emulsifiable aromatic oil. It has shown some promise as a pre-emergence treatment in vegetable crops but results have been erratic.

Iso-Propyl-N-Phenyl-Carbamate (IPC)—IPC is a white, crystalline water-insoluble powder which has selective action on certain plants. It will kill annual grasses, cultivated grains, some perennial grasses and some broad-
leaved plants. It appears to go into solution in the soil and exert a toxic effect on the roots of grasses. It is effective against common chickweed in strawberries and may be used as an emergency treatment for annual grasses in vegetables.

**Pentachlorophenol (PCP)**—This chemical and its sodium salt (Na-PCP) have been used successfully in a number of crops as pre-emergence treatments. Pentachlorophenol is insoluble in water and must be used in oil or as an emulsion. The sodium salt is soluble in water and may be used as post-emergence as well as pre-emergence treatments.

**Petroleum Products**—Most petroleum products are non-selective contact herbicides, however, some of the lighter fractions are selective but none are translocated.

Aromatic oils such as Stoddard Solvent are effective selective weed-killers. Carrots, celery, parsley, parsnips are tolerant of these materials whereas most weeds and annual grasses are readily killed. Such oils are among the most satisfactory materials to use as pre-emergence treatments on small-seeded or rapidly germinating crops because they have no residual effect.

Oils may be used in conjunction with other herbicides, particularly non-selective contact types, because they have excellent penetrating properties.

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**Figure 5.**—2,4-D preparations are mixed in fertilizers to be applied dry to the lawn in early fall.
Phenyl Mercuric Acetate (PMAC)—This is an organic mercury compound that is available in several formulations. It is used to kill young crabgrass seedlings in a lawn without seriously injuring other grasses. Results have been variable, because successful use is dependent upon the proper environmental conditions. Mercury compounds are very poisonous, and, therefore, these materials should be used with extreme caution.

Potassium Cyanate (KOCN)—This compound is a white, flaky substance, soluble in water. It is applied as a spray and acts as a contact herbicide. It is related to cyanamid and adds nitrogen to the soil. It decomposes very quickly upon contact with the soil, thus there is little if any residual effect. It is sometimes used for selective-killing of crabgrass seedlings in lawns but results tend to be erratic, however, it appears to have considerable merit for use in onions and certain other vegetables.

Salt (Sodium Chloride)—Sodium chloride, common table salt, has herbicidal properties when used at high concentrations. It has been used for many years to control weeds in the home asparagus bed. Salt also has selective weed-killing properties when used in beets, onions and certain other crops. A serious objection to salt is its effect on soils.

Soil Fumigants—Materials such as chloropicrin and ethylene dibromide are gaseous chemicals which kill weed seeds as well as soil insects such as nematodes when injected into the soil. They are being used to control weeds in plant propagation beds and in potting soil.

Sulfuric Acid—This was one of the first chemicals to be used for selective weed killing. Most broad-leaved weeds can be selectively killed in small grains, onion and certain coniferous seedlings. Sulfuric acid is very corrosive to metals and very caustic to the skin and clothing, therefore, it is used only when no other effective treatment is available.

Trichloroacetic Acid (TCA)—The salts of this acid have excellent herbicidal properties for grasses. The sodium salt is the material most commonly used. It has been found to be one of the most effective herbicides for Bermuda, Johnson and quack grasses. At present it appears to be satisfactory as a pre-emergence treatment in certain vegetables.

2,4,5-Trichlorophenoxyacetic Acid (2,4,5-T)—This is a hormone weed-killer closely related to 2,4-D. Its action and properties are similar to 2,4-D, excepting that it is somewhat non-toxic. It is effective on certain plants, such as blackberry, dewberry, raspberry and certain other woody plants which are resistant to 2,4-D.

WEED CONTROL IN LAWNS

At the outset it should be stated that chemical weed control is not and should not be considered a substitute for good cultural practices that encourage the grass. In conjunction with those practices, however, it saves much time, labor and expense.

Weed control in lawns should be considered a two-fold attack: (1) Encour-
Figure 6.—A three-gallon knapsack sprayer mounted on a handy two-wheeled cart is shown here equipped with three nozzles to cover a strip 24 inches wide.

age the grass and (2) weed control chemicals after the grass is in a healthy condition. A lawn that is properly fed will be so encouraged that the grass will tend to smother or choke out broad-leaved weeds—even dandelions and white clover. A fall application in Missouri of a complete fertilizer, as 4-12-4, applied at the rate of 20 to 30 pounds per 1000 square feet in October or November gives the grass an early spring start (see Figure 5). During May and June two applications of nitrogen fertilizer, as ammonium sulfate at 8 to 10 pounds per 1000 square feet, suffices for the entire summer and is particularly effective when the short grass clippings are allowed to fall back into the lawn.

Chemicals for Broad-leaved Weeds

Various formulations of 2,4-D are used in the control of lawn weeds since broad-leaved plants are killed while grasses are not harmed when mature. 2,4-D should never be used on a newly seeded lawn as grass seedlings are quite susceptible to damage.

Although the ethyl, butyl and isopropyl esters are more potent killers, they are more volatile and hence may be damaging if their vapors contact shrubbery and flowers. A newer, less volatile ester (Propylene glycol butyl ether) is available on the market and should be of more value on lawns. The sodium and ammonium salt forms in dry powder to be mixed with water or fertilizers are more stable and hence less damaging.
Methods of application are either in water solution or with dry fertilizers. An ordinary sprayer for insecticides is used for the solution, but it is best to have a separate sprayer for this purpose only, as the material is not easily rinsed from the tank (see Figure 6). The use of a contaminated tank could cause serious damage to plants sprayed with insecticides and fungicides from the same apparatus. *The dilution varies with the product found on the market, so the manufacturers directions should be carefully followed.*

When spraying the lawn, keep these points in mind:

1. Spot spray the weeds only, unless so thick that general spraying of the entire area would be more complete. (A sprinkling can with fine nozzle may also be used if not to be used for watering cultivated plants.)

2. Spray when there is very little or no wind.

3. Hold nozzle close to plant being sprayed so there will be no drift into nearby shrubs, flowers, etc.

Figure 7.—Lawns should be sprayed before the dandelions bloom. (Left) This plant already is sowing seeds for another crop. (Right) Even when sprayed at this stage, plants may still produce viable seeds because the killing action of 2,4-D is slow.
Figure 8.—Plantain 2 days after spraying with 2,4-D. The first effect is twisting of leaves followed by death of entire plant.

4. Use a coarse spray nozzle or low pressure that doesn’t break the stream too fine. (A fine spray wets the plant better if drift of the mist can be controlled.)

5. Spray on a warm day in spring or fall when the weeds are actively growing.

6. Spraying in late afternoon or evening is best if wind is not strong, as plants stay moist longer and carbohydrates move out of the leaves into the roots and with them moves the 2,4-D.

7. Spray the lawn before dandelions and other weeds produce flowers. The action of 2,4-D is slow. A dandelion plant sprayed in bloom will mature seeds before it is killed (Figure 7).

8. Rinse spray tank thoroughly with several rinses of clear water after thoroughly washing with warm soapy water.

The dry application may be made by mixing the sodium or ammonium salt of 2,4-D with the fertilizer for the lawn (Figure 5). The most effective is a fall application during August or early September. One-half (1/2) ounce of the 2,4-D salt is mixed thoroughly with 20 pounds of 4-12-4, 6-10-4, or
similar fertilizer for 1000 square feet of lawn. This mixture should be applied as follows:

1. Apply when there is very little wind.
2. Apply when grass is dry.
3. Spread evenly and uniformly over the entire area.
4. Use only on lawns. Any surplus should be carefully marked and never used for other plant feeding. It is better to mix the exact amount needed so there will be no surplus.
5. Do not use this mixture when fertilizing an area for new seeding or reseeding of lawn grass.
6. Measure the ingredients and the area to be treated accurately.

Repeat Applications—If 2,4-D compounds are properly applied, a single application each year should suffice to keep transient weeds under control. At most, a single application in spring and another in the fall will control the weed pests indicated. It must be understood that an annual application is necessary because animals, wind and water carry weed seed from adjoining uncontrolled areas onto the treated lawn.

Weeds 2,4-D Kills:

- Dandelion—**Taraxacum palustre**
- Buckhorn—**Plantago lanceolata**
- Broad-leaf plantain—**Plantago major**
- Common ragweed—**Ambrosia artemisiifolia**
- Ground ivy—**Glecoma hederacea**
- Shepherd’s purse—**Capsella bursa-pastoris**
- Red or sheep sorrel—**Rumex acetosella**

Chickweed—**Stellaria media**
Henbit—**Lamium amplexicaule**
Knotgrass—**Polygonum aviculare**
Sour dock—**Rumex obtusifolius**
Queen Anne’s Lace—**Daucus carota**
Yarrow—**Achillea millefolium**
Burdock—**Arctium minus**
Catnip—**Nepeta cataria**
Wild lettuce—**Lactuca scariota**
Chicory—**Cichorium intybus**

2,4-D Should Not Be Used On

1. Lawns with white clover or other broad-leaved ground-covers.
2. Newly seeded grass.

Chemicals for Undesirable Narrow-leaved Plants

**Crabgrass Control**—The control of crabgrass by chemicals is quite uncertain, because it is dependent upon the proper environmental conditions. No herbicide has been found which will consistently give satisfactory crabgrass control without damage to other grasses. As reported at the 1950 North Central Weed Control Conference the most promising are: S1998 1% in 600 gallons of water per acre; Dow Premerge 6 quarts in 150 gallons per acre; potassium cyanate 8 pounds per 300 gallons per acre; dichloral urea (E.H.#2) at...
4 pounds per acre; and phenyl mercuric acetate (Tat-C-Lect) 1 pound per 100 gallons per acre if given two or three repeat applications and followed two or more years.

The chemicals of questionable value are kerosene, S1980, TCA and Stoddard Solvent. Those giving poor control or injurious effects to the bluegrass are maleic hydrazide, IPC, 2,4-dichlorophenyl Cellosolve sulfate (E.H.#1), chloro-IPC and L-2687.

**Bermuda Grass**—There is no known chemical which will kill this plant and not harm other grasses. It can be eradicated by TCA, 80 to 100 pounds per acre which will tend to kill all plants.

**Wild Onions**—Spot spray with high concentrations of 2,4-D (2 pounds acid per acre) or maleic hydrazide at rate of 4 gallons 30% material per acre.

**WEED CONTROL IN ORNAMENTALS**

Chemical weed killers have been applied to ornamentals as pre-planting, pre-emergence and post-emergence treatments. Not all crops have been tested, nor has there been sufficient testing of all chemicals, but the following are considered safe treatments under the given set of conditions:

**Gladiolus**

Gladiolus in cut-flower production have been successfully treated with pre-emergence sprays of DNOSBP (ammonium salt) 3 to 6 pounds in 100 gallons per acre, the sodium salt of 2,4-D at 2½ to 5 pounds in 100 gallons per acre and Stoddard Solvent, 80 gallons, fortified with 8 pounds of PCP per acre. Post-emergence treatments are not recommended after the plants are 5” high. Until this time the materials found most effective are potassium cyanate at 15 pounds per acre and phenyl mercuric acetate (Tat-C-Lect) at 4 pounds per acre. 2,4-D at one pound per acre gives good control of the broad-leaved plants without harm to the gladiolus but does not give satisfactory control of grasses.

**Peonies**

Peonies are best treated pre-emergence and not later than when shoots are one to two inches in height. Stoddard Solvent, 80 gallons per acre fortified with 8 pounds of PCP controls grasses as well as broad-leaved weeds which have emerged at the time of treatment. The ammonium salt of DNOSBP at 6½ pounds per acre controls broad-leaved weeds and gives a “definite increase in vigor and leaf greenness” to the plants, but grasses are not controlled. Cultivation must be relied upon to control weeds through the balance of the season as any chemical weed control will injure or kill the plants when applied at a later date.

Sodium tri-chloracetate (TCA) at 20 to 40 pounds per acre materially reduces the total weed population in preparing nursery seed and plant beds but plowing and disking must supplement the treatments. To be safe the beds should not be planted until 6 to 8 weeks after treatment.
Figure 9.—If sprayed at the right time and with the right concentration, 2,4-D will kill most broad-leaved weeds in sod. The upper photograph shows sod that had been sprayed once on June 10—about 40 days before the photograph was taken. The lower picture shows an exactly similar area that was not sprayed.
Present recommendations for nursery stock in rows are to spray the soil between rows only, use a hooded boom and low pressure to prevent drift and the fortified Stoddard Solvent (see above) gives the best control with least injury. Applications to the base or trunk of the plant should be avoided.

**USE OF CHEMICALS IN SMALL FRUITS**

At the present time, chemical weed control in blackberries, raspberries, strawberries, grapes and other small fruits is not generally recommended by the Missouri Agricultural Experiment Station. Studies are being conducted and certain chemicals appear promising. Treatments listed in following paragraphs are suggested for trial on a small scale only.

**Brambles**

Blackberries and raspberries are somewhat resistant to 2,4-D. The chemical may be sprayed on the ground at the base of the canes at the rate of $\frac{1}{4}$ to $\frac{1}{2}$ pound acid per acre. The sodium or amine salts are less toxic than the ester formulations. It should not be used during the period the plant is blooming and setting fruit. New canes are easily injured, especially when the tips are sprayed.

**Grapes**

Weeds within the row are usually removed by hand which is very expensive or by a grape hoe, which is not entirely satisfactory because it may damage the root system. A chemical method of control would be of great value.

**Oil Emulsion Fortified with DNOSBP**—Use 10 gallons of aromatic oil or fuel oil plus 2 pounds DNOSBP per 100 gallons of spray. The commercial formulations of DNOSBP contain an emulsifying agent. Make certain that the oil remains emulsified. Apply 40 to 50 gallons per acre in a strip about 18 inches wide under the trellis. Use low pressure (50 to 75 pounds) and fan type nozzles. Apply while grass and weeds are small.

**Strawberries**

Materials which are promising for weed control are 2,4-D, dichloral urea, 2,4-dichlorophenyl cellosolve sulfate and IPC.

**Pre-planting Treatment**—2,4-D (Amine salt)—2 to 4 pounds acid per acre. Prepare field for planting; spray; and disturb soil as little as possible while planting. Use lower rates in sandy soils and higher rates for clay soils and soils with a high organic matter content.

**Summer Foliage Sprays (New Fields)** — 2,4-D (Amine salt) — 1 to 1½ pounds acid per acre. Apply in late June or early July after a number of runner plants have set and weeds within the row must be removed by hand labor.

Clean out all grass and weeds before spraying. 2,4-D at this rate is effective against annual grasses only in the germinating stage. Use a small volume of water, preferably 10 to 15 gallons per acre.

Repeat application after approximately 4 weeks. Do not spray after August 15. Deformed fruit buds may result if treated during period of fruit bud formation (August 15 to October 15).
Figure 10.—Oil emulsions fortified by dinitros killed out most grasses and weeds beneath this grape trellis. (Upper) Sprayed. (Lower) Not sprayed. Courtesy Dow Chemical Company.
Summer Foliage Sprays (Old Fields) — 2,4-D (Amine salt) — 1 1/2 to 2 pounds acid per acre. Apply immediately after renewal. Repeat in July if needed. Do not treat after August 15.

Fall Treatments (New and Old Fields)—2,4-D (Amine salt)—1 1/2 to 2 pounds acid per acre. This treatment kills most overwintering weeds such as chickweed, red sorrel, field cress, and wild beet (primrose). Apply in late October or early November.

IPC—10 pounds per acre. This chemical effectively controls chickweed and red sorrel.

Precautions—1. Both pre-planting and summer sprays of 2,4-D may cause damage if there is a long hot drought period immediately following application.
2. 2,4-D is effective against grasses only in the germinating stage.
3. 2,4-D applied during the period of fruit bud formation (August 15 to October 15) may result in deformed fruits.
4. Strawberries are only somewhat resistant to 2,4-D.

Figure 11.—A pre-planting spray and two summer sprays of 2,4-D saved all but one hoeing of the strawberry row at the left. The other row is equally clean but required four hoeings.
USE OF CHEMICALS IN VEGETABLE CROPS

At the present time, chemical weed control is a standard practice in only a few vegetable crops. The use of oils in carrots, celery, parsley and parsnips, dinitros in peas, and calcium cyanamid in asparagus can be recommended. The use of chemicals in other crops is still "on trial". It has progressed, though, to the stage where suggestions can be made to those who wish to test chemicals on a limited scale. Large acreages should not be treated until the grower has had some experience in the use of weed-killing chemicals. All chemicals listed below are applied in 100 gallons spray per acre unless otherwise noted.

Asparagus

Calcium Cyanamid—Pre-emergence: Apply on the row at the rate of 300 to 500 pounds per acre in the spring before the spears emerge. (Recommended.)

2,4-D—(Sodium salt)—Pre-emergence: 1 1/2 to 2 pounds acid equivalent per acre. Apply after disking and before any spears emerge in the spring and again after disking at end of cutting season. Post-emergence: 1/2 to 1 pound acid equivalent per acre. Apply at base of stalks after plants have "ferned out". Keep 2,4-D off the foliage. (Suggested.)

DNOSBP—Pre-emergence: DNOSBP in oil or as ammonium (NH₄) salt, 6 to 10 pounds per acre. Apply after disking and before any spears emerge in the spring. Use again at end of cutting season. Post-emergence: 1 to 2 pounds per acre as ammonium salt. Apply at base of stalks after plants have "ferned out". Keep off foliage. (Suggested.)

Potassium Cyanate—Post-emergence: 8 to 16 pounds per acre selectively kills broad-leaved weeds and seedling grasses. May be used during or after the cutting season. Weeds must be small. (Suggested.)

Beans—(Green and Lima)

DNOSBP—(Ammonium salt) — Pre-emergence: At the rate of 4 to 6 pounds per acre there is excellent weed control and little damage to beans. Plant beans approximately 2 inches deep. (Suggested.)

Ethyl Xanthogen Disulfide—Pre-emergence: 10 pounds per acre. Very effective against broad-leaved weeds, but not as effective against grasses. (Suggested.)

Beets

TCA (Sodium salt)—Pre-emergence: 8 pounds per acre. Beets appear rather tolerant to TCA. (Suggested.)

Carrots, Celery, Parsley, Parsnips

Aromatic oil—Pre-emergence: 50 to 80 gallons per acre. Post-emergence: 50 to 80 gallons per acre. Can be used until one month before harvest in the case of carrots, parsley and parsnips. Do not use on celery after plants are 4 inches tall. (Recommended.)

Onions

Aromatic Oils—Pre-emergence: 80 gallons per acre. (Suggested.)
2,4-D (Sodium or Amine Salt)—*Pre-emergence*: 1 to 1 1/2 pounds per acre. (Suggested.)

Potassium Cyanate—*Post-emergence*: 2 to 4 pounds per acre. Weeds must be young to be killed. (Suggested.)

PCP (Sodium salt)—*Post-emergence*: 4 pounds per acre. (Suggested.)

DNOSBP (Ammonium salt)—*Post-emergence*: 1 to 2 pounds per acre. (Suggested.)

**Peas**

DNOSBP (Ammonium salt)—*Post-emergence*: 3/4 to 1 1/2 pounds per acre. Apply when plants are 4 to 8 inches tall. (Recommended.)

DNOSBP (Ammonium salt)—*Pre-emergence*: 6 to 8 pounds per acre. Plant peas 2 inches deep and treat at least 2 days before emergence. (Suggested.)

**Potatoes**

Several materials appear promising for pre-emergence use. Post-emergence treatments are not as reliable.

2,4-D (Sodium or Amine salt)—*Pre-emergence*: 1 to 1 1/2 pounds per acre. Red Triumph appears slightly more tolerant than Irish Cobbler. *Post-emergence*: 1/2 to 3/4 pound at early bud stage eliminates most broad-leaved weeds. (Suggested.)

DNOSBP (Ammonium salt)—*Pre-emergence*: 6 to 8 pounds per acre. (Suggested.)

PCP (in oil or Sodium salt)—*Pre-emergence*: 12 pounds per acre. (Suggested.)

**Sweet Corn**

DNOSBP (Ammonium salt)—*Pre-emergence*: 6 to 8 pounds per acre. Plant corn 2 inches deep and spray 2 days before corn emerges. (Suggested.)

2,4-D (Sodium or Amine salt)—*Pre-emergence*: 1 to 1 1/2 pounds per acre. Plant corn 2 inches deep and spray 2 days before corn emerges. Considerable damage can result if a heavy rain leaches the 2,4-D down to the roots. *Post-emergence*: 1/4 to 1/2 pound per acre. Apply while corn is 2 to 12 inches tall and while weeds are young. Such sprays should be used only when weeds cannot be controlled by cultivation. Some injury results to plants and may be reflected in yield. (Suggested.)

**Vine Crops**

The foliage of these plants is very subject to injury. Pre-emergence treatment is the only promising method to date.

DNOSBP (Ammonium salt)—*Pre-emergence*: 6 to 9 pounds per acre. Appears to have some value for cucumber, watermelons. Muskmelons, squash and pumpkin are more subject to injury. (Suggested.)

Ethyl Xanthogen Disulfide—*Pre-emergence*: 10 pounds per acre. Can be used on all vine crops. Effectiveness in grass control is not always satisfactory. (Suggested.)
CHEMICAL WEED CONTROL IN ORCHARDS

Though most weeds are not as obnoxious in the orchard as in a lawn or garden, there are some that are highly undesirable. Many of them harbor disease organisms or insect pests, rob trees of soil nutrients, and interfere with orchard operations. Some are outright nuisances. Poison ivy, the native grape vine, wild blackberry and other brambles are distinctly pests in any orchard. Not infrequently, sprouts of woody plants, such as elm, oak, ash, maple and hickory appear in considerable numbers either among trees along the orchard or in draws. They are not easy and are certainly costly to eradicate by mechanical means.

Figure 12.—One good spraying with 2,4-D or 2,4,5-T in June or July will kill poison ivy. Under an old apple tree, on the area shown above, was a solid stand of poison ivy till June 23, 1945, when the portion at the right was sprayed. A year later it was “spot” sprayed to kill a few scattered plants that were still alive. This photograph was taken June 1, 1947 (two years after the first spraying).

Chemicals Used for Weed Control in Orchards

There are several, more or less successful, methods of weed control in the orchard. Timely mowing, discing, and other cultural practices are commonly employed to destroy or check excessive growth of weeds between and under trees, especially those of the annual type. More recently, various chemical
ground sprays have been used for this purpose. In certain sections of the country, particularly on the Pacific Coast, fruit growers have been applying kerosene and other fuel oils to suppress weeds and other vegetation and thus eliminate repeated cultivation or mowing, which is more costly. When one of the so-called "dinitro" chemicals is added in relatively small amounts to a herbicidal petroleum oil, practically all weeds, excepting certain perennials, are killed to the ground. While this may also kill grass, regeneration usually takes place in three to seven weeks.

Ammonium sulfamate (three-fourths to one pound per gallon) has been used quite successfully for killing perennial weeds and sprouts in orchards. It has the property of not only destroying the top growth but also penetrating to some extent into the roots. However, considering its non-selectivity, the relative cost and other disadvantages, the more desirable "hormone" type weed killers seem to be preferred at present for this purpose by orchardists.

For the most practical control of herbaceous and woody perennials, 2,4-D (2,4-Dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid), the two popular "hormone" chemicals, are most desirable. Apple and other fruit trees are moderately resistant to these substances. When used judiciously and with necessary precautions, both 2,4-D and 2,4,5-T, even in the more volatile ester forms have been applied successfully for the control of perennials weeds in many orchards. During the past four years, we have used them in one of the Missouri Agricultural Experiment Station orchards for control of poison ivy, bull nettle, and various brambles and sprouts that were growing both under apple trees and in open spaces.

Concentration and Time of Application

The kind of chemical and concentration to be used depends on the kind or the predominant weed to be controlled or eliminated. Since the orchardist encounters most trouble in dealing with perennials, they only will be discussed here. Investigations conducted in Missouri and elsewhere show that for the herbaceous perennials, such as poison ivy, bull nettle, etc., the following sprays may be suggested:

1. 2,4-D, in the salt form, at a concentration of two thousand parts per million (.2%).
2. 2,4-D, in ester form, at one thousand five hundred parts per million (.15%).
3. 2,4,5-T ester, at one thousand parts per million (.1%).

For brambles and woody sprouts, which are more difficult to kill, the ester forms of 2,4-D or 2,4,5-T at two thousand parts per million (.2%) seems to be best. In open localities, where there are no fruit trees and no other susceptible crops close by, even a higher concentration than .2% of either 2,4-D or 2,4,5-T esters may be desirable.

Proper timing of the application is important. Perennial weeds are most susceptible to "hormone" herbicides when the largest number of leaves have
been produced, i.e., when the topmost leaves on the new shoots are developing or have just reached full size. For poison ivy, for example, this would be in June or early July in central Missouri. Bull nettle and similar plants should be sprayed when the fruit is just setting. At this time of development, most of the reserve food, that was stored during the previous growing season, has been moved from the roots to the tops for shoot and leaf growth. Injury to the plant then will deprive it of food reserves, while the equipment for food manufacture (the leaves) is destroyed. As a consequence, there will be very little or no subsequent sprouting from the roots. If some growth occurs, this may be destroyed easily by a second spray application, either in the same or next year. Another reason for this being the best time of application of a hormone spray is that at this stage of the development of a plant, the food materials, that are made in the leaves, are beginning to move down into the roots and other underground structures. The hormone chemical, sprayed upon the leaves, enters the plant and moves along with the food into the roots, which are eventually destroyed. Being deprived of most or all of the roots, the weed is either weakened or dies. The smaller the underground food reserve, the easier a woody plant is usually killed.

Repeated tests made in Missouri and elsewhere indicate quite definitely that spraying perennial weeds early in the season, before the leaves are fully grown or late in the summer or fall, will not be nearly as effective. For a quite similar reason, it is difficult to kill weeds after they have been mowed. The few remaining older leaves left on the stubs of cut stems or branches will not absorb enough of the material to kill the roots. After mowing, one should wait for renewed growth and full leaf development before the plants are sprayed.

There are definite indications that "hormone" weed killers are most effective when applied on a warm muggy day and in late afternoon. This most likely is due to the fact that in such weather the foliage remains moist longer, thus permitting the chemical to act upon the leaves better, and that the food materials, together with the herbicide, move out of the leaves and down the stem chiefly late in the evening and at night. Respiration of the plants is also more active at a relatively high temperature, which most likely helps to destroy the plant.

**Precautions to be Taken in Using "Hormone" Herbicides**

Though they are harmless to man and animals, and non-injurious to any mechanical or other equipment, 2,4-D and 2,4,5-T are "powerful" chemicals as far as their effects on broad-leaved plants are concerned. Fruit trees are such plants and, as was stated before, only moderately resistant to these substances at the concentrations used for killing weeds. One should mix the chemicals correctly as per instructions given on the containers. *Read labels carefully.*

Spraying should be done at low pressure or with special nozzles that do not carry the material far and do not create unnecessary spray drift. One should
never apply these herbicides on a windy day. The average orchard power sprayer usually works at too high a pressure and discharges too much material too far. If the pressure of the pump cannot be reduced to one hundred to one hundred fifty pounds, a special low pressure sprayer should be used for this purpose. Some of them are made to work at thirty to one hundred pounds per square inch. There are nozzles on the market that release spray in a short fan or cone-shaped form. In some cases, hoods or covers have been used to restrict spray drift. In killing weeds with a hormone chemical, all that is necessary is to wet thoroughly the leaves, not the ground.

Another precaution worth keeping in mind is the necessity of a thorough cleaning of the sprayer in case it is used for other purposes in the orchard than applying weed killers. Even minute quantities of the chemical left in the sprayer may damage sensitive plants. All parts of the sprayer should be rinsed well several times with water. Then fill the tank with a one to two per cent solution of household ammonia (three to five tablespoons per gallon of water) and let it stay overnight. This should be followed with rinsing a couple of times with water in which some soap powder has been dissolved. When the ester form of a hormone spray has been used, rinse with kerosene, followed by soapy water. Do not take any chances.