3-1956

Weed Control Research in South Dakota

L. A. Derscheid
South Dakota State University

K. E. Wallace
South Dakota State University

CIRCULAR 122 • MARCH 1956

Weed CONTROL RESEARCH IN SOUTH DAKOTA

Above: Patch control will prevent large weed infestations later. Center: One method of controlling large infestations is to spray. Below: Cultivation is another satisfactory control measure.

AGRONOMY DEPARTMENT

AGRICULTURAL EXPERIMENT STATION

SOUTH DAKOTA STATE COLLEGE
BROOKINGS

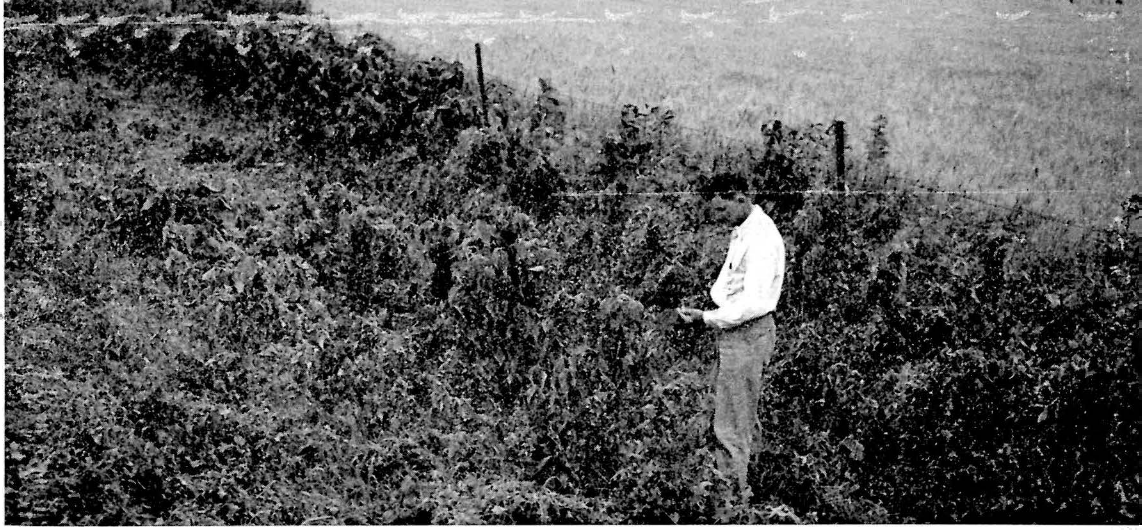
Contents

INDEX OF CHEMICALS

This publication discusses cultural and chemical methods of controlling some of the most troublesome weeds in South Dakota. It replaces C102, "Perennial and Annual Weed Control in South Dakota."

Other publications, "Chemical Control of Woody Plants," "Equipment Used for Weed Control," and "Weed Control in Lawns and Gardens," are available at your County Extension Agent's office or the Experiment Station Bulletin Room, South Dakota State College, College Station, Brookings, South Dakota.

Funds for publishing this circular and for the weed control research were made available from a legislative appropriation to the State Weed Board.



Weed Control Research
in South Dakota

Lyle A. Derscheid and Keith E. Wallace

Clean seed, proper seedbed preparation, good crop rotations, and sound soil management practices are the most reliable procedures for the control of weeds. They will eliminate many annual weeds and prevent infestation by most perennial weeds. Chemicals have proved to be valuable supplements to these practices. However, too many people rely on 2,4-D and, at least partially, neglect the standard practices. Consequently, weeds resistant to 2,4-D are allowed to spread.

Once weeds become established, special practices are needed to eliminate them. These practices include the use of special cultivation, competitive crops, and chemicals in addition to the old reliable methods already mentioned. One application of any one of the practices seldom eliminates all perennial weeds. Even though top growth is eliminated, new weeds come from the seeds in the soil. Some of these seeds remain viable for as long as 20 years and many years of diligent work are required to eliminate them.

The major portion of this circular is devoted to a discussion of research results obtained in South Dakota and neighboring states. The discussion of special cultural and chemical practices is concerned primarily with the control and elimination of weed infestations. It does not dwell on practices needed to prevent reinfestation of areas on which weeds have been eliminated.

[1]Associate Agronomist, South Dakota Agricultural Experiment Station and Extension Weed Specialist, South Dakota Extension Service, respectively.

Research in South Dakota includes over 50 sets of plots established throughout the state. This is in addition to work conducted on the 40-acre Field Bindweed Research Farm near Scotland (1946-50), the 30-acre Leafy Spurge Research Farm near Gary (1951-55), the 8-acre Quackgrass Research Farm near Gary (1951-53), the 12-acre Russian Knapweed Research Farm near Brentford (1952-55), the 25-acre Thistle Research Farm near Castlewood (1955), and the Agronomy Farm at Brookings since 1947.

Perennial Weed Control

Special cultural or chemical practices are needed to eliminate perennial weed infestations. The objective of these practices is to deplete the food reserves in the roots. Plants manufacture food as illustrated in figure 1. Food not needed by the plant for growth or seed production is stored in the roots in the form of root reserves. Reserves can be depleted or reduced in several ways: (1) by shading the leaves of the plants to reduce the amount of sugar produced, (2) by depriving the plants of soil nutrients so that less of other foods are produced, (3) by forcing the plants to use up the reserves already in the roots, or (4) by using a combination of these methods.

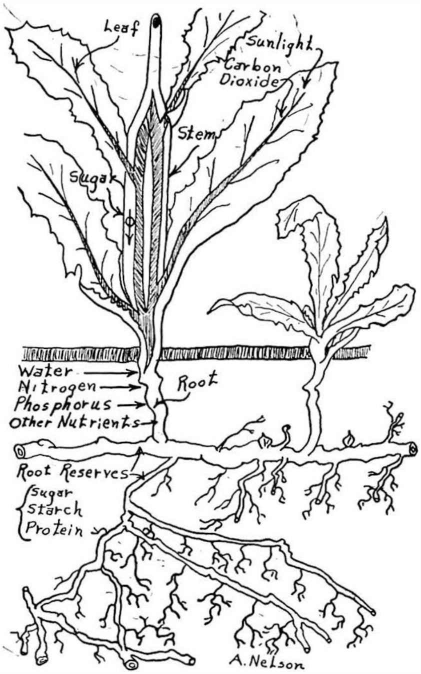


Figure 1. Lower portion of a perennial weed with stem enlarged to show the translocation system. Carbon dioxide is taken through the leaves, while water, nitrogen, phosphorus, and other plant nutrients are taken into the roots. With the aid of sunlight, sugar is produced in the leaves and moves to the roots if not needed for growth. Other plant foods not needed for growth are also stored in the roots. They are the root reserves.

Competitive crops shade the plant so that less sugar is made. They also compete for soil nutrients so that less of the plant foods other than sugar are produced. Consequently, there is less food to store in the roots.

Cultivation is used to cut the roots of plants 4 inches below the soil surface. Experiments have shown that after such a cultivation, it takes about 1 week for the plants to emerge. It takes another week or more before there are enough leaves to produce food faster than it is being used for growth. Therefore, very little food is stored and reserves from the roots are used for plant growth during a period of about 2 weeks. Each cultivation has a similar effect. If repeated cultivations are continued long enough, the root reserves are eventually used up and the plant dies.

Chemicals used in weed control either completely deplete the root reserves or decrease them to the point where competitive crops or cultivation will kill them.

Cultural Methods

Cultural practices include the use of intensive cultivation alone or with competitive crops. Intensive cultivation alone may not be advisable in areas where soil erosion is a problem, however.

Intensive cultivation. Proper cultivation eliminated a high percentage of most perennial weed species. For use on field bindweed, leafy spurge, Russian knapweed, hoary cress, bur ragweed, horse nettle, or toadflax a duckfoot field cultivator equipped with wide sweeps (12 to 24 inches) was essential (see figure 2). The sweeps had to be sharp, overlap 3 to 4 inches, be flat when in the soil, and operate at a uniform depth of 4 to 5 inches to cut every shoot at every cultivation. Although a duckfoot cultivator was preferred for Canada thistle and perennial sow thistle, a wheatland (one-way) disk could be substituted if operated at a depth of 4 to 5 inches.

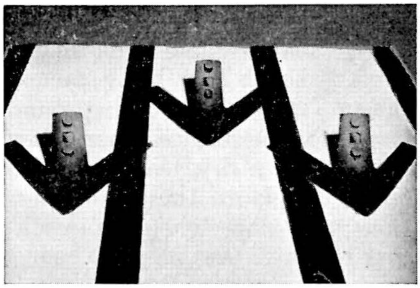


Figure 2. Duck-foot sweeps needed for use in cultivating perennial weeds. Notice how the duck-foot sweeps overlap.

The first operation was to plow 5 inches deep with a moldboard plow 3 weeks after the weeds emerged (about May 15 for leafy spurge, Russian knapweed, or hoary cress; about June 1 for field bindweed; and about June 15 for Canada thistle, perennial sow thistle, or horse nettle). Field bindweed, leafy spurge, Russian knapweed, hoary cress, horse nettle, bur ragweed, and toadflax were then cultivated every 2 weeks until fall. Canada thistle and perennial sow thistle needed to be cultivated or "one-wayed" every 3 weeks until fall.

For quackgrass the first operation was done at a depth of 2 inches about July 1 after a crop was removed or after the top growth of quackgrass was removed by mowing or grazing. A sharp wheatland (one-way) disk was preferred, but a moldboard plow was satisfactory when the area was disked sufficiently to cut up the sod. Succeeding operations were done with a field cultivator equipped with spring shanks and bull-tongue points (shovels) to bring quackgrass rhizomes (underground stems) to the surface where they dried out in a dry year. This also starved the plants. These later operations were done when the quackgrass regrowth was about 2 inches tall.

One year of intensive cultivation generally eliminated 90 percent of Canada thistle or perennial sow thistle plants and a high percentage of quackgrass in a dry year. Fewer plants of field bindweed, leafy spurge, Russian knapweed, hoary cress, or horse nettle were eliminated, however. A second year of intensive cultivation usually eliminated the remaining plants of these species, but it was seldom advisable to do this.

Competitive grain crops. Winter wheat or rye used with cultivation has proved to be effective for controlling field bindweed, Canada thistle, perennial sow thistle, leafy spurge, Russian knapweed, hoary cress, and toadflax. Spring barley also has been an effective crop for curbing bindweed. Rye was the best of the three crops, as winter wheat often winterkilled and barley, being a spring crop, left the ground uncovered over winter.

The area was plowed shortly after weeds emerged in the spring and cultivated at 2-week intervals (3-week intervals for the thistles) until September when winter wheat or rye was seeded. When barley was used, the cultivation was continued another month in the fall and one cultivation was done in the spring before the crop was seeded. The area was plowed as soon as the crop was combined. Cultivation was carried on until the next crop was seeded. With this system at least two or three crops were generally required to eliminate any of these weed species.

Summer crops. Forage sorghum, sudan grass, and soybeans have proved effective for the control of field bindweed, Canada thistle, or perennial sow thistle. Buckwheat, proso millet, or German millet have helped control quackgrass. Buckwheat and sudan grass were very effective on leafy spurge. The area was plowed deep (5 to 6 inches) about June 1 (quackgrass was plowed 2 inches deep when the weed was 2 inches tall) and cultivated at 2-week intervals.

If sufficient moisture was available about July 1, the crop best adapted to the location and for controlling the weed was seeded at a heavy rate with a grain drill. The crop was harvested for forage (except proso millet and buckwheat which were harvested for seed) before the first frost. The area was then plowed deep in early November just before the soil froze. If there was not sufficient moisture on July 1 to produce a crop, intensive cultivation could be continued until fall.

Perennial forage crops. Perennial grass and alfalfa gave a high degree of control of field bindweed, leafy spurge, Canada thistle, or perennial sow thistle, especially when used with intensive cultivation.

Best results were obtained when the area was intensively cultivated for 1 year. Then a crop of alfalfa or a mixture of alfalfa and an adapted perennial grass was seeded when moisture was ample—either in August or early the next spring. The date of seeding depended on the area, but it was done when the chances of getting a good stand were best. A heavy stand was essential to successful control. The crop was grazed or harvested for hay. Four years generally eliminated 95 to 100 percent of bindweed or leafy spurge, but less time was required for thistles.

This method was particularly adapted to areas subject to erosion or areas too rough or rocky to permit regular cropping or cultivation.

Intensive cultivation and 2,4-D. The application of 2,4-D to perennial weeds in small grain, followed by intensive cultivation after harvest, has proved to be effective for the control of several species, especially Canada thistle and perennial sow thistle. The amount of 2,4-D required to control the weed was applied to the weeds in the small grain, preferably barley or wheat. The crop was combined so that the area could be tilled immediately after harvest. The field was then cultivated intensively at 2- or 3-week intervals, depending on the weed present, until fall.

Grazing. Large areas of leafy spurge have been coutrolled by pasturing with sheep with no harmful effects upon the sheep. The degree of control was dependent upon the intensity of grazing that the grass would stand. Sheep were turned into the pasture when spurge plants were 6 to 8 inches tall. Good pasture management practices were essential. When sheep did keep the pasture down, cattle were rotated ahead of them.

Field bindweed has been controlled with grazing sheep. A satisfactory system was to plant winter rye in the fall and graze it early the next spring. Then the land was plowed 5 inches deep in early June.

After this, one of two practices was followed, depending on the soil moisture. With adequate moisture, sudan grass was seeded at a heavy rate and grazed from the time it reached a height of 15 to 18 inches until September. If there was not sufficient moisture for a crop of sudan grass, the area was cultivated intensively. A second crop of rye was seeded in September and was either grazed or combined. The area was then plowed and cultivated intensively until fall.

Mowing. Many perennial weeds can be controlled by mowing at the right time for 2, 3, or 4 years. This method has been especially effective for weed control in pastures. Such weeds as ironweed, ragweed, and similar weeds should be mowed when budding or starting to bloom.

Chemical Control

One application of 2,4-D, MCP, or 2,4,5-T seldom eliminated all perennial weeds present. However, these chemicals have controlled many species by preventing the production of seed and by stunting top growth so that harvesting operations were facilitated.

These chemicals in conjunction with the special cultural practices previously described usually have increased the effectiveness of such practices and decreased the length of time that they have to be used. However, it was necessary to allow time for the 2,4-D to get into the roots of the weeds before any cultivation was done after spraying. This took 2 or 3 weeks.

The heavy applications of chemicals required to control perennial weeds sometimes caused damage to the crop, especially at certain stages of growth. There were two choices: (1) to risk injuring the crop in order to get good weed control or (2) get poor weed control with less chance of injuring the crop. The advantage gained by good weed control usually offset the damage caused to the crop. Also the reduced infestation in the following crops usually made it more practical to get good weed control.

Field bindweed or creeping jenny *(Convolvulus arvensis* L.). For this weed 2,4-D was more effective than 2,4,5-T or MCP. Three-fourths pound of 2,4-D acid per acre controlled it whether growing in small grain, perennial grasses, or in areas that were not cropped. Sometimes when there was plenty of soil moisture, one-half pound of 2,4-D acid per acre gave satisfactory control of the weed growing in crops.

In the more humid portions of the state, the most practical control was obtained by applying an amine form when the bindweed was starting to bud. In drier areas, best results have been obtained by applying an ester form as soon as all plants were up in the spring or by leaving the land idle for a year and spraying when the weeds were in bloom. Cultivation can then be started 3 weeks after spraying.

The high rate of application of 2,4-D sometimes damaged small grain, and early spring treatments increased this risk as then the small grain was in a more susceptible stage of growth. When re-treatments were necessary they were not made until the remaining weeds had recovered from the first application, which was generally 1 year or more after the original treatment.

Small patches have been eliminated by the use of soil sterilants. Five pounds of sodium chlorate or 15 pounds of the borate-chlorate mixtures per square rod were the best chemicals used. Fifteen pounds of "Concentrated Borascu" were also often effective. Applications made in September were more consistently satisfactory than those made in July.

Canada thistle (*Cirsium arvense* L.), ***perennial sow thistle*** (*Sonchus arvensis* L.). For control of perennial sow thistle, 2,4-D was superior to 2,4,5-T or MCP, but in some cases, MCP has been equal to or slightly better than 2,4-D on Canada thistle. The amine form of 2,4-D or MCP was generally more effective than an ester form on Canada thistle. The ester appeared to kill the tops too quickly. However, the ester of 2,4-D appeared to be most effective on sow thistles.

Three-fourths pound of 2,4-D or MCP acid per acre was needed to give satisfactory kill. One treatment of as little as one-half pound prevented seed production. The best results were obtained by spraying in the crop shortly before buds were formed. After the small grain was harvested, the stubble was immediately plowed and intensively cultivated at 3-week intervals with a duckfoot cultivator or a one-way disk.

Less effective fall treatments consisted of (1) plowing after harvest and spraying thistles after they came up, (2) spraying in the stubble and plowing 2 or 3 weeks later, or (3) spraying in the stubble. Late fall plowing, just before the soil froze up, added to the effectiveness of all treatments.

Small patches were eliminated with 5 pounds of sodium chlorate, 10 pounds of borate-chlorate mixtures, 12 pounds of "Concentrated Borascu," 5 pounds of a borate-2,4-D mixture, 4 pounds of amate, or one-fourth pound of CMU per square rod. All compounds were more effective when applied in September than in July.

Limited trials with amizol in other states were very satisfactory for killing thistles and indicate that 4 to 6 pounds per acre of amizol (8 to 12 pounds of 50 percent material) applied to thistles that were 6 to 8 inches tall killed 90 to 100 percent of the plants. Similar trials in South Dakota were less satisfactory.

Leafy spurge (*Euphorbia esula* L.) On leafy spurge 2,4-D was more effective than 2,4,5-T or MCP. The ester forms of 2,4-D gave better results than the amine forms. The amines did not appear to be absorbed into the plant. Top growth was retarded and no seed was set when one-half pound of 2,4-D ester per acre was applied in small grain. However, seed was produced during the fall when a second application was not made. A fall application of one-half pound prevented seed production, while a rate of 1 pound reduced the stand somewhat.

Use of 2,4-D in conjunction with bromegrass and cultivation gave up to 95 percent elimination. The best treatment consisted of cultivation at 2-week intervals from May 15 to August 15. Bromegrass was then seeded in August. It was sprayed with 1 pound of 2,4-D acid in May and again in September for 2 years.

In annual crops 2,4-D was also effective. The best treatment consisted of an application of one-half pound of 2,4-D acid on rye about May 20 and 1 pound of 2,4-D acid in the stubble about August 15. This procedure was repeated a second year and a crop of sudan grass was raised the third year. Over 90 percent of the spurge was eliminated.

Limited trials indicated that 40 pounds of 2,4-D amine applied about October 10 killed a high percentage of the leafy spurge if there was a follow-up treatment in the spring. Before October 10, the soil temperature was high enough to stimulate bacteria to decompose the 2,4-D before it killed the weeds.

Figure 3. Borax compounds eliminated leafy spurge.

A crop of corn grown the next year helped finish off weeds that were not killed. Likewise, an application of one-half pound of 2,4-D the next year helped clean up remaining plants.

Small patches were eliminated with soil sterilants (see figure 3). July and September applications of 10 pounds of "Concentrated Borascu" per square rod killed 95 to 99 percent of the spurge. September applications of 10 pounds of borate-chlorate mixtures, 5 pounds of sodium chlorate, 5 pounds of borate-2,4-D mixtures, or 4 pounds of amate per square rod and a June application of 8 pounds of amizol (16 pounds of 50 percent material) per acre gave similar results. Seedlings that came back from seeds in the soil were eliminated with 2,4-D.

Quackgrass (*Agropyron repens* L.). Several chemicals proved to be effective on quackgrass. However, most of them are too expensive to be used on large areas.

TCA was most effective when applied at a rate of 20 pounds of TCA acid (25 pounds of 90 percent sodium salt) per acre on sod that had been freshly plowed at a depth of 2 or 3 inches. It was most effective when applied in May or September. Late fall applications of 100 pounds of TCA acid (125 pounds of 90 percent sodium salt) was sometimes effective on unplowed sod.

The effect of TCA remained in the soil for some time—longer in heavy soils than light soils. However, flax, oats, or corn could generally be grown the spring after fall treatments were made. Wheat, soybeans, red clover, and alfalfa were more sensitive.

MH gave good temporary suppression of quackgrass. The suppression generally lasted at least 1 year and often resulted in a permanent kill of the weed. Best results were obtained when 5 to 8 pounds were applied to the quackgrass that was 4 to 8 inches tall. The area was plowed 6 days after being sprayed. Corn and small grain were planted immediately and appeared to help eliminate the weed. These crops were not affected by the chemical.

Dalapon was also effective for the control and elimination of quackgrass if applied to foliage that was 4 to 10 inches tall. Fall applications of 10 pounds (15 pounds of 78 percent sodium salt) per acre followed in a week by plowing eliminated over 90 percent of the weeds. Small grain or corn planted the following year were not affected. Spring treatments of 5 pounds (7½ pounds of 78 percent sodium salt) per acre applied when the foliage was 4 to 10 inches tall and followed within 2 weeks by plowing were also very effective. However, corn, wheat, and soybeans were sensitive to small quantities of chemical left in the soil. They were injured if planted less than a month after applying the chemical.

Under trees 6 to 8 feet tall, two applications of 5 pounds of Dalapon spaced 6 weeks apart did not injure the trees and killed most of the quackgrass. A single treatment of 10 pounds caused some injury to the trees.

Small patches of quackgrass have been eliminated with 5 pounds of sodium chlorate per square rod. Likewise, CMU at a rate of one-fourth pound per square rod, or the borate-chlorate mixtures at rates of 12 to 15 pounds per square rod have sometimes killed a high percentage of the weeds.

Russian knapweed (*Centaurea repens* L.). For controlling this weed 2,4-D was equal to or better than 2,4,5-T or MCP and an ester form of 2,4-D gave better results than an amine form. The amine did not seem to be absorbed into the plant. An application of 1½ pounds of 2,4-D acid per acre killed top growth and prevented seed production. However, a second application during the fall was necessary to prevent production of seed by regrowth.

Use of 2,4-D ester, intensive cultivation, and perennial grasses eliminated as much as 90 to 98 percent of the weeds in 2 years. The best results were obtained on plots that were cultivated intensively from May 15 to August 15 and seeded to a perennial grass. The next year 2,4-D was applied at a rate of 1½ pounds per acre about June 1 and again in early September. Bromegrass and crested wheatgrass were equally effective. The spring 2,4-D application prevented seed production and the fall treatment helped reduce the stand of weeds.

Use of 2,4-D ester with rye and intensive cultivation eliminated as much as 90 percent of the weeds in 2 years. The best treatment consisted of a 1 pound per acre application in the rye before it reached the boot stage of growth, followed by a treatment with 1½ pounds of 2,4-D ester in the stubble during early August. Two weeks later the plots were cultivated. After a second cultivation, a second crop was fall-seeded and it was handled the same as the first.

The use of heavy rates of 2,4-D has worked fairly satisfactorily in South Dakota when 40 pounds of amine were applied per acre after about October 10 when soil temperature was below 50°F. The low soil temperature apparently inactivated soil microorganisms so that they did not decompose the 2,4-D before it killed the weeds. The best results have been obtained when a follow-up treatment such as a cultivation or a light treatment with 2,4-D is used the next spring.

Small patches have been successfully eliminated with one application of 5 pounds of sodium chlorate, 15 pounds of a borate-chlorate mixture, 15 pounds of "Concentrated Borascu," 4 pounds of amate, or 5 pounds of a borate-2,4-D mixture applied on a square rod. September treatments were somewhat better than those applied in July.

Hoary cress or perennial peppergrass or white top (*Cardaria draba* L.). An ester of 2,4-D was more effective than any other form of 2,4-D, MCP, or 2,4,5-T. One-half to 1 pound per acre gave good control to top growth in growing crops when applied at the time the weeds were budding. Re-treatment of fall rosettes with 1 to 2 pounds per acre gave substantial stand reductions. Such a combination of treatments gave almost complete elimination in two or three seasons.

Limited trials with high rates of 2,4-D resulted in almost complete elimination of this weed when 10 pounds of 2,4-D amine were applied during early October.

Use of soil sterilants eliminated small patches of this weed. Five pounds of sodium chlorate or 10 to 12 pounds of a borate-chlorate mixture per square rod have been very satisfactory.

Horse nettle (*Solanum carolinense* L.). In the few chemical tests that have been conducted on this weed, 2,4,5-T was more effective than 2,4-D or MCP. Repeat applications of 1½ to 2 pounds of an ester form per acre reduced stands when applied between the time that the weed blooms and the time it sets fruit.

Bur ragweed (Franseria discolor Nutt.) and (*F. tomentosa* Gray). Two pounds of 2,4-D acid per acre in an ester form has effectively controlled these weeds when the application was made before plants started to bud.

Five pounds of sodium chlorate, 15 pounds of "Concentrated Borascu," or 10 pounds of a borate-chlorate mixture per square rod have eliminated a high percentage of these weeds when applied during early fall.

Toadflax or butter and eggs (*Linaria vulgaris* Hill.). Repeated treatments of 2 pounds of 2,4-D acid per acre in an ester form applied in a perennial grass sod have reduced the stand of this weed. Best results have been obtained when the area was intensively cultivated for a season before the grass was seeded.

Soil sterilants have proved to be effective on small patches. Five pounds of sodium chlorate, 10 pounds of "Concentrated Borascu," 8 to 10 pounds of a borate-chlorate mixture, 5 pounds of a borate-2,4-D mixture, or one-third pound of CMU per square rod have proved to be effective.

Control of Patches

Patch treatment is an important part of a perennial weed control program. It is easier to control weeds on a small area than it is to control them after they spread over a large area. Intensive cultivation, 2,4-D, MCP, 2,4,5-T, TCA, MH, Dalapon[2] or any of the soil sterilants (chlorate, borax compounds, borate-chlorate mixtures, borate-2,4-D mixtures, amate, amizol, or CMU) have been used, depending upon the situation. The amount of each chemical needed is given for many of the weeds on the preceding pages.

Soil sterilants were used to good advantage on patches because the proper application of the right chemical gave almost complete elimination of many species of perennial weeds (see figure 4). However, weed seeds in the soil generally were not killed. When the effect of the soil sterilant wore off, these seeds germinated and produced a new infestation. The seedlings were

[2]2,4-D 2,4-dichlorophenoxyacetic acid
MCP 2-methyl-4-chlorophenoxyacetic acid
2,4,5-T 2,4,5-trichlorophenoxyacetic acid
TCA Trichloroacetic acid
MH Maleic hydrazide
Dalapon 2,2-dichloropropionic acid
CMU 3-(p-chlorophenyl) 1,1-dimethylurea

Figure 4. ***Right:*** **Effects of sodium chlorate applied to a small patch of perennial weeds.** ***Left:*** **Applying the chemical to an area that had previously not been treated.**

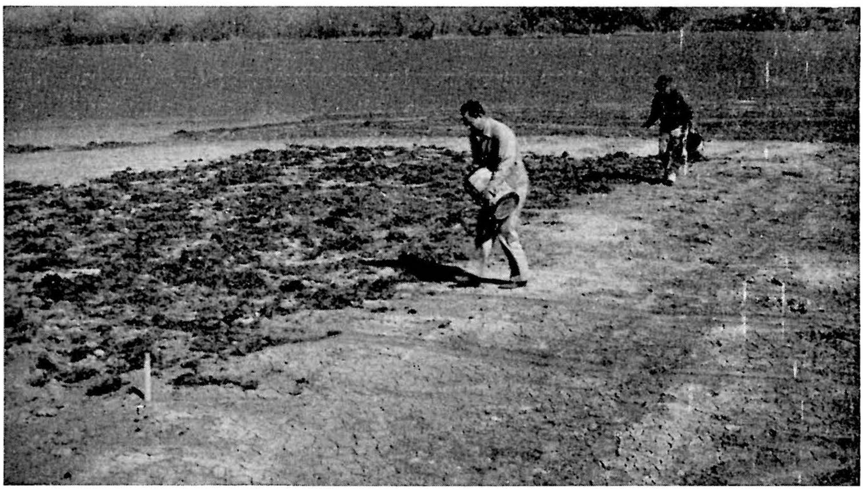


Table 1. Amount of Chemical Needed on 1 Square Rod When Treating Patches

Pounds of Acid Equivalent Used per Acre	Chemical Required on a Square Rod (16½ Ft. x 16½ Ft.)			
	2,4-D,MCP or 2,4,5-T		TCA*	MH
	Contains 4 Lb. per Gallon	Contains 3 Lb. per Gallon	Granular (90% Sodium Salt)	40% Sodium Salt
½	⅔ teaspoonful	⅞ teaspoonful		
¾	1 teaspoonful	1⅓ teaspoonsful		
1	1⅙ teaspoonsful	1¾ teaspoonsful		
1½	2 teaspoonsful	2⅔ teaspoonsful		
2	2⅕ teaspoonsful	3½ teaspoonsful		
5			4½ teaspoonsful	1 cup
7½			6¾ teaspoonsful	1½ cups
10			3 tablespoonsful	2 cups
25	⅝ cupful	11/12 cupful	½ cupful	5 cups
50	1¼ cupsful	1⅚ cupsful	1 cupful	
100			2 cupsful	

*Dalapon required 1¼ times as much as TCA. Example: 5 pounds of Dalapon per acre required 1¼x4½ or 5⅝ teaspoonsful per square rod.

eliminated with cultivation or one of the chemicals that does not sterilize the soil.

When 2,4-D, MCP, 2,4,5-T, TCA, MH, or Dalapon were used, it was just as important that the right amount of chemical be applied to small patches as it was on large fields. If too little was applied, the weed was not controlled; if too much was applied, the tops were sometimes killed without injuring the roots. The amount of chemical needed for a square rod area for several rates of application is given in table 1.

These chemicals could 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 walked. The best method was to mark out a square rod plot (16½ feet by 16½ feet) and measure the amount of water required to cover it. When 2 quarts were needed, the amount of chemical for a square rod (see table 1) was measured into each 2 quarts of water used. The same was true for any other amount of water.

Reaction to Chemicals

The Research Committee of the North Central Weed Control Conference has classified numerous species of perennial weeds according to their reactions to 2,4-D, MCP, 2,4,5-T, TCA, and some of the soil sterilants. The 2,4-D classification is given below. Numerals after the names of several species indicate the sensitivity of the weed to other chemicals. The meaning of these numerals is explained in footnotes following the list.

Group I. Weeds that have been killed with one application of 1 pound or more of 2,4-D acid per acre.

Austrian field cress	Plantain
Dandelion (*)	Sunflower, perennial

Group II. Weeds which were retarded in growth and prevented from setting seed by one application of 1 pound or more of 2,4-D acid per acre. Repeated applications were needed for elimination.

Aster	Nettle
Bindweed, hedge	Nettle, stinging (2) (3)
Bindweed, field (2)	Pucoon, hoary
Buttercup, tall (2) (3)	Ragweed, bur
Cress, western yellow	Ragweed, perennial (2)
Chickweed, mouse ear	Sage, pasture
Daisy, oxeye (2)	Sage, prairie
Dock, curled	Tansy
Garlic, wild	Thistle, bull
Hawkweed, orange	Thistle, Canada (2) (3)
Ironweed (*) (2)	Thistle, perennial sow (3)
Lettuce, blue (*)	Vervain, hoary (2)
Mallow, round-leaved	Yellow rocket

Group III. Weeds which were retarded in growth and prevented from setting seed with one application of 1 pound or more of 2,4-D acid per acre. Complete elimination was seldom accomplished even with repeated applications of 1 to 4 pounds of 2,4-D acid per acre.

Avens, three-flowered	Licorice, wild
Bedstraw, northern	Milkweed, climbing (*)
Bladder campion	Milkweed, common
Blueweed	Milkweed, whorled
Bracken	Poverty weed
Cockle, white	Russian knapweed
Geranium	Sheep sorrel
Goldenrod	Tanweed
Hoary cress (2)	Toadflax
Horsetail	Yarrow
Leafy spurge	

Group IV. Weeds that were not controlled by as much as 4 pounds of 2,4-D acid per acre.

Boneset	Horse nettle (2)
Brier, sensitive	Johnson grass (4)
Cacti (1) (4)	Mallow, alkali
Ground cherry	Quackgrass (4)

(*) Weeds that belong in the next higher classification if treated as late as the budding stage of growth.

(1) Weeds that were killed with one application of 1 pound or more of 2,4,5-T per acre.

(2) Weeds which were retarded in growth and prevented from setting seed by one application of 1 pound or more of 2,4,5-T acid per acre. Repeated applications were needed to give elimination.

(3) Weeds which were retarded in growth and prevented from setting seed by one application of 1 pound or more of MCP acid per acre. Repeated applications were needed to give elimination.

(4) Weeds that were generally killed with one application of TCA.

Annual Weed Control

Annual weeds use soil moisture and soil nutrients for growth. Many of them require more water and plant food to produce a pound of dry matter than our common crops. Since they use some of the moisture and nutrients needed by crops, the yield of the crop is reduced. Table 2 shows how the yield of flax was reduced by three different types of annual weed infestations. It also shows the number of pounds of weeds produced per acre by a light infestation of weeds. There were 1,400 pounds of broad-leaved weeds on 1 acre, 540 pounds of grassy weeds on another, and 1,860 pounds on an acre when broad-leaved weeds and grassy weeds were grown together.

Table 2. Bushels of Flax and Pounds of Weeds per Acre of Weed-Free and Weedy Flax at Brookings, 1950

Weed Infestation	Flax Yields	Weed Yields
	(Bu.)	(Lb.)
None	23.6	
Lamb's quarters, mustard, ragweed	14.4	1400
Foxtail	18.9	540
All four species	14.5	1860

Table 3 shows the number of bushels of crop that could be produced with the amount of water required to grow 1,000 pounds of weeds. For instance, 1,000 pounds of cockleburs require enough water to produce 8 bushels of oats, or 7 bushels of barley, or 4 bushels of wheat, or 9 bushels of corn. If 1,000 pounds of weeds are grown on an acre of land in a dry year, these figures represent the decrease in yield per acre that is caused by weeds. Actually, 1,000 pounds of weeds would be a light infestation, as shown by the yield of weeds in tables 2 and 5.

Table 3. The Bushels of Crop That Could Be Grown with the Amount of Water Required to Produce 1,000 Pounds of Several Species of Annual Weeds

Weed	Oats	Barley	Wheat	Corn
	(Bu.)	(Bu.)	(Bu.)	(Bu.)
Cocklebur	8	7	4	9
Sunflower	13	12	6	14
Lamb's quarters	15	13	7	16
Russian thistle	6	5	3	7
Pigweed	5	5	2	6

Table 4 shows that the amount of nitrogen and phosphorus required to grow 1,000 pounds of weeds would produce several bushels of grain. For instance, the amount of plant food needed to grow 1,000 pounds of foxtail (pigeongrass) is sufficient to produce 16 bushels of oats, or 13 bushels of barley, or 8 bushels of wheat, or 11 bushels of corn. If 1,000 pounds of weeds are grown on an acre of land with a low fertility, the yields in table 4 represent the yield decrease per acre that may be caused by weeds. Since data in table 2 and 5 indicate that 1,000 pounds of weeds would be a light

Table 4. The Bushels of Crop That Could Be Grown with the Amount of Nitrogen and Phosphorus Required to Produce 1,000 Pounds of Several Species of Annual Weeds

Weed	Oats	Barley	Wheat	Corn
	(Bu.)	(Bu.)	(Bu.)	(Bu.)
Foxtail	16	13	8	11
Lamb's quarters	24	19	12	16
Mustard	37	30	18	25
Wild oats	31	25	15	21
Pennycress	32	25	16	21

infestation, it is probable that weeds decrease the yield even more.

By planting clean seed and using good crop rotations that include the use of row crops, forage crops, and fall tillage, annual weed infestations can be almost eliminated over a period of years. Where these practices are not followed, or where they are not well done, it will be necessary to use 2,4-D or MCP and perhaps TCA to keep the weeds to a minimum. In such cases, advance planning for the use of the chemicals should be done. Too often people decide to spray when the weeds have overtaken the crop. Generally they are dissatisfied with the results because it was done too late. Few who plan on using chemicals at the beginning of the year complain.

Cultural Methods

Several special cultivation practices, which were incorporated into the regular cropping system, helped eliminate infestations and prevent reinfestation.

Fall tillage. Plowing or one-waying in August induced many species of annual weeds to germinate in the fall (wild oats is an exception). These weeds were generally killed by frost. However, those that started to set seed before frost were killed by cultivation or spraying. Most of the seeds that were in the upper 2 inches of soil germinated. The area was worked shallowly the following spring to keep from bringing any seeds from lower depths to the soil surface where they could germinate. The usual crops may be seeded, but flax is the crop most commonly handled in this manner. The data in table 5 show how such a practice has decreased weeds and increased flax yields.

Table 5. Flax and Weeds per Acre in Western Minnesota, 1952, After 1951 Croppings Methods*

Cropping System in 1951	Flax Seed Yields 1952 (Bu.)	Dry Weed Yields 1952 (Lbs.)
Small grain stubble plowed in August	21.7	646
Small grain stubble plowed in September	19.8	859
Corn, cultivated three times	15.0	1860
Corn, cultivated and hand hoed	20.1	864

*Data obtained at Minnesota Experiment Station located at Morris and presented in Flax Facts.

Delayed seeding. Weed seeds that did not germinate in the fall germinated the next spring (wild oats is one of the weeds that acts this way). The area was harrowed and packed early in the spring to induce early germination. Weeds that grew in the spring were killed with cultivation just before the crop was seeded. But since these weeds did not grow early enough to permit the seeding of small grains at the normal seeding date, crop yields were decreased. Therefore, late seeded crops, such as soybeans, corn, sudan, or sorghum, or early maturing varieties of small grain or flax were used to partially offset this low yield. A stand of wild oats was reduced 85 to 90 percent by this system. After several years most of the seeds in the soil germinated.

Perennial forage crops. Seeding to perennial grasses or legumes has

ERRATA - C122

Table on pages 18 and 19--Proven Perennial Weed Control Measures:

For Russian Knapweed under "Large Patches" column should read 40 lbs. 2,4-D amine during October--Follow-up next spring

For Hoary Cress under "Large Patches" column should read 10 lbs. 2,4-D amine during October--Follow-up next spring

PROVEN PERENNIAL WEED CONTROL MEASURES

Weed	Cultural Methods°	Chemical Methods		
		Large Infestations†	*Large Patches (1-10 Acres)*	*Small Patches‡ (Chemical per Sq. Rd.)*
Field Bindweed (Creeping Jenny)	Intensive cultivation Cultivation and rye Perennial hay crops Summer crops Grazing	2,4-D amine—¾ lb when budding		5 lb. Sodium chlorate 15 lb. Borate-chlorate mixture 15 lb. "Concentrated Borascu"
Leafy Spurge	Intensive cultivation Cultivation and rye Perennial hay crops Summer crops Grazing	2,4-D ester—½ lb. in grain and 1 lb. or cultivation after harvest; 1 lb. twice a year in grass	40 lb. 2,4-D amine in October Follow-up next spring	10 lb. "Concentrated Borascu" 10 lb. Borate-chlorate mixture 4 lb. amate 5 lb. Sodium chlorate 5 lb. "DB Granular" 1/10 lb. 50% amizol
Russian Knapweed	Intensive cultivation Cultivation and rye Perennial hay crops	2,4-D ester—1½ lb. spring and fall	10 lb. 2,4-D amine during October Follow-up next spring	5 lb. Sodium chlorate 15 lb. Borate-chlorate mixture 15 lb. "Concentrated Borascu" 4 lb. amate 5 lb. "DB Granular" ¼ lb. CMU
Hoary Cress (Perennial Peppergrass or White Top)	Intensive cultivation Cultivation and rye	2,4-D ester twice a year—1 lb. in spring and 1 lb. in fall	40 lb. 2,4-D amine during October Follow-up next spring	5 lb. Sodium chlorate 10-12 lb. Borate-chlorate mixture
Canada Thistle and Perennial Sow Thistle	Intensive cultivation Cultivation and rye Perennial hay crops Summer crops Late fall plowing	2,4-D amine or MCP on Canada thistle 2,4-D amine or ester on sow thistle ¾ lb. at bud and in September or ¾ lb. in crop and intensive cultivation after harvest		5 lb. Sodium chlorate 10 lb. Borate-chlorate mixture 12 lb. "Concentrated Borascu" 4 lb. amate 5 lb. "DB Granular" ¼ lb. CMU
Quackgrass	Intensive cultivation Summer crops	TCA—100 lb. on sod TCA—20 lb. on plowing in September or May MH—5 to 8 lb., plow 6 days later and seed crop Dalapon—10 lb. fall; plow 7 days later		5 lb. Sodium chlorate 12 to 15 lb. Borate-chlorate mixtures ¼ lb. CMU
Horse Nettle	Intensive cultivation	2,4,5-T—1½ to 2 lb. when blooming		

° Intensive cultivation refers to cultivation at 3-week intervals for thistles and at 2-week intervals for other species. Cultivation should be used with all cropping methods listed before seeding and after harvesting rye or summer crops, and before seeding perennial forage crops.

† Rates of application are in pounds of 2,4-D, MCP, 2,4,5-T, TCA, or Dalapon acid equivalent per acre.

‡ CMU required an abundance of soil moisture. Sodium chlorate is inflammable and can be applied as a spray, but is less dangerous if applied dry. Borate-chlorate mixtures, amate, and CMU must be applied as sprays. "Concentrated Borascu" and "DB Granular" must be applied dry.

been helpful in controlling annual weeds, including wild oats, since the frequent cutting or gazing prevented weed seed production. In a few years the weed seeds in the upper levels of the soil germinated and when seeds were not returned, these upper levels eventually became free of weed seeds. When these crops were plowed, seeds from lower depths were brought to the surface and a new infestation resulted. A second crop of grasses and legumes was necessary to eliminate the infestation. Wild oats have been eliminated by including two years of grasses and legumes in a 4- or 5-year rotation for several rotations.

Mowing. Many annual weed infestations have been eliminated by mowing often enough to keep the weeds from setting seed for several years. This was done in a hay crop or in noncropland such as fence rows, feed lots, roadsides, and other rights-of-way.

Chemical Control

Many species of broad-leaved annual weeds have been controlled with 2,4-D (2,4-D-dichlorophenoxyacetic acid) and MCP (2-methyl-4-chlorophenoxyacetic acid). Examples of these are sunflowers, cockleburs, mustards, and kochia. In most cases, the chemicals had to be applied before the weeds were 6 inches tall to get best results.

In one experiment weed-free wheat yielded 42 bushels per acre, while wheat that was infested with 100 plants per square yard of mustard yielded 18.4 bushels, and wheat infested with twice as much mustard yielded 16.0 bushels. Wheat that was sprayed in the 4-leaf and 6-leaf stage yielded 40 bushels or more, as the weeds had not decreased the yield before they were killed.

However, 6 days after the 6-leaf stage, when the wheat was in the flag-leaf stage and the mustard was budding, spraying did not help the yield. Weed-free wheat sprayed at this stage yielded about the same as weed-free wheat that was not sprayed (44 bushels), but the weedy wheat yielded no more than unsprayed weedy wheat. One hundred mustard plants per square yard reduced the yield to 18.8 bushels and 200 plants reduced it to 15.4 bushels. Actual weed counts on farms were running between 300 and 400 weeds per square yard.

This experiment emphasized two points: (1) a thin stand of mustard (or similar weeds) reduced crop yields materially and (2) these weeds reduced the yield before the weeds had started to bloom. Spraying after this time helped harvesting operations but did not help crop yields.

The amount of chemical needed to kill seedling weeds generally did not effect the crop. The maximum amount of chemical that crops would tolerate is given later under a discusion for each crop.

TCA (trichloroacetic acid) controlled several species of grassy annual weeds, such as foxtail and barnyard grass (not wild oats). However, the chemical had to be applied before the weeds were more than 2 inches tall. Small grain crops were injured by TCA, but flax was not damaged by rates needed to control the annual grassy weeds.

Reaction to Chemicals

In 1952 research workers of the North Central Weed Control Conference classified many annual and biennial species of weeds according to their reactions to 2,4-D, MCP, and TCA.

The classification of weeds as to their reaction to 2,4-D is presented in a modified form below. The reaction to MCP and TCA is indicated with numerals after the names of the weeds. The meaning of these numerals is explained in footnotes following the list.

Group I. Weeds that were generally killed at any stage of growth before flowering time with one-third to one-half pound of 2,4-D acid per acre.

Annual sow thistle
Annual vetch
Dragonhead mint (1)
False flax
Goose foot (1)
Henbit
Jewelweed
Lamb's quarters (1)
Marsh elder
Morning glory (1)
Mustards (1)
Plantains
Puncture vine (1)
Ragweed, common (1)
Ragweed, giant (1)
Radish, wild (1)
Wormwood, bitter

Group II. Weeds that were generally killed before they were 6 inches tall or stunted at later stages with one-third to one-half pound of 2,4-D per acre.

Bachelor's button
Blue bur
Carrot, wild (b)
Cinquetoil
Cocklebur (2)
Evening primrose (b) (2)
Goatsbeard (b) (2)
Lettuce, wild (2)
Mustard, hare's ear (2)
Mustard, tansy
Parsnip, wild (b)
Pennycress (2)
Peppergrass, annual (2)
Purslane (2)

Group III. Weeds that were stunted and seed production sometimes prevented when treated at early stages of growth with one-third to one-half pound of 2,4-D acid per acre.

Buckwheat, wild (3)
Chickweed, common
Flixweed
Mare's tail
Mat spurge
Mayweed
Pigweed, rough (3)
Russian thistle (3)
Smartweeds, annual (3)
Speedwells
Sunflower, wild (3)
Velvet leaf (3)

Group IV. Weeds that were not readily controlled with one-half pound of 2,4-D acid per acre.

Barnyard grass (3) (4)
Bedstraw (3)
Black Medic (3)
Bluegrass, annual (4)
Bromegrass, downy (4)
Buffalo bur
Burdock (b) (3)
Catchfly, night flowering (3)
Chess, Japanese (4)
Cockle, corn
Mallow (3)
Mullein (b) (3)
Nettle, hemp (2)
Nightshade, black
Sandburs (4)
Cockle, cow
Cockle, white (3)
Corn spurry (3)
Crab grasses (3) (4)
Cucumber, wild
Flower of an hour (3)
Foxtails (3) (4)
Goose grass (4)
Hemp, wild (3)
Knotweed
Shepherd's purse (3)
Wild barley (4)
Wild oats (5)
Witch grass (4)

(b) A biennial species (germinates one year and sets seed the next).

(1) Weeds that were generally killed at any stage of growth before flowering with ¼ to ⅓ pound of MCP acid per acre.

(2) Weeds that were generally killed before they were 6 inches tall or stunted at later stages with ⅓ to ½ pound of MCP acid per acre.

(3) Weeds that were not readily controlled with ½ pound of MCP acid per acre.

(4) Weeds that were generally killed when treated before they were 2 inches tall with 5 to 8 pounds of TCA acid per acre.

(5) Grassy weeds that were not readily killed with 10 pounds of TCA acid per acre.

Effects of Chemicals on Crops

Application of chemicals to crops caused more damage at certain stages of growth than at others. This was particluarly true when the rates of application required to control perennial weeds were used. If the most tolerant stage of the crop did not occur when the weeds were most suceptible, there were two choices. One could risk injuring the crop in order to get good weed control, or he could get poor weed control with less chance of injuring the crop. Good weed control usually paid off.

The maximum rates of application that crops would tolerate at various stages is discussed on the following pages. Some annual weeds were killed with lower rates; consequently, the rate used was frequently determined by the amount required to kill these weeds.

Small Grains

The ester forms of 2,4-D consistently caused more damage to these crops than the amine forms when the same amount of 2,4-D acid per acre was applied. TCA could not be used in wheat, barley, oats, or rye.

Spring wheat and barley. These crops were most sensitive to 2,4-D before two leaves were formed. They were still sensitive between the 2-leaf stage of growth and the 5-leaf stage (see figure 5), but were relatively tolerant to 2,4-D between the 5-leaf stage and the time that the growing head inside the plant began to swell the boot (see figure 6). They were again sensitive between the early boot stage of growth and the time that milk was formed in the seeds. After the seeds became doughy, these crops were quite resistant to 2,4-D.

Any application of 2,4-D during the sensitive periods of growth sometimes caused injury to the crop. However, one-third pound of an ester or one-half pound of an amine generally did not cause any yield reduction if applied between the 5-leaf and early-boot stages of growth. Likewise, an application of 1 pound of either form seldom

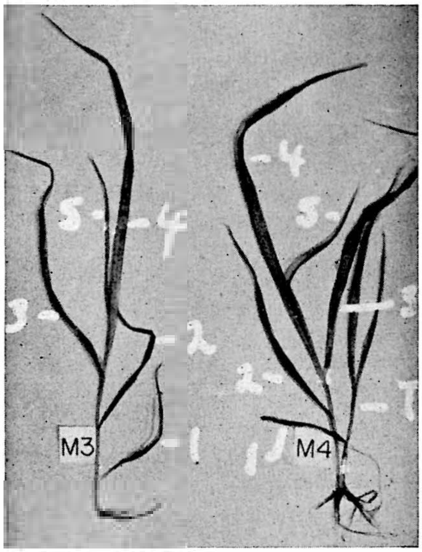


Figure 5. Five-leaf stage of growth in grain. Plant at left has five leaves. Plant at right has five leaves and a tiller (T) which emerged immediately above the first leaf. This leaf dropped off shortly after this picture was taken; therefore, it is necessary to count one leaf for each tiller even if the leaf isn't on the tiller.

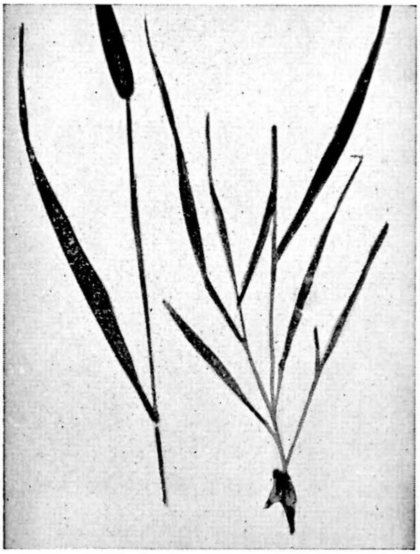


Figure 6. Early-boot stage of growth in grain. Note how the boot is swelling on the stem of the plant shown at the left.

caused damage after the grain was in the dough stage.

Wisconsin 38 has proved to be more susceptible to 2,4-D than such barley varieties as Plains, Feebar, Spartan, Odessa, and Kindred. Likewise, Canadian workers have found that Montcalm, Prospect, and Vantage were more susceptible than several other Canadian varieties.

Only a few wheat varieties have been tested, but there was some indication that Rescue, Thatcher, and Regent were more sensitive than some of the other varieties.

Oats. Varieties of oats differed more in their their reactions to 2,4-D than did varieties of barley or wheat. Mindo and Marion were two of the most sensitive varieties—they were sensitive until after they had headed. Nemaha and Cherokee were also sensitive varieties, but they became tolerant shortly after the boot began to swell. Clinton, Bonda, and Ajax appeared to be relatively tolerant between the 6-leaf and boot stages, while Andrew and Brunker were most tolerant between the 5-leaf and boot stages of growth.

Canadian workers have reported Anthony and Vanguard as being more susceptible than other Canadian varieties. Mo-0-205 appeared to be one of the most tolerant varieties. All varieties were sensitive before the 2-leaf stage and quite resistant after the seeds became doughy.

Small dosages of 2,4-D sometimes decreased yields during sensitive periods of growth, but rates up to one-third pound of an ester or one-half pound of an amine applied during tolerant periods did not generally reduce the yields. As much as 1 pound of 2,4-D was applied after the grain was in the dough stage. Oats was more tolerant to MCP than 2,4-D. Therefore, in some cases it was desirable to use MCP in oats if the weeds present could be controlled with this chemical.

Winter wheat and rye. These crops were susceptible to 2,4-D treatments made in the fall of the year. However, up to one-third pound of an ester form or one-half pound of an amine form could be applied in the spring before the boot began to swell without causing any material decrease in yield (see figure 7). Heavier rates could be

Photo courtesy of Walter Enlow, U. S. Indian Service

Figure 7. Unsprayed field of wheat at the left and a sprayed field at the right.

applied after the grain was doughy, but rates of 1 pound or more per acre sometimes caused a yield reduction even at this late period of growth.

Flax. To control some annual broad-leaved weeds in flax, one-fourth pound of an amine of 2,4-D or one-fourth pound of either an amine or a sodium salt of MCP were used. The grassy weeds were controlled with 5 pounds of TCA acid (6¼ pounds of 90 percent sodium salt) per acre.

The chemicals were applied as mixtures containing TCA and either 2,4-D or MCP in the amounts listed for controlling mixed species of weeds. Results show none of these treatments reduced the yield materially. The 2,4-D controlled or eliminated such weeds as lamb's quarters, pigweed, ragweed, cocklebur, and pennycress if applied when the weeds were young. MCP killed lamb's quarters and mustard. Less 2,4-D was needed for most of the mustards. TCA controlled the foxtails and barnyard grass (not wild oats) if applied before the weeds were 2 inches tall. Mixtures containing TCA and 2,4-D or MCP controlled both types of weeds when they were young. Best results were obtained by spraying flax as soon as the weeds came up.

Although the chemicals did not reduce the yield of flax and did control weeds, flax did better on weed-free land. In experiments, weed-free flax yielded 25 bushels per acre, while weed-free flax that had been sprayed yielded 24 to 25 bushels per acre. Flax infested with broad-leaved weeds (mustard, pigweed, kochia, and lamb's quarters) yielded only 14.4 bushels, and flax infested with foxtail yielded 18.9 bushels per acre. By using 2,4-D on flax infested with both types of weeds, the yield of weedy flax was increased to 18.2 bushels (an increase of about 4 bushels per acre). However, more flax was produced on weed-free land than on weedy land even though the weeds were killed.

MCP was less toxic to flax than either 2,4-D or TCA. It seldom delayed maturity while the other chemicals sometimes caused a delay of 3 to 7 days. The later date of maturity did not directly affect yield, but some varities that normally escape disease infection were delayed long enough to become infected. The yield was sometimes reduced materially by the diseases. Therefore, MCP was more satisfactory than 2,4-D when it would control the weeds. This was particularly true when used in a mixture with TCA.

Sprayed flax often appeared wilted for several days after spraying and the stems were often curved, but this did not necessarily mean that the yield was reduced.

Spraying flax with 2,4-D or MCP right after the bolls were set caused a reduced germination. Therefore, flax grown for seed should not be treated at this stage of growth.

Row Crops

Cultivation of row crops was generally essential for the liberation of nutrients needed for the crops. Chemicals could be used to control weeds that could not be controlled by cultivation. Therefore, chemicals could be used in the place of one cultivation but could not replace all cultivations.

In one test, corn that was cultivated three times yielded 63.8 bushels per acre, while corn that was hoed around the plants in addition to being cultivated yielded 77 bushels. Corn that was cultivated twice yielded 56 bushels; whereas, corn that was sprayed and not cultivated only produced a yield of 25.6 bushels.

Corn. Many broad-leaved weeds in corn were controlled by 2,4-D. An application of one-fourth pound of an ester or one-half pound of an amine per acre seldom had any pronounced effect on yield unless it was applied the week before silking (see figure 8). However, stalks often became brittle after treatment with 2,4-D and a strong wind or cultivation sometimes broke many of them (the larger the corn at time of treatment, the greater chance of getting breakage). Sometimes brace roots were damaged, and severe injury would allow the corn to lodge.

Corn was more susceptible to 2,4-D after a period of hot weather. After several days of 85° F. or above, corn was much more susceptible than it was after a similar number of days at 65° F. The temperature during the period before treatment was more important than the temperature at the time of treatment.

Limited trials with TCA used at lay-by time controlled grassy weeds when drop nozzles were used and when the chemical touched the base of the stock only. When the chemical was sprayed over the leaves, the corn was severly damaged (see figure 9). In Minnesota

Photo courtesy of Glenn Schrader, S.D. Extension Service

Figure 8. *Left:* Corn infested with sunflower. *Right:* Portion of same field that had been sprayed with 2,4-D—sunflowers were eliminated but foxtail was not.

the application of 1 to 2 pounds of a 2,4-D ester and 5 pounds of TCA per acre at lay-by time with drop nozzles, has proved to be an effective method of cleaning up the land for flax the next year.

Sorghum. Forage sorghums were, in general, more tolerant to 2,4-D than grain sorghums. Both types were injured severly and sometimes killed if treated before they were 3 inches tall. They were most tolerant when 4 to 12 inches tall—they usually had 3 to 5 leaves. Applications of one-fourth pound ester or one-half pound amine per acre during this period seldom reduced the yield. However, brace roots were sometimes slightly injured. Plants treated after they were 8 inches tall were sometimes dwarfed and suffered brace root injury to the extent that they would lodge. Plants treated at heading time often did not produce a full crop of seed.

Sugar beets. Neither 2,4-D nor MCP could be used on sugar beets. However, TCA was used to control grassy weeds such as foxtail or barnyard grass (not wild oats). Best results were obtained when 5 to 7 pounds of TCA acid (6¼ to 8¾ pounds of 90 percent sodium salt) per acre were applied just before the beets came up. To reduce the cost, the chemical was sprayed in a swath over the row only. The weeds between the rows were removed more cheaply with a cultivator.

Soybeans. Chemical weed control in soybeans has not been fully dependable. None of the chemicals, applied after the beans came up, was satisfactory. In some cases, a dinitro applied pre-emergence at a rate of 4 or 5 pounds active ingredient per acre has given good weed control. Better results were obtained by applying the chemical just before the beans came up than by applying it at planting time.

Cultivation has been more dependable and the rotary hoe has been very satisfactory for the first cultivations. It gave best results when used at a speed of 6 to 8 miles per hour in dry or slightly moist soil just before the weeds came up. It was not satisfactory for the control of perennial weeds, however.

Forage Crops

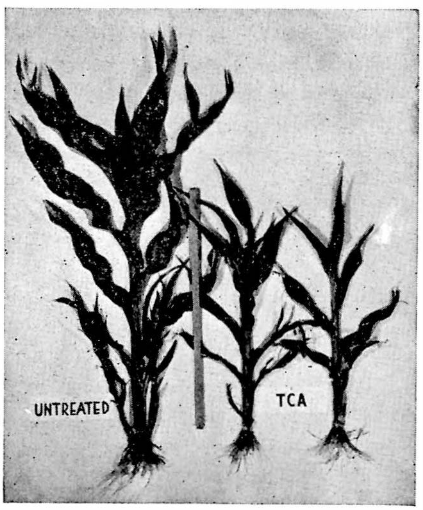
Legumes. The use of herbicides on new plantings of legumes was avoided unless the crop was seriously threatened by weeds. Use of a row crop or after-harvest tillage the preceding year to prevent weed seed production has proved to be more practical than the use of herbicides for controlling weeds in legumes. Also mowing weeds in a new seeding (except sweet clover) that is not in a companion crop is preferred to the use of herbicides.

However, one-fourth pound or less of an amine of 2,4-D or an amine or sodium salt of MCP have been used successfully for controlling susceptible annual weeds in alfalfa, red clover, ladino clover, alsike clover, and lespedeza. The stand was sometimes reduced, but the crop yield the next year was not affected. Best results were obtained when the companion crop was 10 to 15 inches high and formed a canopy over the seedling legume. Some canopy was needed to protect the seedlings from the spray, but the seedlings were more sensitive to 2,4-D or MCP when they were shaded. Therefore, too much canopy was just as undesirable as too little canopy.

The eastern states have tested the dinitro compounds extensively. Their best results were obtained when they used an alkanolamine salt of dinitro-o-sec-butylphenol at the rate of 3 pounds (3 quarts) per acre in 20 to 30 gallons of water.

TCA has controlled annual grassy weeds in seedling alfalfa, sweet clover, or birdsfoot trefoil when applied at the rate of 5 pounds (6¼ pounds of 90 percent sodium salt)

Figure 9. ***Left:*** **Untreated corn plant.** ***Right:*** **Two corn plants sprayed with 5 pounds TCA acid per acre over the tops when they had three to four leaves.**



per acre without injuring the crop materially. It was not satisfactory, however, if the weeds were over 2 inches tall. TCA was satisfactory when flax was used as a companion crop, but it injured wheat, oats, and barley severely. Alsike clover, red clover, and lespedeza were either severely injured or completely killed by similar treatments.

Dalapon killed many annual grasses in seedling alfalfa and birdsfoot trefoil without harming the crop. It was most satisfactory when applied at a rate of 2 pounds per acre one or two weeks after the legume came up. Like TCA, it was harmful to small grain companion crops.

Grass crops. An application of three-fourths pound of 2,4-D or MCP to perennial grasses (bromegrass, bluegrass, or the wheatgrasses) at the 4-leaf stage of growth did not injure them. Broad-leaved annual weeds were readily controlled in new plantings of perennial grasses. However, the removal of these broad-leaved weeds allowed greater grassy weed development.

Established stands of perennial grasses were tolerant of as much 2,4-D, MCP, or 2,4,5-T as was needed to control the weeds. However, rates of 12 to 15 pounds per acre or more, used to eliminate some perennial weeds, caused damage to bromegrass and crested wheatgrass.

Pastures. Heavy rates of 2,4-D, MCP, or 2,4,5-T have been used to control weeds in pastures. A single spraying in June gave better control of more kinds of weeds than a single mowing. However, two applications a year were often required for two or more years for some perennial weeds. This generally resulted in increased production of desirable forage and improvement in grass stands. These materials reduced the stand of some legume species present in the pasture, but many native legume species showed a rather high tolerance to the chemicals.

Good pasture management with controlled grazing prevented an infestation of weeds. Once the pasture was overrun with weeds, however, chemicals or mowing or a complete pasture renovation was needed to eliminate them. Pasture renovation on land where it can be done was perhaps the best method. Renovation was done by preparing a seedbed, seeding, and protecting the grass until established.

Useful Chemicals

In South Dakota, over 100 chemical forms have been tested in the greenhouse or in the field for their effectiveness in controlling weeds. Many broad-leaved weeds were controlled by 2,4-D, but for some weeds 2,4,5-T or MCP was superior. TCA, MH, and Dalapon were effective in controlling grassy weeds, but cost prohibits their use on large acreages. Soil sterilants were useful in eliminating small patches but were impractical for large areas of cultivated land.

2,4-D, MCP, and 2,4,5-T

The most practical chemical tested for the control of large infestations of weeds was 2,4-D (2,4-dichlorophenoxyacetic acid). It has been used selectively in many of our field crops. When applied properly, it often controlled the weeds without injuring the crops. MCP (2-methyl-4-cholorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) are closely related to 2,4-D and have limited use in controlling perennial weeds.

All three chemicals are insoluble in water but are made soluble by treatment with other chemicals. This results in the manufacture of ester and amine form of all three chemicals. However, 2,4,5-T is generally used in an ester form while MCP is most common in the amine form. Emulsifying agents, stickers, and spreaders are added to help get the ester or amine into solution or emulsion with water or oil. They also tend to help make the spray droplets spread in a thin layer on the leaf of the plant so that it will stick until it gets into the plant. Each formulating company uses different compounds or different amounts of the same compounds as emulsifiers, stickers, and spreaders.

Aside from the differences in these added agents, one ester form of 2,4-D acid is about as effective for controlling weeds as another when the same amount of 2,4-D acid is used. Likewise, several esters of 2,4,5-T appeared to be equally effective. The same is true for the various amine forms of 2,4-D or MCP. The emulsifiers, stickers, and spreaders are important, especially if water is used as a carrier. In formulations containing 6 or more pounds of 2,4-D acid per gallon, these additives may be deficient.

The ester forms can be applied in either oil or water as carriers, but the amine forms must be applied in water. The ester forms are, as a general rule, more injurious to crop plants. They appear to get into the plant quicker than the amine forms. They also penetrate some plants, such as leafy spurge, Russian knapweed, or hoary cress, that amines do not appear to enter. This means that esters control some weeds that amines do not effect.

However, the chemicals have to move from the leaves to the roots of perennial weeds to kill them. When an ester enters a plant too fast, as it sometimes does in field bindweed or Canada thistle, it appears to build up a high concentration in the top of the plant. This kills the top without killing the roots (see figure

10). Amines seem to penetrate plants more slowly than esters and trickle into the roots where they build up a toxic concentration and kill the roots (see figure 11). In such cases, the amines gave a slower kill of the top growth, but the kill of the entire plant is more complete.

TCA

TCA (trichloroacetic acid) is a grass killer and is effective for the control of quackgrass and other grassy weeds. It is generally sold in the sodium salt form which can be

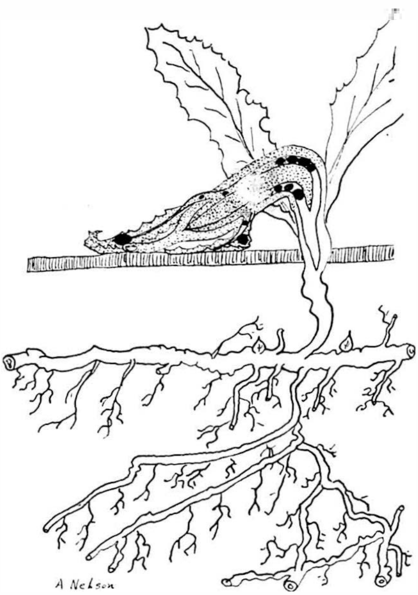


Figure 10. Lower portion of a perennial weed showing how 2,4-D works when too much chemical is applied or when an ester form is applied. Weeds such as field bindweed or Canada thistle are relatively easy to penetrate. The chemical moves into the plant so rapidly that a high concentration is built up in the translocation system (stem enlarged to show system). The top is killed, but the roots are not affected; the weed recovers.

purchased as a granular material and sometimes as a powder or a liquid. All forms can be applied in water as a carrier. Slightly over 1 pound of the dry material will dissolve in a gallon of water. The granular material is the easiest form to handle. The powder has strong caustic properties and will irritate the skin. Liquid forms may eat through metal in which they are sold; therefore, it is not advisable to plan to store liquid TCA more than 90 days.

All three forms will corrode aluminum or copper fittings with which they come in contact. However, a thorough flushing of the sprayer with water removes the danger.

MH

MH (maleic hydrazide) is a growth inhibitor that is absorbed and translocated by some plants. It has proved to be effective for the control of quackgrass and some other grassy weeds. It is formulated as a sodium salt and sold in powder form. It is soluble in water and has wetting agents and stickers added.

Dalapon

Dalapon (2-2-dichloropropionic acid) is a growth regulator that is absorbed and translocated by foliage of grassy plants. It is also absorbed by roots following a soil application. It is formulated as a sodium salt, which is a white to tan-white free-flowing powder that is readily soluble in water. It has proved to be effective for the control of perennial and annual grassy weeds such as quackgrass or foxtail. It has also been used effectively for killing remnant stands of pasture grasses prior to a renovation of the pasture.

Dinitro

The most common dinitro compound is the alkanolamine of dinitro-o-sec-butylphenol, commonly called DN, DNBP, or DNOSBP. Dinitro is a brown oily liquid that emulsifies in water to form a yellowish spray which stains the skin and clothing. It kills by contact and is not translocated; therefore, it gives best results when applied in rather large volumes (20 to 30 gallons) of spray per acre. It is not effective on perennials but is commonly used either post-emergence or pre-emergence on annual weeds in flax, legume seedings, or soybeans, or pre-emergence in corn.

Amizol

The active ingredient in this chemical is 3-amino 1,2,4-triazole. It is white powder that is soluble in water and can be most easily applied as a spray. It is readily translocated in plants and can be applied to the leaves. It has proved to be effective for the control of annual grassy weeds, but it is relatively nonselective and is difficult to use in crops. It was effective for the control of thistles and leafy spurge. Cost prohibits its use on large areas, but it is cheaper than soil sterilants.

Other Chemicals

New chemicals such as CDAA (2-chloro-N,N-diallylacetamide), CDEA (2-chloro-N,N-diethylacetamide), and CDEC (2-chloroallyl diethydithiocarbamate) have looked very promising as pre-emergence

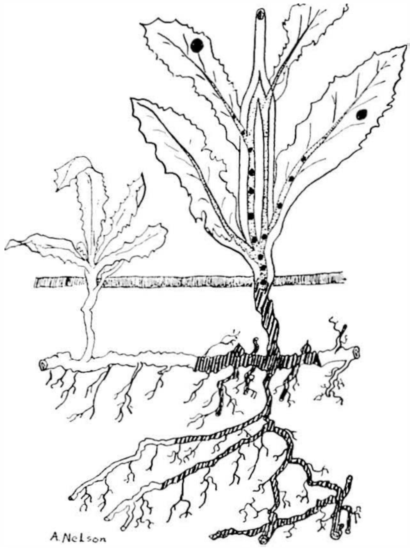


Figure 11. Lower portion of a perennial weed showing how 2,4-D works when used properly. The chemical is applied to the leaf where it slowly penetrates the plant. It gets into the translocation system (stem enlarged to show this system) and moves slowly to the roots where it kills those directly below stem.

treatments for killing annual grassy weeds. In their present forms they are very difficult to handle as they are relatively insoluble in water and give off very pungent fumes.

TCB (2, 3, 6 - trichlorobenzoic acid) is another chemical that appears to have promise as a weed killer. It is readily translocated and may be very useful for the control of perennial weeds as well as annuals. These chemicals have not been tested sufficiently to be certain of what they will do.

Soil Sterilants

Soil sterilants (heavy chemicals) containing sodium chlorate, borax,

EFFECT OF VARIOUS CHEMICALS ON CROPS

Crop	*Safest Time to Spray (Most Tolerant Stages of Growth)*	*Maximum Pounds of Chemical That Have Been Applied Per Acre at Tolerant Stages of Growth Without Reducing the Yield of the Crop*	*Type of Weeds That Were Controlled*
Spring Wheat and Barley	Between 5-leaf and early-boot stages After grain is in the dough	2,4-D: ⅓ lb. ester or ½ lb. amine 2,4-D: up to 1 lb.	Broad-leaved Broad-leaved
Oats		MCP less toxic than 2,4-D	Broad-leaved
Andrew and Brunker	Between 5-leaf and early boot stages	2,4-D: ⅓ lb. ester or ½ lb. amine	Broad-leaved
Clinton, Bonda and Ajax	Between 6-leaf and early-boot stages	2,4-D: ⅓ lb. ester or ½ lb. amine	Broad-leaved
Nemaha and Cherokee	After boot stage	2,4-D: ⅓ lb. ester or ½ lb. amine	Broad-leaved
Mindo and Marion	All stages equally susceptible	2,4-D: ¼ lb. ester or ⅓ lb. amine	Broad-leaved
All Varieties	After grain is in the dough	2,4-D: up to 1 lb.	Broad-leaved
Winter Wheat and Rye	Spring; fully stooled to boot After grain is in the dough	2,4-D: ⅓ lb. ester or ½ lb. amine 2,4-D: up to 1 lb.	Broad-leaved Broad-leaved
Flax	As soon as weeds are up Grassy weeds 2 inches high or shorter	MCP or 2,4-D: ¼ lb. amine TCA: 5 lb. (6¼ lb. 90% sodium salt)	Broad-leaved Grassy annuals
Corn	Before silking and after several cool days; earlier the better	2,4-D: ¼ lb. ester or ½ lb. amine	Broad-leaved
Sorghum	When 4 to 8 inches tall (3 to 5 leaves)	2,4-D: ¼ lb. ester or ½ lb. amine	Broad-leaved
Sugar Beets	Just before beets come up	TCA: 5 to 7 lb. over the row (6¼ to 8¾ lb. 90% sodium salt)	Grassy annuals
Legumes			
Alfalfa; Red, Alsike, and Ladino Clovers	Seedlings when companion crop or weed canopy is 10 to 15 inches high, or established stands right after mowing	2,4-D or MCP: ¼ lb. amine	Broad-leaved
Alfalfa and Sweet Clover	Seedlings in flax or established stands after mowing	TCA: 5 to 7 lb. (6¼ to 8¾ lb. 90% sodium salt)	Grassy annuals
Grasses			
Bromegrass, bluegrass, and Wheatgrasses	Seedlings after they have 4 leaves Established stands anytime except heading time for seed fields	2,4-D or MCP: ¾ lb. ester or amine 2,4-D, MCP, or 2,4,5-T: up to 2 lb.	Broad-leaved Broad-leaved
Pastures	Best weed control in June	2,4-D, MCP, or 2,4,5-T: up to 2 lb.	Broad-leaved

*Rates of application are in pounds of 2,4-D, MCP, 2,4,5-T or TCA acid equivalent per acre amate, CMU, or mixtures of these compounds have proved to be effective for eliminating small patches of perennial weeds. Soil sterilants will leave the soil unproductive for one or more years.

Sodium chlorate. This chemical is handled commercially as Chlorate of Soda" or as "Atlacide." The active ingredient is sodium chlorate. Both chemicals were equally effective for weed control when an equal amount of sodium chlorate was applied. Both are granular compounds that are soluble in water. Approximately 3 pounds can be dissolved in a gallon of water. Both are inflammable, with "Chlorate of Soda" being more dangerous. They can be applied as spray or in the dry form. However, the spray applications are greater fire hazards. Clothing and foliage that have been wet with spray of these chemicals and then dried are highly inflammable.

Borax. There are several borax compounds. The most important is "Concentrated Borascu." It is granulated and is insoluble in water and must be applied dry. The active ingredient is boron trioxide. "Concentrated Borascu" contains 61.5 percent boron trioxide, "Borascu-44" contains 44 percent boron trioxide and was as effective as "Concentrated Borascu," but it takes almost 1½ times as much chemical. "Borascu" contains 34 percent boron trioxide and was effective at 1⅔ the rate required for "Concentrated Borascu." "Polybor" is a powder that is slightly soluble in water and must be applied as a spray. It was as good as "Concentrated Borascu" when applied at the same rate.

Borate-chlorate mixtures. Borax compounds and sodium chlorate are formulated into mixtures known as "Polybor-chlorate" and "Chlorax." Both are soluble in water. About 1 pound of "Polybor-chlorate" or one-half to three-fourths pound of "Chlorax" will dissolve in a gallon of water. They may both be applied as sprays. The main difference is the relative proportion of borates and chlorates. Chlorax contains a higher amount of sodium chlorate.

Amate (ammonium sulfamate). This chemical is a granulated compound that can be applied as a spray. About 5 pounds will dissolve in a gallon of water. It gave quicker top kill than any of the other soil sterilants and left the soil unproductive for a shorter period. It is corrosive to metals. This chemical is sold as "Ammate" (80 percent ammonium sulfamate) and "Ammate X" (98 percent ammonium sulfanate). Four pounds of "Ammate X" are equivalent to 5 pounds of "Ammate."

Borate-2,4-D mixture. The most common borate-2,4-D mixture is sold as "DB Granular." A granular compound containing boron trioxide and 7 percent 2,4-D, it is insoluble in water and must be applied dry. It has proved to be effective on several species of perennial weeds. This mixture gives quicker top kill than most of the soil sterilants and its residual effect in the soil lasts for only about 1 year.

"DB Spray" is a similar compound that is soluble in water and must be applied as a spray. It was as effective as "DB Granular" when applied at the same rate but is higher priced.

Urea compounds. CMU and its relatives are sold as "Telvar" for industrial use and "Karmex" for agricultural use. "Telvar W" and "Karmex W" contain CMU (sometimes called monuron), which is 3-(p-chlorophenyl) -1, 1-dimethylurea. "Telvar DW" and Karmex DW contain 3-(3,4-dichlorophenyl) -1,1-dimethylurea, commonly called diuron. "Telvar FW and Karmex FW contain 3-phenyl-1,1-dimethylurea. The letter "W" indicates that all three compounds are wettable powders. Compounds which have substituted the letter "L" for the letter "W" contain the same material in a liquid formulation. Likewise the letter "P" is used to designate pellets.

The wettable powder, however, is the most common form for all three compounds. They are slightly soluble in water. About one-fourth to one-half pound can be dissolved (suspended) in 1 gallon of water. They should be applied as sprays. They have proved to be effective for killing many species of weeds. Light rates have been used to kill annual weeds in shelterbelts and on irrigation ditch banks. Heavier rates have been used to kill woody plants or completely sterilize the soil. However, they have not been effective on deep-rooted perennial weeds in South Dakota under normal rainfall conditions.

Other mixtures. Two new soil sterilants have recently been put on the market. They have not been tested extensively, but both should prove useful for complete sterilization. One of them is "Ureabor," which contains borax and CMU. It is a bluish gray granular compound that is insoluble in water and is most easily applied dry. The other is "Chlorea" which is composed of a mixture of chlorate, borax, and CMU. It is a white powder that is slightly soluble in water and may be applied as a spray.

Sprayer Adjustment, Chemical Measurement

It is essential that a sprayer operator knows how much spray is being applied per acre. It is also essential to mix the water and chemical in the right proportions. If this is not done, the operator runs the risk of injuring his crop with too much spray or getting poor weed control with too little chemical. He must, therefore, calibrate his sprayer carefully and measure his chemical accurately.

Sprayer Calibration

Step 1. Select an area for a test run that is similar to the field to be sprayed. Accurately measure a distance of one-eighth mile or 660 feet.

Step 2. Place the sprayer on level ground and fill the tank with water. It is best to fill it to the brim.

Step 3. Spray the test run, using the same gear and throttle setting on the tractor that will be used when spraying—usually 3 to 5 miles per hour. Also use the same spray pressure that will be used when spraying—somewhere between 30 and 50 pounds.

Step 4. Return the sprayer to the original filling position, on level ground, and measure the amount of water required to refill the tank to the brim.

Step 5. Multiply "66" times the amount of water required to fill the sprayer. Divide this answer by the width of the spray swath. This gives the gallons applied per acre.

Step 6. Determine the number of acres that can be sprayed with one sprayer tankful of spray. Divide the number of gallons in the tank by the number of gallons applied per acre.

Measurement of Chemical

Step 7. Determine the amount of chemical needed per acre by checking in this circular to see how much chemical is needed to kill the weed in question and also check to see if the crop will tolerate this amount.

Step 8. Use table 6 to determine the number of quarts or pints required to fill the sprayer.

Step 9. Calculate the number of pints needed in the sprayer. Multiply the acres that can be sprayed with one tankful of spray by the number of pints required per acre.

Table 6. Calculating the Amount of Chemical to Apply per Acre

If You Wish To Apply This Many Pounds per Acre	Your Chemical Contains This Much 2,4-D Acid Equivalent or MCP Acid Equivalent or 2,4,5-T Acid Equivalent per Gallon							Your Chemical Contains 90% Sodium Salt of TCA	
	2.00	2.64 or 2.68	3.00	3.34 or 3.40	4.00	6.00	6.40	Powder	Liquid
	Apply This Amount on Each Acre							Apply This Amount on Each Acre	
⅛	½ pt.	⅜ pt.	⅓ pt.	3/10 pt.	¼ pt.	⅙ pt.	3/20 pt.		
¼	1 pt.	¾ pt.	⅔ pt.	⅗ pt.	½ pt.	⅓ pt.	3/10 pt.		
⅓	1⅓ pt.	1 pt.	8/9 pt.	7/9 pt.	⅔ pt.	4/9 pt.	4/10 pt.		
½	1 qt.	¾ qt.	⅔ qt.	1⅕ pt.	1 pt.	⅔ pt.	⅗ pt.		
¾	1½ qt.	1 1/7 qt.	1 qt.	9/10 qt.	1½ pt.	1 pt.	9/10 pt.		
1	2 qt.	1½ qt.	1⅓ qt.	1⅕ qt.	1 qt.	⅔ qt.	⅗ qt.		
2	1 gal.	3 qt.	2⅔ qt.	2⅖ qt.	2 qt.	1⅓ qt.	1¼ qt.		
5								6¼ lb.	1 gal.
7								9⅜ lb.	1½ gal.
10								12½ lb.	2 gal.
20	10 gal.	7½ gal.	6⅔ gal.	6 gal.	5 gal.	3⅓ gal.	3 gal.	125 lb.	4 gal.
30	15 gal.	11¼ gal.	10 gal.	9 gal.	7½ gal.	5 gal.	4½ gal.	187 lb.	6 gal.
40	20 gal.	15 gal.	13⅓ gal.	12 gal.	10 gal.	6⅔ gal.	6 gal.	250 lb.	8 gal.