Proceedings of the Iowa Academy of Science

Volume 53 | Annual Issue Article 12

1946

Weed Control by Means of Chemicals

A. L. Bakke
Iowa Agricultural Experiment Station

WEED CONTROL BY MEANS OF CHEMICALS

A. L. BAKKE

Weed control by means of chemicals has become an important factor in our struggle to aradicate weeds. There are few weed problems which chemicals cannot at least aid. However, in many cases, their use is limited by their cost. It has generally been held that chemicals are too expensive for large infestations of weeds. In northwest Iowa where there are thousands of acres of European bindweed (*Convolvulus arvensis* L.) chemicals of of the present day cannot be recommended on account of the cost. To control this noxious weed it has been necessary to resort to cultivation and competitive cropping, processes which take several years (8, 9, 10, 11), and have for their objective a reduction in the amount of food reserves in the subterranean parts, to the point where there is not sufficient food material to regenerate new shoots.

Weeds are grouped into two general classes, annuals and perennials. These two groups differ particularly in their root systems. The European bindweed, a perennial, may have a root system which penetrates to a depth of 20 feet. An area of European bindweed may double itself in four years even though seeds are not formed. There are differences among weeds, and for their successful control it is necessary to know a good deal about their structure and habit of growth. When studies of methods of eradication of leafy spurge *Euphorbia Esula* L. were first made by the Iowa Agricultural Experiment Station (4, 5) it was reported to be particularly difficult to eradicate with sodium chlorate. Leafy spurge plants grown in small grain and sprayed with sodium chlorate when the flowers first appeared were easily exterminated. Now it has been found that ammate (ammonium sulfamate) will eradicate this plant much more easily than sodium chlorate or Atlacide.

When sodium chlorate was first used to eradicate the European bindweed, there were many conflicting results (6). This was particularly true where there were solid infestations, and where the weed covred th ground in a prostrate manner .Knowing that light is one of the important factors in the growth of plants and noting that the European bindweed growing in shade is more succulent and takes on a climbing habit, it was logical to try to develop such an environment. The ground was plowed and seeded to millet. The millet developed enough shade so that the bindweed leaves were succulnt and at the same time the bindweed twined and climbed the stems of the millet, and placed the leaves in a position so that they could be easily and effectively sprayed. When such bindweeds are sprayed with sodium chloratee, they are rather easily eradicated.

The number of chemicals which will kill plants is large: almost any soluble salt, if applied in high enough concentration, will kill

1. Journal paper No. J-1376 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 932.

plant cells (32). For convenience, the chemicals generally called herbicides or phytocides may be classed as follows:

Contact herbicides—These chemicals are applied to the top growth and kill the tissue with which they come in contact. They may be non-selective, killing certain species and leaving others relatively free of injury. In the first group we have such chemicals as sodium chlorate, sodium arsenite, copper sulfate, ammonium sulfamate. In the selective group are such chemicals as iron sulfate, copper nitrate, sulfuric acid, various nitro compounds and the new 2,4-dichlorophenoxyacetic acid compounds. The non-selective sprays are used principally on annual weeds to prevent seeding, to destroy vegetation that produces large amounts of pollen, and to kill weeds that clutter up our fence rows and ditch banks. The selective sprays are applied particularly to broad leaved species like dandelion and plantain in our blue grass lawns, mustard, ragweed, smart weed, pig weed in grain fields, flax, peas, carrots, parsnips and other crop plants.

Translocated herbicides. Herbicides belonging to this class when applied to the above-ground parts of a plant, not only kill the tissue with which they come in contact, but are moved or translocated to the roots and underground stems. In this category may be found such herbicides as sodium arsenite, sodium arsenate, sodium chlorate. Translocated herbicides are of particular value in the control of perennial weeds.

SOIL STERILANTS

The herbicides belonging in this category kill weeds through contact with the root system. When such materials are used to eradicate perennial weeds, it is desirable in some cases to have permanent sterilization. In this category sodium arsenite probably holds first place. If it were not for its poisonous properties to man and livestock, its use could be generally recommended. Arsenic trioxide acts slowly when applied to the soil, and for that reason cannot be selected where prompt action is desired. However, if one combines the permanent toxicidity of arsenic trioxide with the quick herbicidal activity of sodium chlorate, the results will be immediate. For graveled drive ways, parking areas, one pound of sodium chlorate with five pounds of arsenic trioxide applied at a rate of six pounds per square rod has proven to be effective and lasting. If perennial weeds, like European bindweed, are present ,it may be necessary to increase the amount of sodium chlorate. The mixtures should be made at time of application and should not be stored. Where it is not advisable to use arsenic, borax may be substituted. It takes about 20 lbs. of borax per square rod to eliminate the European bindweed and about one pound per square foot of ordinary salt.

HISTORY AND DEVELOPMENT OF HERBICIDES

Although more attention has been given to the use of chemicals in the eradication and control of weeds the last 15 years, still it is not a new project. In 1908 Bolley (14) of North Dakota Agricultural Experiment Station reported the results of 12 years of experimentation in the eradication of weeds using common salt, iron sulfate, copper sulfate and sodium arsenite. He made this statement: "When the farming public has accepted this method of attacking weeds as a regular farm operation, the gain to the country at large will be much greater in monetary consideration than that which has been afforded by any other single piece of investigation applied to field work in agriculture." Considerable interest in the eradication of weeds by chemicals was present during this period from 1896-1910, but after that there was a lag. However, this dormant period in America was supplanted by a rather active interest in the use of chemicals for weed eradication in Europe. Rebaté (31) of France in 1911 reported the results of his work with copper sulfate, iron sulfate and sulfuric acid. On winter wheat he showed that sulfuric acid at a concentration of 6 to 10 per cent killed annual weeds in grain fields without appreciable injury to the grain. Korsmo (20) in Norway found that broad-leaved weeds growing in spring seeded grain were killed with sulfuric acid, with an increase of better than 25 per cent in ripe grain over the unsprayed. Åslander (2) of Sweden, who had worked with Korsmo, came to Cornell University in 1926. In 1927 he published "Sulfuric acid as a weed spray."

There was still considerable demand, particularly by railroads, for a chemical weed killer. Sodium arsenite had become the standard weed killer of commerce. On account of the extremely poisonous property of arsenic compounds, there are many hazards connected with their use, particularly to livestock. About 1927 Aslander (1) demonstrated that sodium chlorate could be used to eradicate Canada thistle and Lathshaw and Zahnley (22) of Kansas showed that this material was effective in killing the European bindweed. From that time until the present, sodium chlorate has been more or less a standard in the eradication of perennial weeds. The usual concentration is one pound to a gallon, at a rate of four gallons to a square rod. The best plan to follow is to see that all above ground parts are dripping wet. The best time to make the spraying is when the weeds are in an active state of growth—Canada thistle when the flower buds begin to appear. Usually two applications are necessary. Sodium chlorate may also be applied in the dry state at the same rate, four pounds per square rod. Muenscher (29) has made the dry applications during winter months. Loyer (23) in France has employed chlorates in the destruction of weeds in cereals. The Chipman Chemical Company has added certain compounds to reduce the fire hazard and has called their product "Atlacide". Immediately preceding the war the annual consumption of sodium chlorate on farms in the United States was about 12,000,000 pounds. Cherokee County, Iowa, has used since 1937 at least a carload a year.

There have been attempts to fortify sodium chlorate by adding other ingredients, so as to reduce the cost. Hence (18) of the Hawaiian Sugar Planters Association, by adding sodium pentachlorophenate (Santobrite) to sodium chlorate has been able to materially reduce the amount of sodium chlorate. The Iowa Agricultural Experiment Station was able to control the weeds along ditch banks and roadsides at their Crystal Lake Experimental Farm this last year by using 15 pounds of sodium chlorate and three pounds of Santobrite per 100 gallons of water. The cost of this spray is less than three dollars per 100 gallons of spray material. In the studies with Santobrite it has been found that such annuals as rag weed, smartweed, pig weed, goosefoot when young can be killed by rather dilute solutions. The onion is somewhat resistant to this material and consequently it looks as if we can use sodium pentachlorophenate as a differential spray. To control annual weeds in onions on peat ground, there are indications that 0.5 per cent solution of Santobrite at the rate of 100 gallons per acre will be effective but the material should not be applied until the third leaf has been formed. As the onion plant becomes more resistant as it becomes older, it is essential that the onion seed should be placed in the ground as early in the spring as possible so that the onions can be sprayed while the weeds are small. For the second spray a one percent solution is used. As onion growers realize the importance of early seeding, there is no particular change in production tactics. Hirsch (19) had noticed earlier that sodium pentachlorophenate was toxic to water hyacinth.

AMMATE

Ammate (ammonium sulfamate) is another herbicide which has become popular in the eradication of certain perennial weeds. It is not poisonous to livestock nor is it retained in the soil as long as sodium chlorate. Using the same concentration as is generally employed for sodium chlorate, namely, one pound per gallon of water, this chemical has proven to be effective in exterminating Canada thistle, poison ivy and leafy spurge. But Ammate cannot be recommended in the eradication of the European bindweed.

CARBON DISULPHIDE AND TETRACHLORETHANE

The method of injecting a chemical directly into the soil of an infested area has been used, particularly in the West (3) with carbon disulphide. About two ounces are placed in holes 18 inches deep and 18 inches apart,andimmediately the holes are filled in with soil. Special probes and power injecting equipment have been used on the Pacific Coast. Thousands of gallons of CS_2 are used each year in California alone for the eradication of perennial weeds. For the elimination of European bindweed in blue grass lawns the Iowa Station has dug holes 18 inches deep and 18 inches apart and placed 20 grams of dry sodium chlorate in each hole. After the chemical has been poured through a long stemmed funnel into the hole, the holes are filled with soil. The sodium chlorate goes into solution and is absorbed by the main root of the bindweed. As the fibrous grass roots are usually above the 18-inch mark, they are only slightly affected. Tetrachlorethan (7) has been used much the same as CS_2 to eradicate European bindweed in lawns and in fields. By making the injections early in November in holes 12-18 inches deep and 18 inches apart, the bindweed has been destroyed. Usually the soil toxicity has disappeared by the following summer.

Arsenicals and Sulfuric Acid

The State of California (3) with its intensive growing crops has for a number of years employed chemicals to control weeds. For some time arsenicals were generally used, and for the eradication of annuals, particularly mustard, sulfuric acid was the medium. Special spray equipment which permitted the mixing of sulfuric acid and water near the outlet was installed. Spray pumps of acid resistant materials were manufactured. Sulfuric acid is still being used in killing annual weeds in onions, both in the United States and in England.

Sinox

About 1937 Sinox (sodium-dinitro-orthocresylate) was introduced into the United States from France. It is an acid, orange-colored dye made from by-products of the distillation of coal. The commercial preparation is a dense suspension of fine particles forming a paste and is sold in one and five gallon tins. For the ordinary spraying to kill annuals, the dilution is one gallon to 100 gallons of water. By the addition of an acid salt, ammonium sulfate, the herbicidal action is enhanced. Sinox has been extensively used in California (31) and has practically supplanted sulfuric acid. In North Dakota and Montana, Sinox has been of considerable service in killing mustard in small grain and flax fields. It does not ordinarily harm members of the grass family. For this reason Sinox has also been popular with green keepers for the killing of annual weeds in golf courses. This year the manufacturer of Sinox, Standard Agricultural Chemicals, Hoboken, N. J., is making it in the form of a powder, so that it is easier to handle. They also have a product called "Sinox General," a herbicide for controlling all undesired weed growth. Two to three pints of "Sinox General" are mixed with four to six gallons of Diesel fuel oil or stove oil. To this mix is added sufficient water to make 100 gallons of spray.

Growth promoting substances

2,4-Dichlorophenoxyacetic Acid

For a number of years plant physiologists in this country and in England have been working on growth promoting substances. Zimmerman and Hitchcock (36) reported that certain substituted phenoxy substances were extremely active in promoting growth: 2,4-dichlorophenoxyacetic actid and its derivatives, induced cell elongation of tomato with concentrations as low as 0.007 per cent in lanolin and compared favorably with naphthalenacetic acid. Beal (12) noticed certain definite effects upon tissues of sweet pea when treated with 4-chlorophenoxyacetic acid. Mitchell and Tamner (26) found that relatively high concentrations of 2,4-dichlorophenoxyacetic acid in solution with Carbowax 1500 killed bean plants when applied either to the soil or above-ground parts. Hamner and Tukey (17) of the New York State Agricultural Experiment Station, Cornell University and Geneva, showed that 2,4-dichlorophenoxyacetic acid with 0.5 per cent Carbowax 1500 as a carrier in a concentration of 1000 parts per million (ppm) in water applied as a spray to European bindweed (*Convolvulus arvensis* L.) in amount sufficient to wet the leaves lightly killed the plants. The sprayed plants appeared to be wilted within a few hours following application. Within 24 hours the plants became dull green in color and were flat on the ground. Petals of unopened flowers failed to open and the stamens were arrested in development. No terminal growth of shoots appeared. The plants became harsh and woody to the touch; at the end of 10 days the above-ground parts were dry and dead. The subterranean parts five days after spraying were spongy, water-soaked and enlarged to twice the diameter of similar parts of unsprayed plants. Marsh and Mitchell (24) submitted information to the effect that 2,4-dichlorophenoxyacetic acid can be used as a differential herbicide. The narrow-leaf plantain or rib grass (*Plantago lanceolata* L.) is extremely sensitive to treatment, while blue grass and crab grass are resistant. Dandelion, rib grass, Dutch white clover, chick weed, pig weed, wood sorrel, knot weed, broad-leaf dock and bindweed were killed with no apparent injury to blue grass. It was possible to obtain 95 per cent control of dandelion and rib-grass by a single spray application of a solution containing 1000 ppm of 2,4-dichlorophenoxyacetic acid. Hamner and Tukey (17) made applications of 2,4-dichlorophenoxyacetic acid in Carbowax 1500 (26) upon a field mixture of common weeds in midsummer and early fall. There was no visible effect upon the grasses, but bindweed, rib grass, dandelion, mallow, lambs-quarter and rag weed were killed. Germinating seedlings of white sweet clov er emerging 3-7 days after the soil surface had been sprayed were completely killed. Applications were made to a blue grass lawn infested with dandelion, rib grass, mallow and white clover. All dandelion, plantain and mallow plants were dead and disintegrated within 30 days; most of the white clover was dead and that which was not dead was killed back to the main stolons. The blue grass became dark green in color, but otherwise was not visibly affected. Mitchell, Davis and Marsh (28) have found that 2,4-D compounuds are of particular value in controlling weeds of golf links.

Marsh, Davis and Mitchell (25) have developed a dust form. By means of a duster operating at about 9 lbs. of air pressure an even distribution of the active agent was obtained. The results were similar to those obtained from spraying. Several commercial firms will market the dust form this year.

Mitchell and Brown (27), through chemical analyses of the annual morning glory, showed that the rate of starch hydrolysis was accelerated and the readily available carboyhydrates were depleted. The sugar content of sprayed plants increased markedly up to about the eighth day when they contained 73 per cent more sugar than the controls; later the sugar content of the sprayed plants decreased. Eighteen hours after spraying the flower buds contained about 46 per cent less sugar than the buds of untreated plants. On the 20th day after spraying the starch and dextrin were 1/500 as much as were in the untreated plants.

Slade, Templeman and Sexton (32) of England reported that they began their studies of the effect of growth promoting substances on plants in 1936. At first the work dealt with the stimulation of the rootings of cuttings, then was extended to cover the effect of ranges of concentration of B-indolylacetic acid and dnaphthlenaecetic acid upon seed germination and upon the growth of established plants of many species. They found that the higher concentrations of growth promoting substances would depress growth. Twenty-five pounds of d-naphthyleneacetic acid per acre to oats weedy with yellow charlock killed the charlock, while the oats received only a temporary setback. When the application was made shortly after seed-sowing time, 84 per cent of the charlock failed to germinate. Plantain and yarrow behaved in the same manner. These experiments brought out the fact that certain growth promoting substances could be used where selective phytocidal action was desired. Later a chemical survey was made of known growth substances and substances structurally related. Substituted phenoxyacetic acids and naphthoxyacetic acid were outstanding and certain ones were found to be 50 times as active as nephthylacetic acid. Among these active compounds were 2,4-dichlorophenoxyacetic and 4-chloro-2-methylphenoxyacetic acids. In 1943 they reported that in field trials sodium-4-chloro-2-methylphenoxyacetic acid applied at the rate of one lb. per acre gave 100 per cent eradication of yellow charlock in spring oats without damaging the cereal. Blackman (13) made a comparison of certain plant-growth substances with other selective herbicides. With grasses, once the seedling stage is passed, sulfuric acid, cupric chloride dinitro-orthocresol, and 4-chloro-2-methylphenoxyacetic acid can be employed for the destruction of annual weeds. Preliminary trials indicated that maize is resistant to some dinitro-ortho-cresol compounds. The phenoxyacetic acid derivatives show some promise in the control of some perennial weeds.

The 1944 experimental results were so startling that immediately a number of private and public agencies became interested. A research committee of the North Central States Weed Control conference, an organization of weed control workers in 13 North Central

States, set up a number of uniform experiments to test this 2,4-D material. At their annual meeting in St. Paul, Minnesota, the latter part of November, 1945, the results of the experiments were collected, summarized and reported. Although there were many data, the results were not sufficiently conclusive to warrant recommendation for general unrestricted use. The Policy Committee of the North Central Weed Control Conference recommended:

1. That the Conference approve the use of 2,4-D compounds for the control of certain lawn weeds, the qualifications and details to be set up by each state.
2. That, based on experiments to date, this Conference is not prepared at this time to approve the general use of 2,4-D on annual weeds in growing crops.
3. That the Conference approve the general use of 2,4-D on certain annual weeds, not in growing crops, the list of such weeds to be prepared by the Research Committee .
4. Due to variable results and the short experimental period this conference is not in a position to recommend 2,4-D compounds for general use in eradicating deep rooted perDennial weeds.

It is evident that 2,4-D is still in the experimental state. We have found that it is toxic to onions, carrots, peas, tomatoes and soybeans, but members of the grass family are generally resistant. It has been possible to control annuals in oats by using dilute applications of one of the commercial forms. Canada thistle appears to be resistant, while with the European bindweed the eradication results look promising.

Classification of weeds in relation to
the effectiveness of 2,4-dichlorophenoxyacetic acid as
a herbicide

A list prepared by the North Central States Weed Control Conference of annual weeds, winter annual weeds and a few perennial lawn weeds classified as "generally susceptible", "intermediate" or "resistant" to 2,4-D is given below:

GENERALLY SUSCEPTIBLE

Ball Mustard (*Neslia paniculata*)
Beggar's tick (*Lappula echinata*).
Bitter winter cress (*Barbarea barbarea*)
Black medic or yellow trefoil (*Medicago lupulina*)
Buckhorn (*Plantago lanceolata*)
Burdock (*Articum minus*)
Cockle bur (*Xanthium sp.*)
Dandelion (*Taraxacum officinalis*)
False flax (*Camelina sp.*)
Ground ivy (*Glecoma hederacea*)
Hare's-ear mustard (*Conringia orientalis*)
Henbit (*Lamium amplexicaule*)
Indian mustard (*Brassica juncea*)
Kochia (*Kochia scoparia*)
Mallow (*Malva rotundifolia*)
Marsh elder (*Iva xantifolia*)
Mouse eared chickweed (*Cerastium vulgatum*)

Pepper grass (*Lepidium verginicum*
L. apetalum)
Prostrate amaanth (*Amaranthus blitoides*)
Prostrate vervain (*Verbena bracteata*)
Puncture vine (*Tribulus terrestris*)
Ragweed (*Ambrosia artemisfolia*)
Rough cinquefoil five fingers (*Potentilla sp.*)
Rough pigweed (*Amaranthus retroflexus*)
Shepherd's purse (*Bursa bursa pastoris*)
Speedwells (*Veronica sp.*)
Spotted spurge (*Euphorbia maculata*)
Stinkweed, Fanweed, Frenchweed (*Thlaspi arvensis*)
Sunflower (*Helianthus annuus*)
Sweet clovers (*Melilotus sp.*)
Tansy mustard (*Sophia sp.*)
Tumbling mustard (*Sisymbrium altissimum*)
Wild mustard (*Brassica arvensis*)
Wild rape (*Brassica nepus*)
Wormseed mustard (*Erysimum cheiranthoides*)

INTERMEDIATE

Common chickweed (*Alsine media*)
Common Plantain (*Plantago major*)
(*P. rugelii*)
Goatsbeard (T*ragopogon pratensis*)
Knotweed doorweed (*Polygonum aviculare*)
Lamb's quarter (*Chenopodium album*)
Marestail (*Leptilon canadense*)
Mayweed (*Antemus cotula*)
Oak leaved goosefoot (*Chenopodium glaucum*)
Prickly lettuce (*Lactuca scariola*)
Wild lettuce (*Lactuca sp.*)

RESISTANT

Barnyard grass (*Echinochloa crusgalli*)
Black night shade (*Solanum nigrum*)
Buffalo bur (*Solanum rostratum*)
Canada thistle (*Cirsium arvense*)
Corn cockle (*Agrostemma githago*)
Cow cockle (*Saponaria vaccaria*)
Crabgrass (*Syntherisma sanguinale*)
Foxtails (*Chaetocloa sp.*)
Dock (*Rumex sp.*)
Goosegrass (*Eleusine indica*)
Mullein (*Verbascum thapsus*)
Night blooming catchfly (*Silene noctriflora*)
Nimblewell (*Muhlenbergia schreberi*)
Red sorrel (*Rumex acetocella*)
Russian thistle (*Salsola pestifer*)
Sand burs (*Cenchrus pauciflorus*)
Smart weeds (*Persicaria persicaria*)
(*P. pennsylvanicum*)
Squirrel tail grass (*Hordeum jubatum*)
Tartary buckwheat (*Polygonum tartaricum*)
Violet (*Violat sp.*)
White cockle (*Lychnis alba*)
Wild buckwheat (*Polygonium convolvulus*)

Wood sorrel (*Oxalis sp.*)
Yarrow (*Achillea millefolium*)

Obviously no clear line can be drawn between the different classes. Among many factors the age and condition of the plant are important. Many weeds which may be in the "susceptible" list, when young, become resistant later. The list is in no sense complete.

The action of these 2,4-D compounds is interesting; it is slow, taking about three weeks for a "susceptible" plant to be killed. During that time the stems and leaves will curl and twist. The material is non-corrosive, non-irritating to the skin and is not inflammable. It is not poisonous. The U. S. Department of Agriculture fed five grams (about 1/5 ounce) of 2,4-D daily to a cow for two months with no apparent effect. Dr. E. J. Kraus of the University of Chicago reported at the St. Paul Conference that he personally had taken ½ gram (1/50 ounce) of 2,4-D daily for three weeks with no apparent effect.

FURNACE OIL, STODDARD SOLVENTS, AND STOVE OIL

The last two years the Iowa Agricultural Experiment Station has used regular furnace oil in the eradication of annual weeds in carrots with only a slight decrease in yield of marketable carrots. When the carrots had three to four leaves, they were sprayed with furnace oil at an approximate rate of 100 gallons per acre. The oil used had the following specificactions: Initial B P-334°F, 10 per cent 409°F, 20 per cent 439°F, 30 per ccent 454°F, 40 per cent 471°F, 50 per cent 486°F, 60 per cent 509°F, 70 per cent 526°F, 80 per ccent 540°F, 90 per cent 569°F, Maximum 625°F, API (Gravity) 37.2, Flash (Tag open) 155, Color 2 N.P.A., sulfur 0.168 per cent, Pour point 10.

Where carrots are to be bunched and sold, it is not advisable to give them more than the one spray. Just how far one can go with the oil spray, and still have the carrots free of oil taste awaits further experimental evidence. Kerosene was not satisfactory. In Massachusetts (21) and New York (34) Sovasol No. 5, one of the Stoddard solvents generally used as a paint thinner as well as for the dry cleaning of clothes, has given general satisfaction. Lachman (21) sprayed carrots three times with this solvent, without imparting any oily flavor to the carrots, either raw or cooked. During the 1946 season the commercial growers of carrots in the Crystal Lake, Iowa, area used on of the Stoddard solvents in eradicating weeds in carrots. Stanasol of the Standard Oil Co., and Sovasol No. 5 (Mobiloil) of Sacony Vacuum Co., were the most popular. The usual application was 100 gals. per acre. Parsnips, also a member of the Umbellifarae, may be handled much the same as carrots.

In California it is now the general practice in the Imperial and Salinas valleys to spray carrots with stove oil. Crafts (15) of the California Agricultural Experiment Station has pointed out that more than three million gallons of fuel oil were used last year in

California for the control of weeds. Recently he has submitted a method by which it will be possible to conserve much of this oil. The organic compound, 2,4-dinitro-6 secondary butylphenol is soluble in kerosene. By mixing this material in the kerosene at a concentration around 5 to 10 per cent and adding emulsifiers so that the mixture will form a stable mix, a general contact herbicide can be made that will require only 3 to 6 per cent oil. Such a mixture would effect a saving of over 90 per cent of the oil used in weed work.

From the material presented it is evident that weed eradication with the aid of chemicals is becoming a complicated process. Weeds differ in their reaction. It would seem that the time is not far off when cultication will not be the only practical means of controlling weeds. As newer methods of cultivation have served to lessen labor, it now appears that chemicals, too, will make it possible to produce many crops with less labor. It begins to look as if means and methods are at hand to keep our lawns, golf courses, and fields free of weeds, or at least under control.

IOWA AGRICULTURAL EXPERIMENT STATION,
Ames, Iowa.

LITERATURE CITED

1. Aslander, A. Chlorates as plant poisons (a preliminary report). Jour Amer. Soc. Agron. *18*s 1101-1102. 1926
2. Aslander A. Sulfuric acid as a weed spray. Jour. Agr. Research *34*: 1065-1091. 1927
3. Ball, W. S. A. S. Crafts, B. A. Madson and W. W. Robbins Revised by R. N. Raynor. Weed control. California Agr. Ext. Service Cir. 97: 1-111. 1940.
4. Bakke, A. L. Leafy spurge (*Euphorbia esula* L.) Iowa Agr. Exp. Sta. Res. Bul. 198. 1936
5. Bakke, A. I. The control of leafy spurge. Iowa Agr. Exp. Sta. Res. Bul. 222. 1937
6. Bakke, A. L. Experiments on the control of European bindweed. Iowa Agr. Exp. Sta. Res. Bul. 259. 1939
7. Bakke, A. L. The use of tetrachlorethane in the eradication of the European bindweed. Jour. Amer. Soc. Agron. *33*: 759-761. 1941
8. Bakke, A. L. Control and eradication of European bindweed. Iowa Agr. Exp. Sta. Bul. P. 61. 1944
9. Bakke, A. L., W. G. Gaessler and W. E. Loomis. Relation of root reserves to control of European bindweed (*Convolculus arvensis* L.) Iowa Agr. Exp. Sta. Res. Bul. 254. 1939
10. Bakke, A. L., W. G. Gaessler, L. M. Pultz, and S. C. Salmon Relation of cultivation to depletion of root reserves in European bindweed at different soil horizons. Jour. Agr. Res. *69*: 137-147. 1944
11. Bakke, A. L. and W. G. Gaessler. The effect of reduced light intensity on the aerial and subterranean parts of the European bindweed. Plant Phys. *20*: 246-257. 1945

12. Beal, J. M. Some telemorphic effects induced in sweet pea by application of 4-chlorophenoxyacetic acid. Bot. Gaz. *104*: 471-474. 1944

13. Blackman, G. E. A comparison of certain plant-growth substances with other selective herbicides. Nature *155*: 500-501. 1945.

14. Bolley, H. L. Weed control by means of chemical sprays. N. Dakota Agr. Exp. Sta. Bul. *80*: 541-574. 1908.

15. Crafts, A. S. A new herbicide 2,4-dinitro 6 secondary butyl phenol. Science *101*: 417-418. 1945

16. Hamner, C. L. and Tukey, H. B. The herbicidal action of 2,4-dichlorphenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid on bindweed. Science *100*: 154-155. 1944

17. Hamner, C. L. and H. B. Tukey. Selective herbicidal action of midsummer and fall applications of 2,4-dichlorophenoxyacetic acid. Bot. Gaz. *106*: 232-245. 1944

18. Hance, F. E. The factor of synérgism in chemical weed control. Hawaii Planters Rec. *44*: 263-272. 1940

19. Hirsch, A. A. Toxic effects of sodium pentachlorophenate and other chemicals on water hyacinth. Bot. Gaz. *103*: 620-621. 1942

20. Korsmo, E. Ugress i Nutidens Jordbruk. 694 P. illus Oslo. 1925.

21. Lockman, W. H. The use of oil sprays as selective herbicides for carrots and parsnips. Amer. Soc. Hort. Sci. Proc. *45*: 445-448. 1944

22. Lathshaw, W. L. and Zahnley, J. W. Experiments with sodium chlorate and other chemicals as herbicides for field bindweed. Jour Agr. Res. *35*: 757-767. 1935

23. Loyer, M. Emploi des chlorates pour la destruction des herbes dans les céréales de printemps. Compt. Rend. Read. Agr. France *9*: 957-960. 1923

24. Marth, Paul C. and John W. Mitchell, 2,4-dichlorophenoxyacetic acid as a differential herbicide. Bot. Gaz. *106*(2): 224-232. 1944

25. Marth, Paul C., F. F. Davis and John W. Mitchell. Herbicidal properties of 2,4-dichlorophenoxyacetic acid applied in dusts containing hygroscopic agents. Bot Gaz. *107*: 129-136. 1945

26. Mitchell, John W. and Hamner, Charles L. Polyethylene glycols as carriers for growth regulating substances. Bot. Gaz. *105*: 474-483. 1944

27. Mitchell, John W. and James W. Brown. Effect of 2,4-dichlorophenoxyacetic acid on the readily available carbohydrate constituents in annual morning glory. Bot. Gaz. *107*: 120-129. 1945

28. Mitchell, John W., F. F. Davis and P. C. Marth. Turf weed control with plant growth hormones. Golfdom. Oct. 1944

29. Muenscher, W. C. Killing perennial weeds with chlorates during winter. New York (Cornell) Agr. Exp. Sta. Bul. 542. 1932

30. Rebate, E. Destruction des ravenelles par l'acide sulfurique. Jour: d'Agr. Prat: (N.S.21) 75: 497-509. 1911.

31. Robbins, Wilfred W., Alden S. Crafts, and Richard N. Raynor. Weed control. McGraw-Hill Book Co. New York 1942

32. Slade, R. E., W. G. Templeman and W. A. Sexton. Plant growth substances as selective weed killers. Nature *155*: 497-498. 1945

33. Sweet, R. D., R. Kunkel and G. J. Raleigh. Oil sprays for the control of weeds in carrots and other vegetables. (Cornell U.) Amer. Soc. Hort. Sci. Proc. *45*: 440-444. 1944

34. Tukey, H. B., C. L. Hamner and Barbara Inhofe. Histological changes in bindweed and sow thistle following applications of

2,4-dichlorophenoxyacetic acid in herbicidal concentrations. Bot. Gaz. *107*: 62-92. 1945

35. Zimmerman, P. W. and A. E. Hitchcock. Substituted phenoxy and benzoic acid growth substances and the relation of structure to physiological activity. Contr. Boyce Thompson Inst. *12*: 321-344. 1492