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Bulletin 398

WEED CONTROL BY HERBICIDES IN FIELD CROPS

AGRICULTURAL EXTENSION
SERVICE
THE OHIO STATE
UNIVERSITY

Miller Amendment Warning

To assist compliance with the Miller amendment to the Federal Food, Drug and Cosmetic Act, we have attempted to include in this bulletin only those chemicals for which the suggested uses have clearance. However, if the directions that accompany the herbicide as to rates, timing, or crops on which it may be used are different from those in this bulletin, **follow those on the label.** The final arbiter for compliance with regulations under the Miller amendment is the **most recent label.** The user must accept all responsibility for any use of a pesticide other than as directed on the label.

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The Ohio State University cooperating with the U.S. Department of Agriculture, Agricultural Extension Service, W. B. Wood, director, Columbus 10, Ohio. Distributed in furtherance of acts of May 8 and June 30, 1914.

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Weed Control Terms

Active ingredient—That portion of a chemical formulation that is herbicidally active.

Contact herbicide—A herbicide that affects only the tissue in the immediate area of contact and is not translocated to any appreciable extent within the plant.

Drift—Movement by wind of spray as tiny droplets or as vapor during or after application.

Herbicide—A chemical that will kill plants or stunt their growth.

Post-emergence—The application of a herbicide to weeds after they and the crop are up.

Pre-emergence—The application of a herbicide to the soil after the crop is planted but before it or the weeds emerge.

Pre-planting—The application of a herbicide to the tops of weeds or to the soil, or to both, before the crop is planted.

Selective herbicide—A herbicide that is effective on certain plants but not others growing in association with them, even though all are treated alike.

Soil sterilant—A herbicide that renders the soil incapable of supporting plant growth.

Translocation—The movement of a substance within a plant from one part to another that is relatively distant.

Volatility—The capacity of a liquid or solid substance to change readily to vapor (gas).

Conversion Factors

1 pound=16 ounces; 453.59 grams.

1 gallon=4 quarts; 8 pints; 128 fluid ounces; 256 level tablespoonsful; 3,785.4 cubic centimeters.

1 tablespoonful=3 teaspoonsful; 14.79 milliliters

1 acre=43,560 square feet; 160 square rods; an area 208.7 feet square; an area 16½ wide and ½ mile long.

1 mile=5,280 feet; 1,760 yards; 320 rods.

1 rod=5½ yards; 16½ feet.

WEED CONTROL BY HERBICIDES

IN FIELD CROPS

by

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Weeds rob our country of about $4 billion each year. They often reduce the yield and quality of crops, harbor insects and diseases, cause livestock poisoning, lower the quality of livestock products, reduce the value of land, and are harmful to public health. The loss to each farmer averages about $500 annually.

Many farmers can reduce their losses from weeds by the proper use of herbicides. These often can increase crop yield, make crop harvesting easier and reduce cultivation cost. However, herbicides cannot substitute for good cultural weed control practices.

The cheapest and most effective method of controlling weeds is prevention. Sowing weed-free seed is basic to any weed control program. Proper seedbed preparation, adapted crop varieties, adequate fertilization and efficient timely cultivation reduce weed populations and help crop plants "crowd out" weeds.

Nevertheless, most croplands have weeds. A study by Dr. R. G. Robinson in Minnesota revealed that several representative crop fields contained from 100 to 4000 viable weed seeds per square foot to a depth of six inches. It is unlikely that soils in Ohio contain fewer weed seeds. It is not uncommon for weeds to produce 15,000 seeds per plant in one growing season. Seeds of many of our common weed species may remain viable in the soil for at least 40 years. These factors make it difficult to have a weed-free farm.

Herbicides can often be used to great advantage, but rarely can they substitute entirely for cultivation in row crops. Few herbicides give full-season control of all weeds, and, furthermore, the condition of many soils is usually improved by cultivating at least once. Most herbicides are most useful in destroying weeds that emerge during the critical period of seedling crop growth.

Few weeds can be treated alike. The farmer should obtain the best possible information about his weed problems. **He should follow recommended control practices and be especially cautious when trying new herbicides.**

Using Herbicides in Field Crops

The use of herbicides to control weeds is becoming more and more specialized. We do not have a herbicide for every weed, but we tend to increase continuously the number of herbicides used, and to use each for specific plants or purposes. Most herbicides may cause crop injury if applied improperly or under unusual conditions. Weather, soil, rate or method of application, variety of crop, or rate or stage of growth can shift the balance. **Strictly following suggested practices will minimize the hazard involved.**

Pre-planting

Some herbicides are applied to the tops of weeds or to the soil, or to both, before the crop is planted. Perennial weeds often can be satisfactorily treated after they are up but before the crop is planted. Usually the herbicides applied pre-planting are relatively ineffective if applied pre-emergence and will damage the crop if applied post-emergence. Generally, the area treated pre-planting is plowed or tilled by other methods before the crop is planted.

Some herbicides, usually the more volatile type, work best if they are applied pre-planting to the soil and are incorporated immediately. A disk or harrow may be used in the last tillage operation before planting to incorporate the herbicide where it is applied overall. Where the herbicide is applied in a band over the row by an applicator mounted on the front of the planter, a narrow rotary hoe or similar equipment may be attached immediately behind each applicator to incorporate the herbicide.

Few pre-planting soil treatments are made in field crops in Ohio. However, some of the herbicides suggested for tobacco plant beds are applied by this method. Pre-planting as well as pre-emergence treatments eliminate weeds before or shortly after the crop comes up. However, pre-emergence treatments usually control only annual weeds.

Pre-emergence

These treatments will often give excellent results. Many annual broadleaf and annual grass weeds may be controlled by these treatments, but usually perennials are not affected. Pre-emergence treatments can be made at planting time or usually until emergence of the crops and weeds.

Advantages. 1. Weeds are killed early. Weeds may reduce the yield of crops even when permitted to grow in asssociation with them for only two weeks after germination. Early elimination of weeds by pre-emergence treatment is especially advantageous where wet weather delays cultivation or where dry weather causes severe competition between the crops and weeds for soil moisture.

2. Both annual broadleaf and annual grass weeds may be controlled.

3. Planting and herbicide application can be done in one operation with applicators mounted on the planter.

4. In corn, the application of the pre-emergence herbicides simazine and atrazine presents no hazard to nearby 2,4-D sensitive tomato, grape or other crops.

5. Only one cultivation, which can be made after the corn is tall enough for fast cultivation, may be adequate. Where the herbicide applied overall controls the weeds, no cultivation is needed unless it improves the physical condition of the soil, as in most of the heavier soils. Minimum cultivation means less compaction.

Controlling the weeds in the row regardless of the treatment used will reduce the need for close cultivation which may damage the crop by root pruning. Cultivation of a weed-free corn crop to improve the condition of the soil should be delayed if possible until the corn is about 8 to 12 inches tall. However, cultivation of a crusted soil should be done shortly after this situation develops. Cultivation may bring weed seeds to the soil surface that would otherwise lie dormant at lower levels.

Corn that is well established will compete more readily than younger corn plants with the weed seedlings that come up. It is better not to move soil by cultivation onto the treated weed-free area in the row, since weeds may grow in soil on top of the treated soil.

Rotary hoeing of corn to break a slight soil crust one week after pre-emergence herbicides were applied at Columbus in 1959 resulted in slightly better weed control and a slightly higher yield of the corn compared with corn that was treated but not rotary hoed. Whether these results are typical of other similar situations is yet to be determined.

Rotary hoeing and weeding control weed seedlings best if done when the majority of the weeds are in the "white" and are not more than ¼ inch high.

6. There are some crops in which only pre-emergence herbicides work satisfactorily.

Limitations of pre-emergence treatments. 1. If applied on dry soil, and no rain follows until after the weeds are established, pre-emergence applications will be rather ineffective. However, fewer weeds germinate in dry weather, and the crop can be cultivated in the usual way and treated post-emergence by a herbicide where needed. Weeds, in general, are more susceptible to herbcides during and shortly after germination than at later stages. Weed seeds must have adequate moisture to germinate before the herbicides can be absorbed. Most weed seeds germinate near the soil surface. Most crops are planted and germinate at lower depths. The difference in depth at which the crops and weeds germinate usually makes it possible to kill the weeds with pre-emergence herbicides without injuring the crop, although the crop must have some tolerance to the herbicide.

2. If considerable rain (an inch or more) follows within a few days after application, most herbicides may be leached down to the germinating crop seed and cause injury. Most pre-emergence treatments are unsafe on sands or similar readily permeable soils. However, neither simazine nor atrazine has damaged corn, even when applied at high rates.

3. Rough cloddy seedbeds may result in more or less ineffective control. This situation is more likely to occur where the seedbed is prepared by minimum or once-over tillage. However, usually fewer weeds emerge in a rough seedbed. The preparation of the seedbed should be governed by the requirements of the crop for maximum net return. Where the seedbed is rough, it may be better to use liquid or wettable powder formulations rather than granular and to increase the rate of application slightly.

4. Where herbicides can be applied either pre- or post-emergence, rates of the former are usually higher. Most of the new herbicides are expensive. The economy of controlling weeds with them requires more consideration than with the relatively inexpensive 2,4-D. Often, it is feasible to treat only an 8- to 14-inch band over the crop rows with herbicides, leaving the middles to be cultivated.

5. Time and labor usually are at a premium at planting time, so pre-emergence applications often cannot be made on all of the crop acreage. The remaining acreage can be treated post-emergence where needed.

6. Perennial weeds, other than when seedlings, usually are not controlled by pre-emergence treatments in crops.

Post-emergence

Herbicides are most commonly applied on crops after they and the weeds are up. The effectiveness of post-emergence applications does not depend on soil conditions except as they affect plant growth and the plants' response to the herbicide.

Air temperature and moisture greatly influence the response of plants to herbicides. **Crop injury is possible with most herbicides even at recommended rates, particularly during and immediately following periods of high temperature and adequate mosture that favor rapid growth.**

Factors in its widespread use. 1. Most persons want to be certain they have a weed problem before using herbicides. Where weed infestation is sparse, or only in patches, post-emergence treatment often can be helpful; where a dense infestation occurs year after year, pre-emergence applications may be superior.

2. Post-emergence treatments may control some perennial weeds that are up at the time of application.

3. Post-emergence treatments usually cost less than pre-emergence with the same herbicide.

4. There are crops, such as small grains, on which pre-emergence treatments do not work satisfactorily.

5. Treatment may be done when the demand for labor is not so great, but treating weeds while they are still young is extremely important in obtaining satisfactory results.

6. Post-emergence applications may be needed, (a) where a pre- or previous post-emergence application did not give sufficient weed control or failed completely, or (b) where cultural methods cannot be used to control weeds that emerge after the last cultivation, as in corn grown on river bottom land.

Comparing Liquid and Granular Herbicides

Wider possibilities for satisfactorily controlling weeds by using herbicides in granular formulations have been demonstrated. The author and his assistants compared eleven different pre-emergence herbicides in the liquid (or wettable powder) and corresponding granular form on corn, soybeans and sugar beets. Little or no difference in results was detected following these treatments. Weeds were controlled as well by one formulation as the other, and the effect on the crop was not changed.

The use of herbicides in granular form is restricted primarily to pre-emergence and to a lesser extent pre-planting applications to the soil prior to weed emergence. Herbicides such as amino triazole and dalapon that must be absorbed by the foliage to kill the plant are much more effective when applied in liquid form than granular.

Granular formulations of most of the herbicides that are applied pre-emergence on crops in Ohio are available. Most of the herbicides cost more in granular form. For example, 2,4-D granules cost about 50 cents per acre more than the liquid concentrate. The difference in cost of the granules of the newer pre-emergence herbicides is somewhat greater.

The most feasible time to apply granular herbicides on field crops is at planting. Planting and herbicide application can be done in one operation. Uniform application is critical with the granules; however, applicators that meet this requirement are on the market. Planter-mounted applicators cost about $75 to $100, depending on whether a separate compartment for granular insecticides is included, for each two-row unit.

Granular herbicides need not be mixed with water. The hauling of water and preparing spray solutions for sprayers are time-consuming jobs. Premixed granules considerably reduce the chance of error in application.

Both liquid and granular forms of pre-emergence herbicides will be rather ineffective if applied on dry soil and no rain follows until after the weeds are established.

If considerable rain (an inch or more) follows in a few days after application, most herbicides, regardless of whether they are applied in granular or liquid form, may be leached down to the germinating crop seed and cause damage. However, neither simazine nor atrazine has damaged corn even when applied at rates considerably higher than recommended.

The use of granular formulations of certain herbicides, such as 2,4-D, reduces the hazard of drift onto susceptible crops. **However, fine granules that are present in the commercial material when purchased or formed by abrasive agitation in the hopper of the applicator also may be carried by wind and damage nearby susceptible plants.**

The size of the granules of different herbicides may not be the same. Granular applicators must be set to apply the correct amount of granules of each herbicide according to the chart that accompanies the applicator and/or the herbicide. However, as with spraying equipment and grain drills, the granular applicators should be calibrated for each operation.

Granular herbicides can be seen readily on the soil surface after application, thereby reducing the possibility of row skipping.

Herbicides that are rather volatile in liquid form may be slightly less volatile in granular form. However, the difference in volatility has not been reflected in differences in field results.

Toxic build-up in soil of herbicides suggested for fields crops is greatly reduced by their usual ready decomposition in soil regardless of whether they are applied in liquid (or wettable powder) or granular form.

Band Application for Economy

In wide-row crops, applying herbicides in bands over only the rows and cultivating in between may be justified where herbicide costs are high. Overall treatment controls weeds between the rows, as well as in the rows, and may be especially valuable when cultivation is delayed by wet weather. In band application, the herbicide is delivered at the same rate per unit of treated area as when applied overall, but some of the area between the rows is not treated. Spray solutions are made up exactly the same as recommended for overall treatment.

The only difference between band and overall applications is that less area per acre will be treated; consequently, less total spray solution and granules will be applied, the amount depending on the proportion of the overall area that will not be covered. For example, if the suggested rate for overall treatment is 1½ pound per acre, then ½ pound in 14-inch bands on 42-inch rows would cover one "gross" acre.

Band width. In band application the herbicides should be applied in 8- to 14-inch bands depending on the herbicide used and crop treated. An 8-inch band may be satisfactory for narrow-row crops such as sugar beets where disks, set close to the row, throw the soil away from the row in cultivation before thinning. However, for corn and wide-row soybeans, bands at least 14 inches wide may be better, especially where cultivation is delayed for 3 to 4 weeks after herbicide application, or if it is necessary to cultivate soil that is slightly wet. Often many of the weeds that are moved into or nearer the row by the cultivator continue to grow in wet soil.

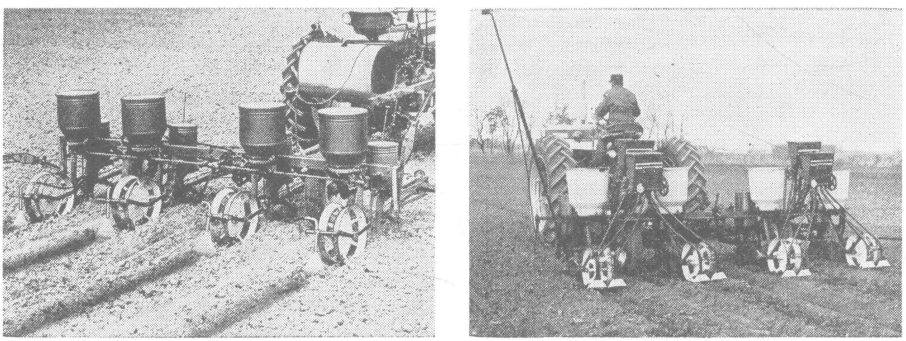

Fig. 1. Left, a planter-mounted liquid herbicide band sprayer. Right, a planter equipped with granular herbicide and insecticide applicators.

Generally, accurate application in bands is possible only with applicators that are rigidly attached to the planter (Fig. 1). Raising the nozzles on liquid sprayers widens the band and reduces the concentration of herbicide per unit area. Conversely, lowering the nozzles narrows the bands and increases the rate of application. Usually, with granular applicators the concentration of the herbicide per unit area is not influenced by the height of the spreader above ground except as it is affected by wind.

Corn

Approximately 80,000,000 acres of corn will be grown in the United States in 1960; about 4,000,000 acres will be grown in Ohio. Most corn is cultivated at least two times. Each cultivation costs about $1.50 per acre. Often weeds continue to grow in the row even after the best cultivation. It is estimated that where only cultural practices are used, weeds reduce the yield of corn an average of 2 bushels per acre annually.

Corn and other crops suffer most from weed competition in seasons that are too wet to permit timely cultivation or too dry to provide adequate moisture at all times. A yield reduction of at least 10 bushels per acre is not uncommon where the corn is cultivated the usual number of times and annual weeds persist in the row (Table 1). Perennial weeds often reduce the yield of corn by considerably more than 10 bushels.

Fig. 2. Corn infested by pigweed which often reduces crop yields in Ohio. Also see Table 1.

Corn is the most important crop treated by herbicides in Ohio. The United States Department of Agriculture recently estimated that about 20 percent of the corn acreage in the United States is treated by herbicides annually; the average for Ohio is probably about 25 percent. Herbicides may increase the yield of corn, and reduce the number of cultivations by one or more. 2,4-D is still the most widely used herbicide in corn, but several others that may give better results are recommended. The type of weed problem largely determines the treatment to use.

Table 1.* **Reduction in yield of cultivated corn and soybeans caused by either pigweed or giant foxtail growing in the row. Average for 1957, 1958 and 1959.**

Pigweed stand	Corn yield bu./A	Soybean yield bu./A
Check—no weeds	102.0	38.7
Band of weeds in row	71.8	20.0
1 weed every inch	75.8	21.3
1 weed every 5 inches	78.2	25.6
1 weed every 10 inches	86.5	30.7
1 weed every 20 inches	87.1	32.6
1 weed every 40 inches	94.4	34.5
Maximum yield reduction	30.2	18.7
Giant foxtail stand		
Check—no weeds	93.5	38.5
54 weeds per foot of row	70.6	27.6
1 weed every inch	78.4	31.9
1 weed every 2 inches	82.1	34.6
1 weed every 4 inches	85.0	36.2
1 weed every 12 inches	86.4	36.8
1 weed every 24 inches	90.4	37.1
Maximum yield reduction	22.9	10.9

* Data obtained at Urbana, Illinois by Dr. E. L. Knake, Department of Agronomy, University of Illinois.

2, 4-D

In many ways, 2,4-D (2,4-dichlorophenoxyacetic acid) approaches the ideal weed killer. It is effective at low rates on many weeds, highly selective, nontoxic to animals, nonflammable, noncorrosive to equipment, relatively inexpensive and easy to apply. In Ohio climate, 2,4-D will not accumulate in the soil or affect it unfavorably. It is decomposed in the soil in 15 to 60 days; however, under dry conditions it may remain toxic all season or longer. Soil microorganisms, insects, farm animals, and humans are unaffected by 2,4-D except at rates far in excess of those normally recommended for herbicidal purposes.

Precautions in using 2,4-D

2,4-D is an extremely potent compound. One tablespoonful can damage an acre of tomatoes or cotton. The following precautions should be observed in using 2,4-D.

1. Apply 2,4-D at recommended rates.

2. Do not apply 2,4-D near susceptible crops on windy days.

3. When applying liquid 2,4-D use low pressures (not over 30 to 40 pounds) to obtain a coarse spray, and nozzles designed to produce droplets, not mists.

4. Keep sprayer nozzles and granular spreaders the minimum required distances from the ground, and do not apply on large areas within several hundred feet of sensitive crops, such as tomatoes, grapes, tobacco, cotton, most vegetables, flowers and ornamentals.

5. Use the amine salts unless the esters are recommended. Most granular formulations of 2,4-D are composed of low volatile esters.

6. Do not use 2,4-D contaminated equipment to apply fungicides, insecticides or other materials on 2,4-D susceptible plants.

Forms of 2,4-D

Pure 2,4-D is an organic acid that is only slightly soluable in water or oil and, therefore, cannot be used satisfactorily in a water spray. It must be combined with other materials to form soluble compounds. These compounds contain different proportions of the pure 2,4-D acid. Since it is the 2,4-D that kills the plants, rates of this herbicide are often given in terms of the 2,4-D acid, that is, as the acid equivalent. All formulations of 2,4-D state on the label the number of pounds of 2,4-D acid equivalent per unit weight or volume of the compounded material.

There are four common forms of 2,4-D on the market: (1) Dry powders, which are used in special situations only. (2) Amine salts, which dissolve in all proportions in water to make clear solutions but do not dissolve in oil. (3) Esters, which have an oil base and contain an emulsifying agent, so that when mixed with water an emulsion is formed which appears milky. Esters are also soluble in oil (diesel oil and kerosene are commonly used). (4) Granules, which contain 2,4-D impregnated usually on attaclay carrier and are applied dry. The granules are applied pre-emergence on corn.

The ester formulations of 2,4-D are generally the most toxic to plants. The esters are more effective than the other forms of 2,4-D under dry conditions, on hard-to-kill plants and under adverse conditions generally. Rain, even when it occurs immediately after treatment, does not materially alter the effectiveness of the esters. The amines are washed off plants readily.

Under favorable conditions the amount of time needed for absorption of the amines in toxic amount varies from about 1 to 6 hours, depending on the susceptibility of the species. Less 2,4-D, regardless of formulation, is absorbed in cool weather (about 50° or lower). Plants that are treated in cool weather may not respond until the temperature rises, or not at all.

The esters are more effective on weeds but are also more hazardous to crops. Ordinarily, lower rates of the esters than the other forms are suggested for crop plants. Usually, whenever a range of rates is given, except for pre-emergence treatments, the esters are to be applied at the lower rates in the range and the amines at the higher rates.

The esters are somewhat more volatile than the other compounds of 2,4-D, and damage to adjacent susceptible plants by vapors from treated areas is possible. However, much of what has been attributed to vapor damage has actually been drift of spray droplets. Sprays containing esters will form smaller droplets than sprays of other formulations, and hence will drift farther and more readily. But drift is a hazard with any formulation of 2,4-D.

The esters first used were short chain alkyl esters (methyl, ethyl, isopropyl, butyl, and amyl). Then much more complex long chain "low volatile" esters were introduced. These are less volatile than the short chain esters, but they are the most active compounds of 2,4-D. These low volatile esters are particularly valuable against plants that are otherwise hard to kill. Most granular formulations of 2,4-D contain the low volatile esters.

Pre-emergence

Pre-emergence treatments on corn are gaining in use, but post-emergence applications are still by far the most popular. Many annual broadleaf weeds are controlled by 2,4-D applied pre-emergence (Fig. 3). This is the only way that 2,4-D may control annual grasses. Usually the stand of annual grasses is reduced 60 to 80 percent. Pre-emergence applications of 2,4-D usually are not effective against smartweed and perennials.

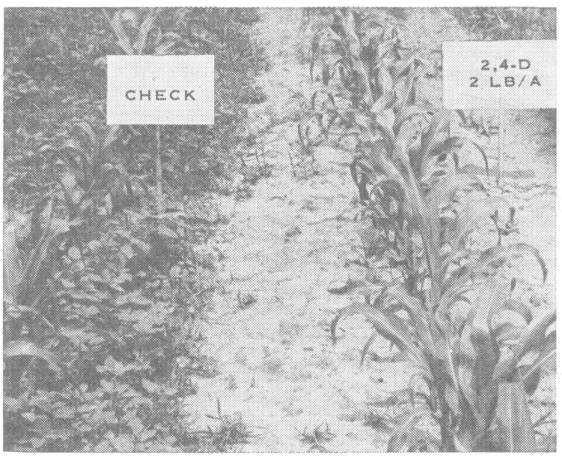

Fig. 3. Effect of 2,4-D applied pre-emergence. No cultivation.

2,4-D liquid and granular formulations are applied pre-emergence at the rate of 1 to 2 pounds (2,4-D acid equivalent) per acre overall or in bands. In band application, the herbicide is delivered at the same rate per unit of treated area, but less total herbicide is applied. Liquid 2,4-D should be applied in about 10 or more gallons of solution per acre overall, proportionately less in bands.

Pre-emergence rates of 2,4-D may be applied at planting time or until shortly after corn emergence, but not after any leaves unfold, except where application is made with drop nozzles after the final cultivation.

Generally the low volatile ester formulations of 2,4-D are suggested for use pre-emergence on corn. Although the esters cost slightly more, they are less likely to injure the corn than the amines because they are not leached as readily. No 2,4-D formulation is safe on sandy soil. If used pre-emergence on sandy soil, 2,4-D low volatile esters should be applied at the lowest rate suggested. On dark soils, usually the 2-pound rate is needed to give good results. 2,4-D must not be used pre-emergence on inbred lines of corn proved to be susceptible to this herbicide, or on soybeans.

Post-emergence

Post-emergence 2,4-D treatment of corn is used widely. 2,4-D controls many annual broadleaf weeds as well as some perennials, if they are up at the time of treatment. It does not control grasses post-emergence.

When to apply 2,4-D post-emergence. There is no specific stage of growth at which corn is particularly resistant or likely to be injured by 2,4-D. Corn at any stage, if growing rapidly, is more readily injured than when it is growing slowly. Plants adequately supplied with water are extremely susceptible during and immediately following a period of high temperature (85°F. and above). Young corn plants that are damaged by 2,4-D recover more readily than older plants; however, little or no damage follows proper treatment.

Fig. 4. Drop nozzles being used to apply 2,4-D to control broadleaf weeds in corn that is too high for overall treatment.

Usually, corn is not damaged by 2,4-D esters applied overall at the suggested rate of ¼ pound (2,4-D acid equivalent) per acre or by the amines at ½ pound provided the corn is less than 10 to 12 inches high. The best time to apply 2,4-D is when the corn and weeds are small. This usually coincides with the 2- to 4-leaf stage of corn. Corn, especially if it is growing rapidly, may be damaged if it is higher than 12 inches when treated overall by 2,4-D at the rate needed to control the broadleaf weeds. Where corn higher than 12 inches is treated by 2,4-D, drop nozzles should be used to spray the top of the weeds and off the corn as far as possible to minimize damage (Fig. 4).

Types of 2,4-D damage. 1. "Leaf roll" is one of the first symptoms of 2,4-D injury to corn. Leaf roll usually develops within 3 days on injured

plants. Leaf roll is not serious, but it may be followed by "onion leaf." In this condition the upper leaves usually remain tightly rolled with the edges grown together. Where this prevents normal emergence of the tassel, the yield may be reduced, and where corn is grown for hybrid seed, detasseling may be difficult.

2. 2,4-D makes rapidly growing corn brittle for 10 days or more, but, if breaking does not occur, the yield is not greatly reduced. Corn of any height may be broken when blown by storms or struck by cultivating. Brittleness is more serious the taller the corn, because the stalks may break of their own weight. Bending of the stalks at the soil level usually accompanies brittleness.

3. Abnormal brace roots greatly increased in size and number or growing in an upward direction are common, but in most instances these have not resulted in lower yields.

4. Shorter, slower growth is a common result of too much 2,4-D.

Hybrid seed production. There are definite differences between hybrids in 2,4-D tolerance, but all double crosses recommended for Ohio will endure the recommended rates and treatments. Some single crosses and especially some inbred lines are much more susceptible to 2,4-D than double crosses.

Lay-by treatment. On rich soil, in river bottoms especially, germination and rapid growth of weeds after the last cultivation of corn often presents a problem. Where the infestation consists of annual broadleaf and annual grass weeds, 2,4-D low volatile esters at 1 pound per acre or the amines at 1½ pound applied overall to the soil and stalk bases only immediately after the final cultivation may prove beneficial. Any delay beyond the last cultivation will require the use of a high clearance tratcor sprayer. This lay-by treatment will suppress weed emergence for 3 to 4 weeks and thus largely eliminate the rank growth of weeds at harvest. This application of 2,4-D in corn that is growing rapidly during or following a period of hot weather (85° to 90° F. and above) may cause bending and twisting at the base of the stalks.

2,4-D plus CDAA

In corn infested by annual grasses and annual broadleaf weeds, a mixture of 2,4-D ester plus CDAA (2-chloro-N, N-diallylacetamide; trade name Randox) applied pre-emergence may prove more satisfactory than 2,4-D applied alone. Under favorable conditions, this mixture may give almost season-long control of most annual weeds (Fig. 5). Although 2,4-D alone will control annual broadleaf weeds almost as satisfactorily as the mixture, the mixture is considerably more effective on annual grasses.

The 2,4-D-CDAA mixture should be applied at the rate of 1 plus 2 to 3 pounds (active ingredient) per acre overall, or in bands as described in this bulletin under "Band Application for Economy." The liquid formulations should be applied in 20 to 40 gallons of water solution per acre overall, proportionately less in bands. The granules are applied dry. The mixture can be applied at planting time or until emergence of the corn and weeds. It must not be used on 2,4-D susceptible inbred lines of corn, or on soybeans.

Fig. 5. Effect of CDAA plus 2,4-D applied pre-emergence; check plot is shown in background. No cultivation.

CDAA is sold as water soluble and granular compounds. It controls primarily annual grasses. It is also effective on a few annual broadleaf weeds, especially pigweed. It controls these weeds best when slight to moderate rains follow application. Heavier rainfall (about ¾ inch or more) shortly after application considerably reduces CDAA effectiveness. CDAA fails to control even foxtail in cool moist weather. The action of CDAA and 2,4-D on plants is affected little or none by mixing.

Water soluble and granular formulations of CDAA volatilize readily, and the vapor causes the eyes to smart. The mixtures of 2,4-D plus CDAA should be prepared where there is adequate ventilation, preferably out-of-doors. If the CDAA concentrate or granules are spilled in a closed room, they should be cleaned up at once. CDAA concentrates and mixtures with 2,4-D should not be allowed to come in contact with the skin, as it may sting painfully. **If accidentally spilled on the skin, wash it off immediately with soap and warm water.**

Simazine and Atrazine

Annual broadleaf and annual grass weeds in corn may be eliminated or considerably reduced by either of the two relatively new pre-emergence herbicides, simazine (2-chloro-4,6-bis-ethylamino)-*s*-triazine) (Fig. 6) and atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine). Each herbicide usually controls the annual weeds the entire growing season. Velvetleaf is the only annual weed usually not controlled satisfactorily by either herbicide. Generally perennial weeds, except some species germinating from seed, are not controlled by these herbicides applied pre-emergence (Fig. 6).

Simazine and atrazine may be conveniently applied overall or in bands over the corn rows at the time of planting. Each herbicide is generally applied at the rate of 2 pounds active ingredient per acre overall, proportionately less in bands (see "Band Application for Economy"). The rate should be increased to at least 3 pounds on soils high in organic matter, such as bottom land, and 4 pounds on muck soil. Unless the cost of these herbicides is reduced, it may be better to band treat and cultivate the middles. As mentioned previously, the condition of many soils often is improved by cultivating at least least once.

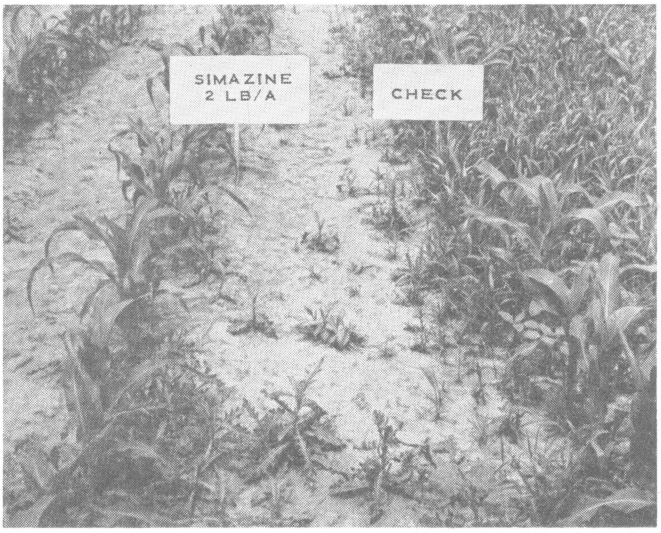

Fig. 6. Effect of simazine applied pre-emergence. No cultivation. Canada thistle not controlled.

Simazine and atrazine are available in wettable powder formulations. In addition, atrazine is available in granular form for farm use. Annual weeds are controlled as well by the granular formulation, and the effect on the corn is not changed. The wettable powders are available as 80 percent formulations. This should eliminate or considerably reduce the problem of plugged nozzles experienced previously by some operators who applied the 50 percent material. The sprayer should be equipped with a pump that will deliver at least 10 gallons per minute, and have 50-mesh or larger screens in the lines and nozzles to apply the 80 percent materials.

The wettable powder formulations should be applied in at least 20 gallons of solution per acre. Since they form suspensions in water and may slowly settle to the bottom, constant agitation is needed. Usually, sufficient agitation is provided by the by-pass placed at the bottom of he sprayer tank. If the spraying operation is interrupted, the settled materials should be agitated back into suspension before spraying is resumed.

Unlike many other pre-emergence herbicides, simazine and atrazine present little or no danger to the germinating crop seed if considerable rain follows soon after application. Heavy rains change their effectiveness as weed

killers only slightly. However, like other pre-emergence treatments, simazine and atrazine will be less effective when applied on dry soil and no rain follows until after the weeds are established.

Ordinarily, the amount of rainfall following corn planted at the usual times in Ohio is sufficient to activate simazine and atrazine. However, atrazine seems to require less moisture than simazine to work well and for this reason may be more satisfactory on late-planted corn when a period of dry weather is rather certain to follow. Since dry weather sometimes follows corn planted at the usual time, a 50-50 mixture of simazine and atrazine may work better than either herbicide applied alone. This has not been investigated yet, but it will be included in field trials in 1960.

Corn seems to be the only field crop in Ohio on which simazine and atrazine can be safely applied pre-emergence to kill weeds. Some research workers have stated that the shorter residual of atrazine in soil may decrease the hazard to winter wheat planted in the autumn following treated corn. We have not investigated his, but we have not damaged winter wheat following corn treated by simazine as recommended. Only by considerably increasing the rate of simazine on corn will the winter wheat following be damaged.

Simazine applied at the suggested rate considerably reduced the stand of sweetclover interseeded in the corn at lay-by at Columbus in 1959. 2,4-D plus CDAA applied pre-emergence at the recomemnded rates did not damage the sweetclover. Further observations of the interseeding will be made in 1960. Atrazine was not included in this experiment.

DNBP

Annual grass weeds such as the foxtails, crabgrass and barnyardgrass (Fig. 7) have become a more serious problem in recent years. Of the herbicides suggested for use pre-emergence on corn, 2,4-D plus CDAA, simazine and atrazine usually give good control of these pests, and 2,4-D alone, fair control. 2,4-D applied post-emergence does not control grasses.

DNBP (4,6-dinitro-2-secondary butylphenol) applied on corn after emergence or until the 2-to-3-leaf stage has given excellent control of most annual grass and annual broadleaft weeds each year for the past 9 years in field trials at the Ohio Agricultural Experiment Station. The alkanolamine salts of DNBP used on field crops are sold under the trade names Premerge and Sinox PE.

DNBP is a contact herbicide. When it is applied post-emergence on corn at the suggested rate of 3 pounds active ingredient (phenol) per acre overall,

Fig. 7. Common annual grasses in corn. Left to right: green foxtail, crabgrass and barnyardgrass.

or in bands, the weeds must be up and the tops covered completely for best results. It is usually applied in 30 to 100 gallons of water per acre overall, less in bands, when sprayed on the foliage of plants. Granular formulations of DNBP are much less effective than the liquid formulations applied post-emergence on weeds.

Like many other herbicides, DNBP can act either as a selective herbicide or as a nonselective herbicide, depending on various factors, two of which are temperature and rate of application. Selectivity diminishes as the air temperature rises above 85°F., and also as the rate of herbicide is increased above a maximum, which varies with different crops.

DNBP applied as suggested on corn does not reduce the yield, although, when applied after the leaves are open, it may burn the leaf tips slightly. Buring may be more severe if spraying is done in hot weather (85°F. or higher), or when corn is beyond the 3-leaf stage, but corn recovers even after relatively severe burning. On hot, humid days, DNBP should be applied at about 2¼ pounds per acre or not used at all.

Small Grains

The standard rate of 2,4-D used for weed control in small grains is ¼ to ½ pound per acre, esters at the lower rate. Some resistant weeds require higher rates, which increase the chance of crop injury.

When to apply 2,4-D

The best time to treat small grains is at the fully tillered stage. This occurs in the spring of the year when the crop is about 5 to 8 inches tall. It is the state of greatest basal leaf growth, just before rapid elongation of the stem begins.

All the leaves of the plant are developed by the end of the fully tillered stage. They retain their relative positions but are spaced farther apart as the stem lengthens. The phase of rapid stem growth is called the jointing stage, because of the joints (nodes) which develop on the stem. The head begins to develop when the stem tip is at or slightly above the ground level. It continue to grow, but remains enclosed in the top leaf ("flag" leaf) as the stem elongates.

During the last several days of stem elongation, the head increases greatly in size while still wrapped in the sheath of the flag leaf; this phase is called the "boot" stage (Fig. 8). Both the jointing stage and the boot stage end when the head emerges above the sheath of the flag leaf. This is followed by the fully headed stage.

In all small grains, spraying at the seedling, boot and milk stages results in serious crop injury (Fig. 9). Treatment at the fully tillered stage in the spring is the least hazardous. Small grains are also rather resistant at the soft dough stage. Oats are usually more susceptible to 2,4-D than wheat and barley.

Generally, wheat should **not** be sprayed in the fall, since injury can occur even with low rates of 2-4-D. The damage appears at heading time the next year. If winter annual weeds, such as yellow rocket, are serious, treat at ½

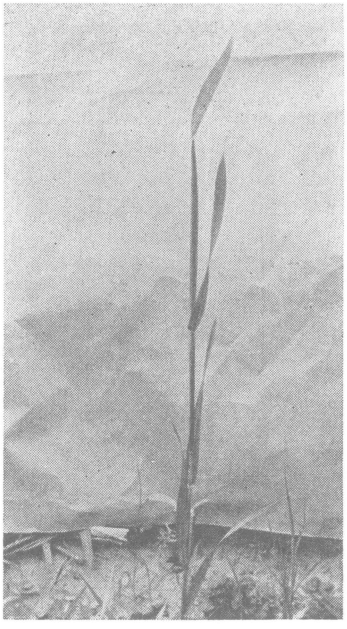

Fig. 8. Oats at the boot stage.

pound per acre about one month after planting, when wheat is at the 3- to 4-leaf stage. Good control also may be obtained by treating in March when winter annuals are at the rosette stage.

Small Grains Underseeded to Legumes

Do not use 2,4-D or seedling legumes underseeded in small grain crops, unless the weeds are serious enough to justify some loss in legume stand. Injury can be minimized by (1) spraying after the weeds and small grains form a protective canopy, at the fully tillered or early jointing stage, (2) using low pressure (about 30 pounds) and low volumes (5 to 10 gallons of water per acre), and (3) using the amine formulation at the rate of ¼ to ⅓ pound per acre. Red clover, ladino, alsike and lespedeza will be injured less than alfalfa, birdsfoot trefoil and sweetclover. MCPA is safter than 2,4-D on red clover, but little difference has been noted on alfalfa. DNBP (trade names Premerge and Sinox PE) may give satisfactory results, especially on dense weed growth. DNBP should be applied when the crop is 3 to 6 inches high, the legumes have 4 to 6 leaves and the weed are small. It burns the leaves of legume seedlings, but recovery is usually rapid.

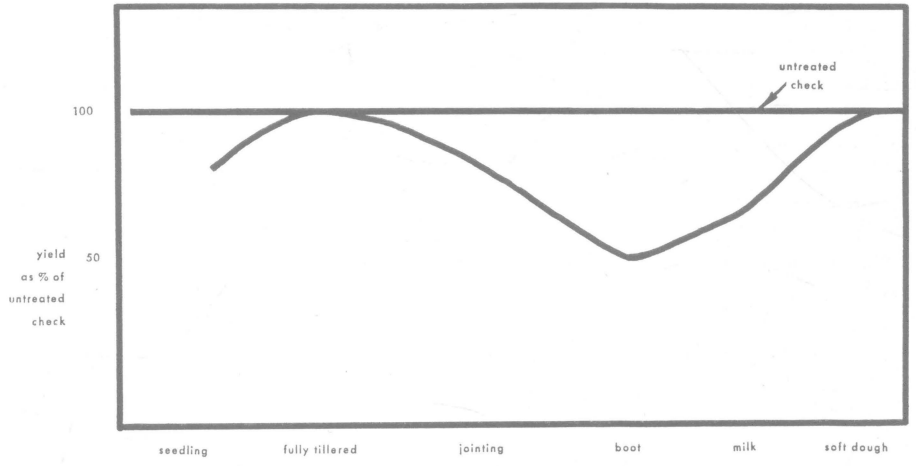

Fig. 9. Effect of 2,4-D at recommended rate on yield of weed-free small grains treated at different stages of growth.

Effect of 2,4-D on Quality and Germination

The use of 2,4-D does not affect the milling quality of wheat or the baking quality of wheat flour unless applied at rates considerably higher than the standard rates. It does not affect the germination of harvested wheat grain unless applied at high rates at susceptible stages of growth. Reduced germination occurs more frequently in oats, but is rather unlikely to occur if the herbicide is applied at the suggested rate at the proper stage of growth.

Soybeans

About 25,000,000 acres of soybeans will be grown in this country in 1960; Ohio farmers will plant about 1,600,000 acres.

Soybeans are able to compete strongly with weeds, and where conditions are favorable they may suppress weed growth considerably. There are several cultural practices that favor soybean growth to the detriment of weeds. Delayed planting, combined with tillage (disking, harrowing, etc.) each time weeds emerge before planting, may destroy two and sometimes more crops of weeds. Growing soybeans in cultivated rows rather than solid makes weed control easier. The use of a rotary hoe, weeder or other similar implements can reduce the weed problem if done early, just as the weeds emerge.

Pre-emergence

Where annual weeds cannot be controlled satisfactorily by cultural methods (refer to Table 1 presented previously), herbicides may be useful. Several pre-emergence treatments have given satisfactory control of annual weeds in this crop. Amiben, Alanap-3, CIPC, a mixture of CIPC plus Alanap-3, and DNBP are suggested for use pre-emergence. As with other pre-emergence treatments, these are subject to all the hazards and limitations of soil applications (discussed previously under "Using Herbicides in Field Crops," "Pre-emergence"). They work best on a smooth seedbed in moist soil, but most of them can injure crops if heavy rainfall occurs shortly after application.

These treatments are more hazardous on sandy soil. However, they may be extremely valuable when applied correctly under favorable soil and atmospheric conditions. Pre-emergence herbicides are rather expensive, so it is often advisable to treat in 12- to 14-inch bands on wide row beans. Soybeans planted solid may be feasibly treated overall where annual weeds are a serious problem.

Amiben (3-amino-2,5-dichlorobenzoic acid) is a relatively new pre-emergence herbicide that appears extremely promising for the control of most annual broadleaf and annual grass weeds in soybeans. **However, until officially cleared by FDA, it is to be used only on soybeans that are grown for seed not to be consumed by livestock or man.** Amiben may be applied at the time of planting, usually at the rate of 3 pounds active ingredient per acre overall, or in bands (see "Band Application for Economy").

Jimsonweed is about the only annual weed that is resistant to Amiben. However, Amiben gave only fair control of smartweed at the Northwest Substation at Hoytville in 1959. Since smartweed is one of the most serious weeds in soybeans in Ohio and CIPC is effective against this weed, combinations of Amiben and CIPC will be included in future trials. Perennial weeds are not controlled by Amiben.

Amiben has not damaged soybeans even when applied at rates considerably higher than recommended. In 1958 Amiben at 4 pounds per acre did not damage beans even when 1¼ inch of rain followed 3 hours after application on a Miami silt loam at Columbus.

Alanap-3 (sodium salt of N-1-napthylphthalamic acid) at 4 pounds active ingredient per acre (overall rate) is effective on many annual broadleaf weeds such as pigweed, lambsquarters, ragweed and purlane, but not smartweed. It also controls most annual grassses. Alanap-3 is applied to the soil surface after planting but before the crop and weeds emerge. Heavy rainfall shortly after treatment can move the herbicide downward to the soybean roots and injure the crop. Lower rates are recommended for sandy soils than for heavier soils.

CIPC [isopropyl-N-(3-chlorophenyl) carbamate] at 6 to 8 pounds active ingredient per acre (overall rate) has given good control of most annual grasses and certain annual broadleaf weeds, including smartweed and purslane. Usually CIPC does not satisfactorily control ragweed and pigweed. CIPC can be applied from the time of planting up to crop emergence, but before the weeds are up. It is widely used on cotton in the southern states.

A mixture of CIPC plus Alanap-3, each at 2 pounds active ingredients per acre (overall rate) has been one of the most consistently satisfactory pre-emergence treatments for controlling both annual broadleaf and annual grass weeds in soybeans in field trials in Ohio. This mixture often has given better weed control than either of its components applied alone at the suggested pre-emergence rates, and it does not cost as much. In fact, it costs less than any of the other pre-emergence treatments on soybeans.

This mixture is especially useful where both smartweed and ragweed are among the annual weeds to be controlled, since CIPC controls smartweed but is rather ineffective on ragweed and pigweed, with the reverse true of Alanap-3. The mixture should be applied between the time of planting and crop emergence, but before the weeds are up. Little or no damage to soybeans has followed this treatment.

DNBP (sold as Premerge and Sinox PE) at 4 to 6 pounds active ingredient per acre (overall rate) gives good control of annual broadleaf and annual grass weeds in soybeans. Best results are obtained if it is applied 1 to 2 days before crop emergence. Some reduction in stand of the soybeans may result, but usually it will not affect the yield. **DNBP at the pre-emergence rate will kill or severely damage soybeans if it is applied after they are up.**

Post-emergence

DNBP is the only herbicide that may give satisfactory control of annual broadleaf and annual grass weeds in soybeans treated post-emergence. DNBP must be applied at 2¼ to 3 pounds active ingredient (3 to 4 quarts Premerge or Sinox PE) per acre (overall rate) when the soybeans are at the cotyledon stage (only the enlarged soybean seed and stem showing above ground) or through the bileaf stage (two leaves showing, but not fully expanded, above the two small cotyledons).

Treatment with DNBP at more than 3 pounds or later than the bileaf stage may kill the beans or cause severe injury. Rather severe leaf burn of soybeans follows even what appears to be the best treatment, the one suggested above. But recovery after this treatment is rapid, and neither maturity nor yield is affected by the burning. Injury may be more severe if the temperature exceeds 85°F. for 2 or 3 days before and/or after treatment.

Sugar Beets

Hand weeding at the time of thinning sugar beets is laborious and expensive. Many herbicides have been tested on sugar beets, but only endothal, TCA and dalapon are suggested for use.

Endothal (disodium salt of 3,6-endoxohexahydrophthallic acid) was applied pre-emergence to approximately one-third of the 22,000 acres of sugar beets in Ohio in 1959. In general, endothal gave good control of smartweed, pigweed and foxtail, fair control of lambsquarters and ragweed (see Fig. 10). Endothal

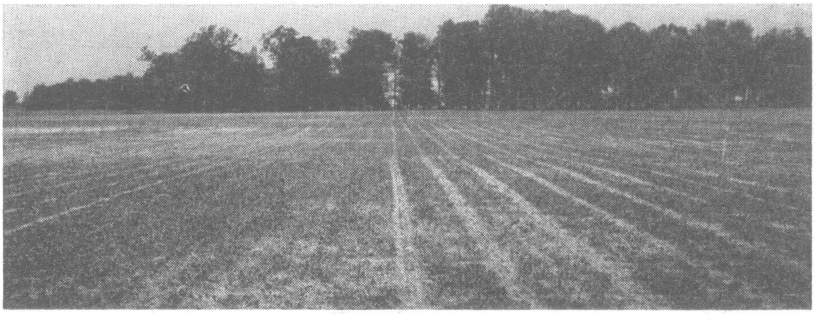

Fig. 10. Sugar beets band treated by endothal pre-emergence on right and far left, untreated beets left center.

should be applied pre-emergence at 4 to 6 pounds active ingredient per acre overall, or in bands (see "Band Application for Economy") on the date of planting. The lower rates in this range are applied on lighter soils.

TCA, sold as sodium trichloroacetate, and **dalapon,** sold as sodium 2,2-dicholoropropionate under the trade name Dowpon, are effective mainly on annual grasses. In addition, TCA controls smartweed. TCA should be applied pre-emergence at 4 to 6 pounds active ingredient per acre (overall rate). Dalapon should be applied post-emergenc at 3 to 4 pounds active ingredient per acre. Best results are obtained if it is applied anytime after emergence of beets until the 4-leaf stage, when the annual grasses are up. Neither TCA nor dalapon injures sugar beets when applied as suggested.

Mixtures of endothal and TCA at 2 to 3 plus 4 to 5 pounds active ingredients per acre (overall rate) applied pre-emergence may prove more satisfactory than either herbicide applied alone where both annual grasses and annual broadleaf weeds are serious problems.

Forage Crops and Lawns

Seedling Legumes

Weeds usually constitute one of the biggest problems in establishing summer seedings of legumes. The use of herbicides in legumes underseeded in small grains is discussed elsewhere in this bulletin. Where no small grain is sown and only annual grass weeds are a problem, dalapon (trade name Dowpon) and TCA may be useful on seedling alfalfa and birdsfoot trefoil. In addition, sweetclover is tolerant to TCA. **However, until officially cleared by the FDA, neither dalapon nor TCA should be applied on forage crops that are to be harvested for feed or grazed during the treatment year.**

Dalapon at 2 to 3 pounds active ingredient per acre or TCA at 5 to 7 pounds should be applied soon after grass seedlings come up. Often this will be 1 to 2 weeks after emergence of the legume, which usually will be at the 2- to 4-leaf stage when treated. These treatments will damage seedling perennial forage grasses if they are sown with the legume. Alsike, red clover and lespedeza, as well as small grains, also are killed or damaged by these herbicides.

Obviously, there is need for a herbicide that will control broadleaf weeds in legumes seeded alone or in small grains without damaging these crops. A relatively new herbicide, 4-(2-4-DB), often abbreviated to **2,4-DB,** shows excellent promise of meeting this need. 2,4-DB is sold under the trade names Butoxone and Butyrac 118. It is a translocated herbicide that is similar to 2,4-D chemically and in many other respects.

Amazingly enough, 2,4-DB post-emergence controls many broadleaf weeds in alfalfa (Fig. 11), red clover and birdsfoot trefoil, ladino and alsike clovers seeded alone or in small grains without injuring these crops. However, **until the FDA approves it for other uses, 2,4-DB can be used only on forage crops that are to be harvested for seed during the treatment year.** 2,4-DB applied at 1 to 2 pounds active ingredient per acre on seedlings legumes at the 2- to 4-leaf stage kills many broadleaf weeds such as wild mustard, pigweed and lambsquarters, and even the tops of Canada thistle. But, like 2,4-D, it is ineffective on grasses. Where both annual broadleaf weeds and annual grasses are pres-

Fig. 11. Left, alfalfa one month after treatment by 2,4-DB at the 2- to 4-leaf stage; right, no treatment.

ent, a mixture of 2,4-DB and dalapon at 1 plus 2 pounds per acre applied at the 2- to 4-leaf stage may be very effective on both types of weeds. **This mixture will damage perennial forage grass seedlings. It has not been officially approved by the FDA for use on legumes that are to be harvested for feed or grazed during the treatment year.**

Established Legumes

The use of 2,4-D and MCPA on established legumes is often hazardous. Serious yield losses may result from spraying done other than when the legumes are dormant. Generally, dormancy begins after the first or second killing frost in autumn and continues until about March 15 of the following year, depending on weather conditions. 2,4-D or MCPA at ¼ to ⅓ pound per acre may control some winter annuals, such as yellow rocket, but not chickweed, if applied shortly after they resume active growth in early March. Legumes may be injured somewhat by this treatment.

2,4-DB at 1½ to 2 pounds per acre will control most winter annual broadleaf weeds by treatment in fall when these weeds are small. The crop may be harvested for feed or grazed the following year.

DNBP and CIPC may be used on established legumes during dormancy in autumn or in early March to control some winter annuals, including chickweed.

The elimination of legumes from legume-grass stands is sometimes desired, as when the grass is harvested for seed. 2,4-D ester at 1 pound per acre, and sometimes less, will usually kill most legumes but will not adversely affect grasses. It should be applied to active growth, which is about 4 to 6 inches high, in autumn or in spring. Autumn treatment at 1 pound per acre may be preferable, since this single application may be sufficient, but if not, a second treatment at about ½ pound per acre can be made in the spring to kill stragglers.

Pastures

In pastures, weeds are often indicators of poor soil and poor management. When enough lime and fertilizer are added to adequately drained soils, grasses and legumes often markedly suppress weed growth. Timely mowing will prevent seed production, kill annual weeds and weaken or eliminate many perennial weeds.

Over-grazing weakens pasture crops, but generally favors germination and growth of weeds. Under-grazing encourages seed production and vegetative propagation of weeds. Where pastures are extremely thin and weedy, re-seeding to adapted species of superior vigor may be the best practice. But pasture fields may become infested with weeds even under the best methods for maintenance.

The control of many broadleaf weeds in perennial grass pastures is readily obtained through proper application of 2,4-D. The amount of 2,4-D needed is determined by the weed species to be destroyed. For example, ¼ pound per acre will kill dandelions and bull thistle, but 2 to 3 pounds repeated twice yearly for 2 years or more, may be needed for wild garlic and wild onion. A rate in common use in grass forage crops is 1 pound per acre.

The preferable time for killing pasture weeds is in the fall after rains have started vigorous new growth. The spaces left by the weeds can be filled by grass before the following summer.

Where brush and other woody plants are a problem, 2,4-D, 2,4,5-T, or mixtures of 2,4-D and 2,4,5-T ("brushkillers") may prove highly useful. Treatment with any of these herbicides to kill undesirable species of plants will also kill or severely injure most legumes. The white clovers (including ladino) are more tolerant than other legumes, but repeated light applications or single high rates will kill them too. In general, these herbicides do not injure grasses when used at the rates needed for weed or brush control.

New grass seedlings may be treated with 2,4-D where broadleaf weeds are a problem. Usually, most grass seedings, except bentgrass, can withstand 2,4-D at rates up to ¾ pound per acre at the 2- to 4-leaf stage. They gain resistance rapidly and remain tolerant until early heading. Treatment at early heading through the flowering stage may reduce forage grass yield slightly and seed production rather markedly. The amines are less likely to cause injury than the esters at any stage of growth. Where annual grass weeds are a problem, mowing to prevent seed production is desirable. TCA and dalapon should not be used, since they are likely to injure the desirable grass seedlings.

Lawns

The most satisfactory method of controlling weeds in lawns is growing a dense healthy stand of grass. The regular and timely application of lime and fertilizer as needed, together with proper mowing (cut at least 2 inches above ground level for most grasses) and watering, favors a dense growth of grass to the detriment of weeds.

If a lawn becomes infested with weeds, the first step in eradication is to determine the cause of infestation. Eliminating the weeds without correcting the underlying cause will give only temporary success, and the work will have to be repeated.

Broadleaf Weeds. Many broadleaf weeds in lawns can be eliminated by 2,4-D. 2,4-D is most effective on plants that are growing vigorously after rains in the spring or in autumn. Autumn is the preferable time to kill broadleaf weeds, because lawn grass will have time to fill the spaces left by these weeds before conditions are favorable for crabgrass germination the following spring. Killing dandelions, plantains and other broadleaf weeds in May and June often merely makes room for crabgrass.

2,4-D at ½ to 1 pound per acre is adequate for most broadleaf species. Bentgrass may be injured by 2,4-D, so that only spot treatment where needed is suggested on this type of grass. Bluegrass seedlings are rather susceptible to 2,4-D, but it appears entirely practical to control broadleaf weeds in bluegrass seedlings at the 2- to 3-leaf stage or later if this can be accomplished with less than ¾ pound per acre.

Care must be taken to prevent 2,4-D spray for drifting onto susceptible plants that one wishes to save. Practically all vegetables and most flowers, ornamentals and trees are sensitive to 2,4-D. Since these are usually grown near lawns, the amines, not esters, should be applied in dilute sprays at low pressure to minimize drift. One tablespoonful of a 4-pound-per-gallon amine formulation in 1 gallon of water, applied to wet the plants to point of runoff, is a standard lawn solution. All lawn "weedkillers" do not contain the same quantity of 2,4-D per unit of the concentrate, so **follow the directions on the container.**

Not all broadleaf weeds commonly found in lawns are killed by 2,4-D. Some strains of wild carrot that are resistant to 2,4-D, even when young and growing rapidly, may be more susceptible to 2,4,5-T or 2,4,5-T mixtures. Ground ivy (creeping Charlie) may be controlled by 2,4-D at high rates when it is growing rapidly in fertile soil, but it is often resistant during midsummer droughts.

A relatvely new herbicide, **silvex** [2-(2,4,5-trichlorophenoxy) propionic acid], at 2 pounds active ingredient per acre will kill ground ivy regardless of the weather or soil conditions. Silvex is sold under the trade names Weedone 2,4,5-TP, Chickweed Killer, Kansel, Kuron and probably others. Silvex at 1 to 2 pounds per acre will kill common chickweed, mouse-ear chickweed and wood sorrel and also all species of lawn seeds that are susceptible to 2,4-D and 2,4,5-T. Re-treatment may be needed to control mouse-ear chickweed.

All precautions regarding the use of 2,4-D near trees, shrubs, flowers, etc., apply to both 2,4,5-T and silvex, since they are also subject to drift and kill many plants more readily than 2,4-D. They are also injurious to bentgrass and may do more damage than 2,4-D to white clover.

Crabgrass is an annual grass that germinates usually about May 1 at Columbus. A few pre- and post-emergence herbicides have given good control of this pest under favorable conditions. **When using any of these materials, follow the direction that accompany them.** The control of crabgrass is discussed in detail in the Ohio Agricultural Extension Bulletin 271, "Your Lawn."

Undesirable perennial grasses. Undesirable perennial grasses such as tall fescue and orchardgrass may infest lawns, often via lawn seed mixtures. They are not conspicuous until well established, usually 2 to 3 years after seeding.

In mowed lawns, tall fescue ordinarily has coarse, shiny, dark green leaves with a short stem. Orchardgrass leaves have a dull cast, are lighter in color, and the stem grows little above ground level. Both species retain their green color during the dry summer months, when bluegrass normally is brown and semi-dormant. They produce many leaves near the soil surface, where they are not reached by the lawn mower, and continue to grow during summer droughts when mowing is usually temporarily discontinued.

Spot treatment by dalapon (1 pound in 5 gallons of water) on the crown of each clump of fescue, orchardgrass, or other similar type grass may be practical for moderately infested lawns. The desirable lawn grass will start to grow into the space left by the weeds within a few weeks after treatment. Avoid contact of dalapon with lawn grass that is to be saved.

Where a lawn is densely infested with quackgrass, tall fescue, orchardgrass or other undesirable perennial grasses, overall treatment by dalapon at the rate of 1 pound active ingredient in 1 gallon of water per 1000 square feet may be desirable. This treatment will kill all grasses, including bluegrass and other lawn grasses.

Where broadleaf weeds are also a problem, 2,4-D should be mixed with the dalapon solution. Till the treated area thoroughly about 5 days after application, and seed 30 or more days later. Any regrowth after tillage can be spot treated before seeding. This method of lawn renovation should begin in August so the seeding can be done in September.

Lawn fertilizers containing 2,4-D. Lawn fertilizers containing 2,4-D are on the market. These materials contain only a small percentage of 2,4-D. Satisfactory control of common broadleaf lawn weeds can be obtained only if the material is uniformly applied at the recommended rate given on the label. Late summer or early autumn application immediately before the resumption of active growth by plants is preferable to spring treatment, but either or both may be beneficial.

Detailed information on the establishment and maintenance of lawns is contained in Ohio Agricultural Extension Bulletin 271, "Your Lawn."

Sorghum

In Ohio, generally, sorghums are planted in early June. Two and sometimes three crops of weeds can be destroyed by timely tillage prior to planting time. Where tillage practices fail to control weeds satisfactorily, 2,4-D at ¼ to ½ lb. per acre may be used to control broadleaf weeds, but it should be used only where the weed problem is severe. Treatment should be made when the sorghum is 4 to 8 inches high. Forage sorghums, such as sudangrass, appear to be more resistant than grain types to 2,4-D.

Tobacco Plant Beds

Tobacco seedlings are extremely poor competitors with weeds. The practice of burning brush to kill weed seed in tobacco transplant beds is still followed in some areas but largely has given way to herbicides. Several herbicides have given satisfactory results: methyl bromide, allyl alcohol, Vapam, Mylone, Bedrench and calcium cyanamide. Some of these materials have also been effective against soil-borne disease organisms in tobacco beds. Directions for application accompany each herbicide. No herbicide is available for satisfactory weed control in tobacco fields.

2,4-D injury to tobacco is rather common in tobacco beds and fields. In beds it usually results from applying materials in sprayers contaminated by 2,4-D. Injury to tobacco in the field is frequently caused by drift of 2,4-D droplets and vapor following application nearby, or by insects from 2,4-D treated areas alighting on the tobacco plants.

Controlling Special Weeds

Bindweeds

Both field bindweed (sometimes called small morning glory) and hedge bindweed ("pea-vine") can be controlled by 2.4-D. In Ohio, hedge bindweed is the more susceptible, but one application at ½ to 1 pound active ingredient per acre frequently gives 90 per cent kill of both species. Where regrowth occurs, re-treatment is needed to prevent spreading. Treatment may be made to the tops any time there is vigorous growth.

Patches of either bindweed in corn after the last cultivation may be treated by 2,4-D with a hand sprayer. Where present in small grain fields late in the season, the patches may be treated at the late milk or soft dough stage of the grain. This will save much trouble in harvesting, and the stand of the bindweed will be considerably reduced.

Canada Thistle

Until the rather recent introduction of amitrol (3-amino-1,2,4-triazole), 2,4-D and sodium chlorate were the only herbicides recommended for the control of Canada thistle in Ohio. 2,4-D kills the tops readily, but has little effect on the roots, so repeated treatment for 3 years or more is necessary to eradicate Canada thistle with this herbicide. Sodium chlorate will kill thistle, but it sterilizes the soil for 6 months to 3 years.

Amitrol has given better results than any other herbicide in controlling Canada thistle. Amitrol is sold as a wettable powder under the trade names Amino Triazole Weedkiller and Weedazol, formulated to contain 50 per cent of the actual amino triazole. The rate recommendations in this bulletin are in pounds of pure amino triazole per acre, so just twice as much of the commercial material as these rates is needed in preparing spray solutions.

Many single applications of amitrol have eradicated entire patches of Canada thistle, but more often they have reduced the stand by 90 to 95 per cent. Amitrol seems to owe much of its effectiveness on thistle to its ready absorption by the leaves and rapid translocation to all parts of the plant, including the roots.

Amitrol will not kill Canada thistle when applied to only the soil; it is decomposed readily by soil microorganisms. Treatment must be made when the thistles are up. Amitrol will kill Canada thistle and other species of plants, including most crops, when applied to the tops. Consequently, amitrol treatment must be made on emerged thistles prior to planting or after crop harvest, except for spot treatment. Under no circumstance has amitrol injured any crop where treatment preceded tillage and planting.

In fields to be planted to corn the thistles should be 6 to 8 inches tall or a little taller before treating with amitrol at the rate of 4 pounds (active ingredient) per acre in 40 gallons of water. Treatment as late as the bud stage may be as good or better than at any earlier stage, but treatment often cannot be made this late in cropland without delaying the planting of the crop. Corn is the only crop that should follow this treatment.

Where there is tall dense growth of thistle and/or other weeds, better

results are sometimes obtained with higher spray volume, about 60 gallons per acre. The improved results are apparently due to better coverage of the thistles. Increasing the rate of amitrol above 4 pounds per acre or making more than one application on the same thistle shoots usually will not alter amitrol effectiveness.

After treatment, the area should be left undisturbed for at least one week before plowing (or mowing), or if fall plowed, before disking. Then the corn may be planted immmediately.

Other places in the rotation, where amitrol is very effective on Canada thistle, are during summer, (1) in hay fields after the first cutting, (2) in clipped small grain stubble (seedings will be killed), and (3) in areas of regrowth after plowing in June or July.

Here again the thistles should be treated after most of them are 6 to 8 inches tall, but before they are at the bloom stage. Treatment should be made the same as in the spring, except that plowing may be delayed longer.

Livestock should not graze in the field until the treated area(s) is plowed. Plowing helps control annual weeds in the treated area and sometimes increases amitrol effectiveness.

Treatment of regrowth thistle in a hay field after the first cutting is somewhat better than other treatments because:

1. Eradication is complete, or nearly so. The treatment is made on thistles that are already weakened by mowing.

2. Two pounds of amitrol per acre often are as effective as the standard 4-pound rate. Any regrowth may be treated overall at 2 pounds per acre or spot treated by October 1 or the following spring before planting corn.

3. Amitrol kills the forage crops, but the treated area may be reseeded within two weeks where a forage crop is desired the following year. Good control sometimes can be obtained by amitrol treatment after the second cutting, but it will be too late to reseed the area to a forage crop, and usually 4 pounds of amitrol will be needed.

4. Generally, the demand for labor is not great at the time of treatment after the first cutting.

It may be better to use 2,4-D on Canada thistle in permanent pastures where killing the forage crop with amitrol is objectionable. However, where the thistle patch is so dense that little or no grass is growing, amitrol treatment may be more satisfactory than 2,4-D. In such circumstances, amitrol should be applied at 4 pounds per acre any time after the thistles are 6 to 8 inches high but before the bloom stage. Any regrowth should be treated as soon as it is 6 to 8 inches high.

Bluegrass establishes itself naturally in the treated area within two years. Timothy, orchardgrass and tall fescue recover more rapidly than bluegrass after treatment with amitrol. Where possible, the treated area may be worked and reseeded within two weeks if desired.

Livestock should not graze in the field until the treated area is plowed, or mowed and burned.

2,4-D readily kills the tops of Canada thistle but the roots are usually not killed and will send up new shoots. Three treatments each with 2,4-D amine

(not ester) at ½ to ¾ pound (acid equivalent) per acre in 10 gallons of water the first year and two treatments each year thereafter for 2 to 3 years or more are needed to eradicate Canada thistle. The first treatment each year should be made at the bud to early bloom stage, and the following on the regrowth in August and/or September.

It usually takes at least three consecutive years to eradicate a thistle patch with 2,4-D. When the land is in crops it is difficult to make consecutive treatments for that long; therefore, 2,4-D has been disappointing in controlling thistles in cropland.

In corn, it is advisable not to treat thistles with 2,4-D in the spring before plowing for corn. The plowing itself is almost as effective. Thistles that are not taken out of the corn by cultivating can be treated by 2,4-D with drop nozzles. An effective second application can be made with a hand sprayer in August or early September.

Since thistles come up late and both wheat and oats will be severely damaged by 2,4-D applied at the jointing stage (phase of rapid elongation), the thistles should be treated before that stage. Increasing the volume of water to 20 gallons or more per acre, applied with 40 pounds pressure, may help get through the small grain canopy to give better results.

Canada thistle in wheat and oats may be treated safely by 2,4-D at the late milk stage of the small grain. This will prevent the thistles from forming seeds and will make harvesting easier. Tractor sprayers will do considerable damage by tramping the grain if used at this time. A hand sprayer may be used; this will save much more time in harvesting than it takes to treat the thistles.

A second application should be made on the regrowth thistles in the small grain stubble after the straw has been removed, regardless of when the first application is made.

It is rather inconvenient to treat thistles with 2,4-D in rotation cropland. However, 2,4-D will not kill grass and may be more satisfactory than amitrol for controlling thistles in pastures and in noncrop areas such as fencerows. The grass will help combat soil erosion and prevent infestation by annual broadleaf weeds.

Chickweed

Of the two types of chickweed commonly found in Ohio, mouse-ear (perennial) and common (winter annual), the latter is the more serious pest and often presents a problem in meadow crops. Normally, both types germinate in late August and in September. The young plants remain dormant over winter and resume active growth early the following spring. The two types of chickweed respond similarly to herbicides.

DNBP (trade names Premerge and Sinox PE) and CIPC may be used to control chickweed in meadow crops. Neither reduces the yield of legumes, but CIPC may damage grasses slightly, so it should be used only where this is not objectionable.

Most effective chickweed control with DNBP is obtained by application at 2¼ to 3 pounds (phenol equivalent) per acre in at least 40 gallons of water

either (a) in autumn after frost kills the tops of the forage crop, or (b) in March before the crop resumes active growth. Application should be made when the air temperature is above 50°F., preferably above 60°.

Application of DNBP in autumn while the chickweed is still upright and 1 to 2 inches high usually is more effective than treatment later in autumn or in spring. Where the forage or weeds are dense, higher spray volume may be needed to get adequate coverage of the chickweed.

DNBP applied in autumn may not be entirely satisfactory where weather is favorable to germination of chickweed after treatment. Under such circumstances, the area should be re-treated at the same rate the following year as soon as the maximum day temperature reaches 50°.

CIPC gives effective control of chickweed in meadow crops but may damage grasses slightly. The best time to apply CIPC is after the tops of meadow crops are killed by frost in late autumn (November to mid-December), or in late winter (February to mid-March). Autumn treatments may require 2 to 3 pounds of CIPC per acre, and may be somewhat less effective than February-March treatment at 1 pound.

Volume of water does not appreciably influence CIPC effectiveness, as long as dense growth of chickweed or other plants does not prevent uniform coverage of the soil, through which CIPC works on plants. Generally, about 20 gallons of water per acre is adequate. The effects of CIPC are seldom evident until 3 to 5 weeks after treatment.

Common Milkweed

Common milkweed appears to be susceptible to amitrol (3-amino-1,2,4-triazole) any time after it is about 1 foot high to the early bloom stage. Four pounds of amitrol (active ingredient) per acre in 40 gallons of water for overall treatment, or ¾ pound in 10 gallons for spot treatment to wet the leaves to point of runoff, is suggested. The spray should not contact plants that are to be saved.

Johnsongrass

Johnsongrass can be eliminated from land only if reinfestation by seeds is prevented. Eradication of this pest with our present methods is almost impossible on river bottoms where floods continuously bring in new seed.

Until all Johnsongrass plants are prevented from producing seed on land along rivers that flood periodically (Fig. 12), control practices will need to be repeated continually. Cultural methods of control usually are more practical and less expensive than herbicides.

The control of Johnsongrass by herbicides is suggested only for, (1) scattered plants that can be spot treated in cropland, (2) small patches in cropland, and (3) noncrop areas. Where cropland is only sparsely infested with Johnsongrass after cultural methods of control, or for any other reason, spot treatment of individual plants with sodium chlorate, TCA, or dalapon (trade name Dowpon) may be desirable. Where applied to corn fields, these herbicides usually kill nearby corn plants, but if the Johnsongrass is allowed to grow it will crowd them out anyway.

Fig. 12. Johnsongrass on bank of a river that floods periodically in southern Ohio.

Sodium chlorate can be conveniently applied dry by hand at the rate of 2 to 3 ounces per Johnsongrass plant. It may present a fire hazard, but this should not prevent its use. Neither TCA nor dalapon presents a fire hazard. They can be dissolved in water and applied with a knapsack sprayer. They are effective at lower rates than sodium chlorate and do not sterilize the soil so long.

Small patches of Johnsongrass, in fields to be planted to corn, can be satisfactorily controlled by TCA or dalapon applied the preceding autumn. However, this method cannot be used satisfactorily on land that is planted to corn every year, as in river bottoms. Neither TCA nor dalapon is effective on Johnsongrass when applied in the spring at rates that will not injure the corn that follows.

In river bottoms, one alternative is to treat the patches with herbicides at high rates in the spring. Since the soil will be sterilized for about 60 days, no crop can be grown n the treated area during that time. TCA is effective mainly through the soil, so less will be needed if it is applied after plowing Johnsongrass. Dalapon is most effective when used as a foliage spray. However, since it is also absorbed through plant roots, better results are obtained when moderate rainfall follows application. If regrowth occurs after these treatments, repeat the application or cultivate frequently.

Johnsongrass in noncrop areas produces each year enough seed to infest thousands of acres of land. The importance of timely mowing to prevent seed formation cannot be overemphasized. Often, it may be advisable to use herbicides to eradicate this pest in noncrop areas. The following treatments may be satisfactory for this purpose: sodium chlorate at 3 to 5 pounds per square rod (480 to 800 pounds per acre); TCA at ⅜ to ⅝ pound per square rod (60 to 100 pounds per acre); monuron (trade name Telvar) at ¼ to ½ pound per square rod (40 to 80 pounds per acre); or dalapon (trade name Dowpon) at $\frac{5}{32}$ to $\frac{5}{16}$ pound per square rod (25 to 50 pounds per acre). These treatments will sterilize the soil, but not indefinitely. **Complete direc-**

tions and precautions regarding their use accompany each compound. (For more information, refer to Ohio Extension Bulletin 342, "You Can Control Johnsongrass".)

Quackgrass

Generally, large infestations of quackgrass can be controlled more satisfactorily by cultural methods than by herbicides. It is important that tillage operations bring the maximum number of rhizomes and roots to the soil surface where they will be quickly dried by the sun and wind. Shallow tillage in late autumn will reduce regrowth.

Small scattered patches of quackgrass may be satisfactorily treated by dalapon (trade name Dowpon) at 10 to 15 pounds, dalapon plus amitrol (trade names Amino Triazole Weedkiller and Weedazol) at 8 plus 4 pounds, or TCA at 30 to 40 pounds (all active ingredients) per acre in August or September. Dalapon alone or in the mixture with amitrol should be applied to actively growing foliage, followed by plowing in 10 to 20 days or in the spring.

TCA at these rates will not be effective unless immediately preceded by tillage.

Improved control by dalapon or dalapon plus amitrol may be obtained if the quackgrass sod is first worked up and then the regrowth is sprayed when 4 to 10 inches high. Following any of the treatments mentioned above, the field should be planted to a row crop, such as corn, the next year and cultivated frequently for maximum suppression of quackgrass.

Spring treatment with dalapon before planting time may give satisfactory control of quackgrass but may cause some injury to corn and to more sensitive crops, such as soybeans. Dalapon at 5 to 7 pounds per acre should be applied when quackgrass is 4 to 10 inches high and growing vigorously. An application of nitrogen fertilizer to the patches 3 to 4 weeks before spraying will stimulate growth and increase susceptibility; the nitrogen will largely be left to benefit the crop.

To reduce dalapon injury to crops, at least 1 week should elapse before the treated area is plowed and an additional 3 weeks before planting. Better quackgrass control and less crop injury will result if moderate rains occur before plowing. Apparently the rain leaches the excess dalapon into the soil where it can be either absorbed by the rhizomes and roots of quackgrass or decomposed more readily by soil microorganisms, or both.

Usually, none of the treatments suggested above will eradicate quackgrass, so retreatment will be necessary.

On noncropland, sodium chlorate at about 300 to 500 pounds per acre (2 to 3 pounds per square rod), or monuron (trade name Telvar) at 20 to 40 pounds per acre may be used to control quackgrass for 2 to 3 years or more. Early spring and late summer treatments are the most effective. In cropland, normal growth of crops in the treated area cannot be expected for at least 2 years or more, following treatment by sodium chlorate or monuron.

A new herbicide, 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (trade name Atrazine 80W) appears promising for the control of quackgrass. Best results are obtained by atrazine applied at 4 pounds active ingredient per

acre on quackgrass in September to mid-October. The area should not be tilled until spring prior to planting corn. Other crops may be injured following this treatment. All crops may be safely planted after the corn is harvested.

Wild Garlic or Wild Onion

Wild garlic reproduces by aerial bulblets, underground bulbs and sometimes by seed. Usually, only two kinds of underground bulbs are produced, hard-shell bulbs and soft-shell bulbs, but occasionally terminal bulbs are formed also. All of these reproductive bodies are developed by late spring or early summer.

Under favorable environmental conditions, practically all of the aerial bulblets and many of the underground bulbs germinate the first fall after they are formed. The young plants remain semi-dormant over winter and resume active growth early the following year. However, many of the hard-shell bulbs lie dormant over winter and germinate the following year or later. Many dormant hard-shell bulbs are usually present where garlic has persisted for a number of years.

The tops of wild garlic can be killed and the formation of reproductive bodies prevented by 2,4-D ester (not amine) applied at the rate of 2 to 3 pounds (acid equivalent) per acre in about 10 gallons of water. This treatment will not kill dormant bulbs in the soil. Since new garlic shoots emerge in both fall and spring, eradication of this species requires two timely treatments each year until all viable bulbs have germinated and the tops killed before new underground bulbs have formed.

The first 2,4-D application can be made in either fall or spring. The fall application of 2,4-D at 2 to 3 pounds per acre should be made in November. This will kill the newly emerged garlic shoots and thus prevent them from producing new bulbs and bulblets the next year.

A second application at the same rate must be made in March to kill the shoots that emerge from previously dormant bulbs. Best results are obtained from treatment after the maximum air temperature has reached 55° to 60°F., mainly because more shoots are up. April treatments will kill the garlic shoots but they will be less effective than March treatments in preventing the formation of underground bulbs. Where only one application can be made, spring is preferable.

Plowing that covers all the garlic tops may effectively substitute for either the November or the March spraying, or both, if done at the time suggested for each application of 2,4-D that it is to replace. In plowing, a jointer should be used to get better coverage of the garlic tops. There is less chance of missing corners and narrow strips in plowing than in spraying. Where plowing is necessary in seedbed preparation and can be done in time to control garlic effectively, spraying at that time of the year is not needed. 2,4-D costs about $2 and $3 per acre for each application.

Wild garlic in wheat may be controlled by 2,4-D ester at 2 pounds per acre applied in March or the first week in April. This treatment will not seriously damage the wheat, and will prevent garlic contamination of the grain. Legume seedings will be killed.

Wild onion can be controlled by the methods outlined for wild garlic control. Wild onion is similar to wild garlic but does not produce hard-shell bulbs. The leaves of wild garlic are nearly round and hollow; wild onion leaves are flat and not hollow.

Killing Woody Plants

Woody Species in General

Woody plants—brush, trees, sprouts and vines—may present a problem in agricultural land as well as in noncrop areas, and often steps must be taken to destroy them. Great progress has been made in the chemical control of woody plants, but all the correct answers have not been obtained.

2,4,5-T is much more effective than 2,4-D on many woody plants. Osage orange, and the briars (blackberry, dewberry, etc.) are readily killed by 2,4,5-T but are affected little by 2,4-D. Cottonwood and the more common species of willow (some are unaffected by 2,4-D) are equally susceptible to 2,4-D and 2,4,5-T, and are sometimes found in sufficiently pure stand to treat with the less expensive 2,4-D. The other more common species of woody plants in this region are more or less susceptible to 2,4,5-T or "brushkillers."

Brushkillers are mixtures of 2,4-D and 2,4,5-T low volatile esters. The most common and generally effective is a 50-50 mixture. If the brush, mixed or consisting of a single species, is rather resistant to 2,4-D, pure 2,4,5-T may be more economical than brushkiller. Where only certain species in mixed brush survive or sprout after treatment by a mixture of 2,4-D and 2,4,5-T, a

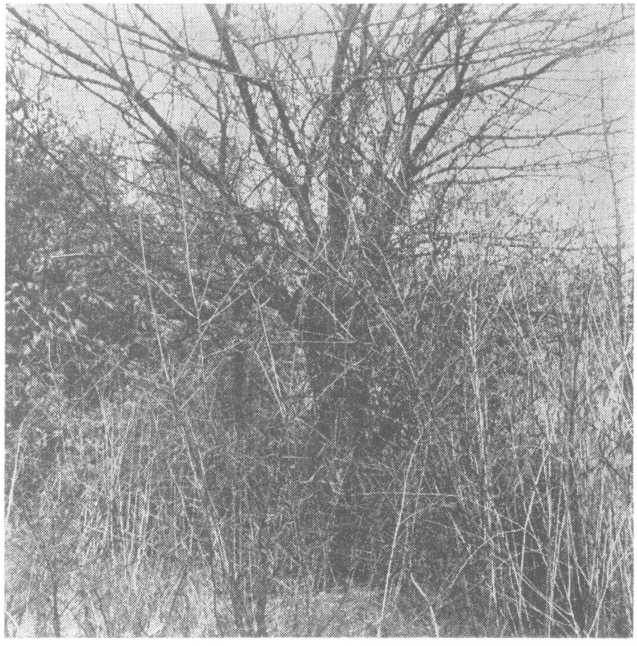

Fig. 13. Thornapple and briars killed by fenuron applied on the soil surface.

second treatment by 2,4,5-T only may prove more effective than a mixture. Herbicides such as silvex, ammonium sulfamate, monuron, fenuron and amitrol are useful in the control of woody plants under certain conditions.

There are many different methods of applying herbicides to control woody plants, but foliage spraying in summer is the most common. Basal, semi-basal, stump, soil application and various special treatments such as airplane spraying, application to girdled or frilled tree trunks, soil injection, or by special tools are also effective.

Generally, foliage spraying of brush over 6 to 8 feet high is not suggested. Brush that is too tall or too dense should usually be cut and then stump sprayed or foliage treated after sprouts emerge. A higher percentage of regrowth usually occurs after foliage spraying than after the other methods.

Basal spraying of small (less than 6-inch diameter) uncut woody plants will give satisfactory results at any time of the year if done properly.

Fenuron, sold under the trade name Dybar, appears extremely promising for the control of most woody plants (Fig. 13). Fenuron is formulated as small pellets and can be readily applied dry by hand. It may be applied any time of the year except when the ground is frozen, but best results are obtained if it is applied in late winter or early spring. Fenuron can be applied on the ground at the base of each tree or cluster of brush, or broadcast at the rates indicated on the label of the container.

Stumps and sprouts also can be killed by this treatment. Fenuron is slow acting. Some species of woody plants do not die until the second year following treatment. Fenuron is especially valuable for use where there is danger of 2,4-D, 2,4,5-T or 2,4-D-2,,4,5,-T mixtures drifting onto nearby sensitive plants. **Fenuron will also kill most desirable woody plants whose roots it contacts.**

Poison Ivy

There is no excuse for the existence of poison ivy anywhere that persons may become affected by its poison. Herbicides are so effective on poison ivy that a single treatment will usually eliminate this pest. These herbicides cost little when compared to the amount spent annually by the countless sufferers who seek relief from the pain inflicted by this poisonous pest.

Poison ivy is often identified as poison oak and vice versa. The most reliable characteristic for distinguishing these species is that poison ivy when climbing develops clinging aerial roots on the stems, whereas poison oak does not climb or from aerial roots. Both species are poisonous. There is little or no difference in susceptibility to herbicides. Poison ivy is more common than poison oak in Ohio.

Three of the most satisfactory herbicides for killing poison ivy are:

1. A mixture of 2,4-D and 2,4,5-T
2. Amitrol
3. Ammonium sulfamate

Each herbicide will give 100 percent kill of poison ivy if applied properly. Treatment to wet thoroughly all the foliage to the point of runoff when the leaves are expanded (May through August preferably) is suggested. Each herbicide may be applied in water.

The directions on the label of the container should be followed when preparing and applying the spray solution. Each herbicide may be conveniently applied with a power-driven sprayer, a knapsack sprayer or a sprinkling can. None of these herbicides is caustic to the skin.

2,4-D-2,4,5-T mixtures and amitrol are rapidly inactivated in the soil. Ammonium sulfamate may sterilize the soil so that nothing will grow in the treated area for several months.

Mixtures of 2,4-D and 2,4,5-T are commonly sold as "brushkillers." These brushkillers, and particularly the 50-50 mixtures, are satisfactory for treating poison ivy. The 50-50 mixture will also kill most other woody plants (shrubs, trees, etc.), vegetable plants and flowers that the spray contacts.

Drift of tiny spray droplets or even vapor of brushkiller may damage sensitive plants. The hazard of drift of spray droplets can be reduced by applying the herbicide when there is no wind. Drift of the vapor will always be a hazard unless the brushkiller is applied at least 100 feet from sensitive plants. Where this hazard exists, it may be better to use amitrol.

Where poison ivy is growing among other undesirable woody plants that are to be killed, too, all the plants should be sprayed with brushkiller after the leaves are fully expanded. 2,4,5-T alone should be used on the woody plants that require re-treatment. 2,4,5-T alone will kill poison ivy but the 2,4,D-2,4,5-T mixture is just as effective and costs less.

Low volative esters of 2,4-D may be used alone on poison ivy, but they are not as consistently effective as brushkiller or amitrol, especially on ivy growing in shade. Neither 2,4-D nor 2,4,5,-T damages lawn grasses except bentgrasses.

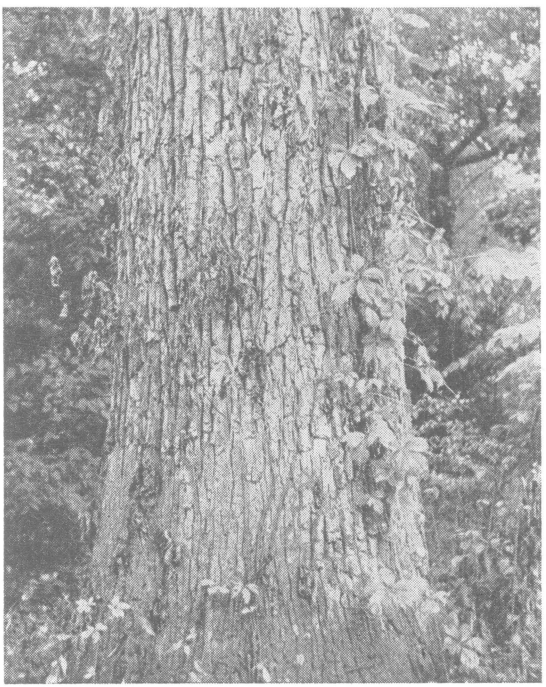

Fig. 14. Poison ivy on tree trunk killed by amitrol. No damage was done to tree or to Virginia creeper on trunk at right.

Leaves of poison ivy plants usually turn yellow within 1 week and die in 2 to 3 weeks after treatment with brushkiller. If any regrowth occurs, it should be treated again as directed for the initial growth.

Brushkiller is also very effective on poison ivy when applied any time in winter, but treatment in late February or March is usually preferable. Treatment in winter is especially desirable in areas where brushkiller-sensitive plants are planted the following spring and/or summer. The brushkiller must be applied in kerosene or diesel fuel. Where ivy is growing on walls, poles, etc., the stems should be drenched as high as can be conveniently reached and an excess of the spray solution allowed to run down the roots.

Poison ivy growing on desirable trees or shrubs cannot be safely treated by brushkiller in winter unless contact of the herbicide solution with these plants is avoided. It may be better to cut the ivy stem at ground level in winter and treat the sprouts with amitrol after the leaves expand (see following).

Amitrol, which is sold under such trade names as Amino Triazole Weedkiller, Weedazol and Poison Ivy Killer, is especially valuable for use on poison ivy near flowers, vegetable gardens, shrubs and trees where there is danger of brushkiller damaging nearby sensitive plants. Amitrol does not vaporize readily, but amitrol sprays may drift if applied on windy days. When drifting occurs, these sprays may damage desirable plants including vegetable plants, flowers and lawn grass at least 100 feet from the intended area of treatment.

Generally, amitrol does not damage trees when applied to the trunk or to the soil over the roots. Where poison ivy is growing beneath and on a tree, amitrol treatment of the ivy foliage beneath the tree and several feet on the trunk may give satisfactory results (Fig. 14). This treatment should not be made on fruit trees unless indicated safe on the label of the amitrol container. After the treated leaves die, the stems should be cut at ground level to kill the upper parts more quickly—where they are high on the tree.

Amitrol will kill most lawn grasses. Complete recovery of bluegrass requires about two years. Where this is objectionable in treating ivy, brushkiller may be used. Brushkiller is also preferable where poison ivy is growing among brush that is to be killed too. Brushkiller will kill many more different species of woody plants than amitrol.

Amitrol is slow acting. Two weeks may lapse before detectable effects are evident. Amitrol does not kill Virginia creeper (Fig. 14).

Poison ivy often becomes intertwined with other plants, particularly hedges and other desirable woody plants. Where there is danger of killing the desirable plants by spraying overall, amitrol can be "painted" on the ivy leaves with a long-handled brush. In such situations, amitrol is usually safer to use than brushkiller.

Two heaping tablespoons of amitrol (of the commercial product) should be mixed in one quart of water and "painted" when the ivy leaves are fully expanded. **The user should wear rubber gloves and take all the other precautionary measures normally suggested or learned through experience regarding poison ivy.** Only a thin coat of the amitrol solution on about one-half of the ivy leaves will usually kill the plant.

Ammonium sulfamate, sold under the trade name Ammate-X, also kills poison ivy. Since it does not evaporate, it presents no hazard to nearby plants unless they are contacted by sprays of this herbicide. Ammonium sulfamate is rather expensive, and it sterilizes the soil for several months.

Problems in Applying Herbicides

Mechanical Considerations

Herbicides in liquid and wettable powder formulations are usually applied in water solution or in oil (No. 2 diesel oil or kerosene). Any equipment that will distribute the spray solution uniformly on the plant or area to be treated will be satisfactory.

Following are factors that may affect the rate of application of a spray solution that has been prepared as directed, assuming that nozzle plugging is not a problem: (1) rate of forward speed, (2) pressure developed by the pump, (3) size of the opening in the nozzle tip, (4) height of the nozzle tip above the surface to be treated, (5) angle of the spray pattern, and (6) distance between the nozzles.

Usually, sprayers with the correct size nozzle tips, traveling at about 4 miles per hour (slightly faster than a man can walk), with 30 to 40 pounds of pressure will deliver the recommended volume of spray per acre in field crops. Higher pressures produce smaller spray droplets that drift farther. Where dense foliage is to be penetrated, as in roadside spraying, higher pressures with more dilute solutions may be justified.

It is desirable to use nozzles with interchangeable tips, so that if necessary, the rate of delivery can be changed without changing the pressure or rate of travel. One must refer to the manufacturer's sprayer manual in selecting the correct size tips.

The height of the nozzle tip above the surface to be treated will be determined by the angle of the spray pattern. For example, a flat spray nozzle with a spray pattern angle of 65 degrees (Fig. 15) should be mounted 4 inches higher than a similar nozzle with a spray pattern of 80 degrees to deliver the same amount of solution per unit area provided all the other factors remain constant. Drift of spray droplets will be slightly less with nozzles that may be operated nearer the surface to be treated.

Usually, the distance between the nozzles on boom sprayers, such as in Fig. 16, is fixed at about 20 inches and the spray patterns overlap for uniform overal application. Special nozzle tips are available for use in band treatments where the spray patterns do not overlap. The spray pattern of these nozzles is rectangular in shape to give a more even spray distribution throughout the pattern than is given by the flat spray nozzle pattern with tapered edges shown in Fig. 15.

Accurate calibration of spray equipment to each spraying operation is important. The best method is first to fit the nozzles with tips of the correct size to deliver the solution at the rate desired at the recommended pressure and rate of travel. Then fill the spray tank with water only.

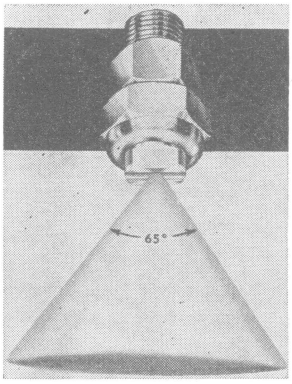

Fig. 15. A flat spray nozzle with a spray pattern angle of 65 degrees.

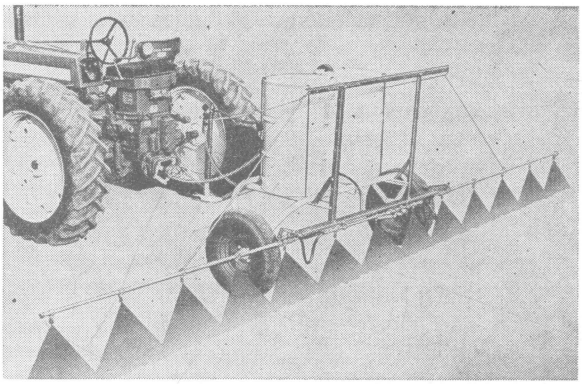

Fig. 16. A trailer sprayer equipped with flat spray nozzles whose spray patterns overlap.

While the equipment is standing, spray enough water to see that all parts are operating properly and to fill the pump, hoses, boom and nozzles. If empty to begin with, some sprayers drain one-half gallon of water from the tank before a drop reaches the nozzle tips. Refill the tank, then spray a measured area of at least one acre at the recommended pressure and speed (usually 30-40 pounds at 3-4 miles an hour for field crops). The sprayer should be equipped with a pressure guage. The speed of tractors without speedometers may be determined by referring to Table 2. Measure the amount of water required to refill the tank, and calculate the amount of water applied per acre. Herbicides can be made up and applied at the recommended rates accordingly. Spray equipment should always be calibrated both before any herbicide is applied and at intervals during operation, especially if abrasive solutions are applied.

Table 2. How to Determine Forward Speed

Distance in feet traveled in 1 minute	88	176	264	352	440	528
Miles per hour	1	2	3	4	5	6

Herbicides in granular formulations are applied dry. Granular applicators should be calibrated for each operation. Planter-mounted applicators may be satisfactorily calibrated while jacked up on blocks. The applicator drive wheel, whether planter or press wheel, should be rotated until about ¼ pound of granules is collected and weighed. By multiplying the circumference of the drive wheel by the number of rotations and the width of the band treated, the amount of granules applied per unit area can be calculated accordingly.

Preparation of the Spray Solution

The amount of active herbicide ingredient in commercial products varies from 10 per cent or less to 100 per cent. In general, it is satisfactory to follow the manufacturer's directions for treatment. Table 3 contains directions for making up solutions with typical liquid formulations.

Table 3. Pints of Commercial Material per Acre Needed to Give Different Amounts of Active Ingredient

Active ingredient per gallon of commercial material lb.	Pints of commercial material per acre needed to give the following pounds active ingredient					
	¼	½	¾	1	1½	2
2.00	1	2	3	4	6	8
2.64	¾	1½	2¼	3	4½	6
3.00	⅔	1⅓	2	2⅔	4	5⅓
3.34	⅗	1⅕	1⅘	2⅗	3⅗	4⅘
4.00	½	1	1½	2	3	4
6.00	⅓	⅔	1	1⅓	2	2⅔

Cleaning Spray Equipment

If crops are to be sprayed by equipment previously used to apply any type of chemical, this equipment should first be cleaned thoroughly. (Wooden tanks are difficult to free of many chemicals.) Immediately after applying herbicides that have an oil base, such as esters, rinse the sprayer twice with gasoline or kerosene; a thorough rinse with water is sufficient for amines or other oil-less compounds.

Next, fill the tank with a 0.5 percent suspension of activated chacoal, prepared by mixing 1 pound of activated charcoal with 22 gallons of water (or any corresponding ratio). Pump some solution through the nozzles and allow to stand for 5 to 10 minutes. Then discharge 5 to 10 gallons of the cleaning solution through the nozzles. If the tank is large, the rest of the solution may b let out the drain plug to save time. A final rinse with water should remove the charcoal.

Household ammonia or trisodium phosphate (TSP) may be substituted for the activated charcoal after the initial cleaning with gasoline, kerosene or water. Ammonia and TSP must remain in the spray equipment for 12 to 24 hours, and may be slightly less effective than activated charcoal for removing some herbicides, but ordinarliy they give good results. A 1 percent solution of household ammonia (about 3 tablespoonsful per gallon of water), or TSP at ⅔ ounce per gallon of water, followed by a rinse with water after the 12- to 24-hour waiting period, is suggested.

When the sprayer is prepared for winter storage, the hoses should be disconnected and all the bare metal parts coated with oil, including the inside of the spray tank if it is not rust resistant. The nozzles should be disassembled and stored in oil. The procedure for preparing the pump for storage should be based on the suggestions of the manufacturer. It usually includes flushing with a suitable oil and removing the drain plugs.

Sprayer Construction

Sprayers should be constructed of materials that are resistant to corrosion by both water and herbicides. Stainless steel and polyester resins reinforced with fiberglass appear to be the most resistant. Aluminum, brass and galvan-

ized iron are resistant, but in some instances they require special flushing or other precautionary measures. The highly corrosive effect of TCA on aluminum and of Ammate-X on brass are example of problems that may be encountered. Natural rubber has poor resistance to many petroleum derivatives.

Generally steel and aluminum will work satisfactorily for most farm sprayers when used with solvent-resistant hose and gaskets. Brass pumps and nozzle fittings may also be used, but a program of careful cleaning and maintaining of the equipment during field use, and particularly during storage, must be followed for satisfactory results.

Broadjet Sprayers

The broadjet or cluster nozzle sprayer (boomless type) may prove useful for spraying roadsides, fencerows, brush in pastures and other areas where boom sprayers are unsatisfactory. Under some conditions they are less accurate than boom sprayers and should be used on only those field crops that are much more tolarent than the weeds to the herbicide. In small grain crops and turf, either type of sprayer may be satisfactory.

The spray pattern recommended for the broadjet by the manufacturer must be followed closely. If there is any wind, spraying should be done cross-wind overlapping one-half of the swath width. Calibration is just as important as with conventional sprayers and should be based on the effective swath width. It is obvious that broadjet sprayers cannot be used in band application.

SOIL STERILANTS

Amitrol plus Dalapon

Where temporary soil sterilization is desired, a mixture of amitrol plus dalapon at 4 plus 7½ pounds (active ingredient) per acre may be satisfactory. This mixture should be applied when the weeds are 5 to 8 inches high. Retreatment may be needed. **This combination presents little hazard to nearby plants, including trees, but contact with desirable plants should be avoided.**

Arsenic Compounds

Many commercial weed killers contain some form of arsenic. **Their use is not suggested to anyone who is not willing to learn and follow directions for safe usage.** The arsenicals are effective and relatively cheap; however, their poisonous nature makes them hazardous to all animals including humans. There have been many cases of illness among workers engaged in the application of arsenicals and many deaths of livestock that have eaten treated vegetation.

The major use of the arsenicals is for soil sterilization. They are fixed readily in the soil and leach less than any other herbicide. When applied periodically at nonsterilizing rates, the arsenicals, by fixation, can accumulate in the soil to sterilizing amounts. Light soils require the lowest rates for sterilization and heavy soils the highest.

Since they are not moved to any extent in most soils, the arsenicals, like the boron compounds, may be slow to kiil deep-rooted perennials. Sodium arsenite ($NaAsO_2$) is sold in both liquid and dry forms and is soluble in all proportions in water. Rates of treatment are usually given in arsenic trioxide (As_2O_3) equivalents.

Boron Compounds

Boron compounds, such as common borax (sodium borate) and crude borate, Borascu, are used as soil sterilants in the midwestern states. When applied to the soil in rather large amounts, boron is toxic to all plants, but is so much less toxic to grasses than to broadleaf weeds that its value as a weed killer is greatly reduced. These compounds usually do not leach downward readily in the soil, so they may require more time than some of the other sterilants to kill deep-rooted perennials. Other boron compounds that are more soluble and may be more effective are sodium metaborate and sodium pentaborate. Boron compounds are of little value in Ohio.

Monuron and Diuron

Monuron [3-(4-chlorophenyl)-1,1-dimethylurea; trade name Telvar] and the closely related diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea; trade name Karmex] are extremely toxic to many plants. They are not recommended for use as herbicides in field crops in Ohio. However, they are used in a few horticultural crops. They are outstanding as soil sterilants where it is desirable to prevent all plant growth, as on drives, tennis, courts, rights-of-way, oil tank farms, around lumber yards, etc. They should not be applied, or equipment drained or flushed, where there is the slightest possibility that they may be washed or moved into contact with roots of trees, grass or other desired plants that are to be saved.

A reasonably safe distance from desirable trees and shrubs where there is no slope is 80 feet. A greater distance is required where the land is sloping or where the roots of desirable plants extend laterally for a considerable distance. Ponds and streams should not be contaminated by these herbicides.

Simazine

Simazine at 10 to 15 pounds active ingredient per acre will give full-season control of annual and many perennial weeds. For best results, simazine should be applied prior to or during weed emergence. Where the weeds are 3 to 4 inches high or higher, a mixture of simazine plus amitrol at 10 plus 4 pounds per acre may prove more satisfactory.

Sodium Chlorate

Sodium chlorate ($NaClO_3$) is a crystalline salt this is most valuable as a soil sterilant. It moves with soil water and so may affect plants and hard-to-kill weeds shortly after application. It sterilizes the soil for 6 months to 3 years, depending largely on the amount of water that moves through the soil.

Sodium chlorate is readily and preferably applied dry, but it can also be used in water sprays. It is not caustic to the skin and is essentially nonpoison-

ous. However, **sodium chlorate is a definite fire hazard.** Pure sodium chlorate will not burn, but if mixed with straw, wood, cloth, leather or other organic materials, or with sulfur, the mixture becomes explosively inflammable and can be ignited by friction or a blow. Consequently, **every precaution must be used to prevent the spillilng of chlorate or its solution on floors or truck beds. Clothing wet with chlorate spray should be removed at once and washed thoroughly. Rubber boots should be worn when applying chlorate. Many fires, personal injuries and some deaths have been caused by the careless use of chlorate.**

Mixtures of Soil Sterilants

Mixtures of soil sterilants (sodium chlorate, TCA, boron compounds, monuron, etc.) are available on the market. The addition of borax to sodium chlorate, which is a potential fire hazard on dead plants or any other organic material, reduces the hazard without reducing the effectiveness of either herbicide on weeds. Mixtures of other soil sterilants are, under may circumstances, more satisfactory than any of the compounds applied alone. **When buying herbicides under trade names, check the label for the active ingredients and also for the type of weeds and conditions for which the materials are intended.**

In addition to the herbicides mentioned in the preceding discussions, there are many others that are valuable for other uses, such as for horticultural crops. There also are others that have performed well for one or two years and may be recommended after further testing, pending approval by the FDA.

Table 4. Effect of 2,4-D on Crops

Selective control of weeds with 2,4-D is not possible in the crops in Column a. With proper dosages and precautions (specific for each crop) susceptible weeds may be killed in the crops in Columns b and c. The crops in Column c are more tolerant than those in Column b.

a.—2,4-D will kill	b.—2,4-D will injure	c.—2-4-D will not usually injure
Alfalfa	Barley	Bromegrass
Alsike clover	Bentgrass	Fescue grasses
Birdsfoot trefoil	Corn	Kentucky bluegrass
Cotton	Flax	Orchardgrass
Cowpea	Lespedeza	Reed canarygrass
Crimson clover	Oats	Timothy
Field pea	Redtop	
Red clover	Rye	
Soybean	Sorghums	
Sugar beet	Wheat	
Sweetclovers	White clover	
Vetches	(includes Ladino)	

Table 5. Seedlings or Young Growth of the Following Weeds Will Usually Be Killed or Controlled by 2,4-D at the ¼- to ½-Pound-per-Acre Rate Recommended for Corn and Small Grain Fields

Annuals	Perennials and Biennials
Black medic or yellow trefoil	Artichoke
Butterprint, Indian mallow or velvetleaf	Bindweed, field* (often called morning glory)
Carpetweed	Bindweed, hedge*
Cocklebur	Buckhorn
Fanweed, Frenchweed, or stinkweed	Bull thistle
Fleabane, daisy	Burdock
Flower-of-an-hour	Canada thistle*
Galinsoga	Chicory
Hemp	Cinquefoils, five-fingers
Lambsquarters	Dandelion
Morning glory (annual)	Heal-all
Mustard, tumbling	Nettle, stinging
Mustard, wild, or charlock	Plantain, common
Peppergrass	Sunflowers, perennial
Pigweed, rough	Wild sweet potato, man-of-the earth
Pigweed, prostrate	
Radish, wild	
Ragweed, common	
Ragweed, giant	
Sunflower	
Tumbling amaranth	

* See discussion section.

Table 6. Weeds Not Usually Killed or Controlled by 2-4-D at the ¼- to ½-pound-per-acre rate

A star (*) indicates weeds usually killed or controlled by 2 to 3 pounds of 2,4-D acid per acre.

Annuals	Perennials and Biennials	
Bitter wintercress	Aster, fall—*Aster,* sp.	Milkweed, common†
Black nightshade	Blackberries	*Milkweed, climbing
*Bedstraw	Bladder campion	*Mouse-ear chickweed†
*Buckwheat, wild	Bermudagrass	*Mullein, common
Catchflys	Bouncing Bet	Night-blooming catchfly
*Chickweed, common†	Butter and eggs	Nimblewill
Corn cockle	*Buttercups	Oxeye daisy
*Dodders	*Carrot, wild	*Pokeweed
*Fleabane, Canada (marestail)	Cattails	Quackgrass†
Grasses, all	*Catnip	*Sorrell, red or sheep
*Henbit or deadnettle	*Docks	Spurges
*Jimsonweed	*Dogbone (Indian hemp)	Swamp or perennial smartweed
*Knotwood, doorweed	Foxglove beardtongue	*Teasel
*Lettuce, prickly	*Goatsbeard	Violets
*Mallow, roundleaf	*Goldenrods	*Water hemlock
*Mayweed or dogfennel	Ground cherry	White cockle
*Purslane	*Ground ivy	*Wild garlic†
*Shepherd's purse	Horse nettle	*Wild onion†
*Smartweed	*Horsetail	*Wild parsnip
Speedwells	Ironweed	*Yarrow
*Wild cucumber	Johnsongrass†	
Wood sorrel		

† See discussion section.