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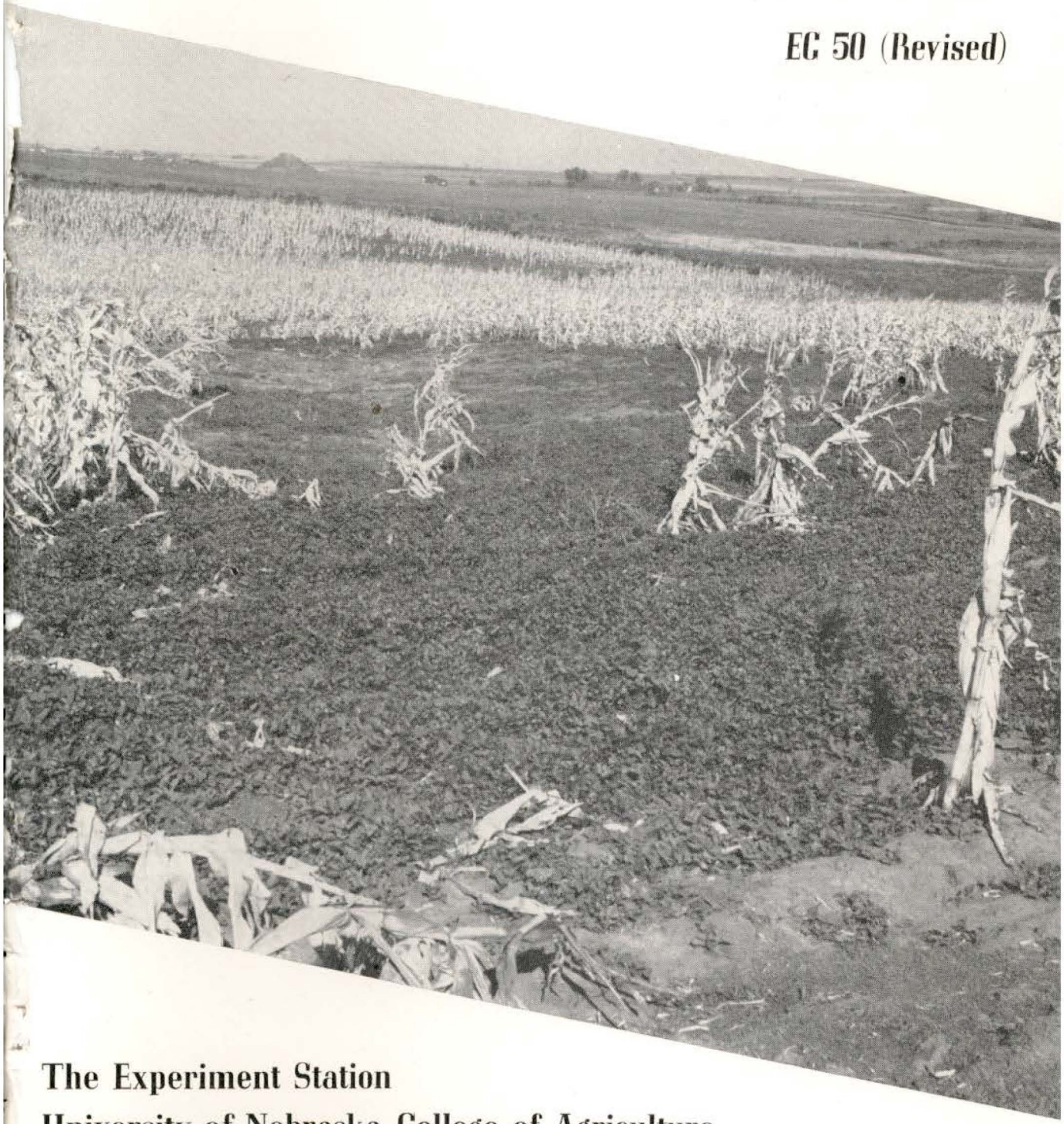

The Experiment Station
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Contents

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Bindweed Eradication in Nebraska

N. S. Hanson, F. D. Keim, and D. L. Gross [1]

BINDWEED, which is easily recognized by its creeping, entwining habit of growth, is Nebraska's most destructive weed because of its effect on crop plants. Its total annual cost to the agricultural industry of the state is several million dollars, which ultimately affects all those citizens who depend directly or indirectly upon income from agriculture.

Known most commonly in Nebraska as bindweed, it is called also by such names as field bindweed, small-flowered morning glory, European bindweed, creeping jenny, creeping charley, and creepers. Its scientific name is *Convolvulus arvensis* L.

Seriousness of Bindweed in Nebraska. Bindweed is believed to have been introduced into the state about 65 years ago by seeds in grain brought from Europe by some of the early settlers. From this early beginning, and as a result of indiscriminate shipment and use of bindweed-infested seed, this weed has spread over the entire state. Infested areas can be found in every county. A general survey conducted in 1939 showed that approximately 415,000 acres of farm land in Nebraska are infested with bindweed. About 96 per cent of the total infestation is located in the eastern half of the state (see Figure 1). Infestations in the western half of the state are located on both dry and irrigated land. Very little bindweed is found in the Sandhills. Each year a large number of newly infested areas are found. It is becoming increasingly important that tenants, as well as land owners, learn to identify this pest and guard against its introduction and spread. Where bindweed has become established, eradication measures should be taken immediately. The seriousness of the bindweed situation in Nebraska and surrounding states is indicated by the enactment of definite legislation dealing with its control and eradication.

Legislation for Weed Eradication. A weed law that pertains to bindweed and the other noxious weeds of Nebraska was passed by the 1937 State Legislature and was amended in 1941 and again in 1943. This law is administered by the Noxious Weed Division of the State Department of Agriculture and Inspection and the State Weed Advisory Committee. It provides for the organization of weed eradication districts, regulates the sale and transportation of seed, feed and other materials containing noxious weed seeds, and requires that all threshing machines, combines,

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and other harvesting equipment be cleaned to prevent the spread of noxious weed seeds during movement of such machinery from farm to farm. The weed law prohibits the sale of noxious weed-infested material as seed or as livestock feed unless the weed seed is removed, or has its viability destroyed by processing. Since the enactment of the law in 1937, forty-three noxious weed-eradication districts have been organized. Twelve counties are covered by county-wide organizations. The eradication work within each district is supervised by locally elected supervisors. Representatives of the Noxious Weed Division assist in the organization and administration of the weed districts, and conduct surveys, meetings, and activities in the interest of weed eradication.

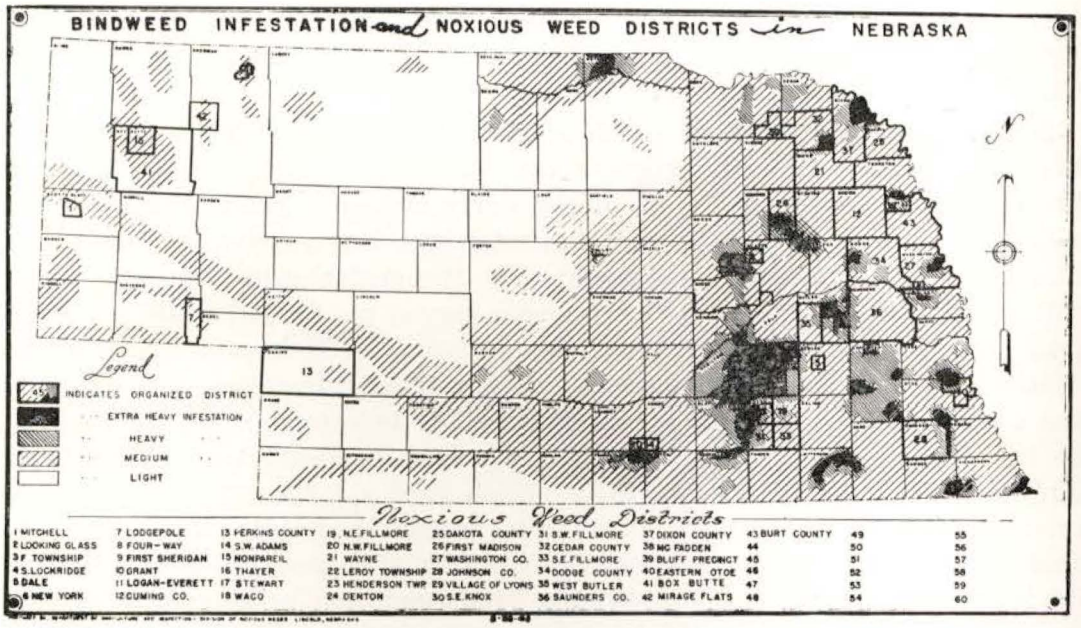

Figure 1. A map showing the areas of Nebraska that are lightly to heavily infested with bindweed. Numbered areas represent organized noxious weed eradication districts.

Description of Bindweed

The true bindweed is a long-lived perennial. It produces trailing or climbing vines. The leaves vary considerably in size and shape, but they are generally shaped like a blunt arrowhead. The bell-shaped flowers are small, seldom exceeding an inch in diameter. The color of the flowers varies from white to pink on different plants, but remains constant on a single plant. Two small scale-like bracts are on each flower stalk about an inch below the flower. From one to four dull grayish-brown to black, distinctly pebbled, seeds are produced in each small capsule.

The underground rootstocks, which are commonly called lateral roots, live over winter and produce growth the next season. The roots extend into the ground to depths of thirty feet or more and can draw moisture from the soil the entire depth.

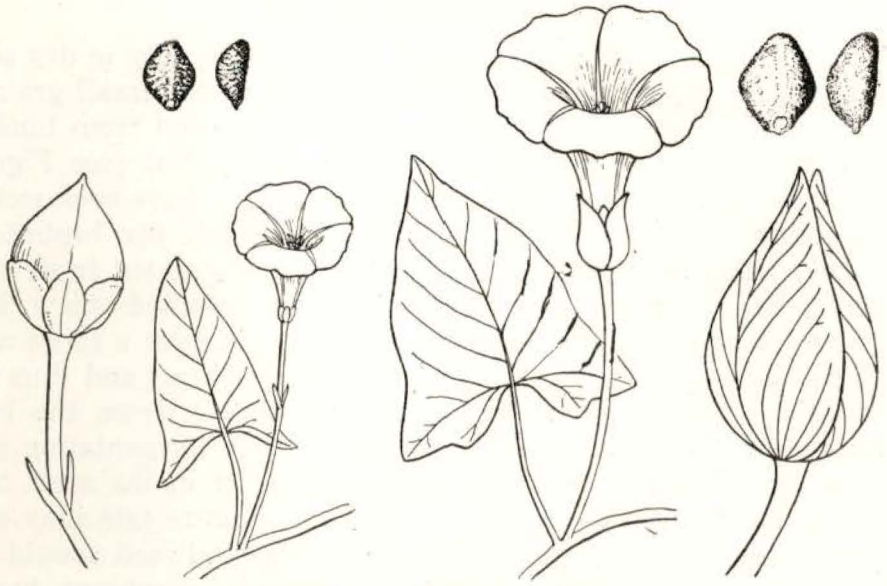

Figure 2. Flowers, flower stalks showing bracts, seed bolls, and seeds of bindweed (left), and hedge bindweed (right). All parts one-half natural size except the seed bolls and seeds which are enlarged by two diameters.

Bindweed Distinguished from Other Climbing Plants

Hedge bindweed, *Convolvulus sepium,* or large-flowered morning glory, closely resembles the bindweed, but it is not a serious weed when compared with the latter. The hedge bindweed has large, pure white bell-shaped flowers about two inches in diameter. Two large, green bracts are found immediately below each flower, enclosing its base. The leaves are larger than those on bindweed and have a shiny, smooth appearance. They are pointed at the tip but wide at the base and have two-pointed, blocky basal lobes (see Figure 2).

The common annual morning glories, of which there are two species *Ipomoea purpurea* Roth. and *I. hederacea* Jacq., to some extent resemble bindweed. However, they are easily distinguished from bindweed by their small annual root systems and large, deeply-colored flowers. The first has large, heart-shaped leaves, and the second has lobed or indented leaves.

Wild buckwheat, *Polygonum convolvulus* L., is a climbing plant which also resembles bindweed somewhat. It may be identified by its small annual, fibrous root system, broad but pointed heart-shaped leaves, five to fifteen very small inconspicuous flowers produced on a flowering stalk, and its black, shiny triangular seeds. Very young leaves of the wild buckwheat plant are rolled from the edges toward the middle and tend to unroll as they enlarge, while the young bindweed leaves are folded and tend to flatten out as they enlarge.

Spread of Bindweed

Seed. Bindweed is prolific in seed production, especially in dry seasons. Its seed generally ripens at about the same time as the small grains, and may be found in many of the crop products harvested from bindweed-infested land where no eradication has been attempted (see Figure 3). In the State Seed Laboratory, samples of small grain have been examined which contained as many as 36,700 bindweed seeds per bushel. Even small-seeded crops like alfalfa and sweet clover harvested from infested fields may contain bindweed seed. Animals fed infested straw, hay, or grain, or which are pastured on infested areas will pass a large number of uninjured bindweed seeds through the digestive tract and thus spread the infestation. Spreading of fresh manure directly from the barn to the fields results in further seed distribution. The fermentation process of silage or fresh manure will destroy the viability of the seed, but the dry material on the top and sides of a silo or manure pile may contain viable seed. Silage or manure known to contain bindweed should not be spread until it is well rotted. Threshing machines, combines, hayracks, trucks, and wagons may carry and spread the seed from infested fields unless they are thoroughly cleaned before moving to another field. Farm implements and road equipment also spread bindweed seed from infested to non-infested areas. Russian thistles entwined with bindweed vines carrying seed pods have been observed tumbling across fields. More seed is spread in this way.

Figure 3. Seed bolls on the butt of a bundle of wheat from an infested area where no eradication measures had been used. A very effective means of spreading bindweed to non-infested areas.

Farmers and dealers should buy crop seed with care, making certain that it is free of bindweed and other noxious weed seeds. Ordinary fanning mills are not effective in removing bindweed from small grains and sorghum seeds. Special cleaning devices may remove a large percentage of the bindweed seeds, but cannot be depended upon to remove them all. Where the purity of seed is in doubt a representative sample may be submitted for analysis to the State Seed Laboratory, State Capitol, Lincoln, Nebraska.

Roots. Underground rootstocks of bindweed may spread the infestation outward in one year as much as a rod in every direction. Small infested areas may double in size in that time. As in the spread of seeds, farm

Figure 4. The effect of planting corn on land heavily infested with bindweed.

implements and road equipment passing through infested areas break rootstocks into fragments which, under favorable conditions, may take root and develop new plants. Rootstock segments six inches or more in length can establish new plants in about five weeks. Those shorter than five inches seldom establish new plants because the food material is depleted before plants can become rooted. Nursery stock, especially that shipped with a ball of soil around the roots, may contain bindweed rootstocks which will take root quite easily.

Eradication Methods

The deep and extensive root system of bindweed makes the weed difficult to eradicate. If complete eradication is to be accomplished, the root system must be destroyed either by depletion of the stored food reserve or by chemical reaction within the root. All the bindweed seeds in the soil must have been destroyed, either by decay or by germination and destruction of the seedlings. Destruction of the plants is only the first step in eradication. The following methods of eradication and seedling

control are based on research conducted at Lincoln and York, Nebraska, part of which was cooperative with the Division of Cereal Crops and Diseases of the United States Department of Agriculture.

Continuous Cultivation

Continuous cultivation is a method by which all bindweed plants are cut off at a uniform level in the soil at designated intervals until the bindweed has been exterminated. It is also the method of fallowing used in the crop and fallow methods to be discussed. Continuous cultivation is recommended for small areas that do not lend well to alternate or continuous cropping. If large areas are continuously cultivated, some provision must be made to reduce the loss of soil by wind and water erosion.

Principle of Eradication. Continuous cultivation of bindweed is a starvation process. Food for plant growth and maintenance is produced in the leaves of growing plants. After the plants have attained a certain growth, more food is produced than used. The extra food is stored in the roots and provides a reserve for unfavorable periods when no food is manufactured in the leaves. Continuous cultivation artificially provides such an unfavorable period, forcing the bindweed to draw on the reserve in its roots. The most effective starvation results when the bindweed is left to grow for about a week before each cultivation. New plant tissues are then built largely from stored food. Growth should be permitted to continue until enough leaves have been formed for food storage to be resumed, and the area should be again cultivated, cutting off all plants below the surface of the ground. Once more the bindweed will be forced to draw food from its roots to renew growth. Repetition of this process will result in starvation of the entire infestation. However, unless all plants are cut off, the unsevered ones will furnish food to all plants attached to the same root system and eradication will be delayed. Old,

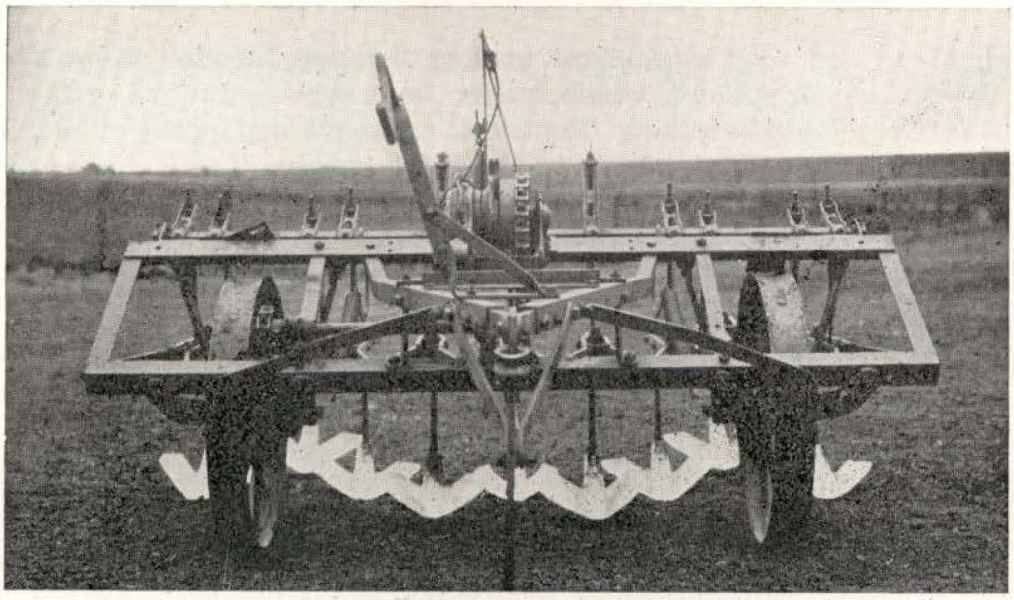

Figure 5. A duckfoot cultivator with sweeps overlapping.

deep-rooted plants usually have much more food in reserve than young, shallow-rooted plants. Consequently, the older plants are the most difficult to eradicate.

It is very important that cultivation should not be delayed after the bindweed plants have become large enough to store food. A delay of one week may mean the loss of the effect of several cultivations, and such delays often cause discouragement and failure in bindweed eradication.

Machines for Cultivation. The most satisfactory machines for bindweed cultivation are duckfoot and large-sweep, subsurface-tillage machines. Duckfoot cultivators are equipped with small sweeps that measure 10 to 18 inches from heel to heel. These sweeps are mounted in two or more rows across the machines, permitting the rear sweeps to cover areas missed by the leading sweeps and overlap them about three inches. This provides thorough coverage of the ground by which all bindweed plants are cut off in one operation (see Figure 5).

Various types of large-sweep, subsurface-tillage machines have been placed on the market. Common sweep sizes are 24 and 30 inches from heel to heel. Larger, 44-inch, sweeps have also been constructed that can be mounted on an ordinary two-row lister (see Figure 6). All sizes have proved satisfactory for bindweed cultivation when correctly adjusted. The sweeps should be set so they will enter the ground point first and level out after entering. Unless the sweeps are operated at a uniform depth, the bindweed will be cut off too shallow at the heels of the sweeps. Duckfoot-type machines with the 10 to 14-inch sweeps cannot operate efficiently where there is much plant residue. It may be necessary in some cases to remove some residue either by cutting and raking or by burning. Weeds and stubble plowed under will continue to cause trouble by clogging the machine. Wide-sweep machines with

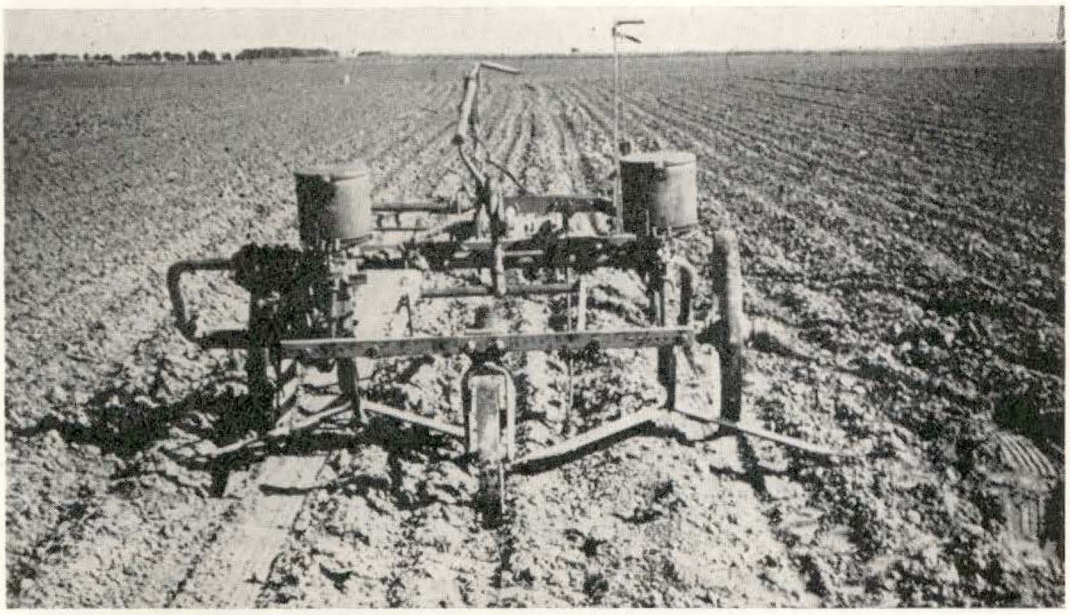

Figure 6. A lister converted for bindweed cultivation by replacing the bottoms with 44-inch sweeps.

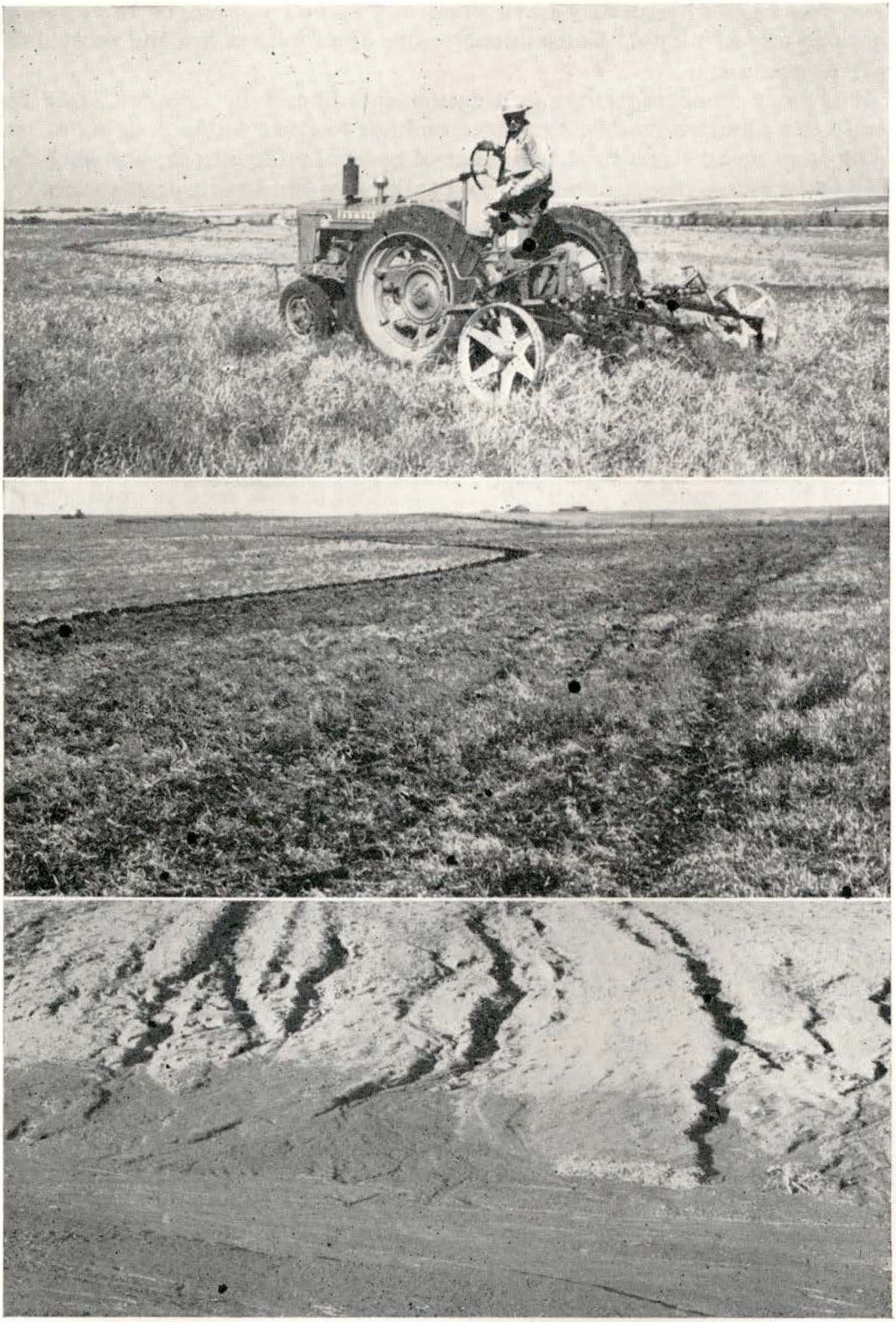

Figure 7. A combination of bindweed eradication and soil conserving methods for use on land subject to erosion. (a) Subsurface tillage on the contour. Bindweed plants are cut off and plant residues are left on the surface for erosion control. (b) An area that was cultivated with the machine shown above. (c) A sloping area that has been continuously cultivated without erosion control.

large rolling coulters ahead of the sweeps will go through a heavy plant residue, cut off the bindweed plants, and leave the residue on the surface. This is desirable where the land is subject to erosion.

Many home-made machines using duckfoot sweeps, large sweeps, or straight blades have proved satisfactory for bindweed cultivation. Plows, discs, one-ways, rod weeders, and other machines have been used, but because of high cost of operation and inefficient eradication with the latter machines they are not recommended.

Time to Begin Cultivation. There are two periods during the growing season, either of which are satisfactory with regard to the availability of the infested area for beginning cultivation. One is in the spring about three weeks after bindweed emergence, and the other is immediately following harvest of winter grains. The end of the three-week period after first emergence will usually fall sometime between May 5 and May 25 from the southeastern to the northwestern regions of the state. The bindweed can be permitted to grow undisturbed for the first three weeks in the spring because little food material is stored in the root during this period. Harvest time ranges from early July in southeastern, to late August and September in northwestern, Nebraska.

Frequency of Cultivation. It is recommended that cultivations be performed every two weeks during the first year and every three weeks, or eight days after re-emergence, in the second and successive years. The recommended frequencies allow for a few days delay beyond the specified intervals. In case of wet weather or the urgency of other farm work, a slight delay will not cause a disruption in the starvation of the bindweed plants. By the end of the first full year of continuous cultivation the bindweed will have become weakened to the extent that the period from cultivation to re-emergence will have been increased by several days. It is then possible to lengthen the period between cultivations, and consequently reduce the cost of eradication.

Soil Conserving Practices. Unless the soil is protected against wind and water erosion, great losses of top soil may occur where an area on rolling land is continuously cultivated. Various soil-conserving methods should be incorporated with continuous cultivation to minimize erosion. Cover cropping, subsurface tillage, strip cropping on the contour, terracing, and blank and basin listing on the contour are a few of the soil conserving practices that can be included (see Figure 7). Land subject to erosion should be planted to rye or wheat for the winter months. By subsurface tillage, residue from these crops can be kept on the surface during the early summer months when water erosion is most important. The alternate crop and fallow method discussed under a separate heading fits very well into a strip cropping plan. Alternate strips on the contour are cropped with winter wheat or rye and the remaining alternate strips are cultivated. Strips that are cultivated one year are cropped the following year and vice versa. Combine stubble must then be kept on the surface by subsurface tillage on the strips from which the crop was harvested. Where an entire area is to be continuously cultivated without a residue

cover this should be done on the contour and the slope terraced if possible. Blank listing or blank basin listing on the contour, in the fall, will prevent much loss of soil during winter and spring months, but does not protect the soil during the cultivation season.

Eradication Plan and Procedure. The procedure for continuous cultivation started in the spring is shown in Plan 1. This plan is arranged to include soil conserving practices and to provide for the control of seedlings after eradication is complete. Cultivating is done at two-week intervals the first year and at three-week intervals or eight days after re-emergence, in the second and succeeding years.

The procedure is the same where cultivation is started after harvest of winter grains, but tillage should be continued at two-week intervals throughout the second year. Eradication will not be completed in this case until some time in the third year.

Cost of Eradication. From 20 to 25 cultivations over a two to three-year period are usually required for complete eradication. Studies conducted from 1935 to 1937 on farms in York and Lancaster counties in Nebraska showed that the total cost for labor (25 cents per hour), fuel, interest and

Plan 1. Procedure for Continuous Cultivation [1] Arranged on a Monthly Basis Throughout the Year.

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
1st Year											
Cover crop or crop residue - - - -			[2]xx	xx	xx	xx	xx	Rye or wheat for winter cover - - -			
2nd Year											
Crop residue, pasture, or hay - - - - -			[3]x	xx	x	xx	x[4]	Wheat or rye for seedling control - -			
3rd Year											
Wheat or rye for grain and seedling control - - - - - - - - - - -						Cultivate immediately after harvest to destroy seedlings - - - - - -					
4th Year											
Repeat the 3rd year procedure for the 4th and possibly for the 5th and 6th years to destroy seedlings.											

[1] Each cultivation is represented by the symbol x.

[2] Begin duckfooting or subsurface tillage about three weeks after first emergence of bindweed (May 5 to 25) and continue at 2-week intervals until seeding time or until the end of the season on small areas where no cover crop is planted.

[3] Begin at the same time as in the first year and either cultivate the cover crop with a subsurface tiller to leave residue on the surface of soil that is subject to erosion, or remove the crop by pasturing or cutting for hay where the land is not susceptible to erosion, and cultivate with an ordinary duckfoot. Where hay is to be removed, it may be necessary to delay beginning cultivation for a week or 10 days for the crop to be cut at heading time. Because of the density of the crop at this period, there will be little gain made by the bindweed, but the area should be cultivated as soon as the hay has been removed. Cultivate every three weeks or eight days after re-emergence of the bindweed for the remainder of the time necessary for eradication.

[4] Bindweed is usually eradicated by the end of the second year with this method.

depreciation on equipment, and repairs for equipment amounted to 32 to 34 cents per acre per single cultivation. Tractors and duckfoot cultivators were used. If 35 cents per acre per cultivation is taken as a figure for calculation, the cost for 20 to 25 cultivations would be $7.00 to $8.75 per acre for eradication. No allowance is made for the loss of two crops.

Alternate Crop and Fallow

It is not always possible financially for a farmer to keep an area in continuous cultivation for two or three consecutive years until bindweed has been eradicated. The alternate crop and fallow method is one in which the area can be cropped with winter wheat or rye every second year during the time that the bindweed is being exterminated. It is a method that fits especially well into the winter wheat and fallow rotation used in western Nebraska, but it is also recommended for all sections of the state where winter wheat can be grown.

Figure 8. A bindweed plant growing in a rye field after one year of continuous cultivation. Crop competition prevented blooming and seed formation. Cultivation was resumed after harvest.

Eradication plan and procedure. Plan 2 gives the procedure to be followed in using the alternate crop and fallow method when cultivation is started in the spring of the first year. Eradication usually can be completed by the end of the fourth year by this method. Wheat and rye are the only grains that have proved satisfactory as competitive crops for bindweed and, therefore, are the only crops that can be recommended for use in the alternate crop and fallow method.

These procedures will vary somewhat in detail for various regions of the state, but in general they are the same for all sections. Harvest in northwestern Nebraska is not completed in normal years until the latter

part of August. Therefore, fewer cultivations can be performed from harvest until freeze-up than in the southeastern and central area where grain is harvested in early July. Nevertheless, the alternate crop and fallow method conforms to the two-year rotations of wheat and fallow for western Nebraska. The only change from the regular rotation is that the eradication method starts with a year of fallow, and cultivations are performed at regular intervals the first and third years, and after harvest in the crop years.

The alternate crop and fallow method works well where soil conservation is necessary. A heavy crop stubble becomes available after harvest and reduces erosion when kept on the surface by subsurface tillage. This method also fits well into strip cropping on the contour. Since the eradication process is continued over a longer period than with continuous cultivation, more of the bindweed seeds will have germinated and seedlings have been destroyed by the time eradication is completed.

Plan 2. Procedure for Alternate Crop and Fallow [1]
Arranged on a Monthly Basis Throughout the Year.

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
1st Year											
Cover crop or crop residue - - - -				[2]xx	xx	xx	xx	xx	Wheat or rye for grain - - - - -		
2nd Year											
Wheat or rye for grain - - - - - - - - - -					[3]xx	xx	xx	Rye or wheat for winter cover - - - -			
3rd Year											
Crop residue, pasture, or hay - - - - -				[4]x	xx	x	xx	x	Wheat or rye for grain - - - - - -		
4th Year											
Wheat or rye for grain - - - - - - - - - -					[3]x	xx	x[5]	Wheat or rye for seedling control - -			
5th Year											
Wheat or rye for grain and seedling control - - - - - - - - - -					Cultivate immediately after harvest to destroy seedlings - - - - - - -						
6th Year											

Repeat the 5th year procedure for one or two additional years to destroy seedlings.

[1] Each cultivation is represented by the symbol x.

[2] Begin duckfooting or subsurface tillage about three weeks after first emergence of bindweed (May 5 to 25) and continue at 2-week intervals until seeding time.

[3] Resume duckfooting or subsurface tillage immediately after harvest and continue at 2-week intervals until seeding time or until the end of the season on small areas where no cover crop is planted.

[4] Begin at same time as in the first year and either cultivate the cover crop with a subsurface tiller to leave residue on the surface of soil that is subject to erosion, or remove the crop by pasturing or cutting for hay where the land is not susceptible to erosion, and cultivate with an ordinary duckfoot. Where hay is to be removed, it may be necessary to delay beginning cultivation for a week or 10 days for the crop to be cut at heading time. Because of the density of the crop at this period there will be little gain made by the bindweed, but the area should be cultivated as soon as the hay has been removed. Cultivate every three weeks or eight days after re-emergence of the bindweed until seeding time.

[5] Bindweed is usually eradicated toward the end of the fourth year by this method.

Cost of Eradication. From 30 to 35 cultivations are necessary over a four-year period to complete eradication by the alternate crop and fallow method. At the cost figure of 35 cents per acre per cultivation that was used previously, the cost per acre for labor and fuel, and interest, depreciation, and repairs on equipment would be between $10.50 and $12.25.

Continuous Crop and Fallow

The continuous crop and fallow method is one in which a crop can be produced on an infested area each year after the first. Winter wheat has proved more effective than rye and is at present the only crop that can be recommended for use with this method. The area must be cultivated throughout the first year. This method is recommended for those winter wheat regions of the state where several cultivations can be performed at two-week intervals between harvest and seeding. The season is too short in northwestern Nebraska to make several cultivations possible.

Eradication Plan and Procedure. Plan 3 shows the procedure to be followed in using the continuous crop and fallow method when cultivation is started in the spring of the first year. The procedure is practically the same when cultivation is started after harvest of winter grains in the first year except that cultivation should be continued throughout the second year before a crop is seeded. Cultivation from harvest until seeding time in the first year does not weaken the bindweed enough for con-

Plan 3. Procedure for Continuous Crop and Fallow [1] Arranged on a Monthly Basis Throughout the Year. (Not applicable to northwestern Nebraska).

| *Jan.* | *Feb.* | *Mar.* | *Apr.* | *May* | *June* | *July* | *Aug.* | *Sept.* | *Oct.* | *Nov.* | *Dec.* |

1st Year

Cover crop or crop residue - - - - [2]xx xx xx xx xx Wheat for grain - - -

2nd Year

Wheat for grain - - - - - - - - - - - - - - [3]xx xx xx Wheat for grain - - -

3rd Year

Wheat for grain - - - - - - - - - - - - - - [3]xx xx xx Wheat for grain - - -

4th Year

Wheat for grain - - - - - - - - - - - - - - [3]xx xx xx Wheat for grain - - -

5th Year

Wheat for grain - - - - - - - - - - - - - - [3]xx xx xx[4]

If the bindweed is not dead by this time, repeat wheat each year until eradication has been completed. Most of the bindweed seeds will have germinated and the seedlings have been destroyed by the time the plants are exterminated.

[1] Each cultivation is represented by the symbol x.

[3] Begin duckfooting or subsurface tillage about three weeks after first emergence of bindweed (May 5 to 25) and continue at 2-week intervals until seeding time.

[3] Resume duckfooting or subsurface tillage after harvest and continue every two weeks until wheat-seeding time. Combine stubble kept on the surface by subsurface tillage will be effective in reducing erosion.

[4] Bindweed is usually eradicated by the end of the fifth year by this method.

tinuous cropping with cultivation from harvest to seeding in subsequent years to effect eradication. Approximately five years will be required for eradication by the continuous crop and fallow method.

There are several reasons why this method is desirable. Most important is the fact that a crop can be grown on the area each year except the first. This will give a return from the area that will offset the cost of eradication. The method fits well where soil conservation is necessary because a heavy stubble becomes available each year after the first. Eradication continues over at least five years and employs the method most effective for seedling control, that of a heavy wheat crop followed by cultivation. By the end of the fifth year a large percentage of the bindweed seeds will have germinated and the seedlings have been killed. During wartime, when the emphasis is on production of food, the continuous crop and fallow method serves a two-fold purpose in that the area can be cropped each year after the first while at the same time the bindweed is being eradicated.

Cost of Eradication. Approximately the same number of cultivations are necessary for the continuous crop and fallow method as for the alternate crop and fallow method. This would make the cost of eradication about $10.50 to $12.25 per acre for labor, fuel, interest, depreciation, and repairs.

Chemicals for Bindweed Eradication

Experiments have been conducted with a large number of chemicals in order to determine their value for eradicating weeds. Many of these chemicals are effective in killing annual weeds with shallow root systems, but only a few have proved satisfactory in destroying deep-rooted perennials such as bindweed. The chemicals that have proved most satisfactory are sodium chlorate, Atlacide, and salt.

Sodium Chlorate

Sodium chlorate is a crystalline salt, closely resembling common table salt. It is not poisonous to livestock unless eaten in large amounts, nor is it injurious to the hands. Like common salt it will take up water and harden into lumps if allowed to stand in a damp place. Since it is an unstable, oxidizing compound it readily supports combustion. For that reason there is a considerable fire hazard connected with its use, unless it is handled properly and carefully. When mixed with certain organic substances, sodium chlorate has explosive properties and as a result comes under explosive regulations during wartime. As a chemical for weed control, sodium chlorate is easily handled and can be applied either dry or as a spray. When the chemical is applied dry, most of the fire hazard is eliminated if it is used when the plants are free from dew or other external moisture. Gloves, pockets, cuffs, and shoes should be cleaned of dry sodium chlorate which may have become lodged in them. Material which is soaked with a sodium chlorate solution is not dangerous so long as it remains wet, but when dry, it may ignite by friction or by spontaneous combustion from direct sun rays. Such material should be washed thoroughly to remove the sodium chlorate.

Time, Rate, and Method of Application. Experimental work has shown that the best time of the year to apply sodium chlorate to non-irrigated land as a single treatment is in the fall during the months of September and October. In order for the single treatment to be effective, the soil must contain sufficient moisture at the time of application and for several months thereafter to cause the sodium chlorate to dissolve and percolate into the soil. If applied to a very dry soil, the chemical tends to remain inactive, or it may be lost through decomposition, resulting in a relatively ineffective treatment. Where sodium chlorate is applied to irrigated land, the date of application is of less importance than when applied to non-irrigated land. It should be applied immediately after a heavy irrigation to avoid loss from leaching and yet insure maximum penetration. Later irrigation of the area may be necessary to maintain sufficient moisture.

Three to four pounds of sodium chlorate per square rod are recommended under average conditions. This amount may be applied either in the dry, crystalline form, or in a solution of one pound to a gallon of water. Where a fertile soil, high in organic matter, is encountered, the rate of application must be increased to give satisfactory results. When four pounds of sodium chlorate are applied per square rod the soil may be rendered non-productive for several years depending on the soil type, fertility, and moisture conditions.

There is very little, if any, difference in effectiveness between the spray and dry applications of sodium chlorate. Dry sodium chlorate may be broadcast by hand or by a chemical spreader (see Figure 9). In either case, extreme care should be exercised to make a uniform distribution. The chemical should be applied at least ten feet beyond the edge of the infested area in order to kill all lateral underground rootstocks. Large

Figure 9. Spreading chemicals with a mechanical spreader.

power sprayers are well adapted for the treatment of roadsides and ditch banks where treatment with the dry chemical is difficult. Small knapsack sprayers are useful for small areas and near valuable shrubbery where the amount of sodium chlorate applied must be controlled accurately.

Preparation of the Ground for Treatment. When sodium chlorate is applied dry, excessive weed growth and other plant residue may prevent the chemical from reaching the ground where it must dissolve and percolate into the soil if it is to be effective. If the area is sprayed, this residue will absorb a large percentage of the chemical, and thereby reduce its effectiveness. It may be necessary in some instances to mow and remove the plant material before the sodium chlorate is applied, but such residue might well be spread over the area again after the treatment in order to increase the moisture intake of the soil, reduce erosion and evaporation, and hasten leaching of the chemical.

Sodium chlorate penetrates most rapidly in a firm but non-compacted soil. No plowing should be done for several months previous to application unless special attention is given to removal of all crop residues, and the soil becomes settled before treatment. Surface tillage to prevent seed development prior to treatment is advisable, however.

Follow-up Treatments. Spot-treatment of individual plants or application of two pounds or more of chemical to the square rod on areas with a large number of surviving plants will generally prove sufficient as a follow-up treatment. Spot treatment should be done by spreading approximately a teaspoonful of sodium chlorate around the plant about 10 inches in all directions (see Figure 10). The follow-up treatment should be made in the spring or late summer following the original treatment and after it has had time to be effective. The ground should be left undisturbed until all the plants have been killed.

Figure 10. Spot treating individual bindweed plants with sodium chlorate.

Cost of Eradication. The cost of eradication with sodium chlorate depends on the effectiveness of the original application and the method used. This emphasizes the need of making the application when there is an optimum of moisture in the soil. Under average conditions a total of five pounds per square rod, including original and follow-up treatments, is required for complete eradication. If the cost of sodium chlorate is eight cents per pound, the cost of eradication would be 40 cents per square rod or $64.00 per acre for the chemical. The labor cost would be extra.

Federal Regulations on Sodium Chlorate. During wartime, sodium chlorate comes under the regulation of the Federal Explosives Act of 1917 as amended in 1941. Its manufacture, storage, and use must conform to that of all explosives. Special licenses are issued to individuals handling explosives and certain storage conditions are required. Five different licenses are issued by the Bureau of Mines, one of which will authorize an individual to handle sodium chlorate. Application for the proper license can be made to the County Clerk. The County War Board is authorized as Regional Officer by the Bureau of Mines to act on appeals from applicants whose applications for licenses have been rejected by the County Clerk.

Atlacide

Atlacide is a proprietary chemical that consists of about 60 per cent sodium chlorate. The other 40 per cent is made up of chemicals that are included mainly because of their fire-retarding effect on the sodium chlorate. Although there is less fire hazard in the handling of Atlacide than there is with sodium chlorate, the same precautions should be taken to prevent its mixture with combustible organic material. Atlacide is not poisonous to animals, except in large amounts, nor does it burn the hands. Because of the combustion-retarding chemicals included in its composition, it is not considered as an explosive and does not come under the Federal Explosives Act during wartime. Experiments have shown it to be slightly less effective than sodium chlorate for bindweed eradication.

Time, Rate, and Method of Application. The time and method of application of Atlacide are the same as for sodium chlorate. Four to five pounds per square rod are necessary for the original treatment since Atlacide is slightly less effective than sodium chlorate. Satisfactory kills have been obtained with four pounds, but more often at least five pounds per square rod are necessary. The ground should be prepared for treatment in the same way as for sodium chlorate. The residual effect on the soil is about the same. There is little difference in effectiveness between dry and spray applications.

Cost of Eradication. Atlacide sells for approximately the same price as sodium chlorate, and since a slightly heavier application is required, the additional cost per acre will be from $5.00 to $10.00.

Salt

Crushed rock salt can be used for weed eradication. It is undesirable for agricultural land because it sterilizes the soil permanently, due to the large amount required for effective treatment. In permanent fence

lines, along roadways, drainage and irrigation ditches, and along railroad rights-of-way, where erosion is not a problem, sterilization of the soil is often desirable. In such places salt can be used satisfactorily. It is neither poisonous to livestock, nor does it cause a fire hazard.

Time, Rate, and Method of Application. Because salt causes permanent sterility and is not decomposed when applied during hot weather, the time of year for application is not of great importance. It may be applied preferably in the spring or early summer, but this is not necessary. Salt should be applied at the rate of one pound per square foot or 272 pounds per square rod.

A chemical spreader can be adapted for spreading salt by replacing the perforated bottom pan with a pan containing holes one inch in diameter and three-eighths inch apart. The spreader then can be calibrated to spread 91 pounds per square rod. By covering the area three times, 273 pounds per square rod can be spread.

Cost of Eradication. Crushed rock salt is shipped to Nebraska from salt mines in Kansas. It can be obtained in eastern Nebraska for approximately $5.00 per ton in 40-ton carload lots. At this price, the cost per square rod is about 68 cents or $109.00 per acre. Labor cost for application is higher than for sodium chlorate or Atlacide.

Hoeing and Burning Bindweed

Bindweed is often found in orchards, gardens, near shrubbery, and in various other places where it is either impractical or impossible to cultivate the area, and where chemicals would destroy valuable plants and sterilize the soil. In such areas it may be necessary either to hoe or burn the bindweed periodically.

Eradication can in most cases be accomplished in two or three years by hoeing or burning the infested area every 10 days. The bindweed will re-emerge in two or three days and should be left to grow for a period of eight days before the next hoeing or burning. A push-type hoe requires less effort and cuts at a more uniform depth than the ordinary pull-type.

For burning bindweed a kerosene or fuel oil burner can be used. A light searing of the foliage is just as effective as reducing the vegetation to ashes. It is very important that the entire area be given a thorough and uniform searing so that there are no plants skipped. The cost of eradication, with kerosene at 12 cents per gallon and labor at 25 cents per hour, is about two cents per square rod for each burning. As many as 30 treatments may be necessary over the two-year period. The cost of eradication per square rod therefore might be about 60 cents.

Bindweed Seedling Control

During the years that bindweed plants have grown on a particular area, thousands of seeds may have been produced, some of which are lying dormant in the soil. A certain percentage germinate and the seedlings are killed during the regular process of eradication. Bindweed seeds may remain viable for 25 years or more. After plant eradication is complete, it is still necessary to work the area to prevent re-infestation by seedlings.

Figure 11. The characteristic heart-shaped leaves of bindwind seedlings.

Successive crops of wheat or rye, followed by cultivation immediately after harvest, have been effective in preventing re-infestation by seedlings. Inter-tilled crops such as corn and sorghum are not entirely satisfactory because seedlings may grow too close to the stalks to be killed by cultivation. These seedlings become established after the crop is laid by. Seedlings that are undisturbed will become established as perennial plants in about six weeks and two or more cultivations are required to exterminate them. Perennial crops such as alfalfa and bromegrass are not satisfactory for seedling control because winter-killing or drought often cause thin stands in small areas of the fields, thus reducing competition and permitting seedlings to become established. When scattered seedlings are found that have become well-rooted they often can be killed more cheaply by spot treatment with sodium chlorate than by cultivation.

Eradication of Bindweed in Lawns and Gardens

Many lawns and gardens in farm yards and on city lots in Nebraska are infested with bindweed. Where a lawn is in poor condition and in need of improvement, it is perhaps most desirable to work the area and eradicate the bindweed by hoeing or individual plant treatment with chemicals. Many lawns having good stands of grass are also infested with bindweed. Such lawns require special treatments to eradicate the bindweed without damaging the grass. Bindweed in either lawns or gardens can be eradicated by one of the following methods.

Spudding or Pulling Individual Plants. Bindweed plants growing in well-established lawns do not seem to have the recuperative power of plants growing in a cultivated field. The infested area should be gone over thoroughly once every two weeks and individual plants either pulled or cut below the surface with a spudder. Approximately two years will be required to complete eradication. This method can be used in gardens also, but the plants should be cut or pulled every 10 days.

Individual Plants Treated with Sodium Chlorate. Individual bindweed plants can be treated with sodium chlorate either dry or in solution and the plants may either be cut or left uncut. If the plants are not cut, the chemical must be applied at the crown of the bindweed plant. The least injury to the lawn results when individual plants are cut with a spudder about one and one-half inches below the surface of the ground and sodium chlorate applied at that depth. Approximately one-half teaspoonful of dry sodium chlorate or an equivalent amount in solution should be placed in each hole. The whole area should be thoroughly watered immediately following treatment in order to leach the chemical deep enough in the soil to prevent injury to the grass. It is necessary to watch the area and give a similar treatment to plants that continue to emerge. One treatment should exterminate the greater percentage of the plants. This method can be used in gardens also for exterminating scattered plants, but where the area is heavily infested, sodium chlorate should not be used, since it will sterilize the soil and damage the garden crop.

Over-all Treatments with Sodium Chlorate. Over-all treatments of one pound of sodium chlorate per square rod at each of five two-week intervals has effected eradication in one year with slight injury to the grass. The application of one-half pound of sodium chlorate per square rod at the same intervals resulted in no apparent injury to the grass, but complete eradication required an additional treatment the second year. Thorough watering after treatment, as indicated above, is essential. The sodium chlorate should be thoroughly mixed with about five pounds of dry sand for each pound of chemical in order to insure enough quantity to facilitate a uniform spread. This method should not be used around small trees and shrubbery or in gardens.

Sodium Arsenite Bottle Method. Where scattered plants are found in lawns or around shrubbery, the sodium arsenite bottle method can be used. A solution of sodium arsenite is placed in a wide-mouthed bottle and the bindweed vine threaded into the solution. The bindweed should be left in the solution over night or for about 12 hours. Enough chemical will have been absorbed by the tissues to kill the main plant as well as other plants connected to the same root system. Sodium arsenite is extremely poisonous to livestock and should not be used where livestock can graze on treated plants. Neither should it be used where it will be a hazard to children. The method is not recommended for gardens.

Carbon Bisulphide. Carbon bisulphide is a volatile liquid, the fumes of which are heavier than air. When it is applied to a bindweed infested area, the fumes move down through the soil and kill the roots. The soil is rendered sterile for only a few days. The chemical must be placed below most of the grass roots. It can be poured or injected into holes six to eight inches apart. Two ounces of carbon bisulphide are placed in each hole and the holes tamped shut after the treatment to prevent the fumes from escaping. This method has proved satisfactory for eradication of bindweed with slight injury to the lawn. The cost of eradication is approximately $1.50 per square rod for the chemical alone. Since this method is very costly it is not recommended for general use in gardens.

Bindweed in Gardens. Since bindweed does not emerge until late April or early May, gardens are often planted before it is realized that the area is infested. In such case, the best attempt possible will need to be made to work in and around the vegetables already planted to cut off the bindweed. Where it is known that bindweed exists on the area to be gardened, erect-growing plants such as sweet corn, early cabbage, onions, and tomatoes to be staked should be planted. It will then be possible to hoe close enough to the stems of the desired plants to cut off all the bindweed.

The infested area should be hoed at 10-day intervals and care should be taken that all bindweed plants are cut off. The plants will re-emerge in two or three days if they are cut about an inch below the surface, and they should be permitted to grow for about a week before again being hoed. This will be a total of about 10 days between hoeings. During the week of growth the bindweed plants draw food from their roots for making top growth. By the end of the 10-day period enough leaves will usually have been formed to permit root restoration to begin. It is then time for the plants to be cut off, forcing them to draw again on the stored food reserve. Continued repetition of this process will result in the starvation of bindweed in two to three years. As long as the bindweed is continuously cut off, it should not reduce the yield of garden plants, especially if the area is watered.

Other Treatments

Various practices such as pasturing with sheep, hogs, and chickens; smothering with manure, straw, or tar paper; and the use of tall-growing smother crops such as hemp, artichokes, Sudan grass, and forage sorghums have been used by some farmers with varying degrees of success. While some of these practices have been successful under certain conditions, they have usually failed. New and untried methods should be discouraged since too often their failure creates a defeatist attitude toward eradication.

Pasturing. Pasturing by hogs is very unsatisfactory because scattered plants are not eaten off or rooted out and these few plants continue to feed the entire root system. Eradication by pasturing with sheep has been successful in a few cases when the area has been pastured closely once every week from spring to fall for a period of three years. This involves the use of two pastures, one being the area infested with bindweed and the other for supplementary pasturing when the sheep have eaten down the bindweed. Few farmers have the time or patience to shift a flock of sheep between pastures each week over a period of three years. Where a large number of chickens are concentrated on an infested area, eradication can be expected in about three years. Such a practice would, of course, be limited to small areas. The seeds of bindweed remain alive through the digestive tracts of all animals except poultry, and bindweed seeds in droppings are often a source of further spread when a bindweed-infested area is pastured.

Smother Crops. Tall-growing crops such as hemp, forage sorghum, Sudan grass, and artichokes have not proved effective for eradication in

experiments conducted in Nebraska. The spread of bindweed has been controlled by these crops, but they have not effected eradication.

Smothering. Straw stacks, manure piles, and tar paper covers have been used in an attempt to smother bindweed. The plants grow up through the straw stacks and manure piles and are usually more difficult to eradicate than they would have been previous to smothering. Tar paper covers are costly and seldom effect complete eradication.

Row Crop Cultivation. The Department of Agricultural Engineering, noting some of the objections to clean cultivation for bindweed eradication, such as the exposure of the land to wind and water erosion, and the lack of income from the land, conducted some experiments in which bindweed was eradicated while growing corn. The procedure was to killefer the field to a depth of 15 to 18 inches, thus cutting off all roots to that depth. Then the seedbed was prepared by plowing and harrowing. The corn was checked, permitting cross-cultivation, and had grown to a height of four or five inches by the time the bindweed emerged. The field was then cultivated in both directions and those vines which could not be removed by the cultivator were taken out with a hoe. After the corn normally was laid by, a horse and one-row cultivator were used to continue cultivation until frost. Killefering was done only the first year. This procedure eradicated bindweed in three years. The greatest objection was the hoeing, the cost of which was more than 25 per cent of the total cost of work. A better than average crop of corn was produced. This method is applicable only where labor is available for hoeing.