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CARBON DISULFIDE FOR THE ERADICATION OF PERENNIAL WEEDS

CHARLES F. ROGERS

and

IRA HATFIELD

A PROGRESS REPORT

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SUMMARY

1. Weeds are causing millions of dollars of loss every year to Colorado farmers. A large part of this loss, which can be stopped by the proper control and eradication methods, is due to noxious perennial weeds. The root systems of perennial weeds must be killed if eradication is to be effected.

2. Eradication of perennial weeds with a single treatment is highly desirable.

3. Sprays have not yet proved to be a promising means of weed eradication in Colorado because their penetration is not as great in the dry climate of this state as in more humid regions.

4. Carbon disulfide injected into the soil has been used successfully to eradicate perennial weeds with a single treatment. It can be applied at times when there will be no loss of a crop. The method of application is described in this bulletin.

5. The poisonous effect of carbon disulfide upon the soil is temporary. After a few weeks the productiveness of the soil is increased.

6. The test plots of 1927 were established upon many kinds and under many conditions of soil. There was a 90 to 100 percent kill on four-fifths of them, and at least a 60 percent kill on the remainder.

7. In a number of cases the killing of the perennial weeds with carbon disulfide was not noticeable for several months, but the final results were as good as tho the killing had been immediately apparent.

8. The use of carbon disulfide has formerly been attended with uncertainty both as to the rate and the amount of killing when the liquid was injected into the soil. In 1928 a chemical was found which would indicate the presence of carbon disulfide and which could be used to test the penetration of carbon disulfide gas thru the soil. The simple method of using this indicator is described in this bulletin.

9. Insofar as the experiments with this indicator have gone, it has been found that when the penetration of the gas is indicated by the chemical, there is immediate killing of the perennial weeds treated.

10. For eradication of perennial weeds, carbon disulfide has proved to be more quickly effective and more dependable than any other method that has been tried. It is the cheapest commercially made powerful plant poison that cannot injure the soil.

11. Because of the present cost of the material and the expense of injection into the soil, carbon disulfide should be used to kill perennial weeds **on small areas only**, or on exceedingly valuable and productive land.

CARBON DISULFIDE FOR THE ERADICATION OF PERENNIAL WEEDS

CHARLES F. ROGERS[1] and IRA HATFIELD[2]

The search for a quick and economical means of eradication of perennial weeds has led to the experimental and small-scale use of carbon disulfide upon limited infestations for the protection of large areas of weed-free land. The experimental work is by no means completed, but results have been so promising that they are being made available to the people of Colorado in this progress report.

Serious Nature of Perennial Weeds in Colorado

Perennial weeds are among the most serious and destructive pests on cultivated land in Colorado. Their general distribution, their capacity to grow and spread, and their persistence make control and eradication a most difficult problem for every farmer who has infested land. Perennial weeds are always spreading by their own root systems and fragments are often dragged to new locations where infestations quickly establish themselves. The menace is increased by the dissemination of seeds, for seeds of perennial weeds can travel faster in wind, in water, or on implements than do the roots by their natural spread or by being dragged. The damage caused by perennial weeds appears as a decrease of crop yield on infested land, lowered value of and increased expense in managing the land, and decreased market value of the crops.

The noxious perennial weeds in Colorado make a formidable list. Several wild morning-glories (*Convolvulus* spp.), also known as bindweeds, are without doubt the worst weed pests of Colorado because of their general abundance and destructive nature. The poverty weeds (*Franseria tomentosa*) and (*Iva axillaris*), are native to Colorado and are nearly as widely spread over the state as the bindweeds. In Northern Colorado they are more abundant especially in the dryland farming regions. Perennial peppergrass (*Lepidium draba*) is known in every agricultural region of the state and is, as yet, the most serious weed in cultivated and untilled fields in some parts of Colorado, but unless Russian knapweed is held in check it will soon supersede the peppergrass in importance.

Russian knapweed (*Centaurea picris* Pallas) has probably been in Colorado as long as imported Turkestan alfalfa seed has been used, but it has been known as a weed pest to farmers for only a few years.

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It has become well established and will probably invade all parts of Colorado. The knapweed is extremely pernicious because of its hardiness and its vigorous, dense growth. Canada thistle (*Cirsium arvense*) has made steady but generally unnoticed advances thruout Colorado, and is only now coming to the attention of many farmers. Perennial sow thistle (*Sonchus arvensis*) has entered the state recently from the north and northeast and is not widespread, but can quickly become so unless every precaution is taken against it. On some range and agricultural land, milkweeds (*Asclepias* spp.) are abundant. They are troublesome in the same way as other weed pests. The whorled milkweed (*Asclepias verticillata*), which persists wherever it gets started, is highly poisonous to livestock as well as being so fast and vigorous a grower that it can crowd out desirable crop and forage plants.

ECONOMIC LOSSES FROM PERENNIAL WEEDS

The losses from perennial weeds in Colorado are enormous when they are counted in money values alone. In 1917, H. R. Cates, a United States Department of Agriculture weed expert, estimated that one-sixth of the market value of a cultivated crop is expended on cultivation. He says that at least half of cultivation is made necessary by the presence of weeds. According to the 1927 Colorado Yearbook the market value for the 1926 crop of corn, potatoes, beans and sugar beets was $47,984,000. If one-twelfth of the market value is accepted as the amount expended upon these four crops in 1926 for weed control, then $4,000,000 is the estimated toll of weeds upon these four crops in one year. On the whole, perennial weeds are more destructive in uncultivated than in the cultivated crops mentioned above, but one-fourth of the loss on these crops due to perennial weeds is not too much to allow for increased expense in the production of corn, potatoes, beans and beets. A yearly loss of $1,000,000 on four crops is too much to take without any effort to stop the leak.

The question is raised as to whether or not the cost of killing the weeds to stop this loss is not greater than the return. On the basis of the returns from a single year's crop it probably is, but when the expense is taken into account for the same number of years that returns are increased, the cost of eradicating perennial weeds is not so great. Expensive measures against weeds are not justified upon large areas because the larger the area the lower the cost per unit area if mechanical means of eradication are employed. When, however, it is desirable or necessary to remove from a large area a menace in the form of a relatively small patch or patches of a perennial weed, more expensive means of eradication are permissable. The

cost should be assessed against the whole area to be protected. It should also be assessed against the time during which a successful treatment or treatments will protect the land when normal precautions are taken against reinfestations and the reestablishment of noxious weeds on weed-free land.

VALUE OF A SINGLE-TREATMENT METHOD FOR PERENNIAL WEED ERADICATION

The ever increasing menace of perennial weeds to crops and agricultural lands has created a demand for effective measures of eradication, single-treatment methods being preferred. The advantage of eradication of a perennial weed by a single treatment is that no more attention is likely to be required after the killing agent is applied. It is also possible that the agent may be used upon the pest at a time when no crop will be lost, and there will be no interference with the regular rotation of the crops. The killing agent whether put upon the tops only, or used on the roots by injection into the soil, should act in a relatively short time, and leave the soil in as productive condition as when it was applied. Whatever such a material would be, and however it is used, the roots of perennial weeds must be killed before any satisfactory and permanent control or eradication is accomplished.

IMPORTANCE OF ROOT SYSTEMS IN THE LIFE OF PERENNIAL WEEDS

Annual and perennial herbaceous weeds behave alike above ground, and cannot be distinguished by their general habits of growth. There are both annual and perennial weeds which behave as do the morning-glories or bindweeds, and many annual or biennial plants are mistaken for perennials. The way to determine the perennial nature of a weed is by its root system, or by its behavior from year to year.

Roots of perennial weeds send up from their horizontal parts vigorous stems that grow faster than seedlings in early spring and when they are unmolested, usually mature their fruit in the summer. Life resides for an indefinite period in the roots of most perennial weeds. The roots serve as storehouses of energy for the plant, and perform the ordinary function of conducting the necessary water and mineral nutrients from the absorptive region of the roots to the food-manufacturing parts above the ground. The tops of these plants may be killed repeatedly, but buds are formed upon the roots and shoots quickly develop to replace stems and leaves that have been

destroyed. The replacement of shoots draws upon the reserve in the roots.

As soon as the leaves open to the sunlight they begin to manufacture food to replace that supplied by the perennial roots. All plants depend upon their roots for the absorption of water and minerals from the soil. Perennial weeds depend upon the lower parts of their roots for their supply of water and the tops die when they are cut off from the vertical portion of the roots, even if they are left attached to the horizontal roots. Whatever the material or method used in the attempted control or eradication of perennial weeds, the effects of the treatment or treatments upon the root system are of primary importance.

THE USE OF SPRAYS

The most common method of attacking perennial weeds has been by cultivation of the soil to a depth sufficient to destroy the shoots but not to drag the horizontal roots about. If this is repeated often and long enough the roots will eventually be starved out. Use of poisonous sprays involves less labor for each treatment than cultivation or the killing of roots by injecting poison into the soil, but sprays which require many applications result in increasing damage to the soil, and the destruction of all top growth whether of weeds or crop plants.

It is possible and even probable that in the future spray poisons will be developed which can kill the roots of perennial weeds far below the surface of the ground every time one of them is applied to the leaves and stems. At the present time, spraying is easy, quick and convenient, but as it is generally practiced upon weeds the results are extremely variable. The effects of sprays cannot as yet be controlled, much less predicted under Colorado conditions. Fortunately when they are used it is not generally expected that they effect eradication of perennial weeds in a single treatment.

Highly favorable conditions are necessary for the maximum effectiveness of sprays. There must be sufficient moisture in the air to keep the sprays from evaporating quickly. This is one of the least common conditions in Colorado. The air is usually dry and has a high evaporating power which quickly reduces a liquid spray upon the leaves to a dry film. Penetration will usually be sufficient to kill the leaves and stems, but does not continue to the roots where life remains. Only under exceptional conditions do most sprays prove to be efficacious in Colorado. Sprays must be applied to weeds when their tops are fully developed, and in such quantities as will destroy

all growth above the surface, which results in loss of some crops in one of two ways. Either no crop is raised upon the infested land where the pest is developing to the stage necessary for application of the spray, or if one is planted, it is lost at the time of spraying.

A new spray, sodium chlorate, is being advertised which it is claimed will kill perennial weeds after early crops are removed and before a late crop is put in the next season. Only under such conditions can a spray be used without loss of a crop. At the time of writing of this bulletin, however, the superior value of this spray over others already tried in Colorado has not been conclusively proved.

When poisons are applied to the upper parts of plants, some of it always falls upon the ground. Almost all spray poisons that are used in quantities sufficient to eradicate perennial weeds have a residual more or less permanent effect upon the soil. The results even after an eradication with sprays is decreased productivity of the soil for several years.

USE OF POISONS INJECTED INTO THE SOIL

Contrasted with the relative impotence of most sprays as now applied for the eradication of perennial weeds in a single-to few-treatment procedure, the injection of poisonous materials into the soil when conditions are right has been found to result in the rapid and usually complete death of the plant.

CARBON DISULFIDE.—Of the poisons used in the soil, carbon disulfide has been found to be the most economical to buy and the simplest and safest to use. Its killing effects have generally become evident in from 4 to 10 days after application, but in some soils, due perhaps to the slow penetration of the poison or to the persistent nature of the plant, death of the tops was postponed for some time in a few instances, even until the following spring.

There are a number of cases on record in Colorado where there was no apparent killing of common wild morning-glory during the summer or fall of 1927, but death was almost complete by the spring of 1928. The pests either failed to appear at all or came up so weakly that a few injections of carbon disulfide near the straggling plants finished the job with no loss of crop and with relatively little repetition of work.

Furthermore, the root system is always in the ground, and can be treated at any convenient time when the conditions are right for penetration of the poison thru the soil.

BENEFITS OF CARBON DISULFIDE TO THE SOIL.—Roots of perennial weeds have been killed by carbon disulfide applied in the spring, summer, late fall and winter. Other plants grew normally upon the soil that had been treated with carbon disulfide, a short time after its injection either in the spring or summer. No difference in productivity could be noted between treated and untreated areas several weeks or months after the use of carbon disulfide, unless it was the more vigorous and rank growth of annual plants upon the carbon disulfide plots. Far from doing harm to the soil there is evidence from these plots and from much experimental work with carbon disulfide in other states that in a short time after injection there is a definitely beneficial effect upon life of all kinds in the soil. (See Figure 1.)

RESULTS OF THE USE OF CARBON DISULFIDE IN COLORADO

Altho carbon disulfide has been used in many places in Colorado to learn its powers of eradication of perennial weeds, most of the tests upon which this bulletin is based have been set up in the San Luis Valley, and in Sedgwick, Washington, Weld and Larimer counties. The test plots of carbon disulfide in the San Luis Valley were put in during June, 1927; those in Sedgwick and Washington counties the first part of July, 1927, and those in Larimer and Weld counties in May, July, September and November of 1927, and June and July of 1928. Heavy and sandy, as well as moist and dry soils were treated. Most of the tests in the San Luis Valley were in moist soil. Altho some of the plots were in open, light soil, many of them were put upon heavy clay or wet sand which gave little promise of satisfactory results. The soil in northern Alamosa county was dryer and more open, making injection easier, giving promise of better penetration and better killing effects.

In almost all of these cases the immediate killing was nearly perfect, but one treatment in southern Alamosa county was not so effective as most of the others. Inspection in 1928 of this and the other tests in the San Luis Valley revealed that in all but this one case there was a high percentage of killing. The effectiveness on the small area, however, may have been more than was apparent. When carbon disulfide was applied to this patch in June, 1927, four noxious perennial weeds, Russian knapweed, poverty weed (*Iva axillaris*), common wild morning-glory and perennial peppergrass were growing together. After practically 14 months without disturbance, and with every chance for recovery there was an apparent killing of 75 percent of the growth on this area.

Two test plots were established in Weld county, on May 13 and

16. One was on the Colorado Potato Experiment Station 4 miles northeast and the other on a farm three-fourths mile east of Greeley. The plot on the Potato Experiment Station was a rather damp, but hard and compact, gravelly loam. Penetration of the carbon disulfide gas thru the soil gave effects so quickly that the plants poisoned in the morning showed signs of wilting before the work was stopped in the evening. The other patch treated with carbon disulfide gave few signs of any damage during the summer and fall of 1927, but in the spring of 1928 the morning-glories failed to reappear excepting for a few struggling plants over the treated area.

The plots in Sedgwick county were for the most part in wet soil altho two were on rather dry soil. None of the plots where the moisture content was extremely high gave immediate evidence of any great effect of the poison, but inspection in August, 1928, revealed that two of them were almost completely killed; whereas in the third plot a wet heavy soil gave indication after a year of only a 75 percent killing. The driest soil treated in Sedgwick county was along a road northwest of Sedgwick. Here the killing was perfect, with no return growth of the common wild morning-glory during 13 months.

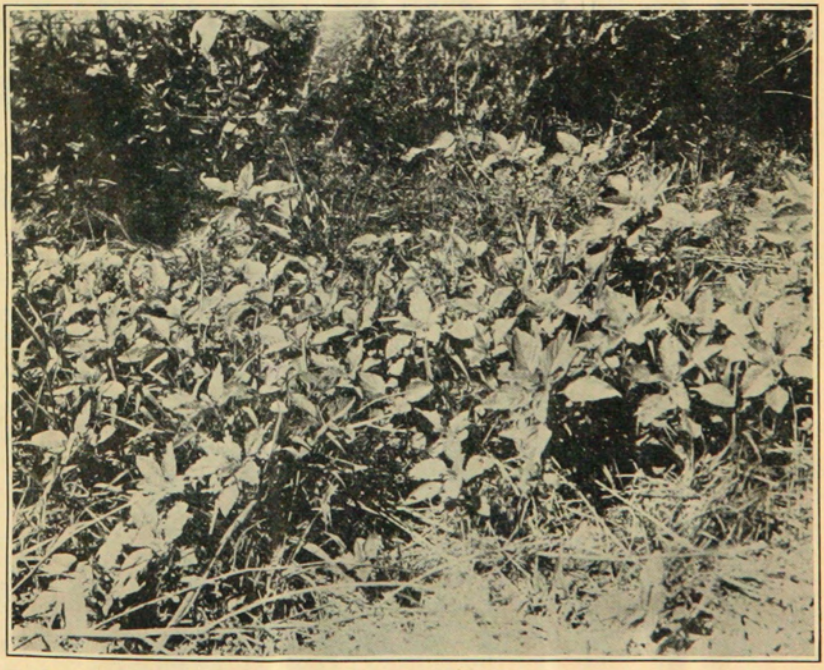

Figure 1.—Abundant, vigorous growth of vegetation upon ground treated with carbon disulfide the year before, showing that this chemical does not injure the soil.

The photograph of the area in Figure 1 shows that no damage was done to the soil. A rank growth of sweet clover may be seen in the background and in the foreground pigweeds are coming up thru a vigorous stand of sweet clover which had been cut once when the picture was taken.

Four plots were established in Akron, Colorado. Two were on the Experiment Station east of Akron, and two were on an intersection in town. The hard, dry, compact soil of the parking at the intersection made the work of injection somewhat tedious but the results were quick and permanent. The plots were completely bounded by morning-glory-infested land. To show the results more clearly, the photograph in Figure 2 was taken in August, 1928. It shows the weed extending across the foreground, and into the street from the edge of the parking. There is a matted mass of vines in the background next to the walk, but the area of parking adjacent to the walk and to the street where the common wild morning-glory is growing, is conspicuously free from this perennial weed, altho other plants have made rapid, vigorous and normal growth. They had, however, been cut down before the picture was taken.

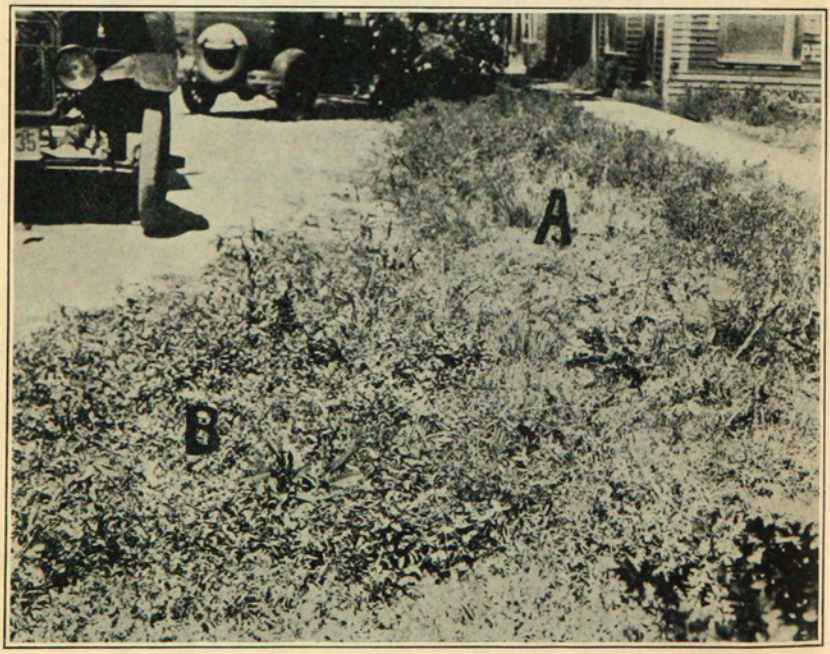

Figure 2.—The effect of carbon disulfide on morning-glories or bindweeds one year after treatment. Note the absence of bindweeds in the treated area A, and the abundance of vines in the untreated area B.

A plot of similar size, but on the south side of this intersection was infested with the common wild morning-glory or bindweed, and a few plants of poverty weed (*Franseria tomentosa*). The bindweed was treated in the same way as the other plot, by making the holes 18 inches deep. The result was a perfect killing of the morning-glories without injuring the much shallower-rooted poverty weed, which by August, 1928, had taken complete possession of the soil previously held by its competitor, the common wild morning-glory.

This indicates that the depth of holes has a bearing on the kind of roots killed. Two plots on the Experiment Station east of Akron resulted in imperfect kills on both morning-glory and poverty weed. The morning-glories were on loose soil along a railroad grade, where the liquid carbon disulfide could go down for some distance instead of spreading out horizontally. The poverty weed was growing in a roadway upon the farm where the soil was compact. Holes 12 inches deep were made in the roadway. The first effects were hopeful, but in August, 1928, there had been some recovery.

In September, 1927, the central parts of several patches of common wild morning-glory or bindweed were treated with carbon disulfide. The ground was exceedingly dry and hard, even to the bottom of the holes made for the injection of the liquid poison. There

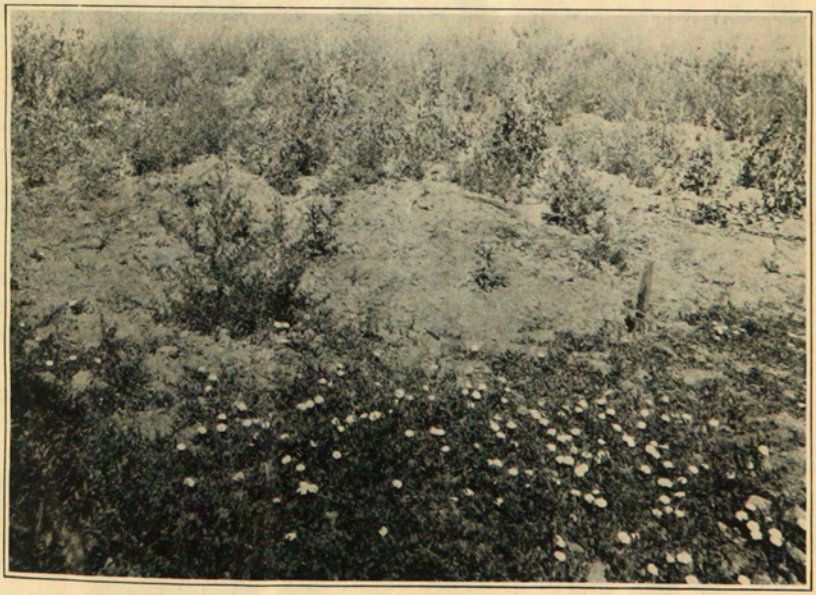

Figure 3.—Appearance of cultivated plot 10 months after treatment with carbon disulfide. Before treatment with this chemical, the weed-free area was infested with morning-glories similar to the area shown in the foreground.

was an abundance of flowers, and healthy growth, much like that shown in the foreground of Figure 3. Several days after injection, the plants close to the holes withered and died. On the whole, even until frost, it appeared that no great harm had been done to these perennial weeds. The ground was plowed early in the spring, so that no observation was possible at the first of the growing season. The soil was not disturbed again, and as the plants appeared, it quickly became evident that there was no return growth of the bindweed in these plots where the carbon disulfide had been injected. The photograph in Figure 3 shows mature plants on both sides of a bindweed-free area, the result of the treatment in September, 1927. All the plots treated in September behaved in the same way.

Results from another trial under different conditions make the use of this material for the eradication of perennial weeds more promising. On November 11, 1927, an area of Russian knapweed was treated with carbon disulfide. The infestation was on low ground southeast of Grover, Colorado, where the water table was only 4 or 5 feet down and the heavy clay soil was exceedingly moist at 5 or 6 inches below the surface. When this plot was inspected on June 5, 1928, the ground was almost bare of all growth, and only one Russian knapweed sprout was found upon the whole treated area. Large and healthy plants were growing thickly on all sides. Excavation for roots revealed that they were black and decomposed, and that only the woody parts of the root could be followed; the rest had disintegrated. Altho this may be an unusual case, it shows that the poison may kill under what would be ordinarily considered unfavorable conditions for penetration of the vapor.

Thirty-two of the tests on the killing power of carbon disulfide made in 1927 have been observed during the summer of 1928. Of this number, 7 were neither perfect nor high-percentage kills, altho none of them was below 60 percent effective. Approximately 80 percent of the tests gave results that may be considered satisfactory.

There must be, however, a greater dependability than this for a method as expensive as this one has proved to be, if it is to have a widespread use. Much labor is expended in treating even test plots with carbon disulfide, and a necessary partial or complete repetition of the treatment of an area of any size would make the use of carbon disulfide for the eradication of perennial weeds, impractical and uneconomical.

If the method of application could be made less laborious, or the certainty of killing be made greater, the use of a carbon disulfide for the eradication of small infestations of perennial weeds would become entirely practical. This would save much time that is now spent in prevention and control measures which are some times not as effective as the use of carbon disulfide at present.

The methods now employed are applicable only to small areas, but when the use of carbon disulfide is attended with certainty of results, mechanical means for its more rapid injection into the soil can be developed.

METHOD OF APPLICATION

Two ounces of liquid carbon disulfide are applied in holes 2 feet apart each way. The alternate rows are staggered so that the holes form triangles as shown in Figure 12. The holes may be made by driving sharpened steel stakes into the ground to the desired depth. The depth to which the stakes are driven depends upon the soil type; for heavy soils 18 inches has been found to be successful, and for light, coarse, sandy soils, 12 inches will suffice. Even tho the cost of application of the carbon disulfide can be reduced by making the holes a distance greater than 2 feet apart, the best results have been obtained in Colorado experiments where the 2-foot distance has been used.

Figure 4-a and b shows the method of applying carbon disulfide. A funnel is placed in the hole and the liquid carbon disulfide is conveyed from a bucket to the funnel by means of a dipper that holds exactly 2 ounces of the chemical. In order to prevent the carbon disulfide from evaporating thru the openings instead of diffusing thru the soil, the holes should be closed with dirt immediately after the liquid has been applied. In soft soils this may be done with the heel, but where the soil is dry and hard, it may be necessary to use a heavy hammer. If there is danger of the "caps" caving in, it is necessary to fill the holes before tamping. When a surplus of the liquid carbon disulfide remains unused in an open con-

Figure 4a

tainer, its evaporation can be stopped by covering with a shallow layer of water.

Figures 4a and 4b.—Photographs showing the method of application of carbon disulfide.

LIMITATIONS OF THE USE OF CARBON DISULFIDE

THE COST

Altho carbon disulfide has proved to be effective in Colorado for the eradication of perennial weeds, it has some disadvantages. Any method of underground application of a poison requires considerably more labor than does a single treatment with a spray or dust, and the work of injection will therefore be more expensive. When the price of carbon disulfide in large quantities is $5.50 per 100 lbs., the freight not more than $2.00 per 100 lbs., and the cost of injection $1.50 to $1.75 per square rod, the range of cost per acre of perennial weeds destroyed will have a maximum of from $260 to $400.

It must be remembered however, that infestations of an acre in extent can be more economically destroyed in other ways. If the area covers 10 square rods, the cost would be from $22.50 to $25.00 for the infestation, and if 20 acres were protected from and freed of perennial weeds, the cost per acre would be from $1.125 to $1.25, which should be charged over as many years as the land remains free from weeds of the kind killed. The increase in crop yield and in land value will more than repay the costs.

Carbon disulfide is much cheaper when purchased in large quantities, than when it is bought by individuals from retailers. When a number of farmers need a large quantity, they should pool their order with the county agent who can procure it from the manufacturers

at the wholesale prices quoted above.

UNCERTAINTY OF RESULTS WITHOUT AN INDICATOR TEST

As the work of 1927 has shown, not every application of the chemical has given a perfect kill. Little is known as to the exact soil conditions necessary for obtaining maximum results. The recommendations from California are that the liquid be applied while the soil is "quite dry," but under different soil conditions which prevail in Idaho, "quite moist" soil is necessary for favorable results. Good and unsuccessful results have been obtained in Colorado in both dry and moist soils. Because of the need for a better knowledge of the proper time to apply carbon disulfide, a chemical test was developed that would indicate the penetration of carbon disulfide vapor thru the soil and correlate well with the killing.

AN INDICATOR FOR CARBON DISULFIDE

During the early part of 1928 a number of chemical indicators were tried out. The chemical finally adopted as an indicator depends upon the formation of a deep yellow color when sodium alcoholate has been exposed to the vapor of carbon disulfide and treated with a solution of cupric sulphate slightly acidified with acetic acid.

Figure 5.—Vial and cord for holding the liquid alcoholate used in making the test for carbon disulfide gas diffusion.

Sodium alcoholate is prepared by allowing metallic sodium to react with absolute alcohol, and for test purposes the alcoholate is used in the following way. Small glass vials are filled with the alcoholate, and a loosely wound cotton cord is partially inserted into the open end of the vial as shown in Figure 5. Soft cord proves more satisfactory than gauze, paper, or cotton wool and affords a medium upon which to make the test. As the cord wick is never pushed to the bottom of the vial, there remains a small quantity of the liquid alcoholate which assures a check test if the reaction on the wick is not conclusive. The vials that have been used are 3 inches in length and ⅜ of an inch in diameter. They are placed in wire cages as shown in Figure 6. The cages are made from hardware cloth which is rolled into a cylinder. These cages afford support and protection for the vials, and furnish an easy method for injecting them into the soil. The wire A is used for inserting the cage into the soil and for removing it at the time the test for the formation of the yellow color is to be made.

In order to test the distance of diffusion of carbon disulfide gas thru the soil, the cages are

placed in holes arranged as diagrammed in Figure 7. The center hole, marked O indicates the dosage hole,, the point of application of liquid carbon disulfide. Three spiral lines of holes are used, for it is advantageous to disturb the soil as little as possible. The dots on the curves marked 1, 2 and 3 indicate the points where the test cages are placed. In each of the 3 rows of test holes, the first is 4 inches from the center, the second is 8 inches, the third 12 inches, and the fourth 16 inches.

The length of time intervening between the application of the carbon disulfide and the time of testing for the yellow color depends upon the distance of the indicator from the dosage hole. It is convenient, however, to apply the carbon disulfide one day and to leave the test vials in the ground until the following day before making the tests. This usually allows ample time for the carbon disulfide gas to reach approximately its maximum distance of diffusion.

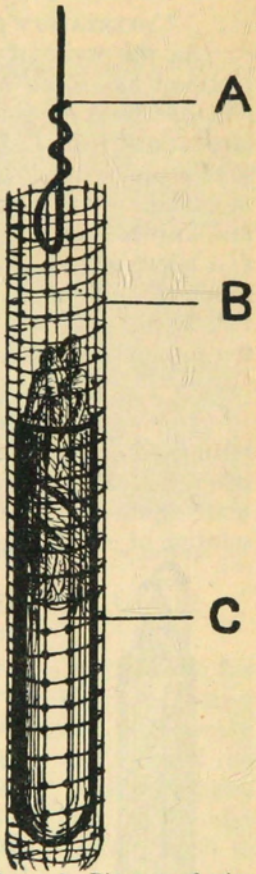

Figure 6.—Diagram of wire cage used in inserting the indicator tests into the soil.

The cages are pulled up, the vials removed from them, and with a small quantity of the acidified cupric sulphate, tests are made separately upon the wick and the liquid sodium alcoholate in the bottom of the vial. The change of the wicks or alcoholate to a deep yellow color, shows that the carbon disulfide vapor has penetrated the soil from the dosage hole to the indicator. If the string or liquid alcoholate takes on a blue-green tint instead of the deep yellow, it is not likely that carbon disulfide has penetrated the soil in quantities sufficient to kill roots of perennial weeds.

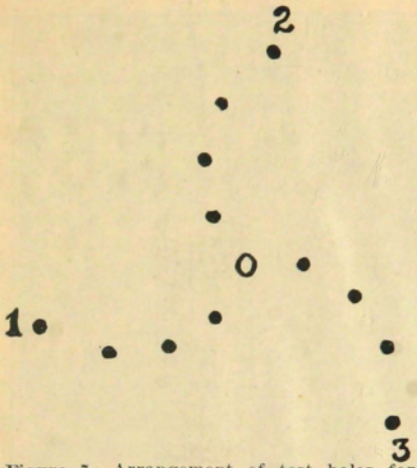

Figure 7.—Arrangement of test holes for determining the diffusion of carbon disulfide gas thru the soil from "O", the point of application.

Experimental data show that the use of this indicator method is advantageous, for in the test plots of 1928 there is high correlation between indication by the alcoholate and the killing of the weeds treated with carbon disulfide. In the test plots where the indicator failed to register penetration, apparently the weeds were not killed, but whenever a bright color change was obtained, a good kill followed.

Figure 8 shows a profuse growth of common wild morning-glory or bindweed along the curbing on Mathews street in Fort Collins. A portion of this plot was treated with carbon disulfide and indicator tests were made. The indicator recorded a high percentage of penetration which would suggest that a good kill would follow. Figure 9 shows the kill obtained.

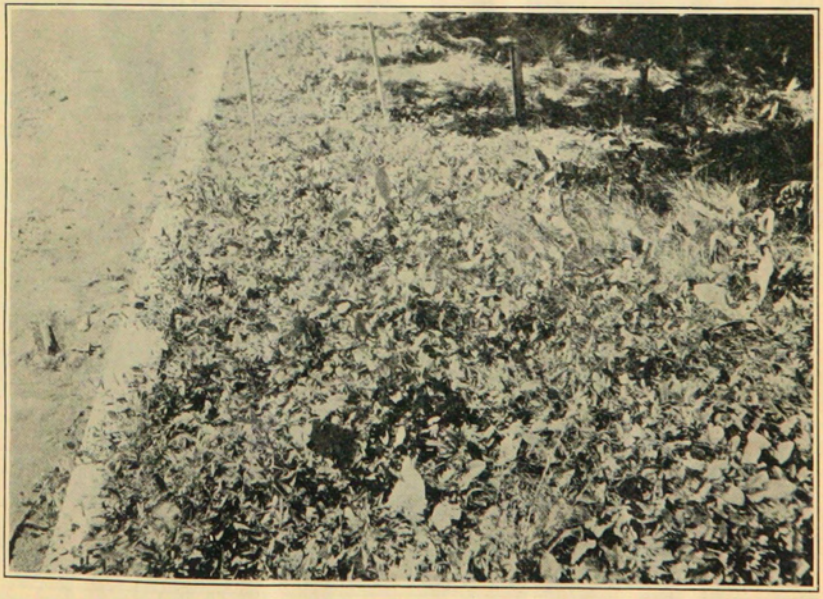

Figure 8.—Photograph of a profuse growth of common wild morning-glory along street curbing.

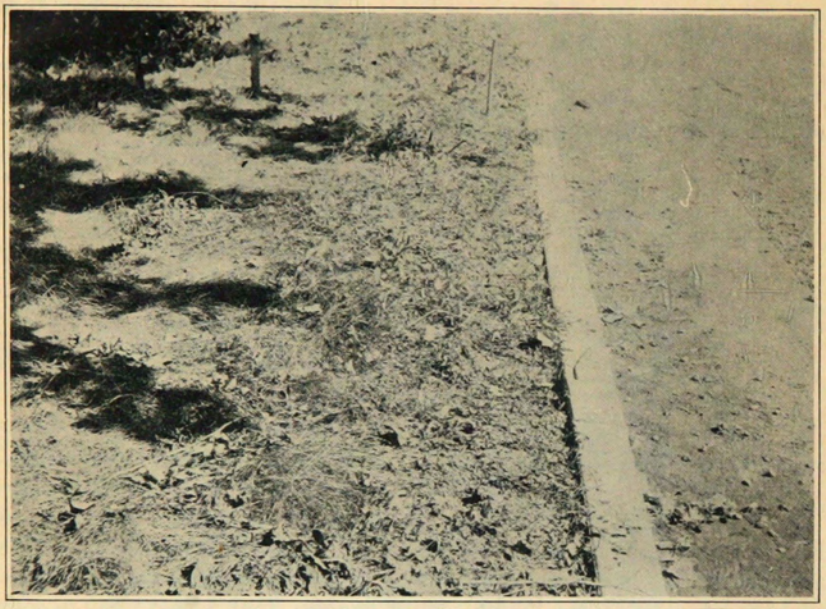

Figure 9.—Photograph of morning-glory plot adjoining that of Figure 8, after treatment with carbon disulfide.

Figure 10.—Photograph of morning-glory plot 20 days after application of carbon disulfide.

Another plot was staked out on a piece of plowed ground and the carbon disulfide injected. Carbon disulfide penetration was indicated in every test hole. Figure 10 is a photograph of the plot 8 days after application of the chemical. On each side of the plot may be seen the dense growth of the wild morning-glories, whereas in the treated portion there is already a striking reduction in the number of plants.

A further example of the correlation of indication with killing is shown in Figures 11 and 12. Figure 11 is a photograph of a plot of poverty weeds (*Franseria tomentosa*) on irrigated land. A good indication and satisfactory results were obtained around the edges of the plot, but in the central portion there was no indication and little or no kill. Figure 12 is a diagram of this same plot. The circles mark the points of application of the carbon disulfide and the dots designate where the indicator tests were made. "T" is placed beside the dots where penetration was indicated, but a failure to get a test is marked "NT." Irrigation water had recently stood upon the area indicated by the shading in Figure 12, whereas the remainder of the plot was "quite dry." The tests showed that there was no penetration in the moist area, and from Figure 11 it may be seen that practically none of the plants in this area was killed.

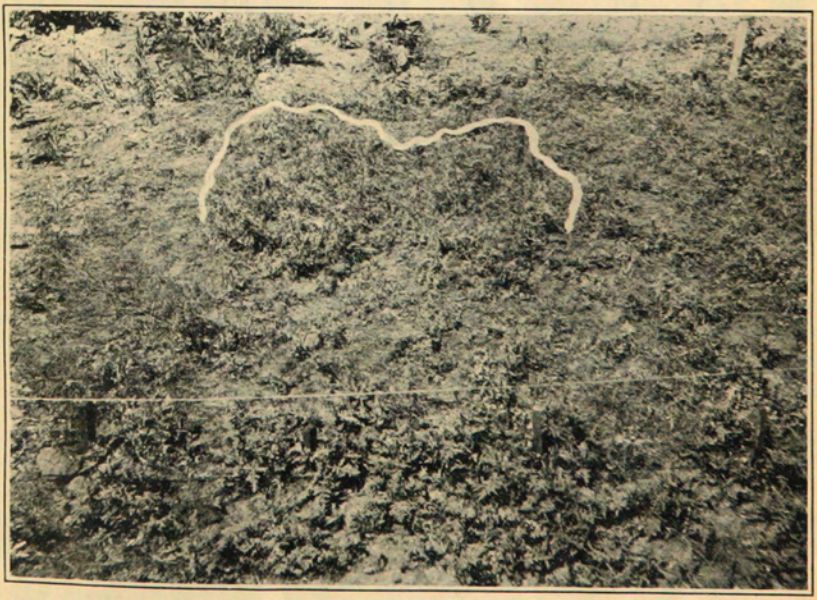

Figure 11.—Photograph showing a poverty-weed plot after treatment with carbon disulfide. The growth shown in the middle of the plot was the point where there was no indication and no killing.

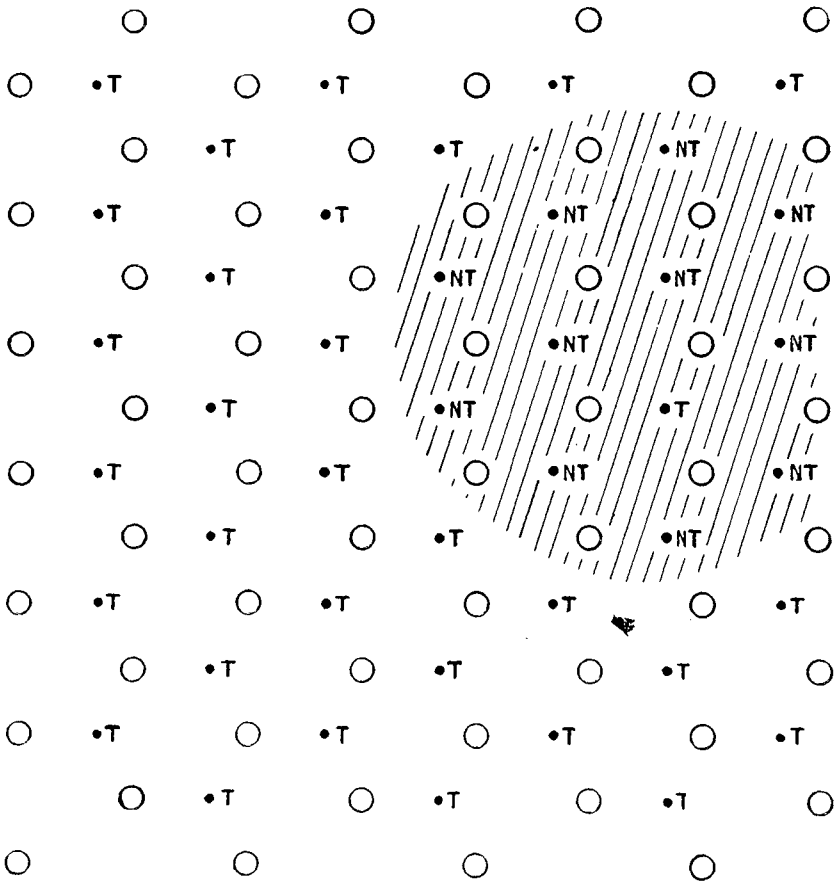

Figure 12.—Diagram of the plot photographed in Figure 11, showing the correlation of indication and killing.

From the experimental data collected from a number of such plots, a good killing always followed a good color indication, and when there was no indication of the penetration of carbon disulfide, the plants survived the treatment.

RECOMMENDATIONS

Carbon disulfide can be recommended as an effective and economical means of eradication of small patches of perennial weeds when large areas of weed-free land are to be protected from invasion.

Treatment with carbon disulfide can be made at times when farm work is slack, provided that the soil is in proper condition for penetration of the poison.

The chemical indicator discussed in this bulletin may be used for determining the penetration of carbon disulfide gas thru the soil and the probable effectiveness of this material for the eradication of perennial weeds under existing conditions. It should be put in representative places in each plot to be treated. Only when it shows penetration of carbon disulfide gas should the poison be used upon the whole area. It is well to treat the plot immediately after a satisfactory test, because soil conditions may change and modify the rate of penetration and the killing power of the poison.

Some of the material for this test is not readily available. It is therefore well to have the county agent or one who is familiar with the handling of chemicals make these tests. Indicator solutions ready for use, are available at the college for county agents. They may be had upon application by the county agents to the Botany department.

Two ounces of liquid carbon disulfide should be applied in holes 2 feet apart in the manner suggested in this bulletin. These application holes should be 18 inches deep for heavy soils, and 12 inches deep for light, coarse, sandy soils.

When carbon disulfide is purchased in quantities of more than 1000 pounds there is a material saving over the price paid for small lots. Farmers should unite their orders into a single large purchase.

When a number of farmers desire to purchase carbon disulfide, their county agent can obtain it at wholesale price direct from the manufacturer and at a material saving for them.

WARNING

Carbon Disulfide is Highly Inflammable and Explosive, Hence Extreme Care Should Be Used to Keep It Away From All Free Flames.

Its vapor has an injurious effect upon the human system. Large quantities of the fumes should not be inhaled and care should be taken to avoid getting the liquid into the eyes or mouth. It does not damage clothing or shoes.

In order to prevent loss by evaporation, the carbon disulfide should be kept in a tightly closed container.