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2,4-D AS A WEED KILLER

W. A. Harvey and W. W. Robbins

THE COLLEGE OF AGRICULTURE
UNIVERSITY OF CALIFORNIA · BERKELEY

SPECIES SUSCEPTIBLE TO 2,4-D

Arrowhead lily
Austrian field cress*
Beggar-ticks
Black medic
Blue lettuce*
Bull thistle
Burdock
Bur-reed*
Buttercup
California mugwort
Canada fleabane
Cattail (young)*
Cheese-weed
Chickweed
Chicory
Cocklebur
Creek nettle
Curly dock
Dandelion
Fanweed
Hoary cress (lens-podded)*
Honeysuckle*
Indian strawberry
Kelp*
Klamath weed (St. John's wort)*
Knotweed*
Lambs'-quarters
Leafy spurge*
Milk thistle
Mouse-ear chickweed
Mustards
Nettle
Oxalis (green)*
Pennywort
Perennial dogbane*
Perennial ragweed*
Plantain
Poison hemlock
Prostrate pigweed
Puncture vine
Purslane
Red clover
Rough pigweed
Russian thistle (young)
Sedge
Sheep sorrel*
Shepherd's purse
Sow thistle (annual)
Spiny clotbur
Spotted spurge
Star thistles (rosette)
Sweetclover
Teasel
Tules*
Tumbling pigweed
Water hemlock*
Water hyacinth
Water plantain
Water primrose
Western ragweed
White horse nettle*
Wild carrot
Wild lettuce
Wild morning-glory*
Wild radish
Wild sunflower
Willows*

* Those marked by an asterisk (*) may require two or more treatments.

Species Resistant to 2,4-D

Alkali mallow
Annual bluegrass
Baby tears
Bermuda grass
Blackberry
Bluegrass
Bracken fern
Button willow
Canada thistle
Crab grass
Dog fennel
Foxtail
Goldenrod
Goosegrass
Horsetail
Italian ryegrass
Johnson grass
Milkweed
Mullein
Nutgrass
Oxalis (red)
Pineapple weed
Poison oak
Quackgrass
Ripgut grass
Russian knapweed
Saltbush
Sand bur
Soft chess
Tansy ragwort
Watergrass
Wild barleys
Wild oats
Yarrow

2,4-D is Dangerous to Crops

Experiments to date show that of the crop plants, only the cereals and other grasses are resistant to 2,4-D. Apparently most other crop plants are injured by contact with the chemical, some of them seriously. For this reason, the use of 2,4-D has so far been limited to control of weeds in grain fields, grass pastures, and lawns, and to ridding soil of weeds well in advance of planting crops.

As experiments with 2,4-D continue, changes are being made in recommendations for its use. Consequently, the present recommendations must be regarded as tentative.

General Facts about 2,4-D

1. 2,4-D acts slowly and two weeks or a month may elapse before the treated plants actually die.
2. Two or more sprayings are usually necessary to effect a complete kill of many perennial weeds.
3. Temporary soil sterilization results from use of 2,4-D. How long soil remains sterile depends upon amount of chemical used, temperature, rainfall or irrigation, soil type, and crop planted.
4. Sprayers or other equipment used for 2,4-D must be thoroughly cleaned before being used for other material.
5. Spray or dust must never be allowed to reach ornamental or susceptible crop plants. *Even small amounts of drift are highly injurious.*
6. The acid 2,4-D and its compounds are nonpoisonous to humans and animals, noncorrosive, and neither explosive nor inflammable.

2,4-D AS A WEED KILLER

W. A. HARVEY[1] AND W. W. ROBBINS[2]

CERTAIN SO-CALLED "growth-regulating" compounds have found use as weed killers. Chief of these is 2,4-D (or 2,4-dichlorophenoxyacetic acid). Weed killers containing this chemical as the effective ingredient are known by many trade names. At present over sixty commercial products containing 2,4-D are registered with the Bureau of Chemistry, California State Department of Agriculture.

The earliest work with the material was carried on in the eastern United States and in England. Extensive experiments and tests have been conducted in California and elsewhere, and much more study is in progress. At present, results are far from complete; and recommendations for use are being constantly revised as new information becomes available.

Although 2,4-D shows great promise as an economical herbicide, it has sometimes been misused and some injury to crop and ornamental plants has resulted. Yet 2,4-D, if used with care and discretion, will undoubtedly find a permanent place in weed control.

Commercial Preparations of 2,4-D

The most common forms of 2,4-D are the acid (2,4-dichlorophenoxyacetic acid) and the salts and esters of this acid. The term 2,4-D applies both to the parent acid and its derivatives.

The Acid. The acid itself is a dry material almost insoluble in water. It is usually mixed with a liquid carrier that will keep it in solution when diluted with water. Such liquid preparations may differ in the amount of 2,4-D they contain, and in the carrier used.

The Salts. Salts of the parent acid, such as sodium or ammonium salt, are dry powders readily dissolved in water, and easily prepared. One dry material now on the market contains 60 per cent of the sodium salt of the acid. A wetting agent is also included in the preparation. This makes it possible to cover the plants more evenly with the spray. Roughly, 1½ pounds of a 60 per cent sodium salt is equal to 1 gallon of liquid preparation having a 9.6 per cent acid content. Several of the newer liquid preparations contain alkinolamine salts, such as triethanolamine and others, which also wet leaves evenly.

The Esters. The esters used in the commercial 2,4-D products dissolve more slowly in water than do the salts discussed above. They will, however, dissolve easily in oil. For this reason, the esters are usually sold in an oil preparation which mixes readily with water to form an emulsion. (The esters now available in California are methyl, ethyl, and butyl, with isopropyl probably available soon.) The content of 2,4-D in these newer preparations is 11 to 36 per cent, depending upon the particular product. The number of pounds of 2,4-D per gallon in any of the liquid preparations depends upon the strength of the 2,4-D (the per cent), and the weight per gallon. For this reason, the products cannot be compared on the basis of per cent 2,4-D alone. Sometimes the label

[1] Associate in Botany and Associate in the Experiment Station.
[2] Professor of Botany and Botanist in the Experiment Station.

states the actual pounds or ounces of 2,4-D contained. This information helps to determine the amount to use, since recommendations are usually made in pounds of 2,4-D per acre.

Other preparations, some of which will undoubtedly contain higher percentages of 2,4-D, are likely to appear on the market.

So far, tests have shown that the various commercial 2,4-D products are about equally effective when compared on the basis of the actual amount of acid or acid derivative they contain. Thus in deciding which product to buy, prices should be compared on the basis of 2,4-D content. Ease of handling and mixing are other factors to be considered—a slightly faster mixing time may compensate for a slightly higher price.

The acid 2,4-D and its compounds are nonpoisonous, noncorrosive, and neither explosive nor inflammable.

How 2,4-D Kills Plants

This new chemical, which acts differently from other weed killers, was first used in very weak concentration to regulate the growth of plants. Later, when stronger concentrations were found to kill certain plants, its use as a weed killer was developed.

Plants sprayed with 2,4-D react in various ways. The first noticeable effect is in the stems and leaves, which twist and bend, the stems sometimes forming loops and coils. In some plants, the stems and leaves dry until the tops are completely dead; in others, the stems remain green for several weeks, but may swell, develop cracks, and form callus tissue. Sometimes thick pads of tissue develop along stems and at the joints. Often, numerous watery, translucent buds appear at the crown but do not grow into new shoots. Before dropping, leaves of some woody plants change their color to red or yellow, as though it were autumn. Several weeks after treatment, seriously affected plants may show spongy, enlarged roots. The outer portion of the root may slough off and leave wet, stringy cores that will later dry up or rot.

On most weeds, 2,4-D acts more slowly than other weed killers. It may require from four to eight weeks for the weeds to die down completely. The effects of spraying show up more rapidly in hot than in cool weather, but the end result is the same.

Plants that form rosettes are especially susceptible in the rosette stage. Other plants should be young and growing vigorously, with a well-developed leaf surface. Old, mature plants respond slowly or not at all. All plants are more easily killed as small seedlings, if application is made at that stage.

In general, broad-leaved plants are relatively susceptible to 2,4-D, but there are exceptions. For example, it is usually easier to effect a permanent kill of broad-leaved annuals than of broad-leaved perennials.

Effects of 2,4-D on Perennial Weeds

Among perennial weeds, these results have been observed in California:

Russian knapweed: Variable—per cent of kill ranges from 95 to 10. Should be treated in the early rosette stage. Difficult to wet, and spray may require a wetting agent.

Klamath weed: Early sprayings not too effective. Better results if plants are treated when well developed, but before bloom stage.

Fig. 1.—Injury of Tokay grapes from an application of 2,4-D in the vineyard for the control of dogbane. Left, longitudinal section through old trunk shows development of callus tissue; right, new shoot shows distorted leaves.

Poison oak and **wild blackberry**: Not seriously affected by a single treatment in early spring. Later applications, following complete leafing, look more promising. Both plants classified as resistant.

Dandelion: Highly susceptible. One application usually kills entire infestation.

Cattail, tule, bur-reed, and **kelp**: Proper applications effective even when plants are rooted below the water surface. Cattails become resistant by early summer. Three gallons of Diesel oil added to each 100 gallons of spray help in penetrating the waxy surface of the plants. Ester preparations are especially effective on these species.

Water hyacinth, yellow water-weed, and **hydrocotyle**: These floating water weeds are easily destroyed by spraying their above-water portions.

Nutgrass (which is not a true grass, but a sedge): Somewhat susceptible. Treatments must be repeated to destroy underground nuts where food is stored.

In consulting lists (cover and p. 2), it would be well to bear in mind that several factors influence the success of any treatment. Among those to be considered are: susceptibility of the weed; stage of growth; amount of leaf surface; ease of wetting; kind and strength of weed killer used; and weather conditions. With further field experience and additional tests, revision of the list may be required.

Effects of 2,4-D on Grasses

Since members of the grass family are more resistant to 2,4-D than are broad-leaved plants, the chemical is being widely used as a selective spray in grain fields.

Barley and **wheat**: The usual rate of application has been ½ to ¾ pound of 2,4-D per acre, applied in 100 to 200 gallons of water, with a ground rig. Although some injury is noted when very young plants are treated, no damage results when applications are made on grain 4 to 6 inches high. Wild radish, mustards, fiddle-neck, and star thistle are readily killed in the young stages by applications that ordinarily will not damage grain.

Corn and **milo**: One spraying before the crop plants cover the rows will greatly reduce the infestation of such perennials as wild morning-glory and kelp for the season. One to 1¼ pounds of 2,4-D per acre is the recommended amount.

Rice: In rice fields, airplane applications of 2,4-D have been successful in control of arrowhead lily, water plantain, burhead, certain sedges, and other water weeds. The usual treatment was 15 gallons per acre of a solution containing 1 to 1½ pounds of 2,4-D. (One pound is probably sufficient.) Where the water was low when spray was applied, there was some damage, but fields sprayed when the water was up and the plants well established showed no serious injury.

Grass pastures, turfs, and **grass seed fields**: These areas may be treated with 1½ pounds of 2,4-D per acre, in 100 to 200 gallons of water. If the grasses are in the seedling stage, however, not more than ¾ pound of the acid should be used. Grass seed fields should not be treated when plants are in bloom. In mixed pastures, 2,4-D will seriously injure or kill clovers, filaree, and other broad-leaved forage plants.

Lawns: The correct solution is about $^6/_{10}$ ounce of the parent acid in 5 gallons of water per 1,000 square feet of lawn (1½ pounds in 200 gallons of water per acre). Treatment has been very effective in controlling dandelion, plantain, chickweed, bur clover, green oxalis, pennywort, heal-all, mouse-ear chickweed, and speedwell. Bluegrass and ryegrass are more resistant than bent grasses and red top. The spray is not effective against Bermuda grass, crab grass, and red oxalis—weeds common in bluegrass lawns.

Use of 2,4-D in Orchards

In orchards, 2,4-D has been used to control wild morning-glory and other perennial weeds, except grasses. Thus far, no serious injury has been reported. Drift has resulted in a slight amount of curling and discoloration of young growth, but there was no stunting of tree growth or reduction in yield and quality of fruit. If 2,4-D is used in orchards, however, care should be taken to reduce drift to a minimum, and to avoid any undue accumulation of the chemical in soil areas resulting from spilling or careless application.

Effect of 2,4-D on Soil

In some instances, the use of 2,4-D has resulted in sterilization of the soil. Some crops, such as broccoli, cabbage, sugar beets, tomatoes, beans, and root crops have been damaged when grown in fields where 2,4-D had been used (see fig. 2). However, in a number of cases, extra large amounts of the chemical had been applied, and most of the fields had remained dry from the time of application until just before the crop was planted.

Tests have shown that 2,4-D leaches out of warm, moist soils in thirty to sixty days, but it may remain in cool, dry soils for six months or longer. Tests also indicate that more 2,4-D is retained by heavy than by light soils. Flood irrigation after an application of 2,4-D will help remove it, especially in summer when the soil is warm. In many areas, soil is safe for spring or summer planting after the winter rains. If areas are treated during the late spring or summer, however, it is not wise to plant susceptible crops until several months have passed.

Fig. 2.—Root systems of onion bulbs: The upper root system was grown in a solution containing 1 part per million 2,4-D (.0001 per cent); the lower, in 5 parts per million 2,4-D (.0005 per cent).

The Use of 2,4-D Dust

Tests to date indicate that while 2,4-D applied as a dust is effective in killing weeds, slightly more 2,4-D per acre may be required than when applied as a spray. Until some satisfactory method is developed for control of drift toward susceptible crop plants, it will be dangerous to use dust near any crops except grain.

Tests in which dry 2,4-D was applied to the soil at the time of seeding grains, to destroy young germinating weed seedlings, have been disappointing. Grain was injured much worse than by spray treatments. Success of dry applications to the soil depends upon the amount of rainfall and, under California conditions, cannot yet be recommended.

The Best Time to Spray

All available information indicates that weeds should be sprayed while still young and growing vigorously. If plants are sprayed when they are old or near maturity, the chemical will have a slow, uneven reaction. Although most weeds should not be sprayed when temperature is low, certain early spring weeds are making vigorous growth at this time, and applications of 2,4-D give satisfactory results.

Cost of Treatment

These weed-killing substances are usually applied as a spray. If an airplane is used, only about 15 gallons per acre are required, as compared with 100 or more gallons per acre when a ground rig is employed. The amount of 2,4-D used depends upon the thickness of the weed growth, but ranges from ¾ to 3 pounds per acre. The following figures are average costs per acre for some of the commercial products: for selective weed control in grain, ¾ pound per acre, $2 to $3; for morning-glory, 1½ pounds per acre, $4 to $6; and for some of the more resistant weeds, $8 to $12. Prices may vary in different localities, depending upon amounts available and quantity purchased.

In addition to the cost of the chemical there is the cost of application. This is about $2 per acre, but varies with type of equipment and amount of acreage sprayed. If a satisfactory method of applying dust is developed, the over-all cost of treatment may be reduced.

Use 2,4-D with Caution

1. Do not expect miracles. 2,4-D is a new material, not thoroughly tested. Its action is slow, sometimes requiring a month or longer to kill the tops and roots of the weeds, especially perennials. Two sprayings may be necessary because some plants are missed during the first spraying, and some new plants may come up from lateral roots which did not die. Watch the sprayed area closely and spray new growth or regrowth as soon as it is large enough.

2. Soil sterilization results from use of 2,4-D. How long the effects will remain depends upon amount of chemical used, temperature, rainfall or irrigation, soil type, and crop planted. While grains and grasses apparently suffer no damage if planted within a few weeks after spraying, beans, peas, lettuce, tomatoes, cabbage, broccoli, sugar beets, alfalfa, and many other crops are extremely sensitive to small quantities of the chemical.

3. A sprayer or any other equipment which has contained 2,4-D must be thoroughly washed before it is used for other material. Otherwise, field, orchard, and ornamental plants may be damaged if even a small amount remains in the sprayer. One cold-water rinse is not sufficient. Use several changes of water (preferably warm) to which a little baking soda or washing soda has been added.

4. When spraying a lawn or other area, never allow the spray to reach near-by ornamental or crop plants. Even small amounts of drift will injure these plants, some of which are highly sensitive.

Recently, grapevines from the San Joaquin Valley have shown what appeared to be damage from 2,4-D after treatment of morning-glory in the vineyard. The effects on the vines may have been due to drifting of spray, to action through soil, or both. Experience with it in vineyards is not extensive enough, however, either to encourage or discourage its use for weed control in such plantings. Other similar cases of injury to near-by crop plants by spray have been reported. This past season, beans next to a rice field which was sprayed from the air were injured by drift.

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