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Chemical Control of Weeds in South Dakota

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South Dakota Agricultural Experiment Station

AGRONOMY DEPARTMENT
SOUTH DAKOTA STATE COLLEGE • BROOKINGS

Contents

This publication discusses chemical methods of controlling weeds and replaces C69, *Chemical Control of Weeds in South Dakota,* Revised 1951. Details for using cultural methods in controlling noxious weeds are in Circular 75, which is available at your county agent's office, or at the Bulletin Department, South Dakota State College, Agricultural Experiment Station, Brookings.

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Chemical Control of Weeds in South Dakota[1]

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Chemicals

There are now many chemicals on the market that have possibilities for use in weed control. This circular explains the use and value of the more important chemicals.

Recommendations are based on experimental results from cooperative tests in South Dakota and from those reported at the North Central Weed Control Conference. The tests in South Dakota include 49 sets of plots established throughout the state from 1945 to 1950, work conducted at the Weed Research Farm at Scotland from 1946 to 1950, work conducted at Brookings from 1947 to 1951 and at a Weed Research Farm near Gary which was established in 1950.

Recommended Chemicals

South Dakota led the nation in the number of crop acres sprayed during the last three years. Recommended chemicals include 2,4-D, 2,4,5-T, MCP, TCA, the dinitro compounds and the heavy chemicals—sodium chlorate, the boron compounds and amate.

2,4-D (2,4-dichlorophenoxyacetic acid) is used to control many broad-leaved weeds in crops. 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) and MCP (2-methyl-4-chlorophenoxyacetic acid) are closely related to 2,4-D, but are more expensive and are not as widely used. 2,4,5-T has proved to be highly efficient in the control of certain woody plants that are tolerant to 2,4-D. It may be used alone on certain species, but is generally used in mixtures with 2,4-D which are sold as "Brush Killers" for use on areas where several species of woody plants are prevalent. MCP is less toxic to some broad-leaved annual weeds in flax.

2,4-D, 2,4,5-T and MCP are insoluble in water, but they are made soluble by treating them with other chemicals. This results in the manufacture of many formulations all of which can be used as ester, amine, or sodium salt sprays or ester, amine or sodium salt dusts. The most common forms of 2,4-D are the alkyl esters, the low volatile esters, and the amine salts. 2,4,5-T is generally

[1]Contribution from South Dakota Agricultural Experiment Station, in cooperation with the Bureau of Plant Industry, Soils and Agricultural Engineering, and with the State Weed Board.

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ERRATUM: Line 7, Column 2; *for* MCP is less toxic to some broad-leaved annual weeds in flax., *read:* MCP is less toxic to some broad-leaved plants, and its chief use will be for the control of broad-leaved annual weeds in flax.

sold in the form of low volatile esters, while MCP is most commonly found in an amine form. All can be used as sprays.

Many alkyl ester forms of 2,4-D are found on the market. Methyl ester, ethyl ester, isopropyl ester and butyl ester are equally effective for weed control. The term "alkyl ester," often found on labels, means that any one or more than one of these esters may be in the compound. Low volatile esters of 2,4-D and 2,4,5-T, which are less hazardous to use near sensitive plants are available. This group includes butoxyethanol ester, polyethlene glycol half ester, propylene glycol butyl ester, polypropylene butyl ether ester, pentasyl ester and others. Although these low volatile esters appear to be about equally effective, there is not enough experimental evidence to be certain. Their higher relative cost prevents their general use for selective weed control in crops. They are, in general, more effective for woody plant control and are used extensively for this purpose.

The triethyl amines, diethanol amines, triethanol amines and morpholine amines of 2,4-D are considered to be equally effective. The term "alkanol amine," found on 2,4-D and MCP containers, means that any one or more than one of the above mentioned "ethanol amines" may be in the compound.

The esters are generally more toxic to annual plants and are more hazardous to use when spraying in crops. The amines and monohydrate sodium salts are about equally effective. The ester forms are soluble in oil and may be applied with oil or water as the carrier. The amines and sodium salt must be applied in water.

Use of dusts is recommended only in areas that have a limited supply of water. Dusts are more difficult to control than sprays as wind will carry the drift for several miles. Therefore, dusts are more hazardous than sprays and more chemical per acre is needed. They should be used only when drift will not contact susceptible crops or trees. The ester dusts of 2,4-D are more effective than the sodium salt dusts. Very little is known about the other dusts.

TCA (trichloroacetic acid) is a grass killer which has proved to be the best chemical available for the control of quackgrass. It also may be used for the control of foxtail in flax. However, it is too expensive to be practical for use on large areas.

TCA is treated with other chemicals to produce the more usable ammonium salt, sodium salt and calcium salt forms. All are in powder form with the sodium being the most common. The ammonium and sodium salts are equally effective, but the sodium salt is the cheaper. The calcium salt has not been tested sufficiently to determine its effectiveness. TCA is nonselective and will kill or damage plants of both the grass and broad-leaved species. *This chemical has strong caustic properties. Avoid contact with the skin as much as possible.*

Heavy chemicals—sodium chlorate, several borate compounds and

HAZARDS AND PRECAUTIONS

2,4-D is a highly selective and highly efficient tool in weed control. Indiscriminate and haphazard use of this chemical and other similar herbicides has resulted in extensive injury to crops in some areas. Lawsuits and restrictive legislation have followed. Since these chemicals do not respect crop or field boundaries, extreme care and a full knowledge of their potentialities are essential before they can be used safely in weed control.

Sprays of 2,4-D, 2,4,5-T and MCP are easily carried considerable distances by air movement. This drift may damage gardens, windbreaks, flower beds, orchards, or other sensitive crops. Sprays applied by airplanes or turbines are more subject to drift than sprays applied by boom-type sprayers. The applications of dusts is also more hazardous in areas adjacent to sensitive crops.

Vapors of standard ester formulations of 2,4-D and 2,4,5,-T may be carried considerable distances in concentrations that are toxic to sensitive plants. This danger may exist for several hours or several days after application of the chemical. Empty containers should not be discarded near gardens growing sensitive crops. Recently, less volatile ester formulations (not so likely to vaporize and be carried to sensitive plants) of 2,4-D and 2,4,5-T have been marketed. These markedly reduce the hazards associated with the use of these materials.

These chemicals, especially 2,4-D are difficult to remove from sprayers or dusters. The later use of 2,4-D equipment for the application of fungicides and insecticides to crops that are sensitive to 2,4-D may cause crop injury.

Do not become alarmed on noting early abnormalities in growth of plants listed as tolerant when treated with recommended dosages of 2,4-D or MCP. These abnormalities may have little or no effect on ultimate yield.

amate (ammonium sulfamate)—are recommended for the elimination of small patches of perennial weeds. Borates are formulated as several boron compounds, including "Borascu," "Concentrated Borascu" and "Polybor." The main difference in these compounds is the different percentage of borates contained in them. Both forms of "Borascu" are granulated and are insoluble in water, but "Polybor" is a powder and can be applied as a spray or as a dust. All are equally effective when the same amount of borates (active ingredient) is applied. "Polybor" is the fastest acting chemical followed in order by "Concentrated Borascu" and "Borascu."

Borates and chlorates are formulated into mixtures known as "Polybor-chlorate" and "Chlorax." Both are in powder form; both are soluble in water and may be applied as sprays. The main difference is the relative proportions of borates and chlorates.

Sodium chlorate is handled commercially as "Chlorate of Soda" or as "Atlacide." The "Chlorate of Soda" contains a higher percentage of sodium chlorate; consequently, less chemical is needed to give the same amount of kill. Both chemicals are soluble in water and may be applied as sprays. *Caution must be observed when using these chemicals. After clothing or foliage has been wet with spray of these chemicals and then dried, they are highly inflammable.* Dry application of sodium chlorate reduces the fire hazard. However, salt-hungry cattle will eat dry applications of this chemical and become poisoned.

Amate is a granulated compound sold commercially in an ammonium salt form. It is soluble in water and may be applied dry or as a spray.

The borates and chlorates leave the soil unproductive for one or more years.

Selective dinitro compounds are recommended for annual weed control in cereals or flax underseeded with legumes. Directions on commercial containers should be followed closely. General dinitro compounds can be used to kill all top growth. Neither group of compounds is systemic and, therefore, does not kill roots.

Other Chemicals Tested

Endothal (3,6 endoxohexahydrophthalate) has been extensively tested at the South Dakota Agricultural Experiment Station. This new material, although promising for selective control of annual grass weeds in certain crops, will not be available for field use in 1952.

CMU (3-p-Chlorophenyl-l-l-dimethyl urea) is a promising new chemical herbicide for use as a soil sterilant[3] and perhaps as a selective pre-emergence treatment. Although a limited amount will be available on the market in 1952, it is suggested that it be used only on an experimental basis on non-crop land.

Certain chemical materials such as MH (maleic hydrazide), Chlorsol-A, Sulfasan, IPC (isopropyl-N-phenylcarbamate), CIPC [isopropyl-N-(3 Chlorophenyl) carbamate] and SES (Crag E. H. 1 or sodium 2,4-dichlorophenoxyethyl sulfate) while widely publicized, have been thoroughly tested at agricultural experimental stations in the North Central states with little or no promise for practical field use.

[3]A soil sterilant is a material which renders the soil incapable of supporting plant growth. Sterilization may be temporary or relatively permanent.

Effects of Chemicals on Crops

Application of chemicals to crops will cause more damage at certain stages than at others. If the most tolerant stage of the crop does not occur when it is most advantageous to spray the weed, then the individual must decide whether he wishes to sacrifice some of his crop and get maximum weed control or get poorer weed control with less risk of injuring his crop.

The effect of chemicals on the important agronomic crops is discussed here, while the effects of chemicals on weeds are outlined in the next section.

Barley, wheat and oats are most susceptible to 2,4-D before the fifth leaf is expanded and during heading time. Applications of 2,4-D for weed control should be made between the five-leaf and early boot stages of growth, or after the milk stage in order to reduce the risk of injuring the crop. The amount of chemical to be used should be governed by the weed to be controlled. If more than one-half pound of 2,4-D acid per acre is needed to control the weeds, one can expect some injury to the crop. However, the advantages gained in controlling the weeds may offset any reduction in yield. The amine forms are less toxic to these crops than the ester forms when the same amount of chemical is used.

The growing period of barley can be divided into at least four developmental periods, each responding in a different way to 2,4-D. The *first* period should not be treated, as it is a susceptible seedling period beginning when the grain comes up and ending when the fifth leaf is expanded (two seedling leaves may have disappeared making it appear to have three leaves). The application of 2,4-D during this period stops the formation of tillers. When the number of tillers is decreased, the number of heads is reduced and yield is generally greatly depressed. Abnormal leaves are also formed.

The *second* period (between five-leaf and early boot stages) is relatively tolerant and is the safest period for applying 2,4-D. Any crop injury is generally offset by the advantages gained in weed control. The application of 2,4-D affects the formation of the head if applied when the head is being formed inside the plant. The severity of the injury is proportional to the number of heads being formed when the 2,4-D is applied. When injury is caused, it appears in the form of abnormal heads and partially filled heads.

In a dry year, heads are formed in the main stems in three or four days, followed by a second interval of several days when no heads are being formed, followed in turn by a third interval of several days when heads are being formed in the tillers. During the time that heads are being formed, an application of 2,4-D may cause serious yield reductions due to a decrease in the number of seeds per head. Many abnormal heads and unfilled heads are produced.

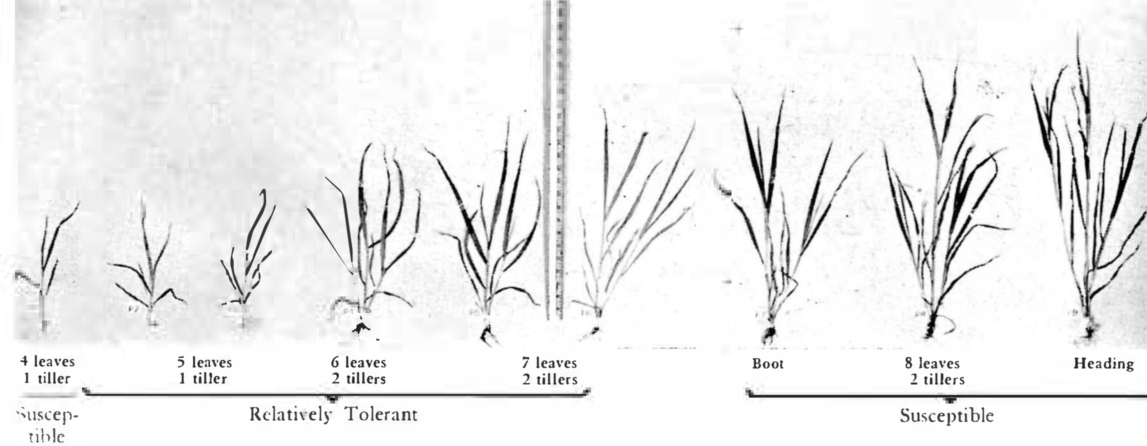

Fig. 1. Nine stages of growth of barley showing the number of leaves and tillers normally found in each of the first three developmental periods of growth. The age of any two consecutive stages differs by three days

In a wet, cool year, some heads are being formed all the time and the three intervals become one period about two weeks long. Consequently, fewer heads are being formed at any one time and the application of 2,4-D does not greatly reduce the yield. A few abnormal heads and a few partially filled heads are sometimes formed, however.

The *third* developmental period (between the boot stage and the time when heading is completed) is another susceptible period that should not be treated with 2,4-D. The effects are not fully understood, but generally, yield is materially decreased. The reduction in yield is associated with a decrease in number of seeds per head, an increased amount of blasting and otherwise unfilled heads, frequent lodging and delayed maturity.

During the *fourth* period (after grain is in the milk), the application of 2,4-D does not normally cause any injury to small grain. When the grain is this far advanced in growth, the weeds have done all the damage they will do. The only reason for spraying at this time would be to dry up the weeds to facilitate harvesting operations.

Wheat and oats are affected in much the same way as barley except that oats are somewhat more tolerant during the first and third developmental periods and sometimes much more susceptible during the second period.

Wisconsin 38, and possibly Moore, are more susceptible than most of the other barley varieties grown in South Dakota. Mindo and Marion are the most susceptible oat varieties commonly grown in South Dakota, but Clinton, Tama and Andrew are more susceptible than several other varieties.

All of the wheat varieties have not been tested, but there is some indication that Rescue, Thatcher and Regent are more susceptible than several other varieties. Canadian workers report that Montcalm, Prospect and Vantage barley and Anthony, Vanguard and Ajax oats are more susceptible than other varieties of the same crop.

Winter wheat and winter rye respond much the same as outlined for spring grains, but the application must be made during the spring.

Flax is the most tolerant of chemicals when very young (3 to 5 inches tall). At this stage susceptible broad-leaved annual weeds may be controlled by the use of 2,4-D or MCP without appreciable injury to the flax. Although MCP is less toxic to flax, the recommendations are the same for both chemicals. MCP costs about three times as much as 2,4-D, but an increase of one bushel of flax per acre will more than pay the difference in cost. Therefore, the MCP is recommended in preference to 2,4-D. Not more than one-fourth pound of 2,4-D or MCP acid per acre should be used. The flax may appear wilted for several days, but the proper application should not cause a decrease in yield. *The use of an ester form is extremely hazardous and injury may result when only one-fourth pound is applied.* If it is necessary to apply more than one-fourth pound of chemical to control the weeds, one can expect damage to the flax. However, the advantage in controlling weeds may offset any reduction in yield.

2,4-D or MCP should be applied as soon as all of the weeds are up, because less chemical is required to kill the weeds and the flax is most tolerant when young. Either chemical may kill the growing point, which is located at the top of the flax plant. If this is done, growing points on the side of the plant will start. The earlier they start to grow, the less will be the decrease in yield or delay in maturity. Flax is extremely sensitive after it starts to bud and before the bolls are set.

Three years' data show that TCA applied at rates of 5 to 8 pounds of TCA acid per acre will control foxtail without injuring the flax. It is essential that the treatment be applied before the foxtail is 2 inches tall.

Corn may be treated with 2,4-D, if weeds cannot be controlled with cultivation. Many annual broad-leaved weeds may be controlled. A maximum application of one-fourth pound of an ester or one-half pound of an amine does not generally reduce yields. Any application of 2,4-D will often cause the corn to wilt shortly after treatment, but the corn will recover. 2,4-D may also cause abnormal growth of brace roots, curvature of stalks or brittleness of stalks. Brittle corn is subject to breakage by wind or cultivator. The application of 2,4-D when corn is in the six- to eight-leaf stage of growth may result in the formation of barren tassels. *Likewise, the application of 2,4-D shortly before silks emerge may cause cobs to be bare and result in a large yield reduction.* Corn is most tolerant before the six-leaf stage, or between eight-leaf stage and five days prior to silking, or after pollination.

If noxious weeds are to be treated in corn, some reduction in yield may be expected. If 2,4-D is used for controlling small patches of perennial weeds, it is advisable to leave the patch uncultivated all summer so that the chemical can have a maximum effect on the weed.

Pre-emergence weed control in corn has proved to be highly successful under ideal weather conditions. Both annual grass weed seedlings and annual broad-leaf weed seedlings may be controlled or eliminated by applications of 2,4-D to the soil just before the emergence of the corn seedlings. Only the esters of 2,4-D should be used in this type of treatment and at rates of 1¼ to 1½ pounds per acre. Treatments of this type should not be used on light or sandy soils as rainfall following applications may leach the herbicides to the corn roots with dire consequences. Extremely dry weather following planting of corn and applications of 2,4-D will result in poor weed control on any soil type.

In using 2,4-D as a pre-emergence treatment, it is essential to make the application as close to the date of emergence of the corn seedlings as possible. Apparent malformations of the corn seedlings following this use are not important if the roots of the seedlings show no injury. Under ideal conditions of field practice this type of treatment with 2,4-D has eliminated the first cultivation commonly employed in corn production.

Sorghum can be treated as outlined for corn. However, *sorghum should not be treated between the five-leaf and nine- or ten-leaf stage of growth as serious root injury, a decrease in the number of seeds and a yield reduction may follow.* Likewise, the application of 2,4-D dur-

Fig. 2. Various degrees of root injury in corn following excessive use of 2,4-D

ing pollination may cause parts of the head to be bare of seeds and result in a reduced yield. Sorghum is relatively tolerant before the five-leaf stage; in fact, the amount of suckering may be reduced if 2,4-D is applied at this stage. Sorghum is also relatively tolerant between the ten-leaf stage and pollination and again after pollination.

Grass **Crops** are relatively tolerant to 2,4-D. New seedlings should not be treated until after the grass is well tillered. No more than one-fourth to one-half pound of 2,4-D acid per acre should be applied at this stage. Where there is a mixed infestation of annual broad-leaved and annual grass weed seedlings, the elimination of the broad-leaved weeds will favor the development of the grass weeds. The grass weeds may offer more competition than the mixed stand of weeds.

Established stands of perennial grasses such as blue grass, bromegrass, and the wheatgrasses are, in general, very tolerant of 2,4-D. Rates of application necessary for the control and elimination of weeds infesting these crops can be used without reduction in yield of forage or seed. Application of 2,4-D should be made when the weeds are most susceptible. Grasses that are to be harvested for seed should be treated before heads appear.

Other crops such as sugar beets, soybeans, peas, buckwheat, potatoes, alfalfa and other legume crops, and most garden vegetables are very sensitive to 2,4-D, 2,4,5-T, MCP. However, annual grasses, such as foxtails, have been eliminated from sugar beet fields with a pre-emergence application of 8 pounds of TCA acid per acre.

Chemical weed control can be accomplished in several types of garden crops, shelter belts, and lawns. Specific chemicals and techniques in their use are required for different crops. Recommendations for control of weeds in vegetable crops, small fruits, orchards and lawns can be obtained from the Extension Service, South Dakota State College by asking for Extension Circular 465, "Controlling Weeds in Gardens and Lawns."

Fig. 3. Foxtail and barnyard grass seedlings showing effect of the new selective grass killers being tested at the South Dakota Agricultural Experiment Station

Fig. 4. Right: Showing the effects of applying sodium chlorate to a small area which was infested with perennial weeds. Left: Applying the chemical to an untreated area

Weed Control

Considerable research has been conducted on the use of chemicals on most of the noxious weeds, making it possible to give more detailed recommendations. Other perennial, biennial, annual and woody weeds have been tested sufficiently to give their reactions to 2,4-D and 2,4,5-T.

Noxious Weeds

Field bindweed (Creeping Jenny) can be satisfactorily controlled with three-fourths pound of 2,4-D per acre whether growing in perennial grasses, small grains or areas that are not cropped. Sometimes, when there is plenty of soil moisture, one-half pound of 2,4-D per acre will give satisfactory control of the weed growing in crops. In the more humid portions of the state, the most practical control is obtained by applying an amine form when the weed is starting to bloom. In the drier areas best results have been obtained by applying an ester form as soon as all of the plants are up in the spring.

The high rate of application required to control this weed may cause damage to small grains and early spring treatments increase this risk. 2,4-D may be used with or without cultivation. If re-treatments are necessary they should not be made until the remaining weeds have recovered from the first application, which is generally one year or more after the original treatment. 2,4-D is more effective than 2,4,5-T or MCP.

Small patches may be eliminated by the use of heavy chemicals. Five pounds of sodium chlorate or 6 pounds of "Atlacide" per square rod are recommended. However, 25 pounds of "Borascu" or 12 to 15 pounds of the other boron compounds per square rod are often effective. Treatments are most effective if applied between July 1 and October 15.

Canada thistle and perennial sow thistle can be controlled with two applications of three-fourths pound of 2,4-D acid per acre. This high rate of application may cause damage to small grains. The first application should be made when the thistles are starting to bud and the second treatment should be applied in September. These weeds can be controlled when growing in perennial grasses, small grains or areas not cropped. 2,4-D may be used with or without cultivation. The amine form of 2,4-D generally gives better control as the esters kill tops too quickly. Two applications will generally kill most of the susceptible plants and other measures of control may be needed to kill plants that survive these two treatments. In some cases MCP has proved to be more effective than 2,4-D when applied as outlined for 2,4-D; 2,4,5-T is not effective. Small patches should be eliminated in the manner described for field bindweed.

Leafy spurge is relatively tolerant to 2,4-D, and is even more tolerant of 2,4,5-T or MCP. It is seldom eliminated with these chemicals. The top growth can be almost completely destroyed with three-fourths to one pound of 2,4-D per acre, but roots remain alive. The ester form of 2,4-D is more effective than the amine. Several repeat applications, made each time the plant is in bud or early flower will greatly weaken or "thin out" stands, but two or three years are required to give appreciable control.

2,4-D is the most practical chemical available for control of large infested areas in crops, but the high rate of application necessary may cause damage to small grains. Where possible, large infestations should be planted to an adapted perennial grass, such as bromegrass. The competitive effect of bromegrass enhances the action of 2,4-D and there is no measurable effect of the chemical on seed or hay yields.

Boron compounds are recommended for elimination of small patches. Fifteen pounds of "Borascu" or 10 to 12 pounds of the other boron compounds per square rod generally give complete elimination. Five pounds of sodium chlorate, 6 pounds of "Atlacide" or 4 pounds of amate per square rod are also quite often effective. Treatments should be applied between July 1 and October 15.

Quackgrass is resistant to 2,4-D, 2,4,5-T, MCP, the boron compounds and amate. TCA has proved to be the most practical chemical available for the control of this weed. Fairly good control can be obtained by treating quackgrass sod with 40 pounds of TCA acid per acre in the fall. At least 100 pounds are needed at any other time of the year. Best results can generally be

Fig. 5. Fifteen pounds of borax per square rod will eliminate leafy spurge

obtained by applying 40 pounds per acre after the area has been plowed shallowly. The cost of the chemical is rather high, making it impractical for use on large areas.

Russian knapweed is relatively tolerant to 2,4-D, 2,4,5-T and MCP. However, one application of 1½ pounds per acre will prevent seeding and kill the top growth. The low volatile esters of 2,4-D appear to be the most effective form for the control of this weed. Small patches can generally be eliminated with 5 pounds of sodium chlorate per square rod or with 6 pounds of "Atlacide" or 16 pounds of "Polyborchlorate." The straight boron compounds are ineffective at normal rates of application.

Perennial peppergrass (hoary cress or white top) can be controlled by repeated applications of 1 pound of 2,4-D acid per acre in the ester form. The first application should be made in the spring when buds begin to turn white. Two or three weeks later a second treatment should be made on plants that were not up when treated the first time. A third application should be made in the fall if the weed reappears. If possible, the infested areas should be cultivated in midsummer, two weeks after the second treatment. Re-treatments should be made the following year if necessary. Small patches can be eliminated by the use of chlorate as outlined for field bindweed.

Horse nettle is resistant to 2,4-D and MCP, but repeat applications of 1½ to 2 pounds of an ester of 2,4,5-T per acre will greatly reduce the stand. Treatments should be applied between the time the weed blooms and the time it sets fruit.

Other Perennials, Biennials

Many perennials and biennials have been treated with 2,4-D and can be classified as generally susceptible, moderately tolerant or highly resistant. The perennial weeds in the following list are followed by the letter "p" and biennials are marked by the letter "b." Some grow as a biennial under some conditions and as a perennial under others. Those are marked "pb."

1. **Generally susceptible** weeds can often be eliminated with one application of one-half to three-fourths pound of 2,4-D per acre. Retreatments are usually necessary.

Austrian fieldcress—p
Bitter wintercress—pb
Buckhorn
Bull thistle—p
Burdock—p
Chicory—p
Curled dock—p
Dandelion—p
Field bindweed—p
Ground ivy—p
Heal-all—p
Hedge bindweed—p
Lawn-pennywort—p
Nettles—p
Sweet clovers—b
Western ragweed—p
Wild carrot—b

2. **Moderately tolerant** weeds are seldom eliminated with one treatment. Top growth is usually killed and the stand reduced by a single application of one-half to one pound 2,4-D per acre.

Blue lettuce—p
Burr ragweed—p
Canada thistle—p
Perennial peppergrass—p
Perennial sow thistle—p
Poverty weed—p
Dogbane—p
Goatsbeard—b
Goldenrod—p
Ironweed—p
Red sorrel—p
Russian knapweed—p
Silverleaf poverty weed—p

3. **Highly resistant** weeds are seldom controlled satisfactorily with 2,4-D.

Alkali mallow—p
Cactus—p
Climbing milkweed—p
Grass weeds—pb
Hoary vervain—p
Horse nettle—p
Milkweed—p
Mullein—b
Oxeye daisy—p
Swamp smartweed—p
Toadflax—p
White cockle—pb
Wild garlic—p
Wild gourd—p
Wild onion—p
Wood sorrel—p
Yarrow—p

Some of the weeds such as prickly pear cactus and yucca are resistant to 2,4-D, but can often be controlled with 2,4,5-T. Elimination of prickly pear cactus can be obtained with applications of a 2 percent solution of 2,4,5-T ester in oil, in either June or early September. (A 2 percent oil spray solution can be made up by mixing 1 pint of 2,4,5-T formulation, containing 4 pounds acid per gallon, with approximately 3 gallons of fuel oil.) Yucca, or soap weed, responds to the same treatment recommended for prickly pear cactus.

Annual Weeds

The greatest use of 2,4-D is in the elimination of annual weeds in growing crops. Sunflower, cocklebur, kochia, frenchweed, mustard, ragweed, pigweed and others can generally be killed with one-fourth pound of 2,4-D acid per acre. Treatments should be made when the weeds are in the seedling stage of growth (2 to 8 inches tall).

Annual weeds in the following list are marked by the letter "a," and winter annuals by the letter "w."

Some act as annuals under certain conditions and as winter annuals under others. These are marked "aw."

1. **Generally susceptible** weeds can generally be killed with one-fourth pound of 2,4-D acid per acre if treated when quite young. More 2,4-D is needed when treatments are made at the blossom and seed-setting stages, or under poor growing conditions such as low soil moisture.

Annual sow thistle—aw
Cinquefoil and other fivefingers—aw
Cocklebur—a
False flax—aw
Frenchweed (pennycress)—aw

Hoary alyssum—aw	Pigweeds—a
Lamb's quarters—a	Puncture vine—a
Ragweeds—a	Shepherds purse—aw
Mallow—a	Sunflowers—a
Marsh elder—a	Speedwells—aw
Most mustards—aw	Wild radish—aw
Peppergrass—aw	Yellow trefoil—a

2. **Moderately tolerant** weeds will be killed, or their growth stunted, if treated with one-third to one-half pound of 2,4-D per acre. The 2,4-D should be applied when the weeds are in the seedling stage of growth, as they become quite tolerant at later stages.

Chickweed—a	Russian thistle—a
Gumweed—aw	Smartweeds—a
Kochia—a	Wild buckwheat—a
Mare's tail—a	Wild lettuce—aw
Prickly lettuce—aw	

3. **Highly resistant** weeds are not killed and are usually only slightly injured by 2,4-D.

Black nightshade—a	Knotweed—a
Buffalo bur—a	Mat spurge—a
Corn cockle—a	Night flowering catchfly—aw
Cow cockle—a	Sandbur—a
Grass weeds—aw	Purslane—a

Woody Plants

Many of the woody plants common to South Dakota have been experimentally treated with 2,4,5-T, 2,4-D or commercial mixtures of the two herbicides. These test treatments have indicated that 2,4,5-T, or commercial mixtures containing a high percentage of 2,4,5-T, are generally more efficient in controlling or eliminating mixed stands of woody species than 2,4-D.

Wild rose, blackberry, raspberry, and other related species of brambles and certain leguminous species are much more readily controlled with 2,4,5-T than with 2,4-D. There are, however, several common species of trees and shrubs that can be eliminated as efficiently with the cheaper 2,4-D formulations.

1. **Generally susceptible** woody plants may be controlled with 2,4-D, 2,4,5-T or mixtures of the two.

For sand sage, three-fourths to one pound acid per acre is sufficient when applied in 4 gallons of oil, or oil-water emulsion, by plane; or in 40 gallons of water per acre by ground equipment.

In treating trees of medium height, or mixed trees and brush, spray volumes of 80 to 100 gallons of water per acre are desirable. Foliage of woody plants must be *thoroughly and uniformly wetted with the spray solution.* Many woody species react most satisfactorily to spray application of 2,4,5-T or 2,4-D when treatments are made shortly after full leaf development in late spring. Species such as sand sage are difficult to control with treatments made after this growth period. Poison ivy is one exception to this general rule and responds well to midsummer treatments with 2,4,5-T or mixtures.

In the following check list of local woody shrubs and trees, the species more efficiently controlled with 2,4-D are indicated with the letter "D," while those that are easily controlled with 2,4,5-T are indicated with a "T" and those requiring a mixture are designated with an "M." Species listed can be economically controlled with 2 to 4 pounds acid per acre.

Alder—D	Poison ivy—M
Blackberry—T	Poplar—M
Boxelder—D	Prickly ash—T
Choke-cherry—M	Sagebrush—D
Cottonwood—M	Silverberry—D
Currant—M	Skunkbrush—M
Elderberry—M	Sumac—D
Gooseberry—T	Thornapple—M
Grape—M	Wild rose—T
Hazelbrush—D	Willow—D
Locust—T	Wormwood—D
Plum—M	

2. **Generally tolerant** species listed below can be defoliated by applications of 2,4,5-T or 2,4-D, but satisfactory control is seldom attained.

Ash	Hackberry
Barberry, Japanese	Leadplant
Buckbrush	Mulberry
Cedar	Pine
Dogwood	Spruce

Dormant treatment of trees and stumps with commercial formulations containing mixtures of 2,4-D and 2,4,5-T has proved efficient in the elimination of stump sprouts and in killing large trees of such species as elm, willow, oak, and wild cherry. Spray solutions made up of 1 pint of a 4-pound acid per gallon formulation in 1 gallon of diesel fuel or kerosene are used. Applications should be made during the dormant winter season, preferably January through March. Where trees are cut, the entire fresh-cut surface and bark to the ground level should be saturated with the oil spray solution. In treating standing trees the bark area from ground level up to a height of 12 inches should be saturated to the point of run-off with the oil spray solution.

Amate is useful for causing stumps to decay and to prevent sprouting. It is applied by boring holes in the top of the stump or side of tree. These holes are then filled with the granular chemical. Two ounces of chemical for every 6 inches of diameter of tree are sufficient.

Application of Chemicals

When low volumes of water (5-10 gallons per acre) are used, the slightest error may be disastrous. Therefore, it is advisable to calibrate the sprayer carefully before using it and to recheck it often to be certain that an exact amount of material is being applied. The entire sprayer system must be kept free of sediment to insure a constant flow from low-volume nozzles.

Amount of Water Required

2,4-D, 2,4,5-T and **MCP** may be applied using from 2 to 80 gallons of water per acre. Water serves as a carrier and the amount used does not influence the results if the applications are made properly. The correct use of suitable equipment is essential. Aerial sprayers frequently use 1 gallon of oil or 2 gallons of water, but most ground sprayers use approximately 10 gallons of water per acre. If the equipment is properly designed and if the operator knows exactly how much spray solution he is applying, volumes of 5 to 10 gallons per acre are recommended for crop spraying. If equipment or operator is not exact, or if there is a heavy growth, such as at roadsides, it is advisable to use more water.

TCA is relatively soluble in water, but only 1 pound of chemical can be dissolved in 1 gallon of water. If 40 pounds of TCA are applied per acre, at least 40 gallons of water per acre are needed. TCA spray solution will corrode aluminum, brass and other metals used in the manufacture of sprayers and, therefore, equipment should be thoroughly rinsed immediately after TCA is used.

Heavy chemicals are applied at high rates and much water is needed. Approximately 3 pounds of "Polybor" or 1½ pounds of "Polybor-chlorate" or 3 pounds of sodium chlorate or 5 pounds of "amate" can be dissolved in 1 gallon of water. "Borascu" and "Concentrated Borascu" are so insoluble that they should be applied dry.

Amount of Chemical

Field Spraying

Field spraying with 2,4-D, 2,4,5-T, MCP, or TCA is a common practice. To get maximum weed control with a minimum of chemical, it is necessary to determine the exact amount of chemical applied. Since this involves the application of a very small amount of chemical to an acre, it is sometimes difficult to determine how many quarts or pints should be applied.

Most liquid forms designate the number of pounds of acid (2,4-D, 2,4,5-T or MCP) per gallon on the label, whereas most powders or dusts (2,4-D or TCA) designate the percentage of acid. This information is used in the calculations. Liquids, powders and dusts are considered separately.

Liquid Chemicals

Three steps are involved in determining the amount of 2,4-D, 2,4,5-T or MCP to be applied in liquid form. The same calculations can be used for mixtures of 2,4-D and 2,4,5-T if the total amount of the two chemicals is used in the calculations.

Step 1. Determine the number of pounds of acid in one pint of chemical with the following formula:

Number of pounds acid equivalent in container ÷ number of pints in container = pounds of acid (2,4-D, 2,4,5-T or MCP) in one pint.

Example: The label on a 1-gallon container states that there are 3 pounds acid equivalent in the container. Since 1 gallon contains 8 pints, the number of pounds per pint is calculated as follows:

3 ÷ 8 = 0.375 or 3/8 pound acid equivalent per pint.

Step 2. Determine the number of pints to be used per acre with the following formula:

Pounds of acid equivalent to be applied per acre ÷ number of pounds of acid equivalent per pound = number of pints per acre.

Example: Suppose you wished to use one-fourth pound of the above mentioned chemical per acre. The calculation is as follows:

1/4 ÷ 3/8 = 2/3 pint per acre.

For ease in calculation the fractions may be converted to decimals and calculated as follows:

.25 ÷ .375 = .67 or 2/3 pint per acre.

Step 3. Determine the amount of chemical needed for each sprayer load. Use the following formula:

Gallons in sprayer ÷ gallons per acre x number of pints per acre = number of pints per sprayer load.

Example: Suppose the sprayer holds 100 gallons and has been set to deliver 8 gallons per acre. Suppose that one-fourth pound of the chemical mentioned above is to be used. The calculation is as follows:

100 ÷ 8 = 12.5 acres sprayed with one load.

12:5 x 2/3 or .67 = 8⅓ pints per sprayer load.

Powdered Chemicals

The amount of powdered chemical needed for each sprayer load of water can be calculated as follows:

Step 1. Using the following formula, determine the number of pounds of chemical needed per acre.

Pounds of acid per acre ÷ percent of acid = pounds of powder per acre.

Example: Suppose a powdered chemical containing 80 percent TCA acid is to be applied at the rate of 40 pounds of TCA acid per acre. The calculation is as follows:

40 ÷ 80 percent = 50 pounds of powdered chemical per acre.

For ease in calculation, the percent may be changed to a decimal as follows:

40 ÷ .80 = 50 pounds of powdered chemical per acre.

Step 2. Using the following formula, determine the number of acres that one sprayer load will cover.

Gallons in sprayer ÷ gallons per acre = acres per sprayer load.

Example: Suppose that the sprayer holds 100 gallons and has been set to apply 40 gallons per acre. The calculation is as follows:

100 ÷ 40 = 2½ acres per sprayer load.

Step 3. Determine the amount of chemical needed for each sprayer load. Multiply the pounds of powder per acre (Step 1) by the acres per sprayer load (Step 2) in the following formula:

Pounds of powder per acre x acres per sprayer load = pounds of chemical per load.

Example: In Step 1, 50 pounds of chemical is needed per acre, and in Step 2, 2.5 acres can be sprayed with one sprayer load. Therefore, 50 x 2.5 = 125 pounds of powdered TCA per sprayer load.

After the amount of powdered chemical needed for each sprayer load has been determined, it is advisable to select a container that will hold the exact amount needed and use one container full for each sprayer load. In the example above 2½ 50-pound drums would be needed.

Dusts

The amount of 2,4-D dust required to apply a certain amount of 2,4-D acid per acre may be determined as in Step 1 of the calculation for powdered chemical.

Example: Suppose that a dust containing 5 percent 2,4-D acid is to be applied at the rate of one-fourth pound of 2,4-D acid per acre. The pounds of dust needed per acre would be figured as follows:

1/4 ÷ 5 percent = 5 pounds of dust per acre.

When changed to decimals, the calculation would be:

.25 ÷ .05 = 5 pounds of dust per acre.

Patch Treatment

Patch treatment is an important part of a noxious weed control as it is easier to control a small area than it is to wait until the weed spreads over a large area. The heavy chemicals (chlorates, boron compounds and amate) can be used to good advantage on these patches because the proper application of the right chemical will give almost complete elimination for several years. The amount of chemical needed for each noxious weed is given with a discussion of that weed. Some of these chemicals must be applied dry, while others can be applied as a spray. The amount of water needed is discussed under the "Amount of Water Required" section.

If 2,4-D, 2,4,5-T, MCP or TCA are to be used, it is just as important that the right amount of chemical be applied to small patches as it is on large fields. Since all of the recommendations are given in terms of pounds of acid equivalent per acre, it is difficult to determine the amount needed for a small patch. Therefore, Table 1 has been computed to show the amount of chemical needed on a square rod.

These chemicals can be applied in 1 quart to 1 gallon of water per square rod, depending on the size of the nozzle and the speed that the operator walks. It is best to mark out a square rod plot (16½ ft. x 16½ ft.) and measure the amount of water required to cover it. If 2 quarts are needed, the amount of chemical needed for a square rod is measured into each 2 quarts that are used. The same is true for any other amount of water.

Adjusting a Field Sprayer

It is absolutely essential that a sprayer operator knows how much spray is being applied per acre. If he does not, he runs the risk of injuring the crop or of not controlling the weeds. He must, therefore, calibrate his sprayer carefully for each field. One easy method of adjusting his sprayer is as follows:

Step 1. Select an area for a test run that is comparable to the area that is to be sprayed. Accurately measure a distance of one-fourth mile or 1320 feet.

Step 2. Place the sprayer on level ground and fill the tank with water. It may be filled to the brim or to a predetermined height on a measuring stick.

Step 3. Adjust the speed of the tractor and the pressure of the sprayer to the speed and pressure that will be used in spraying. Spray for the one-fourth mile that was measured previously.

Step 4. With the sprayer in a level position, measure the amount of water required to fill the sprayer to the original level.

Step 5. Refer to Table 2 to determine the number of gallons to be applied per acre. Locate the length of sprayer boom in left hand column of table. Then find the number of gallons required to refill the sprayer in the top line. Follow the "length of boom" line across until it is under this column. The figure at that point is the number of gallons to be applied per acre.

Example: Suppose that 3 gallons were applied in the test run and the length of the boom is 16 feet. The table shows that 6.2 gallons were applied per acre.

Table 1. Amount of Chemical Needed on One Square Rod

If pounds acid equivalent to be used per acre are:	This much chemical should be used per square rod — 2,4-D, 2,4,5-T or MCP: Contains 4 lbs. per gal.	2,4-D, 2,4,5-T or MCP: Contains 3 lbs. per gal.	TCA: 90% sodium salt
½	⅔ teaspoonful	⅞ teaspoonful	
¾	1 teaspoonful	1⅓ teaspoonsful	
1	1⅙ teaspoonsful	1¾ teaspoonsful	
1½	2 teaspoonsful	2⅔ teaspoonsful	
2	2⅓ teaspoonsful	3½ teaspoonsful	
5			⅔ cupful
7½			1 cupful
10			1⅓ cupsful
25			3½ cupsful
50			7 cupsful
75			10 cupsful or 2½ quarts

Table 2. Calculating the Amount of Spray Solution Applied Per Acre When a Measured Amount is Applied in a ¼-Mile Test Run

Gallons spray solution delivered in ¼-mile test run—read down for gallons per acre.

Gallons spray solution delivered per acre for booms of length at left.

Boom length in feet	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13	14
14	4.7	5.9	7.1	8.3	9.4	10.6	11.8	12.9	14.1	15.3	16.5	17.7	18.8	20.0	21.2	22.4	23.6	26.0	28.2	30.6	33.0
15	4.4	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2	14.3	15.4	16.5	17.6	18.7	19.8	20.9	22.0	24.2	26.4	28.6	30.8
16	4.1	5.2	6.2	7.2	8.3	9.3	10.3	11.3	12.4	13.4	14.5	15.5	16.5	17.5	18.6	19.6	20.6	22.7	24.8	26.9	29.0
18	3.7	4.6	5.5	6.4	7.3	8.3	9.2	10.1	11.0	11.9	12.8	13.8	14.7	15.6	16.5	17.4	18.3	20.2	22.0	23.8	25.6
20	3.3	4.1	5.0	5.8	6.6	7.4	8.3	9.1	9.9	10.7	11.5	12.4	13.2	14.0	14.9	15.7	16.5	18.2	19.8	21.5	23.0
22	3.0	3.7	4.5	5.3	6.0	6.8	7.5	8.3	9.0	9.8	10.5	11.3	12.0	12.8	13.5	14.3	15.0	16.5	18.0	19.5	21.0
24	2.8	3.4	4.1	4.8	5.5	6.2	6.9	7.6	8.3	9.0	9.6	10.3	11.0	11.7	12.4	13.1	13.8	15.1	16.5	17.9	19.2

Gallons spray solution delivered in ¼-mile test run—read down for gallons per acre.

Gallons spray solution delivered per acre for booms of length at left.

Boom length in feet	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13	14	15	16	18	20
26	5.1	5.7	6.4	7.0	7.6	8.3	8.9	9.5	10.1	10.8	11.4	12.0	12.7	14.0	15.1	16.5	17.8	19.1	20.3	22.8	25.4
28	4.7	5.3	5.9	6.5	7.1	7.7	8.3	8.9	9.4	10.0	10.6	11.2	11.8	13.0	14.1	15.3	16.5	17.8	18.8	21.2	23.6
30	4.4	5.0	5.5	6.1	6.6	7.2	7.7	8.3	8.8	9.4	9.9	10.4	11.0	12.1	13.2	14.3	15.4	16.6	17.6	19.8	22.0
32	4.1	4.7	5.2	5.7	6.2	6.7	7.2	7.8	8.3	8.8	9.3	9.8	10.3	11.3	12.3	13.4	14.4	15.6	16.5	18.6	20.6
36	3.7	4.1	4.6	5.1	5.5	6.0	6.4	6.9	7.4	7.8	8.3	8.7	9.2	10.1	11.0	11.9	12.8	13.8	14.8	16.6	18.4
40	3.3	3.7	4.1	4.5	5.0	5.4	5.8	6.2	6.6	7.0	7.4	7.8	8.3	9.1	9.9	10.7	11.5	12.4	13.2	14.9	16.5

Equipment for Applying Chemicals

Knapsack sprayers and hand dusters. For spot treatments of small patches of weeds, these two pieces of equipment are quite useful. A 3-gallon knapsack sprayer can be made more efficient by equipping it with two nozzles spaced about 16 inches apart on a light T-boom.

Power-driven ground sprayer. A good sprayer must have a supply tank that will hold 50 to 200 gallons of water, a good pump, a by-pass valve to regulate pressure, a pressure gauge to indicate pressure, a spray boom, nozzles and the necessary hoses and valves to connect the pump to the tank and boom. Filters should also be included in the system between the supply tank and nozzles, to filter out any sediment that would stop up the nozzles.

Tank, pump and boom should be of non-corrosive materials such as aluminum or brass. Hose should be of rubber, resistant to action of oils and acids.

The pump may be driven by power-take-off or belt pulley of the tractor, or may be driven by an auxiliary motor. The pump must be mounted where it can be shut off while the tractor is moving. Pumps should create a pressure of 20 to 60 pounds when in operation.

Booms may be 16 to 40 feet long, depending upon the capacity of the pump and acreage to be covered. Booms should be adjustable so that changes in elevation can be made when spraying roadsides and hilly fields.

Nozzles that produce a fan-shaped discharge give the best coverage of weeds. These nozzles should be so spaced that they will give complete coverage at a height of 18 to 24 inches above the tops of weeds. The spacing will usually be 16 to 24 inches.

Wide-angle nozzles that will each cover a 12- to 20-foot swath are coming into use. These nozzles have proved to be very practical for roadside spraying. They will apply high volumes of water, making it possible to get good coverage in a dense growth. They are mounted on a short arm so that mailboxes, bridge abutments and highway signs do not interfere with their use. This makes it possible to spray at speeds of 12 to 15 miles per hour. A disadvantage is that a slight breeze will distort the spray pattern and uneven coverage will be obtained. This is especially true when low volumes (5 to 10 gallons per acre) of spray are used, making this nozzle impractical in field spraying.

Trailer-mounted sprayers are best adapted for use where large acreages are to be sprayed. Pumps may be driven by power-take-off or by an auxiliary motor.

Tractor-mounted sprayers are well adapted to small farm use as they cost less than the trailer-mounted type. They may be purchased with, or without, a supply tank which may be mounted on the drawbar or on a trailer. The pump may be driven by power-take-off or by belt pulley.

Power-driven ground dusters. The application of 2,4-D in the form of dusts is more hazardous than spray applications because of the danger of wind drift. Dusters should be used only in areas where crops susceptible to 2,4-D are not grown in nearby fields. Row crop dusters are not well adapted to general field dusting. The general use of dusters should be limited to areas that already have suitable boom-type dusters on hand and to areas where there is not enough water for low volume spraying.

Turbines. This type of equipment is adapted to the application of 2,4-D, 2,4,5-T or MCP as a spray or a dust and has been used with satisfactory results for treating weeds and woody plants in areas inaccessible to conventional sprayers or dusters. Roadsides, ditches or rough terrain in areas not close to sensitive crops have been successfully treated. Drift hazards are high with the turbine type of spray equipment.

Airplane spraying. This method of applying 2,4-D and other spray solutions has been highly developed and is practical in areas of large sized fields where crops sensitive to the spray are not grown in adjacent fields. The advantage of airplane application is in the ability to cover large areas rapidly, and to spray when fields are too wet to permit the use of ground equipment. Drift of spray from airplane application is greater than from ground equipment. There is also a danger of dripping chemical on susceptible crops on each end of the treated fields and on the way to and from the landing strip. Consequently, planes should be equipped with nozzles which automatically close as soon as the operator closes the cut-off valve.

Because airplanes can apply only a low volume of water, they are not suitable for applying TCA, which requires large volumes of water.

Summary

Hundreds of chemicals have been tested. Several show promise for use in weed control, but only eight groups of compounds can be recommended at present. Even the recommended chemicals can cause tremendous crop damage and give poor weed control if not used properly. Therefore, it is important that the correct amount of the right chemical be applied at the proper time. This involves:

1. Use of right chemical.
2. Application of chemical when crop is in most tolerant stage of growth.
3. Application of chemical when weed is in most susceptible stage of growth.
4. Careful calculations to get right amount of chemical.
5. Careful adjustment of the sprayer.
6. Use of proper equipment.

Complete elimination of perennial weeds is seldom obtained with one treatment unless one of the heavy chemicals (soil sterilants) is used. However, it costs more to keep weeds than to kill them.