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Controlling Perennial Weeds

with

Sodium Chlorate, Carbon Bisulfide, and Borax

By

C. I. SEELY, K. H. KLAGES, AND E. G. SCHAFER

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C. I. SEELY, K. H. KLAGES, AND E. G. SCHAFER*

CHEMICALS have been widely used in the control of perennial weeds for many years. Salt, first used of the chemicals, was followed by the various arsenic compounds which in turn were generally replaced by the chlorates, carbon bisulfide, borax, and 2,4-D (2,4-dichlorophenoxy acetic acid). All of these compounds appear to have a place in perennial weed control. Since 2,4-D is used largely as a selective herbicide and the other materials as non-selective herbicides, the use of 2,4-D in perennial weed control is covered in a separate bulletin. A selective herbicide in the sense used here may be defined as a material which is applied in the presence of the growing crop and designed to control the weeds without serious injury to the crop. Non-selective herbicides are used without regard to injury to any crop which may be present. Most chemicals used in non-selective control can be used selectively under some conditions. Many of the selective chemicals can also be used non-selectively. However, in this bulletin only the non-selective uses of sodium chlorate and carbon bisulfide are discussed.

During the period from 1936 to 1945, tests were conducted with the following chemicals: chlorates, carbon bisulfide, borax, arsenicals, sulfamates, and thiocyanates. Some combinations of these such as chlorate and borax were also tested. Many other compounds were tested in a minor way for screening purposes. Tests were conducted on many weeds including: bindweed, white top, Canada thistle, Russian knapweed, yellow toadflax, quackgrass, leafy spurge, blue flowering lettuce, and St. Johnswort (goatweed). As a result of these tests sodium chlorate and carbon bisulfide are being recommended for general non-selective control of perennial weeds, borax for the control of St. Johnswort (goatweed).

Choosing the Proper Method of Control

Perennial noxious weeds can be controlled by a number of methods. Chief among these are the use of carbon bisulfide, chlorates, selective chemicals, cultivation, and crop rotation. Any one method

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of eradication or control has definite limitations, and these should be taken into consideration in choosing a method for a particular problem. The choice of method will usually be determined by whether speed of eradication or cost of eradication is the more important. In figuring costs the loss of crop from the treatment must be included. On this basis, the costs for the several methods will normally be highest for carbon bisulfide followed by sodium chlorate, selective chemicals, cultivation, and rotation methods. The speed of eradication is generally in the same order, that is, the fastest eradication is obtained by the most expensive methods. Under certain circumstances such as with crops of extremely high value, the order of costs may change or with certain weeds the speed of eradication may change. Under these special conditions the proper method may also change. Another factor to be considered is the percentage of the total costs which are cash outlay and which are the use of labor and equipment otherwise idle. Generally, the non-selective chemicals involve the highest percentage of cash costs and the cultivation and rotation methods the lowest percentage of cash outlay. High unit costs of eradication are usually justified only where the area of infested land is small in proportion to the clean land. Under these circumstances, the protection of the clean land from infestation is of first importance, and the quicker eradication is obtained the less is the chance of infesting the adjacent land. This is one of the places for non-selective chemicals. Non-selective chemicals also can be used economically in many cases on land which cannot be cultivated, such as roadsides, ditch banks, rocky areas, etc. Under these conditions they actually may be cheaper than other methods because of reduced labor costs which frequently run high in the treatment of uncultivated land. It should always be remembered that all methods of weed control have specific limitations and none should be considered as the whole answer to the weed problem but rather that each merely supplements the others.

SODIUM CHLORATE

History

Sodium chlorate commonly known to farmers by various names such as "sodium," "chlorate," "chloride," and "powder" was reported as useful in perennial weed control by Aaslander (1)* in 1926. Sodium chlorate was first recommended for controlling bindweed in Washington by Schafer, Lee, and Neller (6) in 1929. It was recommended for general perennial weed control in Idaho by Hulbert, Bristol, and Benjamin (4) in 1931. Since that time it has been one of the most widely used chemicals in perennial weed control.

Description and Precautions in Use

Sodium chlorate is a white crystaline material that looks very much like common table salt. Like salt it is very soluble in water

*(1) Numbers in paranthesis refer to "Literature Cited."

and was first used in weed control as a spray material. Unlike salt it contains oxygen which under certain conditions can be released. The release of oxygen is probably associated with its killing power and likewise is the source of the hazards in its use. Under certain circumstances, it may result in an extremely hot fire that cannot be smothered. The oxygen may be liberated slowly in the presence of heat and light or under favorable conditions can be used by organisms in the soil. Rapid and dangerous liberation takes place only in the presence of material which will burn and then only if the chlorate and the burnable material are in very close contact. Sodium chlorate can be handled safely by preventing it from coming in close contact with burnable material. Most chlorate fires arise from getting a burnable material in contact with a solution of sodium chlorate and then letting the material dry. Any spark may then cause a fire. Chlorate fires cannot be smothered; they must be put out with large amounts of water. Clothes which have come in contact with chlorate and then become wet are a serious fire hazard unless they are thoroughly washed before drying. *All chlorates should be handled with great care to prevent serious accidents.*

The liberation of the oxygen present in sodium chlorate will rapidly corrode most metals with which it comes in contact. Any metal equipment used in the application of chlorates must be thoroughly washed to prevent serious deterioration.

Sodium chlorate is not particularly poisonous to stock, however, when taken in large quantities may kill animals. Chlorates are salty in taste and attractive to stock. Adequate salting of the stock will materially reduce the amount they may eat. Stock which have been properly salted are seldom bothered by chlorate poisoning. Even though normally avoided by livestock, *poisonous plants become attractive* to them when treated with sodium chlorate. Properly distributed applications made to bare soil are reasonably safe but stock should be excluded from the treated areas until at least one heavy rain has fallen to be certain no poisoning will occur. Chlorates should be kept covered and empty containers should be properly disposed of to prevent possible accidents.

Sodium chlorate should not be used close to valuable plants such as shade trees, ornamentals, etc. If the chlorate comes in contact with the root systems of these plants they will either be killed or seriously injured. Shrubs and trees will usually recover from chlorate applications if the treatment is not made under the spread of the branches or is confined to one side of the tree.

Types of Sodium Chlorate

Sodium chlorate is generally used in a relatively pure form with only small additions of other materials to prevent "lumping." The commercial form usually runs from about 98 to 100 percent pure sodium chlorate. The suggested rates of application are based on this percentage. Commercial forms containing various materials such as borax, sodium acetate, sodium carbonate, and calcium chloride are available. In most cases, these materials are added to reduce fire hazard. All materials containing very large amounts of chlorate, however, should be handled with extreme care. Tests conducted with these materials show that in most cases the added materials have little influence on the killing power of the chlorate. When these materials are used the rate should be increased to give the amount equal to high grade sodium chlorate. This may be done rather simply by dividing the rate required with straight sodium chlorate by the percentage of sodium chlorate in the mixture and multiplying the answer by one hundred. As an example, if a product contains 60 percent sodium chlorate and the rate of sodium chlorate required is 3 pounds per square rod then $3 \div 60 = .05 \times 100 = 5$, so the rate required with this material would be approximately 5 pounds per square rod.

Chlorate which is finely ground is undesirable for dry applications. It is difficult to handle safely and hard to spread evenly. It also drifts badly even in light winds. The best forms for dry applications have particles of such a size that they will pass through a 10 mesh and go over a 30 mesh screen. For spray applications smaller particle sizes are satisfactory and may even be preferable since they dissolve more readily in water.

Limitations

Sodium chlorate has two major limitations in addition to its fire hazard. One is cost. The material normally costs from 9 to 14 cents per pound, depending upon freight charges, and rates from 2 to 6 pounds per square rod are required. This makes the total cost for material vary from 30 to 135 dollars per acre. Treatments must be confined to relatively small areas to be practical. The other major limitation on the use of sodium chlorate is soil sterility. Areas treated with chlorate remain unsuitable for crop production for some time after treatment. This soil sterility has both advantages and disadvantages. Its advantages are that the sterility controls seedlings for some time after treatment, and the areas are easily found for any spot treatment that needs to be done later. These advantages are particularly valuable on small patches or on uncultivated areas. The major disadvantages of the soil sterility are the lack of crop production on the treated area and erosion hazards. Areas treated with sodium chlorate are very subject to erosion both because of lack of plant cover and the presence of the residual sodium which seals the soil surface and reduces moisture penetration.

Soil Sterility

The period of time that the soil will remain sterile after a treatment with sodium chlorate varies widely with rate of application, soil, and climatic conditions. It usually averages about 1 year of at least partial sterility for each pound per square rod. On soils of high fertility it will be considerably less than on soils of low fertility. Sterility usually prevails longer under low than under high rainfall conditions.

When soil sterility is undesirable the condition may be partially corrected by any one of the following methods: (1) the addition of large amounts of easily rotted organic materials such as alfalfa, sweetclover, or manure; (2) leaching with water; (3) addition of 600 to 700 pounds of gypsum per acre to soils which are not high in lime; and (4) the addition of about 40 pounds of nitrogen per acre in the form of a nitrate fertilizer to the crop. In some cases it is possible to get the soil back into production quicker by the use of crops which are relatively tolerant of chlorate in the soil. The most tolerant crops tested were the wheatgrasses. These usually have made fair growth when seeded the spring following application, even when treatments were made at rates up to 5 pounds per square rod. The other perennial grasses tested, while not as tolerant as the wheatgrasses, were more tolerant than the cereal crops. The most tolerant cereal crops were oats and rye. White and alsike clover were the most tolerant of the common legumes tested, but even these were more susceptible than oats or rye. The use of tolerant crops is limited in its usefulness since it would seldom be practical to change the crop on the whole field for the small treated areas.

Date of Application

Using sodium chlorate is essentially a soil treatment and the chlorate kills perennial weeds by coming in contact with the roots of the plants. With surface applications it is necessary for the chlorate to be moved down to the roots to be effective. The best kills have been obtained when the chlorate is moved to the lowest depth of roots on shallow-rooted plants or to a depth of 4 to 5 feet on the deep-rooted weeds. Under most circumstances the chlorate is carried down to the roots by rainfall. The date of application must be such that the rainfall will carry the chlorate to the proper depth without any appreciable loss from breakdown on the surface, or from biological activity near the surface of the soil. The best results are normally obtained by applying the chlorate in the fall after temperatures have dropped and just before the fall and winter rains start. The ideal condition is for the soil to be dry at the time of treatment. For greatest effectiveness the fall and winter rains should be just heavy enough to carry the chlorate to the proper depth. Under conditions of very heavy winter rainfall, fall applications usually have been less effective than winter applications due to the chlorate being leached out of the soil. Under these conditions, it may be desirable to delay application so that the expected rainfall between the date of application and April 1 will be between 12 and 16 inches. Where fall and winter rainfall is less than 12 inches, it is important to make applications before the first fall rains to obtain the maximum penetration possible. With shallow-rooted weeds such as St. Johnswort and quackgrass, some delay in application may prevent the chlorate from being carried below the depth of root penetration. The effect of different dates of application of sodium chlorate on the deep-rooted bindweed under conditions of approximately 22 inches of annual rainfall is illustrated in Figure 1.

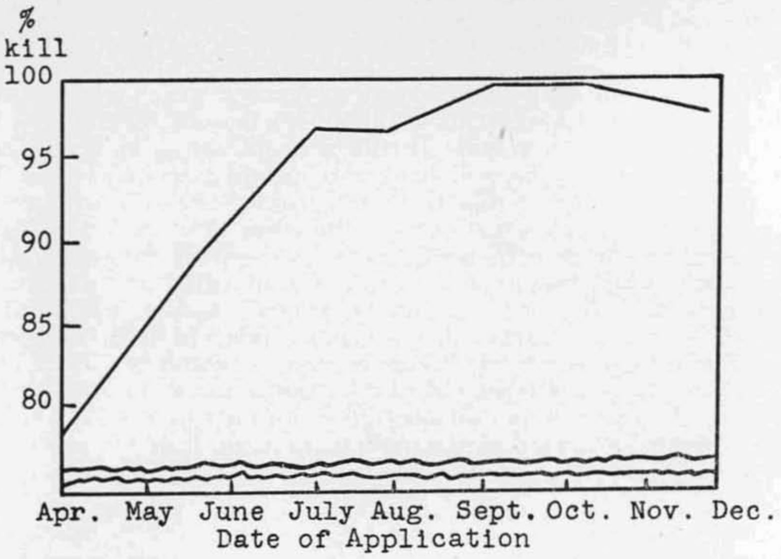

Figure 1. The effect of the date of application of sodium chlorate on the kill of bindweed obtained with a rate of 2 pounds per square rod in an area of 22 inches of rainfall. Average 1936-45.

Over the 10-year period the best kills were obtained from September 1 to November 1. Applications made at any other time gave significantly poorer results.

Rate of Application

Specific rates of application of sodium chlorate cannot be recommended for all conditions because many factors influence the effectiveness of the chemical. Some of these factors are: (1) evenness of distribution; (2) soil fertility; (3) weed species and varieties; (4) soil moisture; and (5) alkalinity (salinity) of the soil. Evenness of distribution is probably the greatest single factor in determining rates. High rates are frequently used as a substitute for uniform distribution, and care in application to insure even coverage will frequently save half of the chlorate required to do the job. Generally, soils of high fertility require larger amounts of chlorate for satisfactory kills than do those of lower fertility. Soil moisture can be extremely important under certain conditions since the chlorate is moved into the soil by the downward movement of water. Where high water tables and high rates of evaporation occur, moisture movement may actually be upward which prevents the penetration of the chlorate, and thus poor kills may be obtained. Chlorates generally cannot be recommended for use on soils which have a high water table. Soils which carry a high salt content (alkali) normally require considerably higher rates of chlorate to obtain kills. Different strains (kinds) of a particular weed may vary considerably in their tolerance to sodium chlorate so that only an average figure can be given for each weed. Table 1, which is slightly modified from Spence and Hulbert (8), gives the rates which are suggested for each of the more common perennial weeds under non-irrigated and irrigated conditions. These rates may be used as a guide for treatment but should be changed to fit local conditions. For uncommon weeds or new weeds that are not given in the table, a rate of about 5 pounds per square rod is suggested.

Table 1.—Suggested rates of application of sodium chlorate on different perennial weeds.

Kind of Weed		Rate of application in pounds per square rod	
Common name	Scientific name	Non-irrigated	Irrigated
Bindweed	*Convolvulus arvensis*	2-3	4-5
Canada thistle	*Carduus arvensis*	2-3	4-5
White top	*Lepidium draba*	5	6*
Per. sow thistle	*Sonchus arvensis*	5	6*
Quackgrass	*Agropyron repens*	5	6*
Blue flowering lettuce	*Lactuca pulchella*	5	6*
Poverty weed	*Iva axillaris*	2-3	4-5
Yellow toadflax	*Linnaria vulgaris*	3	5
Leafy spurge	*Euphorbia esula*	5	6*
St. Johnswort (Goatweed)	*Hypericum perfoliatum*	1-2	....

*Where rates exceed 5 pounds per square rod better results normally have been obtained by making two applications at least a month apart. Approximately 40 percent of the total should be applied on the first application.

When kills are relatively poor a small increase in rate may result in much improved kills. When kills are relatively good, a large increase in rate is necessary to improve the kill to any extent. This situation is illustrated by the average percentage kills of bindweed obtained with different rates of chlorate application for the period 1936-45, as given in Table 2.

Table 2.—Effect of different rates of application of sodium chlorate on bindweed.

Amount of sodium chlorate applied in pounds per square rod	Percentage of weed plants killed: Total	Percentage of weed plants killed: By last pound applied
1	97.9	97.9
2	99.6	1.7
3	99.9	0.3
4	99.9	0.0
5	99.9	0.0

The most efficient use of chlorate is usually obtained by using a rate which will not make a complete kill, but will kill enough plants to make later individual plant treatments practical. For example, in Table 2 where one pound per square rod of chlorate was required to increase the kill from 99.6 percent to 99.9 percent, 0.1 pound of chlorate used as an individual plant treatment the following year would have increased the kill from 99.6 to 100 percent. Since perfect kills cannot be depended upon from any reasonable rate, some spot treating normally will be necessary the following year. If the original rate is adjusted to give the right amount of kill, the cost of eradication can be materially reduced. A stand of 2 plants per square rod after the first treatment (about 99.8 percent kill) can be easily and cheaply spot treated the following year. This can be used as a guide for adjusting treatment rates. More than 2 plants per square rod indicates that the treatment was too light if the plants are uniformly distributed over the area. If the escaped plants are bunched rather than being scattered it is probably due to lack of uniformity in application and this should be corrected rather than the rate. Less than 2 plants per square rod indicates that more chlorate was used than was necessary. If rates are adjusted to this figure, not only will sodium chlorate be saved, but there will be a marked reduction in the period of soil sterility. Erosion following the treatment will also be reduced.

Where the suggested rates are above 5 pounds per square rod, two applications are more efficient than one. In this case, both applications should be made during the same season but about a month apart, with the second being the heavier. For example, better results usually have been obtained on white top by applying 2 pounds per square rod September 1 and following with 4 pounds October 1 than by applying 6 pounds either September 1 or October 1.

Method of Application

Sodium chlorate can be applied either in dry or spray form. It is easier to get uniform distribution of the material in spray form, but this is of importance only when the rates are less than 2 pounds per square rod. At rates higher than 2 pounds per square rod, results are usually better with dry applications. Spray applications are more expensive and are extremely hazardous. The danger of fire is far greater with spray than dry applications. Extreme care must be taken to avoid moistening the clothing of the workers with the sodium chlorate solution. Since rates of application are normally 2 pounds or more per square rod, the use of sodium chlorate as a spray cannot be generally recommended. When chlorates are sprayed, the treatment should be made in the fall and on bare ground. This will reduce the fire hazard. Also, better kills usually are obtained when bare ground rather than vegetation is sprayed.

Hand Application

Dry applications of chlorate can be made either by hand or with a chlorate spreader. Where areas to be treated are very small or otherwise difficult to cover with machinery, applications should be made by hand being careful to get even distribution of the material. To obtain uniform distribution by hand, the area of the patch to be treated should be estimated and the proper amount of chlorate measured out. Generally, one measuring cup level full of sodium chlorate weighs about a pound and this may be used as a guide in determining the amount of chlorate necessary. One-half of the chlorate measured out should be used in treating the patch; being careful to spread this as even as possible. This usually can best be done by spreading about a 5-foot strip on each trip across the patch. After the first half is applied, the second half should be applied while walking at right angles to the first. For example, if the strips run east and west with the first half of the material, they should run north and south with the second half. In treating with sodium chlorate, it is essential to spread the chlorate at least 5 feet beyond the visible edge of the patch since chlorates move almost straight down in the soil and the roots of creeping perennials extend beyond the visible edge of the patch. If the treatment does not extend as far as these roots, a ring of healthy plants around the original patch will be present the next year.

Machine Application

On areas where machinery can be used, it is easier to obtain uniform distribution with a chlorate spreader than by hand. Chlorate spreaders must be calibrated for each lot of chlorate and for the speed of travel. Various lots of chlorate have different flow characteristics, and these change with changes in the weather, so that the machine must be re-adjusted to give the proper dosage under different conditions. With a given setting, the rate of application is lower when the machine is moving fast than when it is moving slow so the speed of operation should be as constant as possible. Care must be used to prevent skipping between strips with the spreader. It is undesirable to spread chlorate by any method during wet weather because of the danger of penetration of the chlorates into clothing and the resulting fire hazard, but with a spreader it is even more important to have dry weather. In wet weather the chlorate will take up enough moisture so that it will not flow readily through the spreader and uneven distribution will be obtained.

Preparing the Patch

Considerable time and material may be saved by locating and properly preparing the patch before treatment starts. Patches should be marked for future treatment whenever they are found. Many farmers find it desirable to carry a bundle of laths on their field machinery, and when a small patch is discovered a lath with a red or white rag on the top is set in the middle of the patch. If this is done all through the season, little additional scouting is necessary at treatment time. If the patches are not marked it is necessary to carefully cover the fields in a special scouting trip. If all patches are located and treated each year costs may be materially reduced. It is very difficult to find every patch each year since in many cases there will be but a single plant, but even when 2 years old, most patches will be only about 10 feet across. A 10-foot patch can be treated with less than a dollar's worth of sodium chlorate.

After the patches are located, the area to be treated should be marked. This is frequently done by plowing a furrow around the patch 5 feet outside of its visible edge. If the patch is on a hillside, an inverted v-shaped furrow should be plowed at the same time above the patch to carry any run-off water away from the area. Poor kills may result if water runs across the patch and carries away part of the chlorate. A clean surface is a distinct aid in uniform distribution, and this can be obtained by burning over the area inside the plowed circle if the vegetation is heavy enough to carry a fire. The plowed furrow will serve as a fire guard for this operation. It is normally undesirable to rake and burn large bunches of material on the area to be treated, for when handled in this manner poor kills frequently have been obtained at these points. If the vegetation is too light to burn, the area may be worked to reduce the effect of the trash on the treatment. Application can be made without disturbing very light vegetation. Providing even distribution is obtained, dry applications appear to be somewhat more effective where there is some vegetation present to assist in moisture penetration. A 10-foot patch prepared for application would appear somewhat like Figure 2.

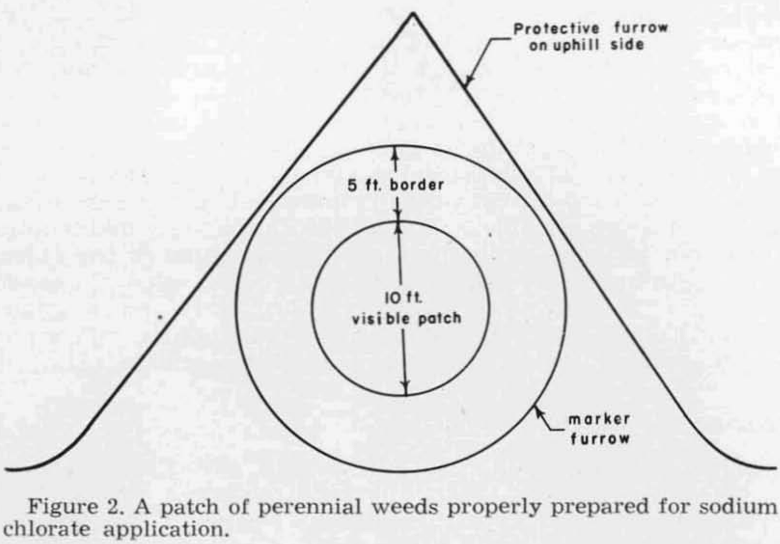

Figure 2. A patch of perennial weeds properly prepared for sodium chlorate application.

Follow-up Treatment

Weed eradication with sodium chlorate may fail completely if the treated areas are not properly taken care of following treatment. After the fall treatment, the areas should be left undisturbed until late the next spring for best results. Light working such as harrowing, drilling, or shallow discing usually does no harm, but deep working should be avoided particularly in the spring. Many failures can be traced directly to plowing through the treated patches early the following spring. Even shallow working may hinder an eradication since it may cut off plants that should be spot treated. All treated patches should be checked in late spring for any regrowth, and these plants should be spot treated. Treated areas should be checked again in late summer to get any plants which may show up after the first spot treating. A common procedure in spot treating is to take out a shovelful of soil where the plant is growing and place a teaspoonful of sodium chlorate around the root. The soil is then replaced. If the chlorate is placed at a depth of four or more inches, it will be undisturbed by shallow cultivation and will be protected from sunlight. Since the chlorate is protected and the rate per unit area used in spot treating is very high, spot treating may be done at any time of the year when the plants are visible. If all of the visible plants are spot treated in August, eradication is probably complete and the area may be returned to crop production. Check the areas again the following year for any plants which may have been missed and for the presence of seedlings.

Seedling Control

Seedling control is an essential feature of any control method used on old established patches. Tests have shown as much as 1500 seeds per cubic foot of soil on some old stands of bindweed and many areas have had as many as 800 seeds per cubic foot. Most other perennial weeds do not produce as much dormant seed as bindweed. These other weeds, however, may have large amounts of seed present in the soil, especially on old stands. Very young patches may not have produced any seed or at least the quantity of seed is much smaller than on older patches. If areas are treated when very small, seedling control, therefore, is not as important as on older infestations. The possible presence of seed in the soil should, however, always be recognized. Sodium chlorate applications have practically no effect on seed in the soil. Treated areas should be watched for seedlings and if they emerge the area should be cultivated lightly within a month to prevent their establishment. Usually the soil sterility of sodium chlorate is adequate to kill any seedlings which come up the year after treatment and sometimes the second year, but since the period of soil sterility is extremely variable the areas should be watched carefully.

CARBON BISULFIDE*

History

Carbon bisulfide commonly known to farmers as carbon bisulfide, "carbon," and "gas" was probably first used in perennial weed control in California (Barnum 1923) (2) and by 1928 was rather widely used for the eradication of deep-rooted perennial weeds.

*Much of the information contained in this section was taken from Idaho Ext. Bul. 106, Eradicating Perennial Weeds with Carbon Bisulfide by H. L. Spence, Jr., which was published in 1937. (7)

Description and Precautions in Use

Carbon bisulfide is a colorless, heavy liquid weighing about 10.5 pounds per gallon. *It is highly volatile and inflammable.* Care is required in its handling to prevent fires. Under no circumstances should it be handled near an open flame, and great care should be exercised to prevent sparks. Drums containing carbon bisulfide should be kept cool to reduce volatility and prevent high pressures from being developed. Carbon bisulfide is irritating to the skin and if spilled should be washed off as soon as possible. *Carbon bisulfide is poisonous* and the fumes may produce headaches and nausea or death. Avoid breathing the fumes by staying on the windward side whenever possible. The presence of injurious quantities of carbon bisulfide fumes is easily detected by the strong odor.

Types of Carbon Bisulfide

Carbon bisulfide is used in both the pure form which is colorless and the "activated" form which is red. Either may be used successfully. The "activated" form contains materials which tend to hold carbon bisulfide in the soil for a longer period of time. This is an advantage on light sandy soils.

Limitations

The major limitation in the use of carbon bisulfide is cost. The material varies from about 45 to 60 cents per gallon in quantity lots which at the normal rate of 320 gallons gives a cost of from 145 to 190 dollars per acre. The application of carbon bisulfide on small areas requires considerable labor which makes the cost prohibitive, except on very small patches or extremely valuable land. A second limiting factor is that the soil must contain the proper amount of moisture at the time of application. Soil texture may also limit its use. Results are not generally satisfactory on heavy impervious soils or on shallow soils underlaid with heavy gravel. Poor results are usually obtained where water tables are within 12 to 18 inches of the surface. The presence of hard pans in the soil may stop the penetration of the gas and result in poor kills.

Soil Sterility

Soil sterility generally has not been a limiting factor in the use of carbon bisulfide. With high temperatures and proper aeration, the effect of carbon bisulfide usually disappears within about 6 weeks after which crops may be planted. This is a definite advantage of carbon bisulfide and is the major factor in promoting its use. Do not plant deep-rooted crops, such as sugar beets, for one season after application since these may show some effects of the treatment. Shallow-rooted crops frequently show stimulated growth after carbon bisulfide applications. This stimulation results from greater availability of plant food and the elimination of many root parasites.

Date of Application

The primary consideration in when to treat is soil moisture. The surface of the soil should be moist, but not muddy, to a depth of at least 12 to 14 inches. Under non-irrigated conditions this usually means that applications must be made in early spring or late fall. This is shown by the results obtained in treating bindweed near Genesee in 1938 as illustrated in Figure 3, when poor kills were obtained during the dry summer months.

Under irrigated conditions application can be made any time during the growing season; the necessary soil moisture conditions can be established by proper irrigation. Under these conditions, the best results are usually obtained during warm weather.

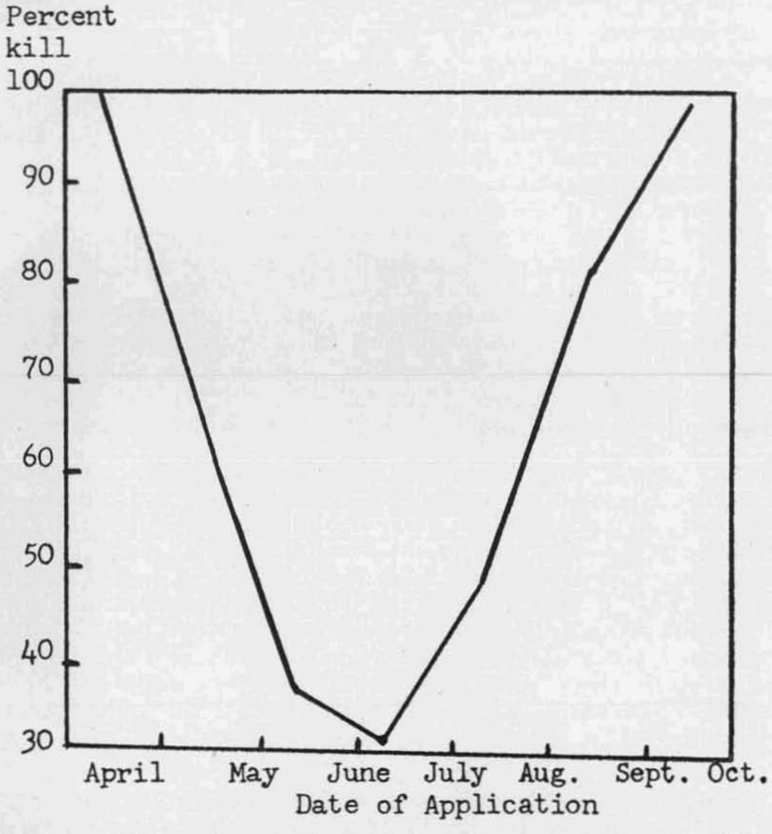

Figure 3. The effect of the date of application of carbon bisulfide on the kill of bindweed. Applications made near Genesee in 1938.

Rate of Application

The killing of weeds with carbon bisulfide is a soil treatment. The rate of application, therefore, is the same for all kinds of weeds. This rate is 2 fluid ounces of carbon bisulfide applied in holes 18 inches apart and 6 inches deep. For bindweed the depth should be 8 inches. At this rate of application, approximately 2 gallons of carbon bisulfide will be required to treat a square rod. The holes should be staggered to form a diamond rather than a square. In extremely heavy impervious soils, if treatment seems justified, the likelihood of getting good results are better if the spacing of the holes is reduced to 12 inches and the depth to 4 to 6 inches. In this case, the rate required would be approximately 4 gallons per square rod.

Carbon bisulfide cannot be recommended for quackgrass with present methods of application because of the difficulty of holding the gasses near enough to the surface to kill the shallow roots.

Soil Preparation

Soils should be properly prepared for carbon bisulfide application. This involves three steps: (1) irrigating where needed; (2) crowning; and (3) smoothing. If the surface of the soil is dry, irrigate to insure good moisture to a depth of at least 12 to 14 inches. Then allow to dry sufficiently to be in good condition for working. If plants are present, they then should be crowned by cutting them off at a depth of 2 to 3 inches with a shovel, hoe, blade, or duckfoot weeder. Do not disturb the soil to a depth greater than 3 inches. Smooth the surface with a rake or harrow. The crowning and smoothing will not only make application easier but will normally prevent resprouting from shallow crowns not killed by the carbon bisulfide treatment.

Equipment for Application

Three types of equipment are normally used for carbon bisulfide treatment. The most commonly used is the automatic hand applicator which in one operation makes the holes, measures the dosage, and delivers the liquid under pressure. The holes should be closed by stepping on them with the heel of the shoe. An applicator, which sells at from 15 to 25 dollars, is an excellent investment where any amount of material is to be used. Its cost soon will be returned in reduced labor and material. Carbon bisulfide can be handled far more safely in these applicators than in open containers. The manufacturer's directions as to calibration and care should be carefully followed. Be sure that the machine is making each delivery since a miss will leave a spot of weeds.

For small areas where the cost of an automatic applicator is not justified, separate tools may be made for making the application. The following are required: (1) a probe; (2) a funnel; (3) a measuring cup (2 fluid ounce capacity); (4) a container for carbon bisulfide; and (5) a tamper. The probe is usually a 1-inch iron rod about 4 feet long sharpened on one end and with a "T" handle on the other. A step should be fastened eight inches from the point. If applications of 6-inch depth are desired, a 2-inch block of wood can be placed under the step. The funnel should be attached to a two foot piece of ½-inch galvanized pipe. It is convenient to fasten the measuring cup in the funnel. The tamper should be made of wood to prevent sparks and be about 3 inches in diameter at the base. For either the automatic hand applicator or the hand tools, a string or rope knotted at 18-inch intervals to mark the holes will be required. Stakes to hold the marker string and to mark the next row of holes should also be provided.

Carbon bisulfide rarely should be used on large areas for perennial weed control, but where this is desirable a large tractor-drawn machine is manufactured which combines the operations of measuring, probing, injecting the liquid, and tamping into one operation. In the use of this machine the manufacturer's directions should be followed.

Treating by Hand Methods

For applications with hand tools set out the marker string, being sure to allow a minimum of 3 feet beyond the visible edge of the patch. Five feet is safer. Probe the holes at the marks on the string and pour 2 fluid ounces of carbon bisulfide in each hole. Immediately tamp the holes shut with the tamper to prevent the escape of the gas. When application of the first row has been completed, move the marker string over 18 inches and in or out 9 inches and treat the second row. When working towards the center of the patch, each row will usually lengthen 9 inches and when working away from the center of the patch will be shortened 9 inches. In either case the objective is to stagger the holes.

With the automatic hand applicator, the same procedure is used as with the hand tools except the prod on the applicator is pushed into the ground to the proper depth, the plunger is depressed to insert the charge, the prod is removed, and the hole is tamped shut with the heel.

Follow-up Treatment

After the area is treated by hand methods, the area should be raked or harrowed to prevent the soil from cracking. After this working do not disturb for at least 3 weeks and do not irrigate during this period. At the end of this period, which should be not less than 3 weeks in warm weather and longer in cool weather, the ground should be plowed deep and left in a rough state so it will air out. After letting it lie rough for about 3 weeks, work again and let it lie for another week. The patch is now ready for seeding to shallow-rooted crops. If any individual weed plants are still alive they may then be killed by making a single application next to the plant.

If the patch has ever formed seed, seedlings may come up on the area since carbon bisulfide has little effect on seed in the soil. Any seedlings which emerge should be killed by cultivation within a month after emergence. Keep treated patches under observation.

BORAX

History

The herbicidal properties of boron compounds were reported by Crafts and Raynor (3) in 1936. The following year Raynor (5) recommended the use of boron compounds for the control of St. Johnswort (goatweed). Since that time large quantities of borax have been used for controlling this pest in the Western states. It also has been used as a temporary soil sterilant on other weeds.

Description

Borax is a white crystaline compound containing approximately 11.3 percent boron. It is only slightly soluble in water. Borax is not poisonous to man or animals and is somewhat fire-retardant in action. It is not palatable to stock. Borax is relatively stable and does not readily decompose. Some fixation occurs in the soil and hence it is resistant to leaching. Borax may be converted into the more soluble meta-borate by reaction with lye (sodium hydroxide) in the proportions of 1 part of lye to 4 parts of borax by weight.

Types of Borax

Borax is sold in both the powdered and granulated forms. The granulated form known as "Agricultural Borax" is the most widely used for weed control purposes. Boron is also available in the semi-refined form "Borascu" which is less soluble than the regular borax. Borascu is somewhat cheaper than the refined form but in the drier areas has not given as good results. Borax is also available in combination with sodium chlorate.

Limitations and Uses

Borax is used primarily in perennial weed control for the eradication of St. Johnswort (goatweed). Borax has been found to be relatively ineffective on most deep-rooted perennial weeds at any reasonable rate and is not recommended for the eradication of such weeds.

Borax is selective in the plants which it kills which is an advantage in the control of St. Johnswort. Most members of the grass family are relatively tolerant of borax, and St. Johnswort may be killed on the range without appreciable injury to the grasses present. In many cases the grasses appear to be stimulated by the application. This probably results from the elimination of competition and the liberation of available nutrients from the dead weeds. The lack of decomposition and slow leaching of borax is an advantage, since it is retained in the soil for a sufficient period of time to give good seedling control. On dry land ranges control of St. Johnswort seedlings for a period of 4 to 5 years has been obtained with applications of 8 to 10 pounds of borax per square rod. Under heavy rainfall this period is much shorter. The lack of fire and poison hazard is essential in a material for use on the open range.

The major disadvantage of borax is cost. Borax costs from 3 to 4 cents per pound, and at rates of 8 to 10 pounds per square rod the cost is from 35 to 50 dollars per acre. This is greater than the value of most of the range land infested with St. Johnswort and can be justified only on small patches to prevent spreading to large areas of clean range. The low value of most range land makes it very important that the first small areas of St. Johnswort be eradicated to protect the range. Once large areas become infested the cost of eradication may become prohibitive. Another disadvantage of borax for the control of St. Johnswort is the high rate of application required. Much of the infested range land is rough and not accessible to machinery. The carrying of this quantity of material is a major obstacle in treating many areas. The use of a mixture of 25 percent sodium chlorate and 75 percent borax, rather than straight borax reduces the weight required from 8 to 3 pounds per square rod but eliminates part of the advantage of borax. Applications must be more carefully timed with the mixture than with straight borax and less seedling control is obtained. The mixture is also more injurious to forage plants than straight borax. Except where bulk is the major consideration straight borax is to be preferred for range work.

Date of Application

Since borax does not deteriorate on the surface of the ground the major factor in the date of application is getting the material into the root zone. St. Johnswort is shallow-rooted and hence under heavy rainfall conditions delayed application may be necessary to prevent leaching below the root zone. However, the relatively low solubility of borax and slow leaching normally prevents this on dry ranges. Under low rainfall conditions, it is frequently necessary to have all of a season's rainfall on the borax to move it to sufficient depth to be effective. As a consequence, applications before the first fall rains are highly desirable under these conditions. Borax usually is somewhat more effective when applied just before the fall rains, but the difference is not normally sufficient to be a primary consideration in the application of the material. The difficulty of finding the patches on the range, and the labor required in getting to them has in many cases justified the application at other times during the year. Many stockmen make a practice of carrying some borax with them when riding the range and making an immediate treatment whenever a patch is located. In this way considerable time may be saved at little additional cost in material. In general, on dry ranges borax may be applied at the convenience of the operator. Where a mixture of borax and sodium chlorate is used, applications should be made in the fall to reduce the decomposition of the chlorates. In some cases, delay of application into the winter months may be necessary to prevent the more easily leached chlorate from moving below the root zone.

Rate of Application

The rate of application of borax for controlling St. Johnswort is influenced largely by soil texture. Heavier rates of application are required on heavy types of soil than on the lighter soils. At the same time, the desirability of obtaining seedling control for a period of time after application influences the rate. Table 3 gives the results obtained from the application of straight borax and four borax-chlorate mixtures June 22, 1945, to St. Johnswort on a dry gravelly soil.

Table 3.—The effect of rate of application of borax and borax-chlorate mixtures on the kill of St. Johnswort.

Rate in lb. per square rod	Percent of weed plants killed with following percentages of sodium chlorate in the mixture*				
	0	25	35	45	55
1	.....	59	87	83	94
2	29	91	92	99	98
3	.....	98	98	100	100
4	81	....	....	....	....
6	98	....	....	....	....
8	98	....	....	....	....

*The sodium chlorate-borax mixtures used were furnished through the courtesy of the Chipman Chemical Co., Portland, Oregon.

Less than three-fourths of an inch of rain fell during the 2-months period following the application of these materials which were relatively unfavorable for the chlorate-borax mixtures, but even under these circumstances cheaper control was obtained with the mixtures than with straight borax. Assuming a price of 10 cents per pound for sodium chlorate and 3 cents per pound for borax, satisfactory control of the old plants was obtained at a cost of 12.3 cents per square rod with the 45-percent chlorate mixture, 14.3 cents with the 25-percent mixture, and 18 cents with the straight borax. To avoid a fire hazard, the percentage of chlorate in the mixture should not exceed 35 percent, so that from the practical standpoint the 25-percent mixture seems to be preferable to the 45 percent. Observations made in 1947 showed much better seedling control on those plots with straight borax than where comparable kills were obtained with the mixtures. Since this is an important consideration, the use of the straight borax at the somewhat higher cost seems to be justified on areas where the increased bulk is not a major factor in the choice of material.

When applied later in the season (fall or early winter) a rate of 3 pounds per square rod of a mixture containing 25 percent chlorate and 75 percent borax should be adequate on most soils. Where straight agricultural borax is used a rate of 6 pounds per square rod is suggested for light sandy and gravelly soils and 8 pounds for heavier soils. Slightly higher rates may be justified for seedling control under some conditions, but in order to avoid injury to the range grasses rates should normally not exceed 10 pounds per square rod. Good grass stands are important in the control of any seedlings emerging after the effects of the chemical have disappeared.

Methods of Application

The methods given for the dry application of sodium chlorate may be used for borax. However, the areas infested with St. Johnswort are frequently unsuited for machinery operation and hand methods must be employed. Less care to obtain uniform distribution is required when using straight borax than chlorate, since the rate per square rod is relatively high. At the same time, it is usually impractical to clean the vegetation from the patch before treating, and since the normal vegetation on the area restricts erosion, ditching of the patch is also unnecessary.

Follow-Up Treatment

All treated areas should be inspected the following year for any missed plants. These may be treated by spreading a handful of borax over the plant. Later inspections should be made to be certain that seedlings do not become established and produce seed. If they become established, they should be treated before seed is produced.

SUMMARY

All methods of eradication and control of perennial weeds have their definite limitations, and these must be taken into consideration in choosing the correct method for a particular problem. Nonselective chemicals, such as sodium chlorate, carbon bisulfide, and borax, are rapid in their action but expensive to use. Their use should be restricted to small areas where the primary consideration is the protection of large areas of uninfested land. On larger areas other methods will usually be more practical.

Sodium chlorate and carbon bisulfide can be used for controlling most of the common creeping perennial weeds. Borax is recommended only for controlling St. Johnswort (goatweed).

Patches to be treated with non-selective chemicals should be properly prepared for application. Proper preparation is different for each type of chemical.

All patches treated with chemicals should be inspected later for missed plants, and these should be spot treated. Seedlings must be controlled to prevent failure with any treatment.

Sodium chlorate is the most widely used non-selective chemical. It must be handled carefully to prevent fires.

Sodium chlorate normally should be applied in the fall just before the start of the fall rains.

The rate of application of sodium chlorate varies widely with different soils, climatic conditions, and weeds. Consult Table 1 for suggested rates.

Sodium chlorate should be applied dry, and care should be taken to obtain uniform distribution. It may be applied either broadcast by hand or with a chlorate spreader.

Carbon bisulfide is both inflammable and poisonous. Handle it with care.

Apply carbon bisulfide on non-irrigated land in early spring or late fall. Under irrigated conditions it may be applied at any time during the growing season.

The soil should be moist, but not muddy, to a depth of at least 12 to 14 inches at the time of application of carbon bisulfide.

Carbon bisulfide may be applied either with an automatic applicator or hand tools. The standard treatment is 2 fluid ounces per hole with the holes being spaced 18 inches apart each way and staggered. The depth of application varies from 4 to 8 inches, depending on the weed and soil conditions.

Borax is not hazardous to use and is of considerable value in the control of St. Johnswort (goatweed) on the range.

Borax is applied dry either with a spreader or by hand. Uniform distribution should be obtained.

Borax may be applied on dry land ranges any time that is convenient to the operator. The rate required varies from 6 to 8 pounds per square rod.

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