Chemical Weed Control
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MICHIGAN STATE COLLEGE
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EAST LANSING

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Chemical Weed Control

By B. H. GRIGSBY, BOYD R. CHURCHILL, CHARLES L. HAMNER and ROBERT F. CARLSON

The use of chemicals for controlling weed plants is not a new idea, but remarkable progress in this phase of crop production has been made since 1943.

Chemical control measures are not a substitute for cultivation, crop rotation and other long-established good farming practices. The cost of chemical weed control is often less than that of hand labor, but there are situations where chemical control may be equally as expensive and no more effective. In other situations, cost may not be a factor and the problem becomes that of selecting a chemical method which will secure adequate control of certain weeds.

In some instances a selective chemical can be used to control weeds in growing crops. In other instances the crop may be as susceptible to injury as the weed. When the weed problem becomes so serious that quality or yield of the crop is materially reduced, the field could be removed from the regular rotation for a year or two. Such a plan would permit (1) the growing of a crop tolerant to a selective chemical or (2) the use of a non-selective herbicide if no crop were grown on the area. How this method may work in practice is indicated in the sections on carrots and small grains.

This publication was prepared to set forth those facts and methods which have been found to be of value in farm practice.

DEFINITIONS

Herbicide—Any compound which will kill plants.

Non-selective herbicides—Those materials which kill above ground parts of most plants.

Selective herbicides—Those materials which kill only some plants.

Translocated herbicides—Those materials which are absorbed by one part of a plant, and exert a toxic action on other parts.

Hormone weed killers—Chemicals which exert an effect upon the growth processes in such a way as to cause death of plants. **Growth regulators** is probably a better descriptive term than hormones.

Pre-planting treatment—Any treatment applied after the soil has been prepared for planting, but before crop seeds are placed in the soil.

Pre-emergence treatment—Treatments applied after seeding, but before crop plants appear above the ground. Such treatments may be **contact** or **residual** in action:

> Pre-emergence, **contact**—Treatments applied to weed seedlings when they emerge before crop plants. The chemicals are quickly broken down into non-toxic substances.
>
> Pre-emergence, **residual**—Treatments applied soon after seeding but before either weed or crop plants emerge. The chemicals remain in the soil long enough to kill germinating weed seeds but are broken down into non-toxic materials before crop plants germinate.

Post-emergence treatment—Treatments made after both weed and crop plants have emerged.

CHEMICALS

AMMONIUM SULFAMATE

This chemical, commonly known as Ammate, is a coarse, granular, yellow substance. It is soluble in water and applied as a spray. Ammate is a contact, translocated herbicide, non-selective in action, and is especially effective on many types of woody plants. The chemical is absorbed through the leaves of plants but does not penetrate the older bark of trees. This fact makes it useful in the control of poison ivy, in and under fruit trees or other valuable plants. Ammate is not poisonous to livestock or other animal life, but is corrosive to metals. Ammate absorbs moisture from the air and may cake or "leak" in storage.

ARSENICALS

Sodium arsenite and other compounds containing arsenic are efficient herbicides. They are non-selective and poisonous to man and livestock. Therefore, **the use of arsenicals for farm weed control purposes is not generally recommended.**

BORAX

A crude grade of borax has herbicidal properties when applied to soil. The chemical goes into solution slowly, in the soil, and thus makes the soil unsuitable for plant growth for a period of 6 months to several years, depending upon the type of soil and rainfall. Borax is not selective, but grasses are more tolerant of this chemical than most other plants and will be the first plants to appear in soil treated with borax. This compound is useful in driveways, and other areas where complete absence of vegetation is desired.

A water soluble form known as polybor is also available.

CHLORATES

Sodium chlorate and potassium chlorate are effective herbicides. They are non-selective, however, and are highly explosive. **Clothing and vegetation which have been wet by the spray solution and then dried are inflammable.** Chlorates may be used as soil treatments to prevent all plant growth and are used for the control of perennial weeds such as bindweed, Canada thistle, and quack grass. **Treated soil, however, will not produce crop plants for one or more years after treatment.**

A combination of chlorate and borax is useful for quick and lasting elimination of plant growth. The mixture is spread dry and the action depends upon the presence of sufficient soil moisture. The mixture is neither explosive nor inflammable and, thus, can be used under conditions where chlorate alone would not be advisable. The mixture should consist of 1 part of chlorate and 9 parts borax, and is applied at a rate of 10 to 20 pounds per square rod.

A mixture of calcium chloride and sodium chlorate has been available for several years under the name of "Atlacide." The effectiveness of this mixture is due to the chlorate content, but the fire risk has been reduced by the addition of calcium chloride. The after-effect on treated soil is the same as that produced by a similar amount of chlorate alone.

CYANAMID AND CYANATE

Calcium cyanamid, a common nitrogen fertilizer, has contact weed-killing properties. Granular and powdered grades are available. The granular form, applied to the soil before seeding, has been used for several years in tobacco seedbeds. Both forms are used extensively

by asparagus growers for weed killing purposes and as a source of nitrogen for the crop. Granular cyanamid is applied to the soil when weed seeds are germinating and is effective for a period of 3 to 5 days, then is broken down into harmless compounds.

The powdered grade usually is applied by means of a power duster. The chemical is a contact herbicide which is effective only when weeds are small and covered with a film of moisture. Heavy dew followed by a warm, bright day, is needed for satisfactory results with this form of cyanamid. Vine killing and defoliation are other uses for cyanamid.

Both forms of cyanamid are heavy, black substances and somewhat disagreeable to handle. The fertilizing value of cyanamid reduces the cost to a point where it is feasible to use the material for weed-killing purposes in crops, such as asparagus, where cyanamid has a selective action.

Potassium cyanate is related to cyanamid and is used for selective weed control in onions. This compound is a white, granular substance which is soluble in water and is applied as a spray. It is effective on many young, broad-leaved weeds but does not kill older weeds.

Ammonium, sodium, and potassium thiocyanates have residual herbicidal properties when applied to soil, but the quantities needed for weed control make it impossible to grow crop plants in treated soil for a period of several weeks to several months.

2,4-DICHLOROPHENOXYACETIC ACID (2,4-D)

(Hormone weed killer)

The pure acid is relatively insoluble in water and does not appear in most retail outlets. It is effective, however, as a weed control chemical when used as a soil treatment, or in a suitable solvent.

The available 2,4-D preparations are of three forms: sodium salt, amine salt and ester. The sodium salt may be sold as a dry powder containing 70 to 80 percent of actual acid or as a liquid containing 10 to 20 percent acid. The amine salts are sold as liquid preparations and may contain 14 to 40 percent of actual acid. The esters (several are available) are likewise liquids and may contain from 10 to 40 percent actual acid. The sodium and amine salts produce a true solution when made up in water as finished sprays, while the esters form a milky suspension.

Dosage suggestions are always made on the acid-equivalent basis, and the quantity of a product that should be used must be calculated

from the data found on the label of the product. All reputable products will indicate the type of compound, the weight per unit of volume, and the percentage composition. Manufacturers usually state the amount of 2,4-D acid equivalent per gallon. Dosage calculations are relatively easy when the required rate per acre, weight and percentage of 2,4-D acid are known.

2,4-D formulations are considered selective on broad-leaved plants, but these compounds exhibit considerable variation on many species of plants. Some grasses and other narrow-leaved plants may be killed by contact with 2,4-D, while some broad-leaved plants are apparently not injured by 2,4-D in any form. The roots of most plants, however, are sensitive to the chemical and some caution must be observed in soil applications, especially at high rates per acre.

Best results are usually obtained from 2,4-D applications that are made when plants are in a state of rapid and vigorous growth. Seedlings of nearly all species of weeds are easily killed and the period just before flowering is often a susceptible stage of growth, especially in the case of resistant perennial weeds such as Canada thistle and sow thistle.

The quantity of 2,4-D that should be used depends upon a number of factors, chief of which are whether it is a pre-emergence or post-emergence treatment, type of weed to be killed, and crop susceptibility. Pre-emergence applications require from 1 to 5 pounds per acre for satisfactory control. Post-emergence applications range from ¼ to 2 pounds per acre. The amount for post-emergence use depends upon the crop, the weed, and the formulation. In most applications of 2,4-D, the amount of water used is not an important factor. It is important, however, to secure uniform distribution of a quantity of 2,4-D acid equivalent which is suitable for weed control, without injury to crop plants.

Small quantities of 2,4-D may cause serious injury to susceptible plants and there have been cases of a complete loss of a crop, owing to drift from spray or dust applications. Drift can be reduced by using low spraying pressures and adjusting spray booms at as low a position as the crop receiving treatment will permit. Spraying during a high wind should be avoided, and valuable plants should be shielded from drift. Application of 2,4-D dusts is not advisable in Michigan because of the numerous types of crops grown in every locality and the difficulty in confining dust to the area being treated.

None of the 2,4-D formulations are corrosive to spray equipment,

but because of the harmful effects of small traces of the chemical and the difficulty in cleaning tanks, hose lines, and booms, it is suggested that 2,4-D should **not** be used in sprayers that may later be used to spray orchards, vineyards, or truck crops.

2,4-D, at the rates generally used for weed control purposes, is not toxic to man or livestock.

For small-scale spraying, a solution containing 0.1 percent 2,4-D acid equivalent is considered to be of standard strength and is applied at a rate of 1 gallon per square rod. Resistant plants, however, may require a concentration of 2 or possibly 4 times this amount. Ester formulations are sometimes more effective on resistant species than other formulations.

2,4,5-TRICHLOROPHENOXYACETIC ACID (2,4,5-T)

This chemical is similar to 2,4-D but is more effective on wild raspberry, dewberry, blackberry, and certain other woody vegetation. It is used at the same rates as 2,4-D and may be more useful in brush control.

ISO-PROPYL-N PHENYL-CARBAMATE (IPC)

This material has selective action on certain plants. It will kill annual grasses, cultivated grains and, under some conditions, perennial grasses. IPC will also kill or injure some broad-leaved plants. The chemical is a white, crystalline powder not soluble in water. IPC is applied as a dry chemical or wettable powder which exerts a toxic action on the roots of grasses. Some residual action is produced, but decomposition is rapid and no further effects are found in most soils after a period of 2 to 4 weeks.

An application of 2 to 5 pounds per acre may give control of annual grasses but considerably more is required for noticeable effects on perennial forms such as quack grass.

IPC does not seem to be poisonous to animal life, but no controlled feeding experiments have been reported, and it is suggested that livestock be kept away from treated areas for two weeks, following treatment.

PETROLEUM PRODUCTS

Many oil refinery products have contact herbicidal properties. Some are general-purpose herbicides, effective upon above-ground parts of plants, while others are selective, but none are translocated in the

plants. Oils generally have excellent penetrating properties and, for this reason, may be used in conjunction with other herbicides.

The lighter grades of fuel oils are useful to control grass and annual weeds in uncultivated areas but have the disadvantage of setting up a condition which is a fire hazard. Oil-sprayed vegetation ignites readily and such fires are difficult to extinguish.

Naphthas of the Stoddard solvent series, with an aromatic content of 5 to 15 percent, are excellent herbicides. Members of the parsley family (carrots, parsnips) are tolerant of these materials, but most other crop plants and annual weeds are killed by contact with Stoddard solvent. Ragweed and beggar's tick, however, are exceptions in the annual weed group. Perennial weeds are killed only to the ground line.

Stoddard solvent is an excellent pre-emergence material for use on small seeded, or rapidly germinating crops because it has no residual effect. It may be applied the day before the crop plants emerge, without reducing the stand of desirable plants.

The rate of application for Stoddard solvent depends upon the weed and crop situation where it is used. When complete coverage of the field is desired, 75 to 100 gallons an acre is generally needed. In some cases, however, the oil is sprayed in a 4- to 8-inch band directly over the row, and satisfactory kill can be obtained with 30 to 50 gallons.

Other naphthas and similar compounds have the ability to kill submerged water weeds. Chlorobenzene and xylene, when sprayed as an emulsion in lakes and irrigation ditches, have given a quick kill of many types of water weeds. They are, however, toxic to fish and other small animal life. Livestock will not drink enough treated water to be harmed and the emulsions soon break down, permitting the herbicide to evaporate or settle to the bottom.

Various petroleum products are used as carriers for the dinitros and pentachlorophenols. These two types of compounds are often much more soluble in oil than they are in water, thus, it is possible to make a concentrate which may be dispensed in low-volume spray applications or used as a base for making water suspensions or emulsions of the toxicant.

PHENOLIC COMPOUNDS

Di-nitro-ortho-secondary-butyl-phenol and various salts of this phenolic compound are available for herbicidal use, and commonly referred to as "dinitros" or DNOSBP. They may be selective or non-

selective, depending upon the type of carrier, the quantity of effective ingredient and the nature of the crop plant under consideration. They may also be used as pre-emergence treatments, especially in large seeded crops and those propagated by roots, bulbs, corms, and tubers. Perennial crops may be given pre-emergence treatments for the control of annual weeds.

Pentachlorophenol (PCP) and sodium salts of this compound have been used successfully in a number of crops as pre-emergence treatments. Pentachlorophenol is soluble in certain oils, but is not soluble in water and must be used as an oil spray or an emulsion. The sodium salts are soluble in water and may be used as selective sprays in crops such as onions, or pre-emergence treatments in other crops.

Concentrated phenolic compounds are toxic to animal life and may cause skin irritation.

SALT (SODIUM CHLORIDE)

Common table salt will kill all vegetation when applied in sufficient quantity. Salt also has selective weed-killing properties when used in beets, onions, and a few other crops. Beets are tolerant of salt, while many young broad-leaved weeds are killed by contact with salt. Lamb's quarters, purslane and large weeds of most species are not killed.

Large amounts of both salt and water are required for successful weed control. A limitation of this method is the fact that mineral soils may be adversely affected by large amounts of salt. Muck soils will tolerate up to 1000 pounds of salt per acre.

SULFURIC ACID

A technical grade of this chemical has been used for weed control purposes for many years. Dilute solutions, 2 to 10 percent by volume, have selective action on small grains, onions, and certain coniferous seedlings. Selectivity seems to be based on the waxy nature of the foliage of these plants which prevents actual contact with the spray solution. Grasses and a few species of broad-leaved weeds, such as lamb's quarters, are not generally killed by this treatment.

The rate of application depends upon the crop being treated, but dilutions are made from commercial, concentrated sulfuric acid with a specific gravity of 1.84, one gallon of which weighs 15.3 pounds. Spray solutions are usually made up on a volumetric basis, but the concentrated acid is generally sold on the pound basis, in 90-, 900-

and 1700-pound containers. 90 pounds of concentrated acid will make up 300 gallons of 2-percent acid spray solution, such as is used in weeding young onions.

Sulfuric acid, in concentrated form, does not attack iron or steel, but the dilute spray solution is corrosive to these metals. This action on metals makes it necessary to use acid-resistant spray pumps and tanks, or inexpensive equipment which may be discarded after one or two seasons' use. Pumps of brass, or other resistant metals, rubber-impeller paddle pumps, and lead-coated or wood spray tanks are required for continued use of dilute acids spray.

The following precautions should be observed in handling sulfuric acid:

1. Always pour concentrated acid **into water,** never the reverse process.
2. Do not use acid in galvanized equipment.
3. Avoid contact of acid with shoes and cotton clothing.
4. Wear rubber gloves when handling concentrated acid.
5. Keep a container of bicarbonate of soda available to neutralize acid which may be accidentally spilled on clothing and skin. In case the skin is burned by acid, wash quickly with water and apply bicarbonate of soda.

TRICHLOROACETATE (TCA)

(Sodium or Ammonium Salt of Trichloroacetic Acid)

TCA has shown some promise for the control of perennial grasses such as quack grass and June grass. This chemical is soluble in water and may be applied as a spray or spread dry as fertilizer is spread. Experimental work is in progress to determine dosage requirements, time and method of application, and crop tolerance for TCA.

Preliminary results indicate that grains, legume crops, and strawberries may be injured by applications of TCA to soil in which these plants are growing. Beets and potatoes seem tolerant of quantities which will give seasonal control of annual grasses. Raspberries, tree fruits, and asparagus, while not killed by similar treatments, may show some burning of foliage and probably should not be treated with TCA during the growing season, except for small spots where losses due to grass competition are already apparent.

Rates of application depend upon a number of factors, but the data now available indicate that from 40 to 100 pounds, acid equivalent, per acre will be needed for satisfactory grass control. Some

regrowth is probable from the lower rates, and crop damage is more severe with higher rates. Applications in fall or early spring have shown some promise, but more data are needed before a time can be suggested.

PHENYL MERCURY ACETATE (PMA)

Several formulations of this compound, an organic mercury, have selective herbicidal properties for certain annual grasses. Research in some areas has indicated that these compounds will kill young crab grass seedlings in a lawn without injuring bluegrass and some other lawn grasses. Successful treatment requires three to five applications at rather close intervals (3 to 5 days), and the dosage must be regulated carefully to avoid injury to lawn grasses.

The fact that all mercury compounds are poisonous to man and livestock, and the slight difference in toxicity levels for crab grass and desirable grasses, limits the usefulness of PMA for grass control purposes. Climatic and soil factors affect the results obtained. The use of organic mercury compounds must be considered as still in the experimental stages and no suggestions for usage can be offered. Careful attention to the manufacturer's directions is essential for successful use of these materials.

EQUIPMENT

The type of equipment that is needed depends largely upon the acreage and type of crops grown. For the home gardener or commercial grower, with five acres or less of land, a 5-gallon knapsack type sprayer is suitable. One man can spray up to one acre per day of row crops with a knapsack sprayer. For this purpose, a brass sprayer should be purchased because of the light weight, longer life, and possibility of using corrosive solutions without damage to the sprayer.

A power sprayer will be useful on many farms for spraying fields, roadsides, fence rows and turf. Sprayers now are available with auxiliary gasoline motors or, without motors, for use on the power take-off or pulley of most farm tractors. Sprayers built for use on motor vehicles are also available. Jeep mounted sprayers (Fig. 1) are especially useful on soft, wet soil and on rough terrain.

Special spray booms, designed for weed control work have been developed and may be obtained from many sources. Such booms may also be constructed on the average farm if pipe cutting and threading

Fig. 1. A jeep-mounted power sprayer. Note the chain drive from power take-off of jeep and boom mounting. Better visibility on the part of the operator is obtained by mounting the boom in front of the vehicle.

facilities are available. The length of the boom depends upon the capacity of the pump, the crop to be treated, and the character of the land to be sprayed. A shorter boom is required on rough, rolling land than on level land. Under most conditions in Michigan, a spray boom should not exceed 20 feet in length and many farmers find a 12- or 16-foot boom to be the most practical length.

Nozzle spacing on the boom depends upon many factors, such as the volume of spray to be applied, tractor speed, row spacing and height of the crop. For general usage, a spacing of 18 to 20 inches between nozzles and a boom height of 20 to 24 inches is satisfactory. Crops planted in 14- to 16-inch rows obviously will require some modification in the boom arrangement.

Spray nozzles designed to give a flat, fan-shaped spray pattern have been found more satisfactory for weed control than the cone-shaped pattern delivered by the typical insecticide or fungicide spray nozzle. These nozzles are now available in a wide range of sizes, and the technical data supplied by the manufacturer will make it possible to select the size to be used under a particular set of conditions. Because a very definite relationship between nozzle opening and spray delivery per minute exists, it is necessary to know the tractor speed,

gallons per acre wanted, and pump pressure before a nozzle size can be selected. All dealers in spray equipment have charts which can be used to determine the proper nozzle for use under various conditions. Nozzles to be used for low-volume spraying have a small opening, and a screen with openings no larger than that of the nozzle is essential to prevent frequent stoppage of nozzles.

The term "low-volume spray" is usually used to describe applications in the range of 5 to 20 gallons per acre, although 30 to 40 gallons may also be considered as a low-volume application. At the 5- to 20-gallon rate, a nozzle opening corresponding to a .020- to .025-inch drill size is required. These low-gallonage nozzles are most efficient at spraying pressures of 20 to 40 pounds per square inch. Rates between 30 and 60 gallons may be applied with nozzles with openings of .032- to .046-inch diameter. A nozzle with an .059-inch opening is satisfactory for volumes of 50 to 100 gallons per acre. Variations in rate of delivery of any nozzle may be obtained by changing the pressure developed by the pump and the speed of the tractor or other vehicle. See Table 1 for selecting a nozzle that will deliver from 5 to 128 gallons per acre.

Equipment used for weed spraying should have a pressure gage, a pressure regulator, and a quick-acting shut-off valve. There should also be a screen on the intake side of the pump, as well as screens on the pressure side between the nozzles and the pump.

Numerous spray pumps are now available, but they may be classified into four major groups. The large-capacity sprayers are generally equipped with ordinary piston-type pumps and are used for large-scale operations, especially where the water supply is abundant and high-volume application is made at pressures of 100 p.s.i. or greater.

Paddle pumps, rubber or fiber blades rotating on a shaft inside a metal housing, are satisfactory for certain types of herbicidal applications. They operate best at the lower pressures and generally cannot be used to apply the solvent type of oil sprays.

Many of the newer, low-volume sprayers are equipped with gear pumps. The pumps are compact, relatively inexpensive, and are satisfactory for all types of spray solutions. Water which is free from sand or other abrasive material is necessary to insure long life of gear pumps.

Some sprayers have been built which use various types of centrifugal pumps and have given good service. Such pumps, however, are

TABLE 1—*Delivery in gallons per acre for two types of fan-type nozzles at different pressures. Data based on nozzle spacing of 20 inches, boom height 18 to 20 inches and tractor speed of 4 miles per hour*

Nozzle number		Pressure, in pounds per square inch			
Monarch*	Tee Jet*	30	40	60	100
25		6.4	7.1	8.9	11.2
	640067	5.0	5.5	6.7	7.8
32		10.0	10.8	12.6	16.7
	65015	10.7	12.4	15.2	19.6
39		16.7	18.9	23.6	30.5
	6502	14.3	16.5	20.2	26.1
46		20.8	23.1	27.8	36.1
	6503	21.4	24.8	30.4	39.2
59		37.5	41.7	51.4	52.3
	6504	28.6	33.0	40.4	52.3
99			83.0	102.0	128.0
	6408	57.2	66.0	80.8	

*Similar nozzles are available from other manufacturers.

somewhat more expensive than paddle or gear pumps. This cost differential is offset by the longer life of the centrifugal pump.

Where brush control by spraying is contemplated, a spray gun of some sort is essential. A spraying pressure of 200 to 400 pounds is advisable. Various types of guns are available, and selection is largely up to the individual operator. Crop and turf spraying will not require the use of a gun.

In lawn work or other spray operations where 2,4-D is to be used near valuable plants which are susceptible to injury by this compound, the spray boom should be provided with some sort of hood or covering. This safety device, along with low spray pressure, will reduce the amount of spray drift and thus reduce the risk of injury to ornamental plants.

When spray applications of a number of herbicides are made on crops whose resistance to herbicides is variable, care in cleaning spray equipment is essential. With the exception of 2,4-D and related compounds, it is a relatively easy matter to wash out residues from herbicidal applications. Two or three rinsings of pump, tank, hose and boom with clean water will suffice. It is practically impossible, however, to remove all traces of 2,4-D from spray tanks and the minute amounts left by the most careful washing may be sufficient to ruin a crop which is sensitive to 2,4-D. For that reason, it is suggested that a sprayer which has been used to apply 2,4-D should not be used for any purpose in crop plants or fruits which are subject to injury by this chemical.

The use of aircraft for spray and dust applications of herbicides, is practiced in some sections of the United States and Canada. In Michigan, however, the acreage devoted to a particular crop is seldom great enough to make airplane spraying feasible. The great difficulty in confining the dust or spray to a specified area also poses somewhat of a problem in this state. Many farmers will have fields of one crop which will tolerate a specified herbicide, along side other crops which may be killed or injured by that herbicide. Because of the diversity of crops and their differing susceptibilities to herbicides, it seems that applications of herbicides by means of aircraft is not likely to become widespread in this state.

SUGGESTIONS FOR THE USE OF CHEMICALS TO CONTROL WEEDS

ASPARAGUS

In newly established asparagus beds, annual weeds and grasses become a problem, while in older beds, many other weeds including perennial grasses, seriously interfere with the production of asparagus. The control of these weeds by chemical means, without injuring crowns and spears, is not simple.

Cyanamid, a nitrogen-carrying fertilizer, gives satisfactory control of most of the young broad-leaved weeds, if applied at the proper time. The granular form is applied at the rate of 200 to 400 pounds per acre, in a band over the row, early in the season. The powdered form is applied during the cutting season at a rate of 75 to 100 pounds per acre, when the foliage is wet from dew or rain. This treatment is effective on small weeds and should be repeated during the season as required to control weeds.

Some perennial weeds, such as Canada thistle and bindweed, may be controlled by spot-spraying, using the ester form of 2,4-D at the rate of 2 pounds per acre. Grasses in older beds can be controlled by the use of TCA. For such use apply ½ lb. TCA per square rod.

The disking operation at the end of the cutting season, made by many growers, tends to destroy buds and may cause injury to the asparagus crowns. A spray application of a contact herbicide, in place of disking, will often give satisfactory weed control and avoid mechanical injury to the asparagus. Stoddard solvent, 80 to 100 gallons per acre, can be used for this purpose and will kill most annual weeds except ragweed. Selective formulations of the dinitrophenols or pentachlorophenates may also be used at this time.

BEETS

Weed control in both red beets and sugar beets is of considerable importance, especially when these crops are grown on muck soil. The problem is complicated by the fact that the germination period for beet seed is rather short and young beet seedlings are sensitive to many chemicals. Many pre-emergence, residual, treatments reduce the stand of beets, and selective sprays are often unsatisfactory. Lamb's quarters and annual grasses are especially difficult to control by chemical sprays. The need for weed control measures in beets has not been met successfully by chemical methods.

Stoddard solvent can be used at any time before actual emergence. The preparation has no residual effect and will kill most weed seedlings. For good weed control, 40 to 80 gallons per acre of the undiluted petroleum are required.

PCP, at the rate of 5 to 10 gallons per acre of an aromatic oil containing 5 percent of the phenolic compound, has given promising results as pre-emergence treatment. The method requires further testing, however, and is suggested for trial purposes only.

Post-emergence sprays for beets have not given entirely satisfactory results. A solution of common salt, 2 pounds per gallon of water, applied at the rate of 150 to 200 gallons per acre, will control many young weeds. This treatment is not effective on lamb's quarters, purslane, and wild mustard. The use of salt spray is not advisable before the beets have two to three true leaves nor after weeds have developed more than three to five leaves. The continued use of large quantities of salt may have injurious effects upon mineral soil.

Small patches of quack grass in fields intended for beets should be sprayed in the fall with ½ pound TCA per square rod. This will control quack grass and reduce the possibility of injury to beets which might exist following spring treatment.

CARROTS AND RELATED CROPS

Carrots and parsnips, when planted in early spring, are slow to germinate and frequently emerge in a soil which is already covered with annual weeds. This weed growth may shade the crop plants to such an extent that stands are reduced and subsequent growth is poor. Costly hand weeding is often required to save the crop.

Transplanted celery is often crowded by growth of purslane (pussley) and grasses. Other common annual weeds may become serious pests in wet seasons. Removal of these weeds cannot be accomplished by ordinary tillage operations.

All members of the parsley family are tolerant of certain petroleum products and can be weeded with these chemicals. Pre-emergence, contact, sprays may be used in these crops, but selective sprays are so satisfactory that they are generally preferred.

Stoddard solvent, applied at any stage of growth of carrots and parsnips, will control 95 percent of the annual broad-leaved weeds and grasses which are common in Michigan. The rate of application ranges from 40 to 80 gallons per acre, depending upon the method of application. When the spray is confined to a 6-inch band directly over the row, 40 gallons are sufficient, but the larger quantity is needed for complete coverage of the soil surface. Parsley, dill and caraway may be sprayed in the same manner as carrots, but should not be sprayed when in flower. **Carrots and parsnips that have developed roots more than ½ inch in diameter may develop an objectionable flavor if sprayed with petroleum products.**

Celery seedbeds can be weeded by spraying with Stoddard solvent, but transplanted celery sometimes develops a condition known as "black heart" following petroleum sprays. Some growers, however, have used this method of weed control in celery with excellent results. It is suggested that, in such use, the spray, 40 to 80 gallons per acre, be directed to the side of the celery plants. Treatment should be made before the celery is more than 4 inches tall.

Ragweed, beggar's tick and some mustards are resistant to Stoddard solvent and must be removed by hand or cultivation. Perennial weeds and grasses may be killed to the ground by this treatment, but regrowth will occur.

Fields infested with nut grass can be planted to carrots and sprayed 2-3 times with Stoddard solvent. This will control nut grass while the crop is growing, and if followed for two seasons will permit use of the field for other crops in which nut grass cannot be readily controlled.

CORN

Ragweed, wild mustard, cocklebur, smartweed and annual grasses are the most common weeds found in corn fields. Perennial weeds that are most troublesome are Canada thistle, sow thistle, bindweed, horse nettle and quack grass. Under average conditions, these weeds can be controlled by three or four cultivations. Cultivation alone may not control these weeds in wet seasons.

Post-emergence spraying with 2,4-D, at the rate of ¼ to ½ pound, acid equivalent, per acre will control broad-leaved annual weeds.

The spray will be most effective when applied to small weeds. Cultivation after the spray application, usually will be required to control annual grasses.

The pre-emergence use of 2,4-D at the rate of 2 pounds, acid equivalent, per acre has given control in some seasons, of both annual grasses and broad-leaved weeds without injury to corn. In other seasons, however, poor results have been obtained with this method of control. Pre-emergence treatments in corn, therefore, should be considered as an experimental procedure and used only on a limited scale until more information is secured.

Corn is sometimes injured when sprayed with 2,4-D. The symptoms of such injury include rolling of leaves, brittleness of stalks, malformation of brace roots and lodging. When 2,4-D is used at the rate of ¼ to ½ pound per acre, some injury may be observed, but the yield of corn is not generally affected.

BLUEBERRIES

Cultivated blueberry plantings usually become infested with annual grasses in the early life of the planting. Later, various perennial weeds may become a problem.

Young blueberries may be injured by most chemicals used for weed control purposes. Older plants are hardier and more tolerant of chemicals. Several chemicals are being tried for such purposes, but no suggestions for grower usage can be made at the present time.

GRAPES

Annual broad-leaved weeds and grasses are the chief problem in young vineyards. Older vineyards frequently become matted with bluegrass and quack grass.

The only satisfactory weed control measures for use in grapes are cultivation and hand hoeing. Dinitro compounds at 1–1½ lbs. per acre in 5-10 gals. of oil have been used for temporary control of weeds in the row, but this treatment will not kill perennial weeds. Grape vines should be at least 3 years old before dinitro compounds are used for weed control.

The grape plant is extremely sensitive to 2,4-D and **this chemical should not be used in or near a vineyard.**

RASPBERRIES

Broad-leaved weeds do not cause much trouble in raspberries, especially if the hill-system of growing is employed. In some locations, quack grass and Kentucky bluegrass become established in older beds.

Young broad-leaved weeds can be controlled by using 2,4-D at a rate of ¼ to ½ pound, acid equivalent, per acre. The spray should be directed toward the ground to avoid contact with raspberry leaves and should not be applied when the plants are in flower. Abnormal fruit and leaves may result if the material comes in contact with the plants.

Quack grass and Kentucky bluegrass may be killed by the use of TCA. However, some injury to raspberry plants may occur and it is suggested that TCA be used only in old plantings. For best results, TCA should be applied in the fall (November), after the old fruiting canes have been removed and the leaves have dropped. At this time, new fruiting canes are dormant while the quack grass is usually green. Thiry pounds per acre, applied as a spray, gives satisfactory control. The spray should be directed toward the base of the canes and limited to an 18-inch strip.

STRAWBERRIES

The control of weeds in strawberries is an annual problem in which much labor is used in hand weeding, hoeing and cultivating. Annual broad-leaved weeds and grasses are the most troublesome in the first-year bed, while the fruiting bed often becomes infested with perennial weeds and grasses. Proper preparation of the land before setting out the plants will eliminate many of these weeds.

2,4-D has been used satisfactorily on commercial plantings for the control of broad-leaved weeds in first-year beds. One-fourth to one-half pound per acre, 1 or 2 weeks after planting, will eliminate many of the young weeds. 2,4-D should not be used in fruiting beds.

Common chickweed can be kept under control in strawberry plantings with IPC. The material is available as a 50 percent wettable powder and should be applied as a spray. It can be used to advantage for spot applications at the rate of 15 pounds of the wettable IPC in 100 gallons of water per acre. Since all the facts about the material are not known it is suggested that it be applied as a spray and not as a dust.

For large scale applications use about 10 pounds of the wettable IPC in 100 gallons of water per acre. A sprayer that delivers 75 gallons or more per acre will work satisfactorily provided good agitation

is maintained. September, October and early November are suitable times for the use of IPC in strawberries.

TREE FRUITS

The most troublesome weeds in an orchard are sand burs and poison ivy. In some cases, broad-leaved annual weeds are a problem.

Poison ivy on the trunks and around trees can be killed by spraying with Ammate. Three-fourths pound of this chemical in one gallon of water will treat one square rod of area. The spray should not be applied to the foliage of the tree, nor in sufficient volume to wet the soil. Ammate temporarily controls all weeds, grasses and crops, therefore, it should not be used where a cover crop is grown.

Sandburs can be controlled by spraying with Stoddard solvent before the plants produce burs. The solvent should be applied at the rate of ½ gallon per square rod. This treatment will also control many other annual weeds.

In young orchards satisfactory control of grasses can be obtained by spraying a small area at the base of each tree with a special grade of Stoddard Solvent (Standard Weed Killer F). Perennial grasses, such as quack and Bermuda, will make new growth following such treatment but two or more sprayings during a season can be made without injury to the trees. Two successive years of spraying will kill out most of the grass rhizomes. Enough oil to wet the grass should be applied at each spraying.

SMALL GRAINS AND FLAX

Weeds often become a serious problem in small grains and flax, even when good cultural practices have been used. Quack grass, field bindweed, thistle, wild mustard, and ragweed are among the most troublesome weeds. Tests have shown that spraying such fields with chemicals is sometimes a practical and effective method of controlling some of these weeds.

A 3- to 5-percent solution of sulfuric acid, applied at the rate of approximately 100 gallons per acre, has been used successfully for controlling wild mustard in small grains.

Dinitro herbicides can be used to control wild mustard and ragweed in small grains and flax, even when a legume seeding has been made with the grain crop. The dinitros should be applied at the rate of ½ to ¾ pound per acre. These preparations will require 75 to

100 gallons of water per acre. If a legume seeding is made with the grain, it is important that the dinitro be applied at an early stage when the grain is 6-8 inches high. Later spraying will result in some injury to the legume seeding, especially clovers.

2,4-D can be used in small grains to control wild mustard, ragweed and some other broad-leaved annual weeds. Serious injury may result, however, to legume seedlings. The amount of injury will depend upon time and rate of application, kind of legume and conditions prevailing at time of spraying. In general a rate of ¼ pound acid equivalent per acre applied when the grain is 6-8 inches high can be used, however some injury to the seedings should be expected. Heavier rates or later applications are more injurious. Sweet clover is injured most and red and white clover least. Field bindweed may be killed back to such an extent that it causes no trouble in the small grain crop. Thistles, although not completely killed, will not produce seeds.

If fields are badly infested with field bindweed the following plan is suggested. Remove the field from the regular rotation and plant to oats or barley for two years without a legume seeding. About one week or ten days before the grain heads out, spray with one-half pound of 2,4-D per acre. Some injury to the grain crops should be expected. After grain harvest, summer fallow twice and plan to spray again in September.

Low and high volumes have been equally effective, provided the proper amount of the chemical was used. Spraying should be done when the grain crop is 4 to 8 inches high, at the rate of ¼ to ½ pound, acid equivalent, per acre. Heavier rates are needed for control of field bindweed, and the spray application is made at a later stage of growth. Under such conditions, some reduction in yield of grain may occur.

Flax is often injured by 2,4-D. The dinitro compounds at the rate of ½ to ¾ pound per acre will control annual weeds in this crop.

When there are small, scattered patches of persistent perennial weeds present, it may be worth while to spray with 2,4-D or TCA at a much heavier rate to check weeds, even though the grain in that small area is killed or injured by the spray.

Chess, corn cockle, quack grass, wild buckwheat, and smartweed are not killed by any of these chemicals at rates which will not injure the grains.

ALFALFA AND CLOVER

Hay fields are often very weedy, probably because they are so far removed from a cultivated crop in the rotation. Special effort should, therefore, be made to get a clean seedbed for the new seeding. When seedings are made with a grain crop, the new seedings frequently contain ragweed, foxtail, and tickle grass. Older seedings frequently contain downy brome, quack grass, yellow rocket, wild carrot, curled dock, buckhorn, catchfly, thistles and field sorrel. The older the stand, the weedier it becomes, therefore, hay fields should not be left too long before being plowed and put back to a cultivated crop.

The dinitro compounds can be used on very young seedings of legumes without injuring the stand, but the same chemical applied on established stands may cause serious damage. Alfalfa seedings are more resistant to the spray than clover. Mustards, yellow rocket, ragweed, lamb's quarters and pigweed are killed or effectively checked by the spray. The dinitro compounds should be used according to the directions of the manufacturers. These chemicals are most effective on weeds in the seedling stage. Perennial weeds, such as Canada thistle, dock and buckhorn are not seriously injured by dinitros. Small patches of these weeds should be sprayed with 2,4-D, 1 to 2 pounds per acre, even though legumes in the patches may be killed.

BEANS

(Field, lima, snap, and soybeans)

Weeds causing the most trouble in beans are ragweed, pigweed, velvetleaf and grasses. These weeds in field beans or soybeans interfere with harvest operations.

The bean plant is readily injured by contact with all herbicides now in use and no selective sprays can be suggested. Selective control by flaming has been accomplished in lima beans, but the equipment is large, expensive, and requires a skilled operator.

Control of annual weeds in beans can be accomplished by the use of certain types of pre-emergence treatment. The dinitros, used at the rate 1 to 2 pounds per acre, have given good weed control without permanent injury to beans. Some burning or yellowing of the first leaves may occur, but the plants recover and yields are not affected by the treatment. The spray should be applied soon after planting in order to allow time for it to decompose and become harmless before emergence of the beans.

Experimental trials of 2,4-D as a pre-emergence treatment have shown that beans will tolerate soil applications of 2,4-D. The foliage of beans grown under such conditions may develop characteristic symptoms of 2,4-D injury in the early stages of growth. Recovery usually occurs, however, and the only serious effect is a delay in maturity. 2,4-D-treated beans may be 1 or 2 weeks later than untreated beans. Soy and lima beans are more tolerant than other forms.

Pentachlorophenols can be used as pre-emergence sprays. The rate of application depends upon the formulation, but not more than 2 to 4 pounds per acre of the parent phenolic compound should be used.

Spot infestations of quack grass, bindweed and Canada thistle in bean fields should be treated with chemicals suitable for the control of these weeds. Such treatment, however, will destroy the beans in the treated areas. For bindweed and thistle 2,4-D at 2 pounds, acid equivalent, per acre should be used. Quack grass patches may be treated with TCA at the rate of 60 pounds, acid equivalent, per acre. These treatments may not eradicate the weed plants but will keep them from seeding or spreading over wider areas and follow-up treatments in succeeding seasons lead to eventual eradication.

PEAS

Weed control problems in peas are of two distinct classes. One of these is the control of annual weeds such as ragweed, smartweed and mustard. The other is the control of Canada thistle or other perennial weeds. Annual weeds are important because of the competition they offer during the growing season and because they make harvesting operations more difficult. Canada thistle infestation not only presents the problem of competition between peas and weeds but, because this weed approaches flowering at about harvest time for the peas, also makes canning operations difficult. The unopened buds of thistle are similar in size to shelled peas and are difficult to remove by mechanical methods.

Control of annual weeds can be accomplished on a selective basis. The dinitro compounds, applied before the peas are more than 4 to 6 inches in height, will kill most broad-leaved annual weeds without injuring the peas. The quantity of dinitro to be used depends upon the preparation available, and the manufacturers' directions must be followed. No important differences in response to the dinitro

Fig. 2. Effects of sulfuric acid spray on young onions. Upper portion sprayed with 2½-percent sulfuric acid solution, lower not sprayed.

sprays have been observed in varieties of peas tested. Light and dark green foliage types appear equally tolerant of the chemical.

The control of Canada thistle, bindweed and quack grass in peas is not possible on a selective basis. Spot infestations of these weeds should be treated, however, to prevent further spread of weeds. 2,4-D at the rate of 2 pounds, acid equivalent, per acre will give seasonal control of Canada thistle, and bindweed, thus preventing seeding and spread of these weeds. Peas in the treated areas, however, will be destroyed. TCA, at the rate of 60 pounds, acid equivalent, per acre can be used to control patches of quack grass, but the crop will be lost in treated areas.

ONIONS

Annual weeds and grasses often present a serious problem in producing onions, especially in wet seasons when cultivation is difficult.

Pre-emergence treatment can be made with dinitros, PCP, 2,4-D and cyanamid, but there is some risk of reducing the stand of onions. The dinitro compounds will give good weed control, but may remain in the soil long enough to affect the germination of onion seeds. PCP, sodium salt, in water will give good control when used under conditions of warm temperature. Yields may show less effect than the reduced stand of onions would indicate because the surviving plants produce larger bulbs. Results from the pre-emergence use of 2,4-D have been variable. Some trials have shown that the growth and yield of onions is not affected. Other trials, under different conditions, have resulted in a poor yield and small onions. The degree of weed control that can be expected on muck soil treated with 2,4-D is always less than that which can be expected from pre-emergence usage on mineral soils. Because of the unpredictable results, the pre-emergence usage of 2,4-D in onions must be considered as an experimental procedure only. Granular cyanamid, at a rate of 100 pounds per acre will control weeds, but it should be applied several days before crop emergence.

A 3-percent solution of sulfuric acid (3 gallons of acid in 97 gallons of water) as a pre-emergence contact spray, will give good control of weeds and will not injure the onion sprouts which are below the surface of the soil. This treatment, however, will not kill grasses. Stoddard solvent, at the rate of 40 gallons per acre, can be used to kill all weed seedlings. The petroleum product is volatile, has no residual action, and can be used as late as the day before onion emergence.

Post-emergence treatments in onions are generally required because of weed growth which is more rapid than that of the crop. Such treatments can be made when the young onion plants have developed one to three true leaves. Earlier treatments usually reduce the stand and may result in complete destruction of the crop.

Dilute sulfuric acid, 2½ percent (by volume), applied as soon as the onion plants have developed two true leaves, has given consistently better weed control and better yields of onions than any other selective herbicide used in this crop. This treatment on warm, bright days, may cause some wilting of the onions, but recovery is rapid and no serious injury is produced. A second spraying 2 to 3 weeks later may be made if weed growth occurs.

In warm, dry weather, dinitro and PCP, sodium salt, sprays will kill broad-leaved weeds. The onion plants may be severely burned, however, and careful attention to dosage of the herbicide is required. These chemicals do not give satisfactory weed control in cool, wet weather and do not control grasses under any conditions. Dinitro compounds should be used at a rate of ¾ to 1 pound in 100 gallons of water per acre.

Potassium cyanate, 1 to 2 percent, by weight in 60 to 100 gallons of water, will control many kinds of broad-leaved weeds. This compound must be used before these weeds have developed beyond the three to four-leaf stage. An application of a 1-percent solution when the onions are 2 inches high, followed by another spraying with a 2-percent solution when the two- to three-leaf stage of development has been reached, is suggested. A combination of pre-emergence treatment, with granular cyanamid, and one application of cyanate spray has given good results in some trials.

POTATOES

Weed problems in potatoes are dependent upon the type of soil in which the crop is grown. In upland soils, annual weeds seldom present a serious problem, but quack grass and other perennial weeds may cause considerable difficulty. On muck land, annual weeds such as smartweed, pigweed and lamb's quarters as well as perennial weeds, may become a serious problem. The fact that potatoes are rather slow in emerging often permits a heavy growth of weeds before the crop is above ground.

Pre-emergence control of weeds can be obtained by the use of both contact and residual type herbicides. For **contact** control, when weeds

are present before the potato plants appear; the dinitros, at 1 pound per acre; pentachlorophenate (PCP) 16 pounds per acre in water; sulfuric acid, 3-percent solution; and Stoddard solvent, 40 to 80 gallons per acre, all have given good results without injury to potatoes. These chemicals should be applied when the weeds are small, but they may be used as late as the time when the first leaves are breaking through the ground. Slight burning of the leaves at this time is not serious and will not reduce the yield.

Pre-emergence, **residual,** treatment may be made in potatoes as follows: 1) Dinitros in oil, at the rate of 1 to 2 pounds per acre, 2) pentachlorophenol in oil (PCP) at 2 to 4 pounds per acre, 3) granular cyanamid at 150 to 200 pounds per acre, and 4) 2,4-D at 2 pounds per acre. Treatments should be made shortly after planting in order to allow for breakdown of the chemical before the potatoes emerge.

Post-emergence weed control in potatoes does not seem advisable with the chemicals now available. 2,4-D has been suggested as a possible herbicide in this crop because potatoes are not killed by rates of application which are satisfactory for weed control purposes. Limited trials, however, have shown that considerable leaf modification may follow such treatment.

Because of the limited tolerance of potatoes to 2,4-D, it is possible to use a potato sprayer for other weed control purposes. The small amounts of 2,4-D remaining after weed spray operations will not cause serious injury to the potato crop when the sprayer is used for applying insecticides and fungicides. Thorough cleaning of the sprayer after using 2,4-D is necessary and can be done by means of several rinsings with clean water.

Small patches of quack grass in a field which is to be planted to potatoes in the spring can be treated with TCA at the rate of 60 pounds per acre, in early fall. This treatment will destroy most of the grass, and potatoes will generally germinate and grow in the treated areas. Some reduction in yield may occur. Spot treatment of patches of quack grass may be made during the growing season, but potatoes in the treated areas will be injured.

CUCUMBERS, MELONS AND TRANSPLANTED CROPS

Weed problems in these crops are not usually of a serious nature. Proper seedbed preparation and a small amount of hand hoeing will usually control most annual weeds. Early preparation of land, which will allow seeds to germinate, followed by spraying with dinitros,

pentachlorophenols, sulfuric acid, Stoddard solvent or other contact herbicides are of considerable value in getting crop plants started in weed-free soil. A period of 4 to 7 days should elapse between treatment and transplanting. When such treatments are made, cultivation should be delayed as long as possible because new weed seedlings will appear when the soil is stirred.

ORNAMENTALS

Michigan is one of the leading producers of tulips, gladiolus and other bulb crops. Weed control in these plantings often involves considerable hand work.

Pre-emergence treatments may be made with 2,4-D, cyanamid, dinitros and Stoddard solvent. 2,4-D is used at the rate of 2 to 5 pounds, acid equivalent, per acre in gladiolus, but should not be used in other bulb crops. Other herbicides are used at the rates suggested in the section on potatoes.

Post-emergence sprays have not been entirely successful in any of the bulb crops. Dinitros are used as selective sprays in gladiolus but must be applied in such a way as to avoid getting the tips of the leaves wet. 2,4-D can be used on gladiolus plants grown from "bulblets" but should not be used on flowering stock.

Tulips and daffodils should not be sprayed with 2,4-D.

NURSERY CROPS

The slow growth of most nursery stock seedlings makes considerable hand weeding necessary. Annual weeds and grasses are especially troublesome.

Pre-emergence, contact treatments may be made in nursery plantings. A 3-percent solution of sulfuric acid, at the rate of 1 quart per 100 square feet, will kill most broad-leaved weeds. Stoddard solvent, at the rate of 1 quart per 200 square feet will kill both broad-leaved weeds and grass seedlings.

Post-emergence treatments can be applied to conifer seedlings. For such use, Stoddard solvent, at the rate of 1 quart per 150 square feet is suggested. The use of Stoddard solvent will effectively reduce the weeding problem in pine seedling beds. No injury to the seedlings will occur if the spray is applied while the seed coats are still over the cotyledons or after the seedlings are one year old.

Fig. 3. Power sprayer and spray gun for use in brush control. High pressure aids in getting spray to penetrate mass of foliage. (Photo—Dow Chemical Company)

BRUSH

The growth of woody plants in abandoned fields, pastures and along creek banks, drainage ditches and under power lines is often a serious problem. 1 to 2 pounds of 2,4-D, ester formulation, in 100 gallons of water, applied as a spray to wet all the leaves will control willow, hazel, alder, box elder, poison ivy and grape. A similar amount of 2,4,5-T will be more effective on maple, oak, raspberry, blackberry and osage orange. A mixture consisting of equal amounts of 2,4-D and 2,4,5-T is sometimes more effective than either alone. Ash and hawthorne are not usually killed by either 2,4-D or 2,4,5-T. Most woody plants can be killed by spraying with Ammate at the rate of ¾ pound per gallon of water. Enough solution to thoroughly wet the leaves should be applied.

When brush is more than 4 feet in height, removal of old growth is necessary. This can best be done while the plants are still green. Sprouting can be prevented by spraying the cut stumps with a solution consisting of 3 to 4 pounds 2,4-D, ester, acid equivalent, in 100 gallons of kerosene or diesel oil. When new gorwth appears, the sprouts should be sprayed with either 2,4-D or Ammate as suggested for small brush.

LAWN

The growth of dandelion, plantain, chickweed and other common broad-leaved weeds spoils the appearance of many lawns. Crabgrass is often a problem in weed-infested lawns during late summer and fall.

2,4-D is the best chemical to use in treating lawns and turfs to control broad-leaved weeds. Sprays may be applied any time when weeds are growing, but most rapid killing is obtained when temperatures are above 60° F. during and following application. 2,4-D can be applied as a dilute solution (0.1%) at the rate of 1 gallon per square rod (Table 2). A concentrated low-volume spray may be used, and in this case, 1½ pounds of 2,4-D, acid equivalent, per acre should be used and may be applied in as low a volume as 5 gallons per acre. The effectiveness of 2,4-D in the control of dandelions is shown in Fig. 4.

When weeds are killed in infested lawns and turfs, bare spots will appear. Unless reseeding with grass is accomplished, other weeds

Fig. 4. Effects of 2,4-D on dandelions in turf. Lower right, unsprayed. (Photo—Dow Chemical Company)

TABLE 2—*Dilution table for making up 2,4-D solutions for small sprayers*

Percent of 2,4-D in product	Teaspoons for 1 gallon of water	Tablespoons for 5 gallons of water	Ounces for 10 gallons of water
	Liquids		
10	8⅓	14	14*
14	5⅔	9½	9½
20	4	6½	6½
32	3	5	5
38	2½	4½	4½
40	2	3½	3½
	Powders (spoon level)		
60	2¾	4½	2¼**
70	2½	4	2
80	2¼	3½	1¾

*Fluid ounces
**Avoir. weight.

These quantities are approximate only because of differences in the nature of various trade name products, but will give satisfactory results under average conditions. The percent 2,4-D refers to the **2,4-D acid equivalent** which should appear on the label.

and undesirable grasses may fill in the bare spots. Reseeding may be done 2 to 3 weeks after an application of 2,4-D. It is advisable to spray every year until the grass is well established so that weeds do not become a problem. 2,4-D should not be used on newly established lawns nor on bent grass.

Control of crabgrass may be obtained by the use of PMA, cyanate, dinitrophenol, and Stoddard solvent, but some risk of injury to lawn grasses is present. PMA, used as recommended by the manufacturers will kill young crabgrass. An overdose of this compound will injure lawn grasses and weed grass that is more than 2-3 inches tall is not usually killed. A 2-percent solution of potassium cyanate to which a wetting agent has been added, is effective on young grass seedlings. One gallon per 500 square feet should be applied before crabgrass has more than 3 true leaves. Some browning of lawn grasses may occur but is of a temporary nature and the grass will recover.

Dinitrophenol, 2 pounds per 100 gallons of water, will destroy young grass seedlings but will also cause considerable burning of desirable grasses. Injured grass recovers quickly if sufficient soil mois-

ture is present. Stoddard Solvent burns all grass to the ground line, but does not affect the roots and recovery is rapid.

Selective control of crabgrass, with little or no risk to lawn grasses, can be obtained by the use of a petroleum compound (sold as Standard Crabgrass spray). One gallon of this product on 500 square feet is the usual dosage. The spray should be applied as soon as crabgrass is observed in the lawn and the treatment repeated in 10 days if the grass has not all been killed. This schedule may be followed two or more times during the season if new crabgrass germination is brought about by rainfall or lawn watering.

Proper fertilization, mowing and watering will go far toward keeping a lawn free from crabgrass and broad-leaved weeds. The use of herbicides is not a substitute for proper care of a lawn. Instructions for proper lawn care may be found in Ext. Bul. 224.

PERMANENT PASTURES

Low fertility, lack of moisture and over-grazing cause most of the weed growth in bluegrass and white clover pastures in Michigan. The most common weeds are thistles, dandelion, buckhorn and mullein. Woody plants commonly present are black locust, hawthorne, sumac and brambles. Many of these plants can be controlled by spraying with chemicals. However, this procedure should be co-ordinated with other good management practices if the pasture is to be made more productive.

2,4-D and 2,4,5-T and Ammate are not poisonous and can be used in pastures where animals are grazing. 2,4-D, applied at the rate of 1 to 2 pounds, acid equivalent, per acre, will kill bull thistle, dandelions, buckhorn and many broad-leaved annual weeds. Any white clover in the pasture will be injured considerably but usually re-establishes itself in a year or so, especially if conditions of moisture and fertility are favorable. If the pasture is largely white clover, or some other legume, a blanket spray of 2,4-D should not be made.

2,4,5-T and Ammate can be used for spot spraying of the more resistant kinds of brush as discussed for woody plants.

TABLE 3—*List of herbaceous and woody plants, classified as to their reaction to 2,4-D and 2,4,5-T*

HERBACEOUS. Reaction to 2,4-D.

Group 1. Susceptible. Killed in early growth stages by low dosage	Group 2. Intermediate. Require higher dosage but can be killed	Group 3. Resistant. Not generally killed
Beggar's tick	Bindweed	All grasses
Bull thistle	Canada thistle	Asters
Burdock	Chickweed	Black medic
Cocklebur	Chicory	Bouncing bet
Crop plants (Broad leaved types)	Crane's bill	Butter-and-eggs
Gum weed	Curled dock	Buttercup
Hemp	Daisy flea bane	Catch fly
Horse weed	Dandelion	Cockle
Lamb's quarter's	Dog fennel	Ground cherry
Mustard (most species)	Evening primrose	Horse nettle
Pigweed	Goat's beard	Hound's tongue
Plantain (buckhorn)	Golden rod	Knapweed
Ragweed	Hawkweed	Knotweed
	Heal-all	Mallow
	Hoary alyssum	Milkweed
	Horsetail	Nightshade
	Money wort	Ox-eye-daisy
	Mullein	Smartweed
	Sorrel	Spurge
	Sow thistle	Tansy
	Speedwell	Velvet leaf
	St. John's wort	Wild buckwheat
	Stinging nettle	Wild lettuce
	Water hemlock	Yarrow
	Wild carrot	
	Wild garlic	
	Wormwood	

WOODY PLANTS. Reaction to foliage spray of 2,4-D and 2,4,5-T

Group 1. Killed by 2,4-D	Group 2. Killed by 2,4,5-T	Group 3. Not usually killed by 2,4-D or 2,4,5-T
Alder	Aspen	Ash
Cherry	Bittersweet	Bracken
Elderberry	Brambles	Buttonbush
Elm	Currant	Hawthorn
Grape	Dogwood	
Hazel	Hickory	
Peach	Maple	
Pear	Oak	
Poison ivy	Osaga Orange	
Poison sumac	Prickly ash	
Shad bush	Sassafras	
Spirea		
Stag-horn sumac		
Sweet fern		
Walnut		
Willow		

TABLE 4—*Control measures for common weeds where crops are not present*

Weed	Chemical	Rate per acre	Remarks
Annual grasses including sand bur	Stoddard solvent TCA	80 gallons 20-40 pounds	Apply when plants are small
Annual, broad-leaved weeds	2,4-D	1 pound	Not effective on smartweed and wild buckwheat
Wild carrot	2,4-D	1 pound	Fall application gives best results. Flowering plants resistant
Burdock	2,4-D	1 pound	Apply before seed stalk appears
Bindweed	2,4-D	2 pounds	Repeat treatments usually needed
Quack grass	TCA	40-100 pounds	Do not apply near trees or shrubs
Thistles	2, 4-D	2 pounds	Bull thistle is easy to kill, but Canada thistle may require repeat treatments
Poison ivy and poison sumac	2, 4-D, ester Ammate	2 pounds 75 pounds	Do not use in orchards Ammate kills everything hit by spray. Perennial grasses recover
Brambles	2, 4, 5-T	2 pounds	Apply when plants are in full leaf stage
Nut grass	Stoddard Solvent	60 gallons	Apply when plants are 3-4 inches tall, repeat as needed during season
Wild garlic	2, 4-D ester	2 pounds	Apply in diesel oil before bulblets develop. Repeat in fall.

TABLE 5—*Guide for use of chemicals in weed control*

Crop	Chemicals	Amount per acre	When to use	Remarks
Asparagus	Cyanamid, granular	200-400 lb.	Pre-emergence	Apply dry
	Cyanamid, defoliant	75-100 lb.	During cutting season	Apply when weeds are wet. Repeat as needed
	Dinitro, selective grade	½ to ¾ lb.	End of cutting season	Use 75 gallons of water per acre
	Stoddard solvent	40-80 gal.	End of cutting season	For annual grasses
Beets	PCP (5% in oil)	5-10 gal.	Pre-emergence	
	Stoddard solvent	50 gal.	Pre-emergence	
	Sodium chloride	200-400 lb.	Post-emergence	Use 100-200 gallons of water
Carrots	Stoddard solvent	40-80 gal.	Post-emergence	Spray before carrot roots are more than ¼ inch in diameter
Corn	2,4-D	2 lb.	Pre-emergence	Heavy soil only
	2,4-D	¼-½ lb.	Post-emergence	Use when weeds are small. Ester at lower rate
Grains not seeded to legumes	2,4-D	¼-½ lb.	When crop is 4-8 inches tall	Any formulation. Ester at lower rates
Grains seeded to legumes	Dinitro, selective	½-¾ lb.	When crop is 4-8 inches tall	75-100 gallons water as coarse spray at low pressure
Lawn	2,4-D	1 lb.	Spring or fall	
Onions	Sulfuric acid	2-3 percent	Post-emergence	Onions must have 1-2 true leaves
	Cyanate	8-12 lb.	Post-emergence	1st true leaf stage
		16-20 lb.	Post-emergence	When onions have 3-4 leaves. Weeds must be small
	PCP, sodium salt	4-8 lb.	Post-emergence	Same as above
Pastures	2,4-D	2 lb.	Spring or fall	Do not use on legume pasture
	2,4,5-T	2 lb.	Spring	For brush
	Ammate	75 lb.	Spring	For brush
Peas	Dinitro, selective	½-¾ lb.	When crop is 4-8 inches tall	For annual weeds
Strawberries	2,4-D	½-¾ lb.	2 weeks after planting	Annual weeds
	IPC	10-15 lb.	Fall	For chickweed

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