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Field Bindweed

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By

C. J. Franzke and A. N. Hume

Field Bindweed increasingly infests areas of cropped land for the reason that crop systems employed there make conditions favorable to its growth.

Control or eradication of the pest on infested areas will have to come through a modification of crop systems now widely employed.

Introduction directly into crop rotations of a succession of: (1) summer fallow, succeeded by (2) winter rye with repetition two successive seasons, and longer if necessary, will provide this modification on areas that have become infested.

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Summary and Contents

Bulletin 305

Summary

This bulletin states facts that relate themselves to four things about Convolvulus arvensis, commonly called Field Bindweed: **First,** how to identify it; **second,** narratives about attempts at eradication (whether successful or not); **third,** to point out how the pest may be controlled; and **fourth,** to make sufficient reference to the scientific principles involved to explain why some methods, especially that of combined fallowing and smothering, are effective.

It has seemed worthwhile, even necessary, to put down details about attempts at eradication in narrative form. This department has made scores of unsuccessful attempts at controlling Field Bindweed, in order ultimately to arrive at successful ones.

It will be necessary to read this bulletin in order to arrive at its conclusions. It might be necessary to study it.

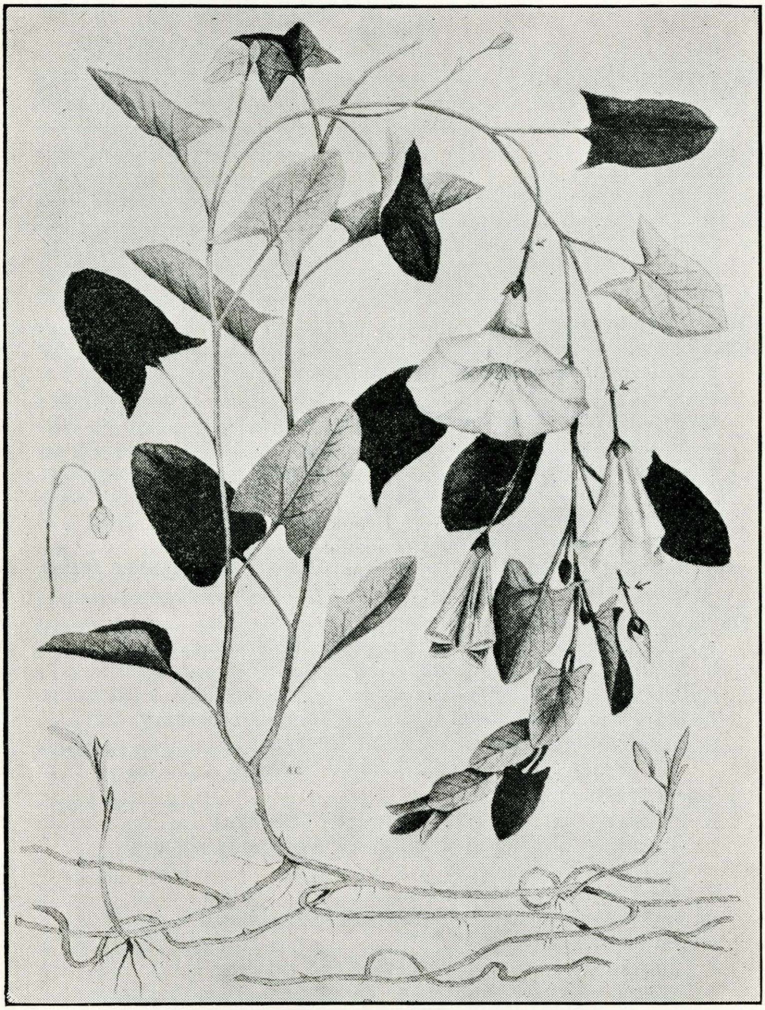
Introduction of Summer Fallow with Winter Rye Smother-Crop into Cropping Systems Proves Unfavorable, to Bindweed—It is possible to state here as a deduction from the numerous and long time trials reported herein that the introduction of summer fallow, which in turn shall serve as preparation for winter rye, directly into crop rotations now in general use, will interfere with the growth of field bindweed. Such introductions will accomplish measurable results even in one season. However, no examples of complete eradication can be cited that are the result of one season's work. Observations cited herein indicate that it will be necessary to repeat the process of summer fallowing with winter rye thereafter at least two consecutive seasons, and apparently three in most cases.

Such an apparently simple process of utilizing summer fallow with winter rye smother crop, making it virtually an addition to and part of a cropping system on infested areas, is an apparently successful method of bindweed control or eradication for this area. See pages 47-50.

Eradication or Control is Based on Principles—The writers have been increasingly impressed with three things during the course of these observations and experiments. **First:** Field Bindweed did not, and does not, exist under natural conditions where there has never been opportunity for it to develop in the plant population of any given area. **Second:** Its later development within such areas has been brought about, if at all, through changes in ecologic conditions favorable to its growth. **Third:** Eradication or control of bindweed, will have to come about through another change in the conditions of plant and crop growth such that the latter may prove unfavorable to it.

Table of Contents

Index



(Illustration from Pammel—Iowa Geologic Survey)
Another name, beside Creeping Jenny is Small-flowered-Morning-Glory

Field Bindweed

and

Control Methods for South Dakota

C. J. Franzke, Assistant in Agronomy (Crops) and

A. N. Hume, Agronomist and Superintendent of Substations

What Is It?

Field Bindweed might be defined for many crop producers by calling it at once the most widespread and troublesome perennial pest of its class. An additional number of people would know it by the name Creeping-jenny. That is its most common name in South Dakota.

Another common name is small-flowered Morning-Glory, which is more scientific since it is a member of the morning glory family, with bell-shaped blossoms like those found on the cultivated varieties except that they are generally smaller—an inch or less in length. The flowers of other species of the morning-glory family growing cultivated or wild, are as much as two inches in length.

There are several members of the morning-glory family which may become troublesome. Creeping-jenny, or small-flowered Morning-glory, is Convolvulus arvensis. It belongs to the plant family called Convolvulaceae, which means according to derivation, "binding or rolling around." It will be easy to recall that Creeping-jenny or Convolvulus arvensis has this characteristic of creeping or rolling around, and thus choking crop plants. This quality alone, however, does not distinguish it from all members of the Morning-glory family. Several characters of Creeping-jenny plants serve to set them off and distinguish them from other weeds generally known to be somewhat less noxious in South Dakota, nevertheless similar in appearance.

Plant Characters

Generally speaking, the above-ground parts including stems or vines and leaves are smaller than those of other species of morning glory. The whole plant appears finer, less coarse as it grows under field conditions comparable with other species. This character alone, of finer growth and smaller plant parts (leaves and stems) may go a good way toward identifying Creeping-jenny where a direct comparison is possible. Such direct comparisons, however, are often not possible, so that relative fineness or coarseness of stems and leaves can only be estimated from memory, which is far from exact. Variations in the conditions of plant growth may cause Creeping-jenny plants in favorable spots to become as large and coarse as other species growing in less favorable spots and vice versa.

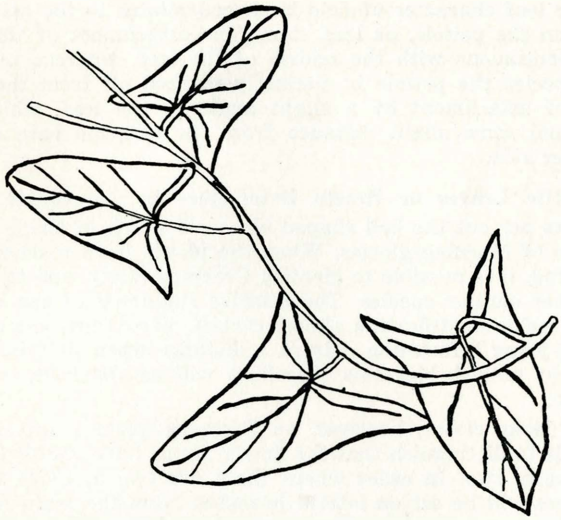
The Leaves

The leaves of Convolvulus arvensis or Creeping-jenny are one to two inches long, oblong, arrow shaped. At the base of the leaves are extensions, or lobes, that come to a point at the bottom. The shape of the leaves is described as ovate, which in this connection means, shaped like an egg with the large end attached to the main stem.

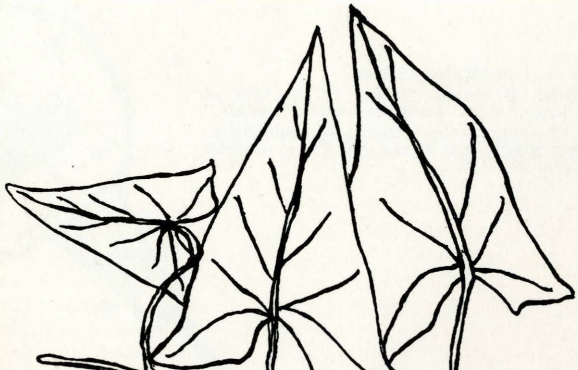
Any written description such as the foregoing, whether of leaves of Creeping-jenny or any other part, is inadequate in expressing the most specific marks of indentification. A good deal of practice is necessary to become expert in making the closest distinctions between the "ovate" leaves of Creeping-jenny and for instance those of some other species that are "acuminate" or more pointed. Occasional leaves on two species also are likely to deviate enough from typical shapes so that some of those from the two species are not very far apart in shape. That is the reason why it is so difficult, even impossible, to identify Creeping-jenny absolutely by size and shape of leaves.

The reproductions on the following page, from "Flora of Northern States and Canada, Britton and Brown," give an outline of leaves from Creeping-jenny (Convolvulus arvensis) with leaves, and incidentally stems, of another common species of Morning-glory for comparison. Careful inspection will emphasize the generally smaller size, lower degree of pointedness, i.e. more ovate shape of leaves and other plant parts on Creeping-jenny.

Another difference in leaf characteristics between Creeping-jenny and Great-bindweed which may help in identification of species before blossoming time, has been observed by C. J. Franzke during the course of these investigations. This pertains to the collection of veins in the base of the leaf area in the region where they converge at a point where the stem of the leaf sets on. If one takes hold of the upper part of the leaf-blade with thumb and forefinger and pulls upward, in the case of Great-bindweed, the lower part of the leaf will wrinkle and become puckered; whereas in the case of Creeping-jenny such pulling upon the upper part of the leaf, even to the extent of tearing it off entirely, will leave the lower part still smooth. Apparently the wrinkling referred to in the leaves of Great-bindweed comes about due to the tenacity with which the veins in that part of the leaf are embedded in the leaf area. Perhaps they are less firmly embedded in the case of Creeping-jenny. At any rate, the leaves do not wrinkle or buckle in the case of the latter, and this serves to identify the species.



Creeping Jenny—(Convolvulus arvensis).
(Britton & Brown, Chas. Scribner's Sons, N. Y.)
Typical leaves are smaler and more ovate than those of other similar species most common in this territory.



Great Bindweed—(Convolvulus Sepium).
(Britton & Brown, Chas. Scribner's Sons, N. Y.)
Typical leaves of this species illustrate that those of Creeping Jenny are smaller and not so sharply pointed.

Another leaf character of field bindweed relates to the attachment of the blade on the petiole, or leaf stem. The attachment of the petiole is smoothly continuous with the midrib of the leaf, whereas in the large-flowered species the petiole is distinctly marked off from the midrib at its point of attachment by a slight angle to the leaf, which point is always found some slight distance from the extreme base of the leaf on the under side.

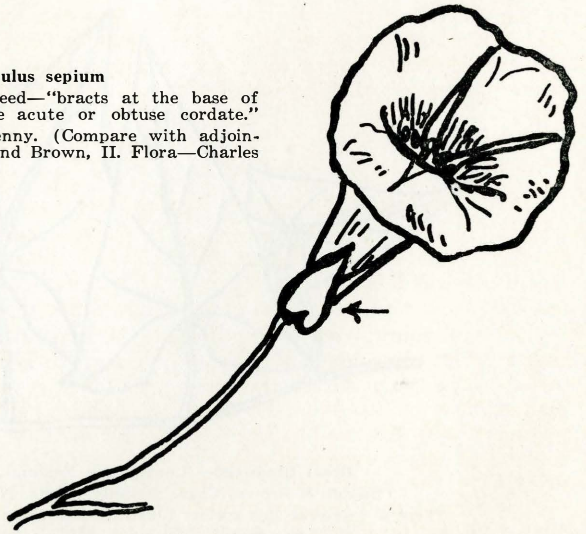
The Little Leaves or Bracts Determine—In due course, Creeping-jenny plants put out the bell shaped blossoms which in shape are typical of all kinds of Morning-glories. When the plants have reached the stage of blossoming, it is possible to identify Creeping-jenny, and to distinguish it from other similar species. The relative smallness of the blossoms in itself may make identification almost certain, even when one can observe a Creeping-jenny infestation only at a distance when it is in full bloom. The white or pinkish blossoms (corollas) will be apparent, but not very conspicuous.

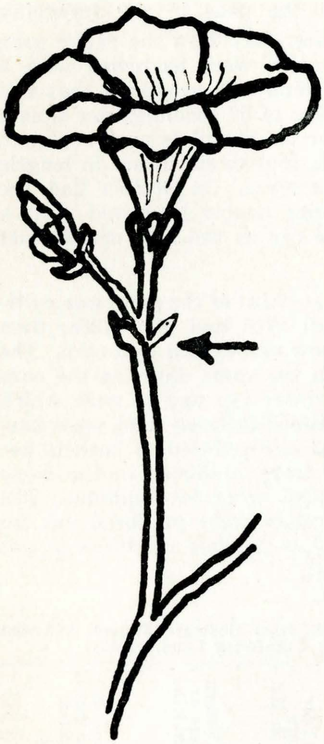
As one looks closer, however, on Creeping-jenny plants in blossom, it is possible to distinguish that the flower stems have one to four flowers set on, usually two. In cases where there are two or more flowers, the extra flowers will be set on lateral branches from the main flower stem.

On the main flower stem of Creeping-jenny, one third of the distance from the blossom to the main stem will be found a group of from one to three tiny leaves or bracts. Also in those cases where additional flowers are attached by secondary flower stems or pedicels, the same kind of little leaves or bracts will appear on such pedicels. (Note in illustration, Page 9). These secondary bracts also will be found at a point one-third the distance from the base of the flower to the attachment

Convolvulus sepium

Hedge, or Great Bindweed—"bracts at the base of the corolla large, ovate acute or obtuse cordate." This is not Creeping Jenny. (Compare with adjoining cut). After Britton and Brown, Il. Flora—Charles Scribner's Sons, N. Y.





Convolvulus arvensis

Small Bindweed. "Peduncles 1-3 bracted at the summit, usually with another bract on one of the pedicels." (Compare with adjoining cut). After Britton and Brown. Ill. Flora. Charles Scribner's Sons, N. Y. The size and position of these bracts or little leaves on flower stems, makes one say this is Creeping Jenny.

of the pedicel at the main flower stalk. **The nature and position of such tiny leaflets or bracts on the flower stems of Creeping-jenny constitute the characteristic which may be commonly used to distinguish it from** other species of Morning-glory. Obviously they cannot be observed on the plant as a mark of distinction unless and until the plant or plants have reached the stage of producing buds or blossoms, with the corresponding flower-stems.

Bindweed May Reduce Corn Yield 90 Per Cent—It is unnecessary to present proof to people familiar with the depredations of bindweed to convince them of its damaging effects. It appears interesting to put down figures which demonstrate the possible extent of such injury on corn—likewise the comparative lack of injury on winter rye.

On Agronomy West Farm, Brookings, one of the cropping systems long used for comparison has been: (1) Corn, (2) Wheat, (3) Peas (turned under). The purpose of including peas in the rotation as originally planned was to observe their effect in furnishing nitrogen and organic matter to the soil. It has been found incidentally that peas have some controlling effect upon bindweed—due apparently to their ability to make growth in the early spring. However, the mere fact of having peas included in the third year of a rotation as above did not in itself eliminate bindweeds entirely.

Winter Rye was seeded—July 5, 1934 the peas in the foregoing rotation were plowed under for green manure. July 23rd the entire area of plots 440 and 441 included in this rotation were harrowed with a spring-toothed harrow to free the land of bindweed seedlings that had made their appearance. There was an average of 57 seedlings per square foot. On July 27th, August 17th, and October 1st, the plots were replowed five inches deep. Bindweed vines varied from four to six inches in length, a thick stand practically covering the soil surface. On October 2nd, the north two thirds of plots 440 and 441 were double harrowed with a spring-toothed harrow and **seeded with fall rye at the rate of two and one-half bushels per acre.**

The spring of 1935 the remaining south one-third of the plots was cultivated, using a duckfoot cultivator on April 27th and May 12th; then double-harrowed with a spring-toothed harrow and drilled into corn. The corn was given only ordinary cultivation on the same dates as the corn on the bindweed free land. The crops of winter rye and of corn which had been planted, as foregoing, on the bindweed-infested land were harvested in due course, and the yields secured and reduced to bushels per acre in each case. Yields from the same crops produced in the same season on uninfested land in the same rotation were not available. The same crops, viz. corn and winter rye, however, were produced not far away, on land not infested with bindweed. It is possible therefore to put down some yields for comparison as follows:

Comparative Yields of Crops (Corn and Winter Rye) from Ordinary Though Different Rotations, on (1) Bindweed Infested and (2) Uninfested Land, (1935).

Crop	Plot No. West Farm	Regular Rotation on Land	Infestation	Given Year Per Acre Yield in Bu.	Gross Return Per Acre At Current Price	Per Cent Reduction Due to Infestation
Corn	141	Corn Wheat Sweet clover	No bindweed	38.9	$18.28	0.00
Corn	441	Corn Wheat Peas	Bindweed	3.7	1.74	90.5
Rye	549	Sorghum Rye	No bindweed	37.3	13.80	0.00
Rye	441	Corn Wheat Peas	Bindweed	46.6	17.24	0.00

Deductions from Foregoing Table—The figures in the foregoing table, although in no sense exactly mathematical, bring out two facts of importance in dealing with bindweed infestations in cropping systems:

1. It becomes evident from the last column of the preceding table that bindweed infestations which may occur on land in corn may reduce the yield of that crop fully ninety per cent.

2. The same did not apply to such a crop as winter rye, judging from the foregoing table. In the lower two horizontal lines it may be observed by comparison that winter rye actually yielded higher and produced a larger return on land infested with bindweed than on uninfested land. It seems obvious that this is not to say that bindweed infestation can be beneficial to growth of rye, but rather that rye can somehow compete with bindweed for growth on the same land.

It may be put down here as related to later statements in this bulletin that the ability of winter rye to make late fall and especially early spring growth abundantly, is associated with the apparent fact that it can hold bindweed in check. It seems possible that in case any other crop could be found to make similar late fall and early spring growth, it would serve as a good smother crop to that extent. It has been mentioned that peas have some value in this connection—perhaps due to their growth in early spring.

Winter Rye, on Bindweed Infested Land Paid Some Return (1935). Spring-seeded Grains in Such Land—Nothing.

It has been pointed out elsewhere in this bulletin that winter rye is relatively better equipped to withstand infestations of bindweed than some other crops, specifically corn. (See Table page 12.)

It is possible here to make comparison of winter rye in this respect with three other small grains—viz. oats, barley, wheat. It becomes evident in the following table that the three kinds of spring grain are incapable, under the conditions of this experiment, of overcoming bindweed in and of themselves—altogether inferior to winter rye in the respect indicated.

Explanation of the Following Table—The figures of the following table seem to substantiate the general conclusions of this bulletin in the respect that winter rye is capable of making effective growth on bindweed infested land. The inference may rest here also that winter rye is an effective smother crop. It may be assumed further that since the comparative yield of other cereals, wheat, oats, barley, as put down in the fifth column, are exactly zero from bindweed infested land, these latter cereal crops are relatively much less effective than winter rye from the standpoint of holding bindweed in check.

Comparative Yields (and values) of Winter Rye, and Three Other Small Grains (Oats, Wheat, Barley) from Three-year Cropping Systems Seeded on Land (a) Uninfested, and (b) Infested with Bindweed

Crop	Plot No. West Farm	Regular Rotation on Land	Infestation	Yields in Bu. Per Acre Given Year	Gross Return Per Acre at Current Price	Per Cent Pounds of Grain per Acre (Small Grain no Bindweed as 100%)
Oats	365	Corn	No Bindweed	60.3	$13.97	100.0
Oats	643	Oats	Bindweed	0.0	0.00	0.0
Rye	643	Sweet Clover	Bindweed	37.0	13.69	107.4
Barley	246	Corn	No Bindweed	38.5	$12.32	100.0
Barley	343	Barley	Bindweed	0.0	0.00	0.0
Rye	343	Sweet Clover	Bindweed	40.2	14.87	121.8
Wheat	241	Corn	No Bindweed	21.3	$18.53	100.0
Wheat	644	Wheat	Bindweed	0.0	0.00	0.0
Rye	644	Sweet Clover	Bindweed	48.2	17.84	211.8
Av.—Oats, Barley, Wheat			No Bindweed		$14.94	
Av. Oats, Barley Wheat			Bindweed		0.00	
Av.—Rye			Bindweed		15.47	

Observations from Foregoing Table—The practical question which the foregoing table may help answer is whether to seed winter rye, or some other cereal crop on land where bindweed has appeared. The answer so far as it may be expressed in dollars may be found in column six. The returns in dollars from said column are constructed by multiplying the yields in bushels per acre of the preceding column by the current market price of the several cereals.

On this basis, it appears that $13.97 worth of oats grew on land in a three-year rotation with corn and sweet clover where there was no infestation of bindweed. On similar land infested with bindweed winter rye returned $13.69, whereas oats again, on bindweed infested land, made no financial return whatever.

The same observation in regard to barley in the middle section of column six shows a money return of $12.32 from land clear of bindweed. Winter rye returned $14.87 even from land which was infested with bindweed, whereas barley on such infested land made no yield of grain, and consequently no return whatever.

The comparative returns from wheat and winter rye were altogether similar. The return in dollars from wheat where there was no bindweed was $18.53, which was only a small increase over the money return from winter rye (even on bindweed infested land) where the return was $17.84; whereas the money return of wheat from just such bindweed infested land was exactly nothing.

Summary from Foregoing Table—Under the conditions of this one-year experiment at Brookings (1934-1935), the foregoing table indicates:

1. Spring grains, i.e. wheat, barley, oats, made no money return on bindweed infested land, even though the same kind of land was capable of returning an average of $14.94 from the same cereals when uninfested.

2. The obvious thing to do is to avoid seeding wheat, barley, or oats, when bindweed infestation is present.

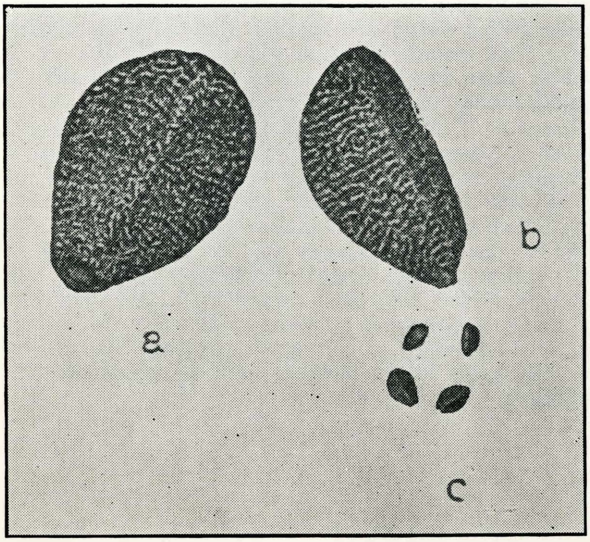
3. Such infested land might be seeded to winter rye with reasonable hopes for a return of $15.47 per acre.

Bindweed Eradication

What to do First?—Avoid sowing the seed. Creeping-jenny has been, and is, distributed into new locations by sowing the seed as an impurity, generally with one or another kind of small grain. Spots thus infested, later become centers of local distribution, whether seed is produced every year under the conditions or only in occasional years.

Whoever has land not already infested, can afford to learn what Creeping-jenny seed looks like definitely enough to detect it or any seed similar to it by examining seed carefully before sowing.

The Seed—The seed of Creeping-jenny (Convolvulus arvensis) is described as 3-5 m.m. (millimeters) long, which would be approximately one-sixth inch in length. The general shape is oval, one side is convex, or curved outward; the other side with a broad ridge, and a depression at one extremity representing the scar-surface of the seed, is roughened, and is dark brown in color. In case of any doubt whatever, or if weed seeds are found present that have some resemblance to Creeping-jenny, they may be submitted to this department for identification by M. Fowlds, Seed Analyst.



Seeds of small or Field Bindweed. a & b—different faces of seed: c—actual size (After Pammel, drawing by Charlotte M. King.)

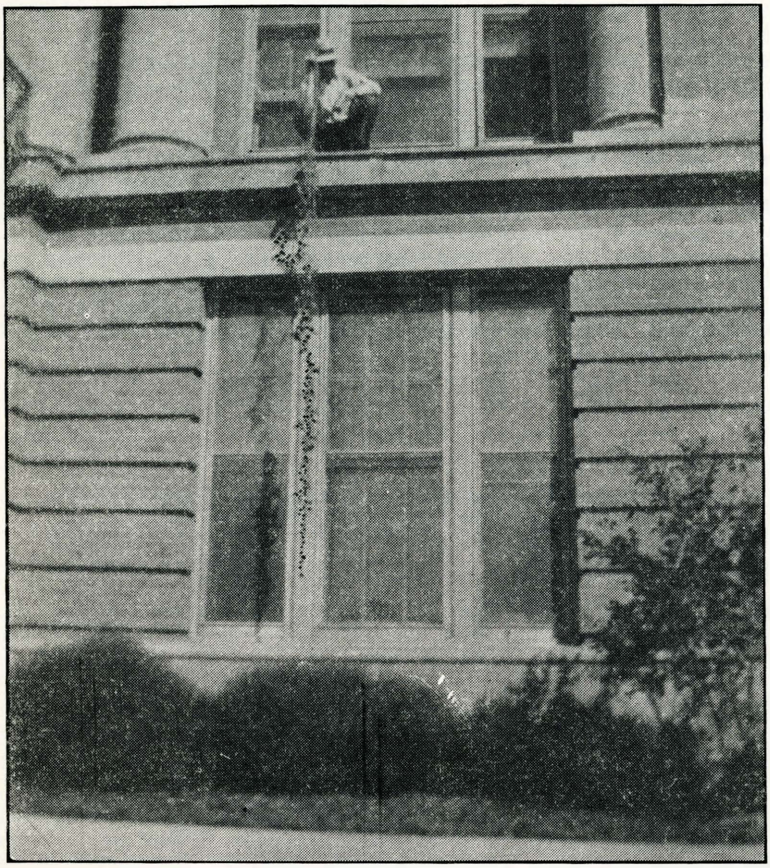
May be Carried by Wind, Water or Animals—One should not only be watchful against weed impurities that come in with impure seed. Unfortunately, clean land is likely to be surrounded by land infested with weeds. Creeping-jenny may be one of such weeds. That may explain the appearance of one or more Creeping-jenny plants where none existed before, and where none would be expected to appear. One such plant is that many too many. It is enough to infest an entire field and likewise an entire farm. That is the reason why every owner and manager of land should be on the alert to observe whatever weeds infest his area, in order to drive out Creeping-jenny in case it appears, and do it with reasonable effort.

Fallowing May Eradicate Small Areas—A statement has been made by Muencher, quoting Cox, that "the earlier methods of controlling this weed were based entirely on intensive cultivation and summer fallowing of the infested areas." (Muencher—Weeds—M.M. Co.) Such a statement is general. It may reflect the assumption carried in the minds of people that of course thorough cultivation as ordinarily understood would keep land clear of weeds—All weeds!

Fallowing may be defined as any process of keeping the surface of the soil stirred to a greater or shallower depth, in a manner designed to destroy all vegetation on the land affected. Fallowing as usually carried out would prevent the production of crops on the given piece of land during the process and presumably also the growth of weeds. Sometimes it does.

Theory of Fallowing—The assumption with regard to destroying Creeping-jenny, as well as other weeds by method of fallowing, is that all ordinary plants in order to live must have (1) above ground parts, and (2) underground parts; and further, that if these several parts are torn apart so they cannot function, the plant will die; simply because every flowering plant has to have stems and leaves in order to live and breathe. Experiments summarized herein indicate that such assumption is correct, based as it is, on established laws of plant physiology.

Isolated observations of a number of individuals have brought out the exceeding tenacity of Creeping-jenny plants, enabling the underground roots and root-stalks to send up new aerial stems even when the above ground parts are removed with some thoroughness by fallowing processes. The tenacity of the Creeping-jenny pest has been so pronounced that although it has not exactly caused experimenters to doubt the laws of plant physiology, it has well nigh caused them and various growers to despair of using a fallowing method practically for Creeping-jenny eradication. Such an indication serves to emphasize the thoroughness and persistence with which fallow methods must be carried out in case they are to be effective.



Morning-glory specimen, unwrapped from Corn Stalks. West Farm, Brookings, by Hume & Ulvin, in 1928. The piece of broken root here shown is 3.5 ft. in length—top eleven feet.

Eradication by Fallowing Pure and Simple—Plus Persistence (Brookings Experiment)—The principle and practice of eradication by summer-fallowing may be deduced from a successful experiment at Brookings. In 1929 Creeping-jenny was found to have invaded acre 550-559 east agronomy farm, Brookings. The crops growing on the acre in question were part of a soils experiment in direct charge of Professor J. G. Hutton. The plan of attack upon the weeds was arranged by him. A part of the plan was that some one individual should give first attention to performing the handwork necessary to the surface fallowing or removal of tops of Creeping-jenny plants (every morning if necessary), within the area. After that was accomplished it was the plan that the individual being responsible for it would proceed to other work—not before. The individual who accepted the foregoing responsibility for the Agronomy Department was Mr. Clarence Stockland. The almost metriculous attention in looking after the foregoing details may indicate the extent to which success or failure with fallowing as a method depends on their being carried out. One may read between the lines of the following table that occasional lapses, in scraping or otherwise removing the tops of Creeping-jenny plants by the fallowing method, will make the method seem to fail. **Fallowing is a sure method of eradication where properly and thoroughly carried out.**

Eradication of Creeping-Jenny by Fallowing—(Brookings)
Summary of dates and essential details, 1933-1935

Number and Date of Given Cultivation	
1st, 6-19-33; 2nd, 6-20-33; 3rd, 6-21-33; 4th, 6-22-33; 5th, 6-23-33; 6th, 6-24-33; 7th, 6-26-33; 8th, 6-27-33; 9th, 6-28-33; 10th, 6-29-33;	Beginning cultivation (Surface scraping with sharp blade) every day. Raked off all roots and stems to facilitate cultivation.
11th, 7-1-33; 12th, 7-3-33; 13th, 7-5-33; 14th, 7-7-33; 15th, 7-8-33; 16th, 7-10-33; 17th, 7-12-33; 18th, 7-14-33; 19th, 7-15-33; 20th, 7-17-33;	Beginning cultivation every other day.
21st, 7-19-33; 22nd, 7-22-33; 23rd, 7-26-33; 24th, 7-29-33; 25th, 8-1-33; 26th, 8-4-33; 27th, 8-7-33; 28th, 8-10-33; 29th, 8-12-33; 30th, 8-16-33; 31st, 8-19-33; 32nd, 8-21-33; 33rd, 8-24-33; 34th, 8-26-33; 35th, 8-29-33;	Beginning cultivation every third day. Heavy rain Aug. 2. Small shoots present Aug. 4. Rain Aug. 15. Small shoots hoed instead of cultivated. Leaves appear to form in loose surface soil.
36th, 9-1-33; 37th, 9-5-33; 38th, 9-8-33; 39th, 9-12-33; 40th, 9-15-33; 41st, 9-19-33;	Very heavy rain Sept. 1st—2.4 in. Begin cultivation every 4th day. Many small plants appearing. Plants vigorous.
42nd, 9-23-33; 43rd, 9-30-33; 44th, 10-5-33;	.56 in. rain Sept. 10. No plants above surface. .7 in. rain Sept. 17. No plants.__
	Cultivation gone one week. Few shoots appearing. Perhaps retarded by cold weather. Two very small plants growing.
10-12-33; 10-14-33;	Examined plots. No plants. Close of season.

Continuation of Creeping-jenny Eradication 1934.—(Brookings)
Summary of Dates and Essential Details.

Number and date of given Cultivation	
1st, 5-5-34	1.26 in. rain 4-30; 5-2-34. A few plants barely appearing. Much wild buckwheat, and Russian thistle.
2nd, 5-11-34	Black—two small shoots only.
3rd, 5-15-34	No plants. Many roots at 4-9 inches.
4th, 5-18-34	No plants.
5th, 5-22-34	No plants.
6th, 5-30-34	1 plant—little moisture. Heavy rains, week of June 3.
7th, 6-9-34	No plants. Very moist.
8th, 6-16-34	No plants.
9th, 6-23-34	No plants.
10th, 6-28-34	One small plant.
10-30-34	No plants.
11th, 7-7-34	No plants. Last cultivation with cultivator. Other weeds: fleshy pigweed, rough pigweed, etc. kept down between dates 7-7-34 and 10-30-34 by hoeing. No bindweed was found after 6-28-34.
1st, 6-4-35	Examined closely for young plants. None visible. All winter annuals cut from plot and raked off. **No bindweed present.** Experiment closed June 4, 1935. (C. Stockland).

Observations and Conclusions from Foregoing Experiment With Eradication by Fallowing—The most outstanding observation about the foregoing experiment is that the outcome was successful from the standpoint of actual eradication of Creeping-jenny (Convolvulus arvensis) by fallowing under the conditions at Brookings. The successive details put down in the foregoing tables, pages 16 and 17, might be generalized as follows:

1. Creeping-jenny was completely eradicated under conditions at Brookings by the method of fallowing with use of a sharp blade either attached to a wheel hoe or with the use of a sharpened (filed) ordinary hand garden hoe.

2. The total number of fallowings (surface scrapings) required to accomplish the foregoing was fifty-five (55), forty-four (44) first season, and eleven (11) second.

3. It proved necessary to extend the period of fallowing over more than one growing season—the pest plants having remained active up to the date 6/28 of the second season although they were in a weakened condition, even at the beginning of the second season.

4. The tenacity of this perennial weed pest is illustrated and measurably explained by the note put down by Stockland 8/16/33: "Leaves appear to form in loose surface soil." Apparently this pest plant can come as near living entirely underground as is possible for any flowering plant.

The same is indicated also by the notation of 5/15/34, second season: "Many roots at 4-9 inches." It is fairly obvious that some or all of such roots early in the second season, even after having tops removed as often as forty-four (44) times in the previous growing season, would grow again and re-establish the infestation.

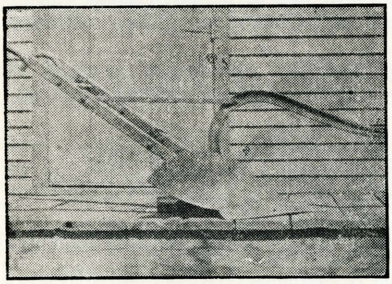
5. Examination at the beginning of the third season established the fact that the process of thorough fallowing had destroyed the pest plants within the second growing season.

Conclusion—The process of fallowing (surface scraping with a sharp blade) under the conditions of the growing season in 1933 and 1934 at Brookings was effective in eradicating all plants of Creeping-jenny (Convolvulus arvensis) previous to July 7 of the second season.

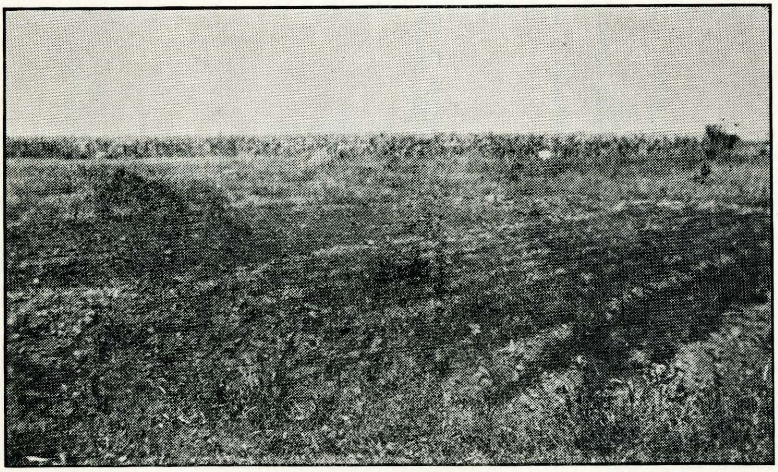
Fallow at Highmore Experiment Farm— An additional example of bindweed eradication is recorded in connection with soil and crop experiments at Highmore Experiment Farm where S. W. Sussex is foreman. Details of the eradication experiment were carried out by him in line with, and in addition to, the aforesaid experiments being pursued on the same land.

The summer of 1927 several small bindweed infested areas in rotations at the Highmore Experiment Station were plowed shallow, at frequent intervals for two or more seasons. Actual dates of plowing at these successive intervals cannot be put down in detail. The plan as outlined by one of the writers included the plowing of infested areas which were in all cases only a small number of rods across, with a walking two-horse plow once **every five days** at the beginning of the experiment. It was also recognized at the beginning that the time between cultivations might be extended.

Beginning with the latter part of the first season (1927) when the growth may have become slow, it was observed by Mr. Sussex that plowing at nine-day intervals was enough to hold the weeds in check. At the beginning of the second season (1928) plowing at five-day intervals was resumed for a time—likewise with extending the length of intervals later in the season to nine days.



An Ordinary Walking Plow
The implement utilized at Highmore Experiment Farm on a small area of bindweed infested land where eradication by fallowing was successful.



Field Bindweed Eradication

Fallowing method was a success at Highmore Experiment Farm. A portion of plot 1111 was plowed shallow every 5th to 9th day for 151 days throughout season 1927, by Mr. Sussex| Field Bindweeds were formerly here—now they are not. Photo of cleared land 8-31-28.

Conclusion from Fallowing Method—(Highmore)— The foregoing method of **eradicating bindweed at the Highmore** station **by the summer fallow method proved successful.** Summer fallow every five to nine days for two seasons completely eradicated bindweed under conditions at Highmore. It was observed that in the case of an old established patch, the fallowing would have to be continued part or all of the third season.

Part Season Fallow—(Brookings)— The degree of success with the fallow method of eradication at Highmore Experiment Farm, along with other observations, led to the belief that such a method might be successful when pursued in the latter part of the season after the time when staple crops are harvested.

The summer of 1930, several crop rotations infested with bindweed on Agronomy West Farm, Brookings, were utilized for after harvest fallow. This might be described as late summer fallow.

Such a method of late summer fallow had been absolutely successful at Brookings Agronomy East farm for the eradication of Quack Grass, in the rotation of: (1) Corn, (2) Oats, (3) Winter Wheat, and (4) Sweet clover. Quack Grass was eradicated in such a rotation with:

1. Plowing the land shallow immediately after removing the sweet clover hay in the fourth year of the rotation, then:

2. Every fifth day thereafter for the remainder of the season the land was summer fallowed, and "kept black," with utilizing a plow, or a spring-toothed harrow, or a cultivator—whatever implement seemed to keep the surface black most successfully. This fallow process was continued in the beginning of the next season until time for planting corn. The land was thus prepared for checking in the corn. Thereafter the corn was given very clean cultivation with some hand hoeing, if necessary, to destroy any lurking root stalks or seedlings of the Quack Grass.

After-Harvest—Late Summer Fallow Experiment
Single Season (1930) Bindweed-Infested Rotations—(Brookings)

Crop Rotation Infested:	Continuous Field-Peas	Corn Wheat Sweet Clover	Corn Oats Sweet Clover	Corn Barley Sweet Clover
Plot and Method:	**345—Spring toothed**	**344—Plowed 5 in.**	**644—Plowed 7 in.**	**343—Plowed 11 in.**
July 8		Bloom	Bloom	Bloom
July 15		Shoots started	Few shoots	Few shoots
July 19		Many dead rootstalks	Few shoots	Few shoots
July 24		Shoots started	Few shoots	Few shoots
August 1	Plowed 5 in. after peas harvested	Shoots started	Few shoots	Few shoots
August 6	3 in. vine growth	Shoots started	Few shoots	Shoots 5 or more in. in length, running beneath plowed surface, few leaves.
August 11	5 in. or more vine growth, plow 5 in.	Many shoots	Few shoots	Shoots started
August 16	2-3 in. vine growth	Few shoots	Few shoots	Shoots started
August 21	2-3 in. vine growth	Few shoots	Few shoots	Shoots started
August 27	5 in. or more vine growth, plowed 5 in.	Several shoots	Few shoots	Shoots started
September 2	2-3 in. vine growth	Few shoots	Few shoots	Shoots started
September 8	2-3 in. vine growth	Few shoots	Few shoots	Shoots started
September 13	5 in. or more vine growth, plowed 5 in.	Several shoots	Few shoots	Few shoots
September 19	5 in. or more vine growth, plowed 5 in.	No shoots	Few shoots	Few shoots
September 29	4 in. vine growth, plowed 5 in.	Some shoots	No shoots	Few shoots
October 9	Coming up	Few shoots	Few shoots	No shoots
October 29	2-3 in. vine growth	Few shoots	Few shoots	No shoots
November 13	No growth		Few shoots	No shoots
April 27	4/1 seeded in peas	Seeded in wheat 4/1	Seeded in oats 4/10	Few shoots
May 13	Very few plants	Many plants	Many plants	Many shoots Planted in corn 4/15.

Inasmuch as such a method of late summer-fallowing had been successful with Quack Grass eradication, it was thought that it, or some modification of it, might be successful with Creeping-jenny. Accordingly several modificatoins of the part-season, or late summer-fallow method, were tried with said pest. Enough is put down here as a matter of information to indicate that **this method with late summer fallow one single season was found insufficient for the eradication of Creeping-jenny.**

The crop rotations in which these trials were made on West Agronomy Farm, Brookings, were:

1. Continuous field peas (plot 345),
2. Corn, small grain, sweet clover, (1st crop for hay, 2nd crop plowed under), (plots 344, 644, 343).

The foregoing table may serve to summarize the procedure and the outcome of the method with after-harvest summer-fallow. It is deemed well worth including here as a basis for discussion even though it may not arrive within itself at a complete formula for eradication.

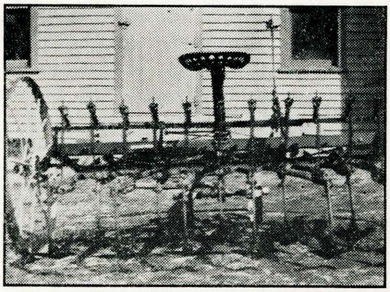
The four columns of the foregoing table, where the names of the crops are put down as headings, represent the four separate crop rotations, all of which became thoroughly, if not equally, infested with Creeping-jenny on one plot or small field of which eradication was attempted by after-harvest late summer-fallow for one season.

Attention is directed to the following sentences in regard to the procedures of the foregoing table:

1. The method of late-summer-after-harvest fallowing, as carried out in four separate one or three-year rotations at Brookings, West Agronomy Farm, was in no instance enough to provide for eradication. That is indicated in the lowest horizontal line of the table. **The outcome emphasizes the apparent fact that no practical method has been found to eradicate Creeping-jenny in a single season nor part thereof.**
2. It is to note that the course of after-harvest fallowing on plot No. 345 where the crop of peas preceded the fallowing, reduced the weeds to a point where few plants appeared in the following spring. Some explanation of this may be found in the apparent fact that the peas constituted a fairly effective smother crop in the early part of the season.

The Spring-Toothed Harrow was Serviceable—It may be noted also from the foregoing table that the implements used for fallow are the spring-toothed harrow and plow—in this instance, an ordinary two-horse mould-board plow.

The Spring-Toothed Harrow.
Where the spring-toothed harrow was used it had advantage in acting to pull up and break off root stalks of Creeping Jenny deeply. Page 20.



The Duck-Foot Cultivator
A good many plants of Creeping Jenny could slip between the teeth of the harrow. The duck-foot cultivator cuts them off clean below the surface.

Franzke observed that on plot No. 345 where the harrow was used, it had apparent advantage in acting to pull up, and break off, the roots and root-stalks of Creeping-jenny deeply, as contrasted with any cutting action near the surface. Nevertheless, the action in the spring-toothed harrow left something to be desired in the respect that a good many plants of Creeping-jenny could slip between the teeth of the harrow, and thus remain without being either cut off or pulled up. The longer they remained thus, the more tenacious they become in this respect. Thus the plow with its cutting lay, became a valuable and necessary adjunct to utilize four times during the season, especially to cut off the roots and root-stalks which might escape the harrow teeth.

Bindweeds Came Back After One Season Late Summer Fallowing—The ineffectiveness of the attempt to check Creeping-jenny infestations with only one season of after-harvest fallowing as described in the foregoing table, Page 20 and accompanying test, was observed in the season fallowing, by comparing the crops on said land with crops where Creeping-jenny weeds were not present.

In the season of 1931, subsequent to the late summer fallowing, the several crops indicated in the following table were put in on the seed bed thus prepared on the several plots. The results as measured in comparative crop yields are summarized:

Reduction in Yield of Crops Due to Bindweed Infestation of Land, Season (1931), Subsequent to Late Summer Fallowing, One Season—(Brookings).

Conditions and Procedure in 1931	Plot Number and Crop (1931) as recorded in Preceding table, Page 20:			
	345	344	644	343
	Peas	Wheat	Oats	Corn
Bindweed present. Fallowed as in previous table	1.5	9.5	17.8	9.1
Yield from uninfested land used for comparison	3.2	20.2	30.0	21.6
Per cent reduction due to bindweed	53.1	52.9	40.6	57.0

The foregoing table may visualize in the form of figures that which the appearance of the plots indicated in the field. The outstanding indications of the foregoing are the following:

1. The percentage reductions in yield of the several crops put down in the lowest horizontal line indicate within limits the **high survival of Creeping-jenny plants remaining after a single season of after-harvest fallowing under four different rotations.**

2. The reduction due to the presence of the weed was more than half in the case of all crops except oats.

3. It is not necessarily assumed by the writers that after-harvest fallowing is ineffective in itself as a method of Creeping-jenny control. Rather, it is emphasized that a single season is too short a time in which to accomplish valuable results. It is even possible that such an incomplete procedure of summer fallowing may multiply root cuttings and the consequent number of plants.

Mechanics of Fallowing—It is hardly enough to recognize that the fallowing process involves fundamental principles which may be used to check or destroy bindweed and other perennials. It is important in practice to conform to details.

One reason why the Fallow—Rye, or Rye—Fallow method of control, as announced herein is successful is that it employs fallowing at the right time and manner, as demonstrated by long and numerous trials.

The work of fallowing should be started immediately after rye harvest. The process may be started by plowing the stubble, which method has some advantage where there is little or no excess stubble, or other trash on the surface. Such excess material may need to be raked and hauled away before beginning the fallowing process, whether with or without plowing, for the reason that much vegetation mixed with the surface soil will evidently clog the duck foot cultivator, or whatever kind of surface cultivator is used for fallowing later. Even heavy rye stubble plowed under will often be effective in clogging the blades of the duckfoot or other cultivator, thus preventing clean work in cutting off bindweed plants at the surface.

It may be necessary and often desirable to burn over stubble land, before beginning the fallowing process. To do a thorough job of fallow with a duckfoot cultivator, the field should be as free as possible from trashy material.

The fallow cultivations should be made at comparatively frequent intervals during the remainder of the season to prevent excessive top growth, though in practice better results can be secured by not cultivating with a duckfoot field cultivator too often, allowing from two to three inches of top vine-growth on the higher percentage of bindweed. The bindweed plants are thus less apt to pass undisturbed between the shovels of the field cultivator, and it is easier to bring the bindweed plants upon the cultivated surface. Allowing some vine growth causes the latter to take root less frequently even though many plants are covered with soil. It also reduces the number of times the field will be cultivated, therefore reduces the control costs.

It is not necessary to cultivate deep; just deep enough to do a good job. It is important at all times to do a thorough job, not leaving any area undone. The best results in fallowing with a field cultivator are obtained by tilting the shovels downward. The degree of tilting the shovels will depend upon the soil type and texture. Tilting the shovels downward gives suction and setting the field cultivator at a shallow depth, tends to bring more bindweed rootstalks near the surface, exposing them to weathering elements.

If in the first part of the season, fallowing is well done, a very high percentage of the bindweed plants will be considerably weakened by the close of the season before seeding to a heavy rate of fall rye.

Covering with Mulch Paper Is Also a Process of Smothering—It is asserted in these pages that persistent fallowing proved effective in bindweed eradication. It will hardly be questioned that the underlying principle involved is that such a process deprives the plants of leaves and stems which are necessary in the life processes of the plant. A successful fallowing process cuts off these parts, or measurably covers them with earth.

It is possible to accomplish this by covering with an area of mulch paper—either common building paper, or a special kind of mulch paper which is more tenacious and less likely to tear into holes.

Successful Eradication of Bindweed With Mulch Paper Covering at Highmore Experiment Farm—The earliest experiment undertaken by this department with killing out bindweed infestation by covering its surface with mulch paper was accomplished at Highmore Experiment Farm at a time earlier than other projects of a similar nature recorded herein in greater detail. An outbreak of bindweed infestation occurred at the experiment farm as indicated in season 1922. S. W. Sussex, Foreman at Highmore, was requested to arrange for spreading a tar paper mulch over the infested area in such a way as to shut out the light and air from the weed plants, and thus smother them if possible.

The kind of mulch paper immediately available for this puropse was ordinary tar paper such as is utilized for buildings. Such paper covered the bindweed infestation fairly well when it was first laid down. This was the more the case in view of the relatively small area involved in this instance—approximately three rods by two rods.

After some weeks the effect of sun and wind caused this tar building-paper to become brittle and consequently to break and tear into holes in a number of places. In one instance it is recorded that a hail storm caused holes in the tar paper used as mulch. The number of breaks or holes was not actually recorded. Where they occurred, leaves and stems of bindweed soon protruded, thus finding light and air and becoming able to function for the entire plants, even though under-ground parts remained under the tar paper.

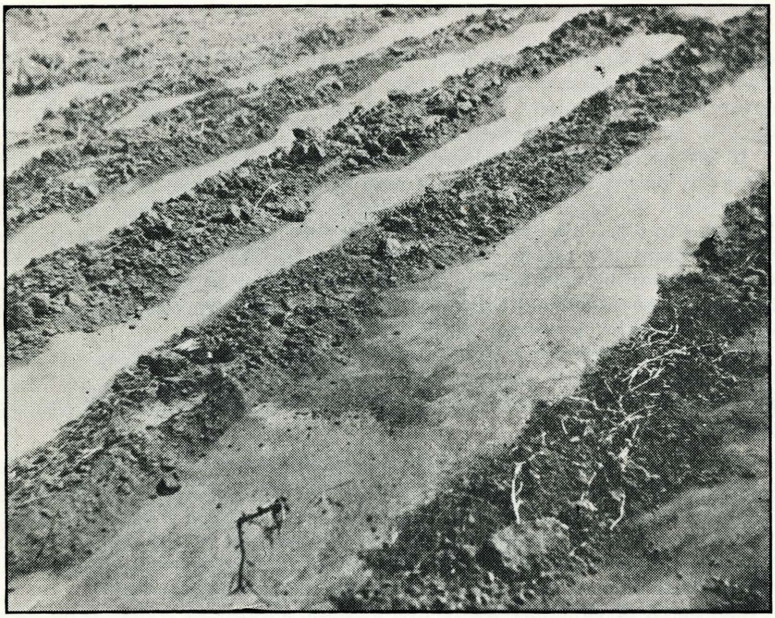
It was observed that bindweed plants cannot be smothered out in that manner. The expedient was adopted of laying an additional thickness of mulch paper (in this instance ordinary tar paper) directly over the first application which had become broken, in such way as to shut up the holes entirely and deprive the weed plants altogether of light and partially of air for the remainder of the season.

The tar paper mulch was allowed to remain throughout the first season, and into the second season. **It was found that the mulch paper, thus applied and held intact one entire season and part of the second, supplied a successful method of eradication.** The pest plants had apparently been entirely killed out by lack of air and light, which in turn made it impossible for the above-ground leaves and stems to function.

Eradication by Covering With Mulch Paper Successful at Cottonwood Experiment Farm—In season 1933 an area of bindweed (Convolvulus arvensis) appeared on acre 151-60 South Farm, Cottonwood Experiment Farm. This is in the extreme southwest corner of the section where the experiment farm is located (Sec. 16, Twp. 1 S, R. 19 E.) on upland soil. The cropping system on the land is and was, Rotation No. 6, namely: (1) corn, (2) small grain, (3) sweet clover, (4) sorghum, (5) small grain, (6) sweet clover.

Plants of bindweed appeared in the season of 1933, over an area about four (4) rods across its widest diameter. It was found practicable to cover it with a kind of black mulch paper manufactured for such purposes.

How to Lay Mulch Paper—The following precautions were noted about the manner of laying down mulch paper which may be applied generally. Care must be taken that underground parts do not grow out beyond the covered areas. This necessitates covering a larger area than may be infested. The strips of paper must also overlap sufficiently to prevent the plants from coming up between the strips. The bindweed plants should be allowed to grow before applying the covering of tar or mulch paper—allowing about five or more inches of vine growth. The area



The right way to kill Creeping Jenny with tar paper. Lay the paper flat and hold down the edges and cracks with soil. Highmore plot 1121. Photo by S. W. Sussex

The wrong way is to neglect a tar paper or straw mulch permitting Creeping Jenny to escape by growing through holes in paper or through insufficient straw. Highmore, plot 1121. Photo by S. W. Sussex.

to be covered should then be hoed off smooth. It may be necessary to level down with an ordinary garden rake. If the ground is leveled off smooth before laying the paper, it eliminates air pockets, and the paper is not likely to be blown off or torn by the wind.

If the surface is nearly level, it is possible and sometimes preferable to use old boards, fence rails, or stones, to hold the paper in place because soil utilized in weighting down the paper may retain moisture and cause the paper to rot. This method can only be used successfully on fairly level ground where the paper can be held close to the surface. In case the paper becomes dry and broken so that holes appear in it, it may be necessary to lay an additional thickness of mulch paper directly over the first covering in order to recover such areas.

A point to remember in this connection is the desirability of using mulch paper of good quality under conditions and within areas where the covering may be disturbed by small animals or where wind velocity is likely to be high.

More Than One Season of Mulching With Paper Was Necessary—The notation was made in the record of Acre 151-160 south farm Cottonwood that the Creeping-jenny growth which had been covered with mulch paper by Foreman Wesley Feurstenau at the direction of one of the writers in 1933 was "Apparently killed, as none came up this season (1934). The mulch paper was on the patch of Creeping-jenny about a year."

The patch of Creeping-jenny was examined again at a date later than that of the foregoing record and a small number of plants remained alive and growing. These few remaining plants were "mopped up" by Mr. Porter who gave personal attention to cutting off the tops of any remaining plants with a sharp-bladed hoe on alternate days in the early spring of 1934—thus making the process of eradication complete.

Conclusion from Mulch Paper Eradication Experiment at Cottonwood—1. The foregoing successful experiment at Cottonwood Experiment Farm with creating a mulch over a comparatively small area infested with bindweed (Convolvulus arvensis) demonstrated once more that if and when said pest plants are so covered that leaves and stems absolutely fail to function for a sufficient time (evidently more than one season) the plants will die.

2. Practically, under the conditions of this experiment, the method of applying mulch paper **over a small area** of bindweed for a period longer than one year with subsequent "mopping up" of remaining plants was found feasible.

Paper Mulch Measurably Effective at Eureka Experiment Farm—An infestation of Creeping-jenny (Convolvulus arvensis) was discovered the summer of 1932 at Eureka Experiment Farm by W. Schonbrod, foreman. It occurred on two plots, numbered 229 and 230, of the farm. The division strip dividing the two plots was found to run approximately through the center of the area infested so that it divided said area into nearly equal parts; thus about equal areas of infestation existed on the two small fields. The total diameter of the infested area was approximately two rods.

The attempt to smother out the pest from the infested area was begun July 8, 1932. At the beginning, neither a special brand of mulch paper, nor even a sufficient amount of ordinary tar paper was available. Accordingly, some pieces of miscellaneous materials which remained on the experiment farm were utilized. These remnant materials consisted of worn out grain sacks, blankets, binder canvas, an old linoleum, and some tar paper.

At the beginning, care was taken by Mr. Schonbrod to outline the boundaries of the infested area, in order to avoid the escape of any plants that might possibly grow beyond the edges of the main infestation. The border of infestation thus outlined was scraped off with a sharp hoe, and kept thus cleared off throughout the period of this experiment. No bindweed plants escaped to start new infestations.

Before applying any of the materials which were to be used as mulch or covering, the above-ground parts of the weeds were mowed off with a scythe, and all refuse raked from the surface was dried and burned. This was done in order to insure, if possible, that the paper or other material spread down for mulch might adhere closely to the ground surface, without being torn or broken. Likewise, the cloth materials were moistened before laying so they might adhere to the ground the better. The several materials were then laid flat on the ground over the infested area, each kind of material in its place to extend as far as might be, also so that the entire area was covered with one material or another. Care was taken, whatever the material, to have its edges overlap so the bindweed plants might not easily grow between the pieces.

After the several materials were thus laid down, the area was covered with a layer of rotten straw to a thickness of 18 to 20 inches. The mulch covering thus put down extended beyond the edges of actual infestation at all portions of its border.

Bindweeds Penetrated Any Pervious Mulch, at Eureka—After four or five weeks, the bindweed plants began to grow through the covering on all parts of the area except where the old linoleum covered them, even being able to penetrate said material in some spots—presumably where it was torn. The somewhat accidental use of these several materials for mulch coverings, after all, made opportunity to observe that one of the requisite characteristics necessary for any material to be used for mulch is that of a degree of tenacity approaching air tightness. Porous materials such as cloth will apparently prove ineffective, even though light is excluded, and evidently a straw covering, even one of considerable thickness, would be ineffective as a mulch. Presumably the piece of linoleum utilized in this trial served fairly well to the extent that it was impervious.

At the close of the five-week period it was evident that the covering, far from serving an effective mulch for smothering was virtually providing a favorable condition for growth of the bindweed. Accordingly, an attempt was made to burn off the mulch by setting fire to the straw. It failed to ignite, and it proved necessary to rake off the mulch, straw and all. After this removal, it was possible to note that the bindweed plants in certain portions had been considerably reduced in size and number by the previous covering.

Chlorates on Surviving Bindweed,—Less Effective, Account Reduction of Above Ground Stems and Leaves—The foregoing account has not stated the additional fact that commercial chlorates were applied to the surviving plants each season, 1933, 1934, and 1935, at the times when the removal of mulch from the area made such application possible. This application of chlorates seemed to have little effect in driving out the small number of remaining plants.

The plants had already been reduced in total number and size by mulching, and the top growth of stems and leaves may have been less vigorous due to drought, as well as to previous mulching. Thus the chlorate solution may have fallen largely on the ground, rather than on the leaves and stems of bindweed. In the present season, 1936, approximately twelve bindweed plants have appeared on the area, indicating that the method of eradication by smothering was practically effective.

It also emphasizes the persistence of infestation consisting in this case of one dozen bindweed plants, that have so far lived through attempts to smother them out with one kind or another of artificial mulch under the conditions at Eureka Experiment Farm, with seasonal applications of commercial chlorates in addition.

Deductions—(1). It seems reasonable to conclude that the application of an artificial mulch as a method of bindweed eradication under the conditions at Eureka in 1933, 1934, and 1935, constitute a method practically effective.

(2). Bindweeds may grow upward through materials that are pervious to air and light, even with a thickness of straw on top.

(3). Consequently, application of an artificial mulch, whether paper or whatever else, evidently depends very much for success upon the degree with which such material resists strain and weather, remaining impervious to air and light.

(4). The experiment emphasizes again the tenacious character of field bindweed. It will be necessary to complete the process of eradication, apparently by scraping off every remaining plant from the area daily, or as often as any appear for one remaining season.

Bindweed Eradication with Chemicals Successful in Specialized Areas—Numerous studies and observations by this department with the treatment of bindweeds with various chemicals on infested areas over a period of years continuing since 1926 have brought out some facts and fairly well established conclusions.

In order to make practical deductions which readers may find it desirable to use in actual eradication measures, the following statements are put down immediately here with the details upon which they are based following:

(1). After having used different chemical substances in attempted bindweed eradication, it appears that chlorates, whether sodium chlorate, calcium chlorate, or mixtures of chlorates sold commercially are most effective practically.

(2). Among the limitations of chemicals for bindweed eradication are original cost of materials, and cost and difficulty of application. In the case of sodium chlorate, inflammability is also a limitation.

(3). Accordingly, the use of chemicals for bindweed eradication is considered applicable to areas, not easily accessible to any kind of team or mechanical power-farming.

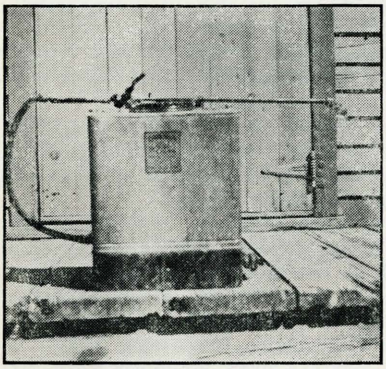
Chemicals Applied, Details—The summer of 1926, the north half of plot 144 on the Agronomy west farm at Brookings which was badly infested with field bindweed, was laid off in two series of 22 plots each, making 44 plots in all. Each series of plots was so laid off, running east and west, length-wise of plot 144, to include the entire infested area. Each plot was two yards square—four square yards or 1/1210 of an acre. Each was separated from its adjacent plots by a one foot alley. The spray materials were applied with an ordinary knapsack sprayer, utilizing a small sized nozzle. This particular experiment with chemicals and their application was arranged and the chemicals applied by the late Alfred Bushey, then Agronomy Analyst.

The following table indicates exactly in one specific instance that bindweeds treated with chemicals as a means of eradication were "all killed."

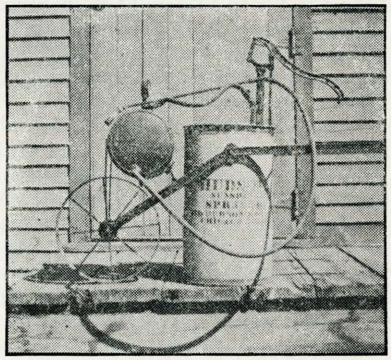
Said instance was namely:

(1). Infestations of bindweed sprayed three times in the season 1926 with a 10 per cent solution of Potassium Chlorate were **all killed.**

(2). Infestations of bindweed sprayed three times with solutions of sodium arsenite of 5 per cent strength or higher (5, 7, 10 per cent) were **practically** all killed.



A "Knapsack" Sprayer
Arranged with straps so it may be carried over the shoulders—not very comfortable to handle but serviceable for small areas and corners not easily accessible for large pressure sprayers.



A Small Pump Pressure Sprayer
Rigged on a wheelbarrow—more comfortable to handle than a "Knapsack"—nearly as easy to transport to small areas and corners.

Chemicals Applied in Solutions of Increasing Strength (1, 3, 5, 7, 10%) On Several Bindweed Infested Areas.—(Brookings, 1926)

Chemical Applied	Gal. or Lbs. Per Acre	Successive Dates Of Application	Effect Noted on Bindweed
Aluminum chloride	50	May 29, June 12, June 30, Aug. 5, August 23, September 22.	Most all bindweed plants having a chloratic appearance: 5, 7, 10% solution—slight kill.
Sodium dichromate	50		1, 3, 5% solution—slight kill. 7, 10% solution—fair kill.
Potassium permanganate	50		Most all bindweed plants have a chloratic appearance. No kill.
Ethyl gasoline	25 50 75		Rapid evaporation, instant injury of foilage. Top growth killed only temporarily. No kill.
Calcium chlorate	50	June 30, Aug. 5, September 22.	1, 3, 5% solutions—slight kill. 7, 10% solutions—fair kill.
Potassium chlorate	50		1, 3, 5% solution—slight kill; 7% solution—practically all killed; 10% solution—all killed.
Sodium arsenite	50		1 and 3% solution—slight kill; 5, 7, 10% solution—practically all killed.
Used cylinder oil	50 100 200 300 500		Higher the rate of application, shorter and sturdier vine growth, and deeper green the leaf color.
Cyanamid	200 400 600 800 1000		Some bindweed plants have a chloratic appearance. 800 and 1000 lbs. application—slight kill.

Without attempting here to comment on all facts in the foregoing table, it may be noted that substances effective in killing bindweeds chemically were chlorates or arsenites. Such statement, based upon this early experimental work substantiates the somewhat **general practice of utilizing chlorates (Sodium or calcium chlorate) in weed control or eradication.**

It seems likely that chemicals which not merely inhibit the growth of tops but which also kill the underground parts, i.e. roots and root stalks, of perennial weeds are measurably effective in eradication. Chemicals which by their nature or method of application merely kill the tops of perennial weeds leave opportunity for new top growth, with only a temporary set-back to the weeds.

One limitation which causes weed control by chemicals to confine itself to small areas is the fact that when such substances are applied in sufficient quantities to be effective in actual eradication of weeds, they may also do harm to subsequent crops by injuring the soil.

Arsenites in particular are known to be so poisonous to livestock and human beings that the safest thing is to avoid them entirely for the purpose indicated. Sodium chlorate is such an active oxydizing agent that it may cause dangerous fires even during or immediately after application to weeds, grass, or incidentally, to shoes or clothing of workers.

Additional Eradication Trials with Chemicals—Brookings, 1933—An additional series of plots thoroughly infested with bindweed were arranged and utilized on plots 343 and 643 West Farm, Brookings, in 1933. Plots were arranged by C. J. Franzke, and chemicals for application by Leo F. Puhr.

Area 343 was laid off in plots numbering twenty-one in duplicate series, running east and west, 42 plots in all; area 643 likewise laid off in series numbering sixteen east and west, 32 plots in all. Thus a total of 74 plots thoroughly infested with bindweed were included in the trial of chemical substances for bindweed eradication.

The stand of the infestation was counted at the beginning before the application of chemical sprays was started. Thus it was possible to use the number counted as the basis for computing the percentage of plants eradicated by treatment.

The size of each plat was one by two meters or a plat area of 1/2033 of an acre. Each plat was separated from its adjacent plats by a one-foot alley. The spray materials were applied with a high pressure, five gallon knapsack sprayer equipped with a number 2 Chipman disc nozzle. (Illustration, page 29.) One hundred gallons of the spray solution were applied per acre, respectively, for each spraying.

The land occupied by plots 343 and 643 in this experiment in the course of crop rotation had been seeded in the spring of 1932 previous to the chemical treatments here recorded, in small grain and sweet clover therewith. Sweet clover was permitted to come on subsequent to the time of harvesting the small grain. The sweet clover served as a support for the bindweed plants in the latter part of the season.

It was observed that the bindweed plants thus held up from the ground could be more thoroughly moistened by any of the several solutions used for spraying than plants that were allowed to run on the ground.

Applications of spray material as listed in the following table were thus applied to the plants with a minimum amount of spray material falling on the soil, and also with the minimum effect of such spray material upon the soil itself. This entire program of applying chemicals was carried out in the summer of 1933 following small grain harvest and previous to the plowing of the land for winter rye.

Effects of Solutions Applied in Several Strengths to Bindweed—Single Season (1933). Agronomy West Farm.—(Brookings).

Chemical	Strength Of Sol.	Effects on Bindweed Plants 12 Days After Spraying	Effects on Remaining Bindweed Plants Sept. 9th	Average % Kill Taken Sept. 9th
Sodium Thi-Sulfuric acid	1%	⅓ leaves brown	none	none
Sodium Thi-Sulfuric acid	5%	½ leaves brown	none	none
Sodium Thi-Sulfuric acid	10%	⅔ leaves brown	none	slight
Sodium Thi-Sulfuric acid	15%	¾ leaves brown	none	slight
Sulfurous acid	1%	few leaves dried, many spotted	none	slight
Sulfurous acid	5%	¼ leaves brown	none	slight
Sulfurous acid	10%	¼ leaves brown	none	2.5
Sulfurous acid	15%	½ leaves brown	none	6.0
Sodium Hypo-chlorite	1%	¼ leaves brown	none	2.0
Sodium Hypo-chlorite	5%	⅓ leaves brown	none	2.5
Sodium Hypo-chlorite	10%	½ leaves brown	none	6.0
Sodium Hypo-chlorite	15%	½ leaves brown	none	12.0
Calcium Hypo-chlorite	1%	⅓ leaves brown	slight stunting	2.0
Calcium Hypo-chlorite	5%	½ leaves brown	slight stunting	3.0
Calcium Hypo-chlorite	10%	⅔ leaves brown	plants stunted	6.0
Calcium Hypo-chlorite	15%	¾ leaves brown	plants stunted	11.5
Formaldehyde	5%	½ leaves brown	few vines partially dead	3.0
Formaldehyde	10%	¾ leaves brown	many vines partially dead	10.0
Formaldehyde	15%	¾ leaves brown	many vines partially dead	16.0
Formaldehyde	20%	all leaves brown	many vines partially dead	31.0
Formaldehyde	40%	all leaves brown	plants stunted	41.0
Copper sulphate	5%	½ leaves brown	few vines partially dead	10.0
Copper sulphate	10%	½ leaves brown	few vines partially dead	17.0
Copper sulphate	15%	⅔ leaves brown	many vines partially dead	23.0
Copper sulphate	20%	¾ leaves brown	many vines partially dead	27.0
Slaked lime	2 T. @ A.	⅓ tops dried	yellowish	6.0
Slaked lime	4 T. @ A.	½ tops dried	yellowish	8.0
Slaked lime	8 T. @ A.	⅔ tops dried	yellow	27.0
Lime stone	2 T. @ A.	⅓ tops dried	slightly yellow	slight
Lime stone	4 T. @ A.	⅓ tops dried	yellowish	4.0
Lime stone	8 T. @ A.	⅓ tops dried	yellow	19.0
Commercial chlorates	½ lb. @ gal.	many leaves brown	slightly yellow	6.0
Commercial chlorates	1 lb. @ gal.	all leaves brown	yellowish	8.5
Commercial chlorates	1½ lb. @ gal.	all leaves brown	very yellow	23.5
Commercial chlorates	2 lb. @ gal.	all leaves brown	very yellow	38.0
5% copper sulphate & 5% formaldehyde	10%	⅓ leaves brown	few vines partially dead	none
10% copper sulphate & 10% formaldehyde	20%	½ leaves brown	few vines partially dead	3.0

The foregoing table gives a summary of the kind of spraying material used with strength of solution, and likewise, brief notations of apparent effects with also the percentage of plants killed, based, as indicated, upon the number of plants observed previous to spraying.

Number of Applications—In making observation for the foregoing table the chemical sprays were applied twice during the season (1933) in all instances except where slaked lime and lime stone were used in the experiment. In the latter cases, only one application was made.

The date of making first application in all cases was June 15 (1933) on which date the bindweeds were at the full-bloom stage.

The second date of spraying in all cases where such applications were made was July 25, (1933), at which time the bindweed plants in general had measurably recovered from effects of the first application, and had made considerable secondary growth. It had been the original plan to make three applications of chemical sprays during the season, on all plots except those where limestone and quick-lime were applied. The third application, however, was omitted due to seasonal conditions.

Observations from Foregoing Table—The foregoing table summarizes a list of substances or mixtures. The names are found in the first column of the table (page 31). It is easy to observe from the second column that the solutions were applied in successive strengths extending from weaker to stronger—usually four separate strengths of solution. The third and fourth columns are notations put down directly from field notes made by Franzke, indicating the state of the bindweed plants, **first** soon (12 days) after spray was applied, the **second**, at the close of the season, when more permanent effects on the bindweeds might be apparent.

In the last or fifth column of the foregoing table, where the apparent effects of chemical treatment were put down in percentage of plants apparently killed at the close of the season (September 9), it appears fairly clear that all the chemical substances or mixtures chosen for trials in this particular experiment were most effective where they were applied in the most concentrated solutions.

It occurs that the highest percentages of "kill" stand opposite the applications for substances in the following order:

Formaldehyde	41 per cent
Commercial chlorates	38 per cent
Formaldehyde	31 per cent
Copper sulphate	27 per cent
Slaked lime	27 per cent
Copper sulphate	23 per cent
Limestone	19 per cent

Chemical treatments in none of these instances killed even as many as fifty per cent of bindweed plants treated in a single season.

The time required for killing Creeping-jenny by means of chemicals would be more than one season; would therefore correspond to the time required for eradication by other means, at least two growing seasons or parts thereof—sometimes longer.

Influence of Seasonal Conditions on Chemical Sprays—It was noticed when spraying bindweed plants under the extreme droughty conditions of 1933, that even though a fine spray mist covered the entire leaf surface, it soon collected in large drops. Many of these drops then ran down the vine or fell to lower levels. Other drops soon disappeared through evaporation. Thus, apparently, it was only a short time after applying the spray on bindweeds under the conditions of extreme drought that their entire vine and leaf surface was again dry. Their surfaces were then covered with the precipitate of dry chemical salts. Much of this dry chemical salt would later fall on the soil surface, where it could do no immediate good and might even do harm. There was apparently not ample time for the spray solution to take effect upon the plants, under conditions of low humidity, before its evaporation.

Franzke observed that during extreme drought, the bindweed leaves appeared to be thicker and became more leathery in texture than ordinarily, and the leaves also had more of a waxy covering. Sprays applied when the bindweed leaves exhibited these characters regardless of the fineness of the spray mist applied on the leaf surface gathered in large drops running down the vine or dropping off the plants entirely. The kill of the above ground growth under these circumstances was in most cases not satisfactory, for there was regeneration from above ground parts as well as from the parts below the ground. Therefore, spraying should not be proceeded with under droughty conditions.

The foregoing observations are believed to accord with the idea that weed eradication with the use of chemicals is a method adapted for use on limited areas, and especially in corners and out of the way places where cultivation and other means of control are impracticable.

Late Fall Spraying with Commercial Chlorates—The fall of 1932 two 40 inch bindweed infested alleys between plots 640-641, and 441-442 on the Agronomy West Farm at Brookings, were sprayed with Commercial chlorates, 2 pounds per gallon of spray solution at the rate of 75 gallons per acre. The solution was applied with a high pressure 5 gallon knapsack sprayer equipped with a number two Chipman disc nozzle. (Illustration page 29).

The spray was applied the morning of October 21, 1932, following a heavy white frost. The minimum temperature was 23 degrees F. There had been several light freezes earlier. The earlier light freezes and the one on Oct. 21 killed all annual weeds, leaving the bindweed unharmed. With all foreign vegetative growth thus eliminated with the exception of the bindweed, the spray material applied would be absorbed the more readily by the bindweed.

In the summers of 1933, 1934, and 1935, no bindweeds were observed in the alleys which had been thus sprayed, excepting that in 1935 many bindweed plants were spreading beyond the borders beyond the infested and sprayed plots.

The 1932 late fall spraying thus proved so successful that in the late fall of 1933 nine 1/10 acre bindweed infested plots on the Agronomy West Farm were treated the morning of Oct. 12 with commercial chlorate. The minimum temperature was 21 degrees F. All vegetation was covered with a heavy white frost. The bindweed was not injured from the freeze. Oct. 17 all bindweed leaves and vines were black. They took on the appearance of tender vegetative growth recently frozen. On Dec. 16, several rootstalks were dug and examined for spray reaction. The rootstalks in the upper four inches of the soil were a slimy blackish mass, gradually taking on a brownish cast below for two or more inches.

On Feb. 12 several more rootstalks were dug to study the reaction and chlorate movement. The upper six inches were more or less withered and brown. The next six to eight inches were a soft slimy black mass gradually taking on a brownish cast below. April 4 several observations of rootstalks were made. The upper 14 to 18 inches of the rootstalks examined were withered and brown. About 2 to 4 inches below the new growth buds had developed. These buds showed sign of spring development.

The spring of 1934 one third area of each of the nine 1/10 acre sprayed plots was planted in spring crops, wheat, oats, corn, soybeans, sorghum, sudan grass, foxtail millet, proso millet, and spring seeded winter rye. The object in seeding the plots to spring seeded crops was to study the residual effect of the commercial chlorate spray.

The bindweed produced a normal, luxuriant growth, choking out all crops except rye, sudan grass, and other sorghum. It was practically impossible to make a comparative study of the residual effect on the crops planted; bindweed having taken possession of most all crops.

Insofar as it was possible to determine, there was no kill from the 1933 late fall spraying of commercial chlorates.

Commercial Chlorate Dust Treatment Before Fall Plowing—Bindweeds Eradicated—Effect on Succeeding Crops Delayed—One form of commercial chlorates for use on above ground parts of bindweeds is fine dust or powder. Such material applied to leaves or stems with a blower adheres readily. Theoretically, it comes into contact with enough moisture in the plants themselves or in the atmosphere to make it penetrate and become effective.

An experiment was made with applying commercial chlorates thus in the form of fine dust at a time just before fall plowing. In this instance, on the date Sept. 19, details are put down as follows because it is believed they may have been important factors not only in eradication, but in the effect on the succeeding crops.

An area infested with bindweed was found to extend over a considerable part of two plots or small fields numbered 477 and 478 West Farm, Brookings. The regular cropping system or rotation on this land consisted of (1) sorghum, (2) oats, (3) beans—alfalfa. In the fall of 1930 several small patches of bindweed on these areas were dusted by hand with dry commercial chlorates, about four hundred pounds per acre. The day was rather raw and misty.

Plots were fall plowed at a depth of seven inches within a few hours after the infested areas were dusted. There was ample soil moisture to do a good job of fall plowing. **The immediate result of this dust treatment with chlorates under the conditions given was completely successful in respect to driving out the bindweeds.**

The latter have not reappeared on the ground in the subsequent six years.

An additional outcome of this treatment relates to the possible effect of the treatment upon crops produced in later successive years upon the same land. In the spring of 1931 the land, including the treated area, was planted in cultivated rows of soybeans. They made normal growth, and indicated no residual effect of the previous treatment so far as could be observed.

The spring of 1932, June 1, the land was planted with sorghum in cultivated rows. This sorghum likewise made apparently normal growth on the dusted areas as compared with the untreated land contiguous.

In the spring of 1933, April 5, the land was seeded to oats and this crop likewise apparently produced normal growth on both treated and untreated areas so far as could be observed.

Furthermore, May 19, 1934, the land was planted to navy beans in cultivated rows. Observation indicated that the growth of this crop was similar on both treated and untreated areas.

Again in 1935 in the regular rotation of crops, sorghum was planted in rows for cultivation over the entire area treated and untreated with the result that growth was similar throughout.

Apparent Effect of Treatment Appeared in 1936—It was not until the present season, the sixth after the dust treatment was applied, that after-effects on the oats crop of this year in the regular rotation seemed apparent. It was observed by Franzke that the growth of oats on the areas where bindweed infestation was treated in the fall of 1930, was less vigorous and otherwise impaired in manner of growth. **The assumption is that the dust treatment which destroyed bindweeds as described in the fall of 1930, and which has not been apparent since, until the present year, has appeared in this season, which is the sixth season after treatment.**

In order to arrive at an expression of these effects, an area was harvested from the oats crop from each of the treated and untreated plots, three square yards in each instance. Computation revealed the following:

Yields of Oats in 1936
Bushels per Acre from Land:

With dust treatment on bindweed, before plowing in 1930.	With no bindweed, and no treatment.
8.0 bushels per acre.	35.4 bushels per acre.

Deduction from Foregoing Experiment with Dust Treatment Before Plowing—(1). One application of commercial chlorates as dry dust, directly to bindweeds immediately before fall plowing at the rate of 400 pounds per acre, eradicated them under the conditions outlined.

(2). Although no deleterious effect of said treatment seemed apparent on several crops in five successive seasons, injurious effect of said treatment has appeared on the oats crop in the rotation of the present year—six seasons after. Attempt is not made here to define the cause.

(3). These deductions are in general agreement with others concerning the use of chemicals for bindweed eradication, whether dry or in solution, from the standpoint of weed control, and also the effect upon succeeding crops.

Residual Effects of Spraying with Chlorates Upon A Succeeding Crop—It has been generally conceded that chlorates of some kind have been best adapted from all standpoints, among the various chemicals tried for weed control or eradication. The same may be true of sodium or calcium chlorate, or of a commercial compound made up largely of either or both.

In the summer of 1930, the north half of acre 260 infested with bindweed on the Agronomy West Farm was given three sprayings with sodium chlorate. The solution was prepared by dissolving two pounds of the salt to each gallon of water. The material was applied with a high pressure potato sprayer utilizing 180 to 190 pounds pressure as indicated by the pressure gauge. Seventy-five gallons per acre of the solution were applied at each respective spraying. The first spraying was made September 22, and the other two were made at the stages when the bindweed plants recovered sufficiently to produce ample new growths. The last spray was applied after the first severe killing freeze in the fall.

Residual Effect of Spray on Corn—In 1931, acre 260 was regularly planted in a corn variety test (29 varieties). The order of planting the corn varieties was so arranged that one section of any given variety would be planted on the sprayed area, and a similar section on the unsprayed area. The corn was all given ordinary seed bed preparation and cultivation. Several straggling bindweed plants were found growing on the treated area. These plants were dusted with commercial chlorates late in the fall after the variety corn was well along in the glazed stage.

The following table summarizes yields of corn in 1931 from the various varieties on land (1) treated, and (2) untreated for comparison.

Comparative Yields of Corn (Bu. Per Acre)
(1) From Bindweed Infested Land Where Sodium Chlorate (Commercial Chlorates later) Were Applied, (2) Uninfested and Untreated Land.

Variety of Corn	Yield Per Acre Untreated	Yield Per Acre Treated
Early Northwestern Dent	11.5	8.0
Northwestern Dent	9.7	4.0
Early Minnesota No. 13	14.7	2.0
Squaw (Flint)	30.4	4.0
White Cap (Minn. No. 23)	13.0	3.0
Longfellow Flint	7.2	0.5
Minnesota No. 13	10.5	2.0
All Dakota	10.2	1.0
Alta	12.1	2.5
Brookings No. 86	8.3	1.6
EXI	12.4	1.8
EXK	9.8	3.0
Wisconsin No. 8	9.2	3.1
Golden Glow (Wis. No. 12)	11.5	7.0
Fulton Yellow Dent	14.0	4.0
Golden Jewel	20.2	5.5
Wimples Yellow Dent	25.0	5.4
Wimples Hybrid	24.5	7.5
Hybrid No. 55	19.0	6.0
Hybrid No. 101	24.0	8.5
Rustlers White Dent	18.5	5.7
Average	15.03	4.1

The foregoing table of yields may serve as a present statement of facts:

(1). The yields of 21 separate varieties of corn where bindweeds had been chemically treated, and largely eradicated, were decidedly reduced, with no exception. It is not attempted here to arrive at fundamental causes for this reduction—whether due to the previous infestation of the bindweeds, or to the later effect of the chemical treatment itself.

(2). The average yield as put down in the lowest horizontal line of all varieties of corn on land not infested, and consequently not treated, was 15.0 bushels per acre; whereas it was 4.1 bushels per acre on treated land previously infested. There was a reduction of 72.7 per cent in yield of corn in the single year following the partial eradication of bindweed by chemical treatment.

Residual Effect on Wheat (following corn), Second Year After Application of Chlorates to Bindweed—The corn ground described in the foregoing section was seeded to Ceres Wheat in the spring of 1932. The separate areas (1) where chlorates had been applied to bindweeds, and (2) where no infestation occurred, consequently no spray applied, were harvested and threshed separately. The following table summarizes returns:

Comparative Yields and Weights of Wheat from Land Where Bindweeds Were Sprayed With Chlorates, and From Land Uninfested and Untreated (Second Year After Treating)

Land	Yield (Bu., Per Acre) of Ceres Wheat In 1932	Weight Per Bu. Wheat Harvested
Uninfested and untreated in 1930	26.4	58.5
Infested and sprayed with chlorates	13.8	51.0
Higher or unsprayed and uninfested land	12.6	7.5
Percentage reduction in yield on infested and sprayed land	47.7	12.8

Reduction in Wheat on Bindweed-Infested Land Second Year After Chemical Treatment (Deductions from Foregoing Table.)—The yield of wheat in 1932 which followed corn, on land infested with bindweeds and sprayed with sodium chlorate in 1930 (straggling plants "mopped up" with dust), was reduced 12.6 bushels (47.7 per cent per acre in 1932). Likewise, the quality of wheat produced on such land was lower, as indicated by the reduction of 7.5 pounds (12.8 per cent) in weight per bushel.

Observation of Crops (Oats, Sorghums, and Barley) on Land Infested with Bindweed and Chemically Treated, in Third, Fourth, and Fifth Years After Treatment—In 1933, acre 260 was drilled in oats. The summer of 1933 was dry. Oats drilled on the sprayed area was the first to show the effects of the drought. The entire acre of oats failed. After the oat crop failed, a number of scattered bindweed plants were found. These plants were dusted with commercial chlorates.

In 1934 acre 260 was planted in cultivated rows of variety sorghums. Before the cultivation of the sorghum, a number of scattered bindweed plants were noticed. These plants were dusted with commercial chlorates. The sorghum produced an apparently normal crop on the treated area, showing no evident effects after a period of five seasons from the sodium chlorate spray applied in the fall of 1930, plus dusting of remaining isolated plants in succeeding years.

In 1935 acre 260 was drilled in barley varieties. A fair barley crop was produced. Rust and drought reduced the quality of grain. Certain of the barley varieties showed slight after-effects on land previously infested and chemically treated. **Several observations were made; no bindweed plants were observed in 1935.**

However, acre 260 in 1936 is planted with varieties of sorghum in drilled cultivated rows. The land had been fall plowed in preparation for this sorghum, and the latter crop planted and cultivated as usual. The sorghum was planted June 1, and on June 6 bindweeds were observed coming up on the land. Said plants were not seedlings or new plants, but were evidently old established plants that had not been killed by previous chemical treatment. The plan will be to "mop up" these straggling plants in the seventh year by applying additional chlorates in dust form to the individual plants.

Smother Crops Have Some Similar Effects of Fallowing—In the previous pages enough has been stated about the effect of fallowing and the use of mulch paper as a covering to warrant the assumption that plants of field bindweed may be killed when the foregoing processes are carried out persistently for more than one season. The principle involved in thus killing bindweed plants seems to depend upon the fact of plant physiology that leaves and stems have to function in order that plants may live, even bindweeds being no exception.

Having demonstrated the foregoing principles fairly well in the course of present experiments, the writers considered that other methods might be found which would likewise have the effect of depriving bindweeds of leaves and stems, completely or partially, for an entire growing season or the most important part of the season.

It was believed possible that crop plants of one kind or another might be seeded thickly enough and in such manner that they could grow more rapidly than bindweed plants, and grow ahead of them in point of time, thus overtop them, and cut off air and light from their above ground parts—in **effect, smother** the weeds **by** thus interfering with the functioning of leaves and stems, the above-ground parts. The kind of crops which thus have a smothering effect are popularly **called smother crops.**

The effect of such crops may not all be included in the mere processes of smothering, or of inhibiting growth of above-ground parts, and it is therefore not attempted here to define the effect exactly.

Several Smother Crops were Tried—It is possible to state, after making the observations here recorded, that the most promising smother crops to employ under the conditions are: (1) Winter rye, (2) Sorghum, and (3) Sudan grass. In order to arrive at such conclusion, numerous smother crops were tried in various rotations. **These included: Tame Sunflower, Hemp, Oats, Spring Wheat, Barley, Field Peas, Soybeans, Navy Beans, Proso, Annual Sweet Clover, Sudan Grass, Sorghum, Foxtail Millet, Castor bean, and grasses including Brome, Chee, and Quack—**

Perennial Grasses for Possible Smother Crops—The question has been asked at various times whether some perennial grass of vigorous growing habit might not be employed to drive out field bindweed. The writers had considered the possibility that quack grass, with its well known persistence, might serve the purpose. More recently trials of "Chee-grass" (Calamagrostis epigeios) introduced by Dr. N. E. Hansen from Siberia, gave reason for considering that it might be effective.

The summer of 1931 plot 342 partially infested with bindweed was planted in chee grass and bindweed. In the spring of 1932 the west one half of plot 442 was planted to quack grass and bindweed, and the east one half of the plot planted to brome grass and bindweed. Rootstalks of the grasses were planted in rows 24 inches apart and the hills within the rows were planted likewise 24 inches apart, excepting for the chee grass. The chee grass was checked in 36 inch rows and the hills likewise were 36 inches within the row. The bindweed rootstalks were checked midway between each row of grass, alternating midway between the grass hills.

A very good stand was secured from the grasses, but a great deal of trouble was encountered in establishing the bindweed away from the infested areas established within the plot. The past four seasons have been unfavorable, moisture has been limited, and the spread and top growth of the grasses has been below normal. The four years the tests have been under observation, both the grasses and bindweed are holding their own. The continual normal production of the grass over a long period of years will be the ultimate determining factor of the experiment. It is hoped to get information regarding the longevity of bindweed in sod land.

At present writing, August 12, 1936, there is some indication that the Chee grass might prove itself "fit to survive," against field bindweed on the same land.

One Smother Crop was Hemp—A piece of land consisting of plot 422 West Farm, Brookings, by the spring of 1930 had become completely infested with Creeping-jenny.

The spring of 1930 this land at Brookings was seeded in close drill rows to bird seed hemp. July 17 the hemp was 23 inches tall, most of the bindweed plants were in bloom, some setting seeds and the vines above the hemp making a rather tangled mass. The hemp was harvested for seed Sept. 28. The plot was plowed 9 inches deep respectively Sept. 29, Oct. 10 and 29, and Nov. 18.

In the spring of 1931, April 27, the plot was double spring-toothed and reseeded in close drill rows with hemp. On July 9, the bindweed vines were taller than the hemp stalks. By Aug. 15, the bindweed had practically choked out the hemp. It was a very matted tangled mass. On Aug. 21 the hemp was called a failure.

A Retrial of Hemp for Smothering Bindweed at Brookings—In the spring of 1935 an additional trial was installed with hemp for smothering on Plot 448. By 1935 the land was thoroughly infested.

May 10, 1935 it was planted to common hemp. The rate of seeding the hemp was 5 pecks per acre. The hemp came up May 18, a very good stand. June 20 the height of the hemp was 13 inches, making a dense, rapid growth, and apparently ahead of the bindweed. By July 2 the height of the hemp was 28 inches. The bindweed was making a fine undergrowth beginning to climb the hemp stalks. On July 13 the height of the hemp was 42 inches; many of the lower leaves on the hemp plants were falling.

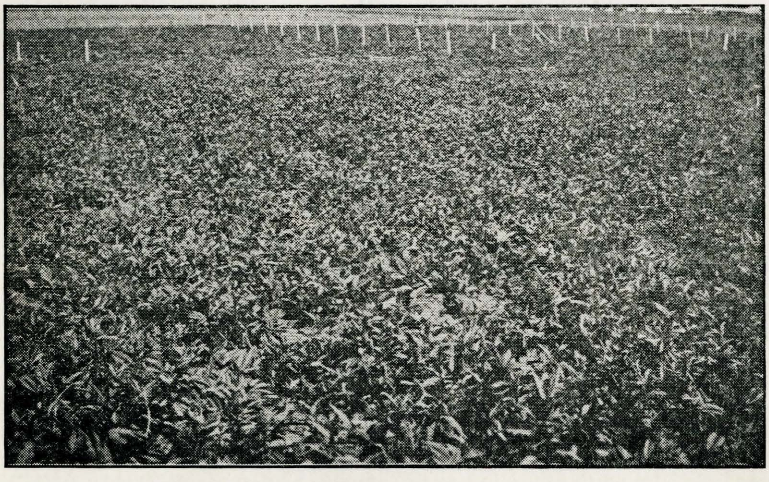
July 25, height of the hemp was 52 inches. Hemp showed signs of blossoming. Most all lower leaves had fallen, only a few upper leaves were left, and many of these leaves were about to fall.

August 23 the height of hemp on land where no bindweed was present was 52 inches, and where the bindweed was present, the hemp was weighted down to a height of 27 inches. The bindweed had climbed the entire height of the hemp stalks. Many bindweed plants were in blossom on this date, and some seed was setting.

In season 1936 the hemp was reseeded on the foregoing land on April 13. The hemp was emerging April 23. **The bindweed, however, had been observed coming up previous to that date, thus superceding the hemp in occupying the land in the early part of the season.** The weeds came into blossom as early as June 1, which is previous to the usual date of blossoming.

The growth of the hemp, on the contrary, was correspondingly small. It was slow in coming up. The plants were chloritic or yellowish in color. Consequently, the smothering effect of the hemp upon the growth of bindweed in this second season has been even less than in the first season.

Observation—At the date this is written, July 3, 1936, in the second season of attempting to control bindweed under the conditions here outlined, with the sole use of hemp as a smother crop, the method appears evidently insufficient.



Hemp—used experimentally as a smother crop. Plot 448 West Farm, a spring sown crop seeded April 13, 1936. The hemp is overtopped by bindweed, which blossomed as early as June 1.

All-season Smothering with Winter Rye and Sorghum in Succession was Attempted—The foregoing attempt to smother out bindweed with a single crop like hemp, along with other observations, led to the belief that such a single crop might die out too early in the fall or summer to keep the bindweed sufficiently shaded. The idea then suggested itself that a succession of thickly seeded sorghum and winter rye, or vice versa, winter rye and sorghum, would furnish a crop covering above the lower growing bindweed which would maintain itself throughout almost the entire summer, especially the latter part thereof, and consequently give the bindweed small chance to grow.

Two separate crop rotations have been conducted on corresponding plots or small fields of Agronomy West Farm, Brookings, for many years. The rotations are: (1) Corn, (2) Wheat, (3) Sweet clover, and (1) Wheat, (2) Oats, and (3) Sweet clover.

By the season of 1932 one of the fields in each of the foregoing rotations was thoroughly infested with bindweed uniformly over its entire area. The small fields or plots are designated respectively by the numbers 143 and 144. In order to make the present trials with all-season smothering with rye and sorghum, each of these plots was divided into three equal parts, and lettered a, b, c.

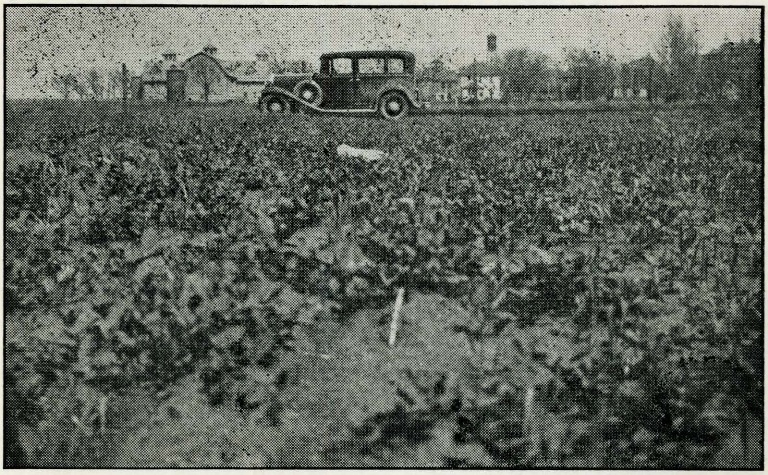
In 1932 when smothering experiments were started both plots 143 and 144 were occupied by sweet clover. The first crop of sweet clover was harvested for hay June 22. After the removal of the hay, both plots were plowed to a depth of five inches. This was on date June 24, when the bindweeds were in bloom. After being thus plowed, the land was all fallowed, with the use of a spring-toothed harrow. The number of these after-harvest fallowings was thirteen (13), consisting of four plowings, and nine harrowings with a spring-toothed harrow, over all divisions of the two areas, except that 143c and 144a, were fallowed five (5) additional times in the spring of 1933.

The outline of procedure with seeding two of the divisions in each of these areas with successions of rye and sorghums for smother crops (leaving 143b, and 144b, respectively, for checks) and the outline of results in terms of bindweed stands taken before and after treating are summarized in the following table. It may be well to state in advance that results in all instances are negative so far as eradication is concerned. **Putting down these negative results is deemed worth while to demonstrate the apparent fact that the use of smother crops alone, under the conditions was ineffective as a method of control or eradication.**

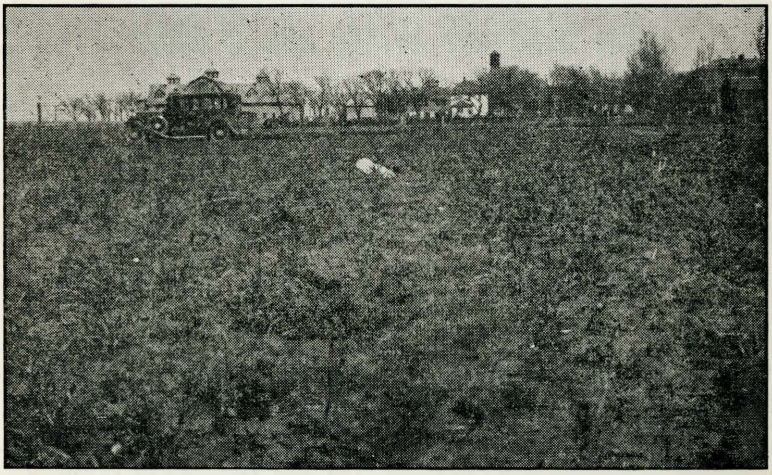
Certain things of importance appear from the following table that seem fairly clear after following the course of the experiment.

Measure of Bindweed Control, With Combinations of Winter Rye and Sorghum. Introduced into Two Separate Rotations—Brookings 1932-1935.

Plot & Division	1932 After Sweet Clover	1933 Regular Crops, In Rotation or Succession For Smothering	1934 Regular Crops, In Rotation or Succession For Smothering	Bindweed % Stand 7-3-1934	1935 Regular Crops, In Rotation or Succession For Smothering	Bindweed % Stand 7-14-35 Before Fallowed	Bindweed Increase in % Stand, 1934-1935
143a	Fallow & Rye 9-22	Rye Harvest 7-3 Sorghum 7-7 Rye 9-21	Rye Harvest 7-2 Sorghum 7-6 Rye 9-23	26.2	Rye harvest 7-12 Fallow Rye 9-21	56.9	30.7
143b(ck)	Fallow	Corn 5-17	Barley plus Sweet clover 4-20	100.0	Sweet clover Rye harvest 7-12	100.0	3.8
143c	Fallow	Fallow Sorghum 6-10 Rye 9-19	Rye harvest 7-2 Sorghum 7-6 Rye 9-23	66.1	Fallow Rye 9-12 Rye harvest 7-12	97.3	31.2
144a	Fallow	Fallow Sorghum 6-10 Rye 9-19	Rye Harvest 7-2 Sorghum 7-6 Rye 9-23	77.8	Fallow Rye 9-21 Sweet clover	98.7 100.0	20.9 7.4
144b(ck)	Fallow	Wheat 3-29	Oats plus Sweet clover 4-7	100.0	Rye harvest 7-12 Fallow	68.3	36.8
144c	Fallow & Rye 9-22	Rye Harvest 7-3 Sorghum 7-7 Rye 9-21	Rye Harvest 7-2 Sorghum 7-6 Rye 9-23	31.5	Rye 9-21		



Bindweed Smothering
A course of smothering with: (1) Fall seeded winter rye; (2) After-harvest sorghum; (3) Winter rye again. The rye lacks moisture and some "Creepers" remain. (See 143a in foregoing table) page 41.



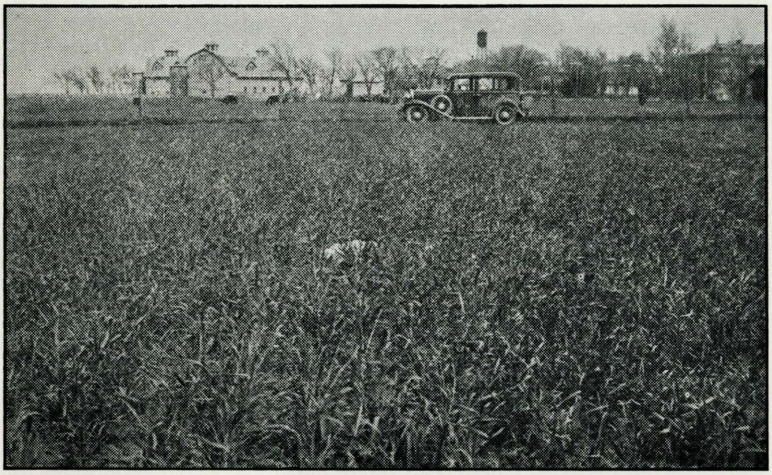
Bindweeds were reduced somewhat by fallowing after sweet clover, and up to June of next year, then seeding sorghum to plow under 9-23 and seed again 9-23. Line dividing 143c and 144a preceding table page 41.

(1) The procedures on 143b and 144b, marked ck. in the first vertical column of the table, being the regular crop sequences namely, (1) corn, (2) barley, (3) clover, and (1) wheat, (2) oats, (3) clover respectively, evidently had no effect in reducing the growth of bindweed. The percentage of such growth appears in both fifth and seventh columns of the table to be 100.

(2) In the fifth column of the table the percentages of bindweed are shown as reduced below those of the checks on all land where smother crops were employed, throughout the two seasons 1933 and 1934.

Moreover, such **reduction was greatest** on plots 143a, and 144c **where winter rye had been seeded in the fall of 1932,** in September after sweet-clover stubble had been subjected to fallow.

(3) On other plots—namely 143c and 144a, where sorghum and rye were also utilized for smother crops, but in the order named and where land was also fallowed in the early part of the summer before seeding sorghum, reduction of bindweed was not so noticeable. There is thus **no**

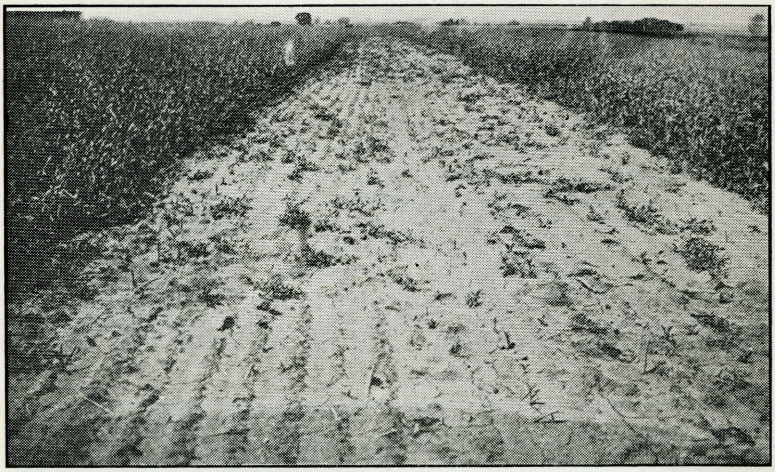


Bindweed Infestation 100 Per Cent
(See 143b. ck. in previous table)
In regular crop rotation: 1-corn, 2-barley, 3-sweet clover, barley barely discernible.

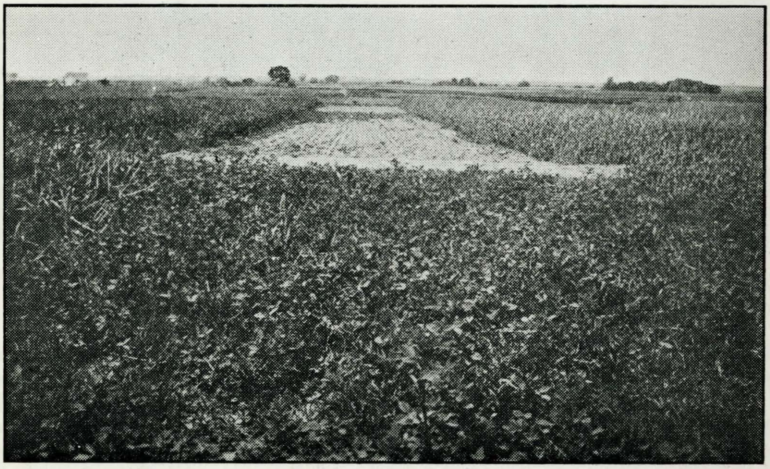
indication that the process of fallowing (with a spring toothed harrow) **under the circumstances here was effective in the direction of eradication.**

(4) The percentage of bindweed remaining in 1935, as put down in the next to last column of the foregoing table also accords with the foregoing observation leading toward the conclusion that winter rye and sorghum were effective as smother crops in greater degree when the winter rye was seeded in the previous fall and the sorghum put in immediately after rye harvest; more effective than seeding sorghum in the summer ahead of winter rye put in in the fall thereafter. The latter procedure allowed for the process of fallowing in the earlier summer previous to putting in the sorghum smother crop.

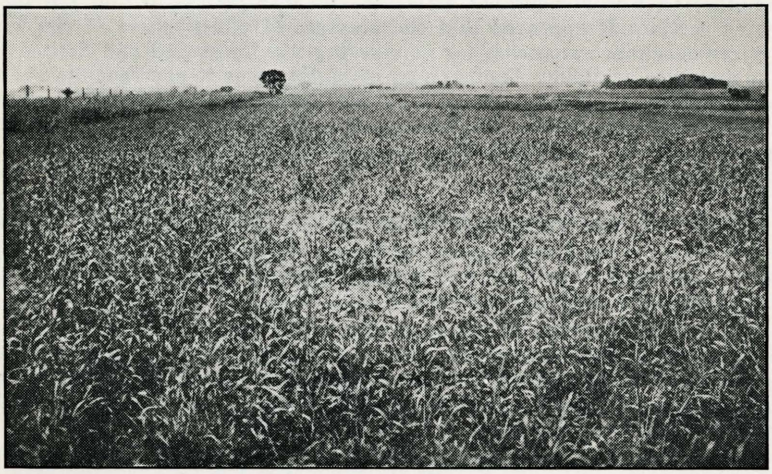
Summary—The hypothesis was arrived at by the writers, on the basis of these observations that the use of smother crops may be of great practical help in the control of Creeping-jenny, but that it is insufficient as a sole measure of eradication or practical control.



Corn—100% infestation with field bindweed—considered as check for comparison where eradication is attempted. Crop rotation here: (1) corn, (2) barley, (3) sweet clover. Something additional is necessary to hold back the bindweed.



Sweet clover (foreground) overcome by creepers—343a, West Farm, Brookings. Rotation (1) corn, (2) barley, (3) sweet clover. Something additional is necessary to check field bindweed.



Winter rye—seeded after field peas plowed under in rotation of: (1) corn, (2) wheat, (3) peas. Growth of winter rye too restricted to check bindweed completely. Heavy infestation present—compare below.

Winter rye—plot 440c. Rotation: (1) corn, (2) wheat, (3) peas—plowed under. Rye seeded same date as above on land thoroughly summer fallowed. Note greater vegetative growth and more effective smothering of bindweed.

A Properly Adjusted Succession of Fallowing with Winter-rye for Smothering was Measurably Effective—As was pointed out in the foregoing section: **It appeared that the measure of effectiveness of the winter-rye-sorghum succession for smothering was measured and limited by the moisture available.** Another way of stating it is to say that the use of a succession of smother crops (rye and sorghum) "fell down" because the smother crops (plus the bindweed) apparently utilized all moisture available, then ceased growing; after which time the bindweed without interference grew apace.

Fallowing may Conserve Moisture for Rye Seeded Later—The writers were aware from these experiments that the process of fallowing will check bindweed when it is consistently applied, and in addition, that it would conserve moisture throughout such time.

It was logical then to devise a plan which would provide for a succession of the fallowing process with later seeding of winter rye, which might then find moisture to grow vigorously enough to smother the Creeping-jenny plants effectively, and incidentally, make a crop to yield some return from the land.

Observations in these experiments justify the placing of considerable emphasis not only upon the effectiveness of introducing summer-fallow in combination with rye, but likewise the superiority of winter rye rather than some other smother crop.

The following table may summarize results with introducing the process of fallow subsequent to a rye crop on land infested with bindweed, with the same process along with other crops in comparison.

Percentage Survival of Bindweeds on Infested Land—After Treatment of Fallow —With Smother Crops, Including Winter Rye

*Plot Sub-divisions	Crop in Regular Rotation or Special Treatment Given	Bindweeds Per Square Yard, Before and After Foregoing Crop or Treatment		Percent
		Before (1934)	After (1935)	Survival, 1935
1-a	Corn 5-18	57	57.00	100.00
1-b	Rye-fallow-rye	58	1.28	2.20
1-c	Wheat-fallow-rye	58	2.55	4.40
2-a	Corn 5-18	59	59.00	100.00
2-b	Foxtail-millet-fallow-rye	63	19.47	30.90
2-c	Proso millet-fallow-rye	61	21.66	35.50
3-a	Corn 5-18	57	57.00	100.00
3-b	Oats-fallow-rye	63	4.79	7.60
3-c	Barley-fallow-rye	61	5.00	8.20
Acre 170	Fallow-rye	67	0.71	1.01
Acre 270	Sudan grass-rye	63	50.00	79.37

* Division 1-a, 1-b, 1-c: Previous rotation; corn, wheat, sweet clover.
Division 2-a, 2-b, 2-c: Previous rotation; corn, barley, sweet clover.
Division 3-a, 3-b, 3-c: Previous rotation; corn, oats, sweet clover.

In explanation of the foregoing table, it may be observed from the first column that three separate cropping systems were involved at the start of this experiment. These are indicated by the numbers 1, 2, and 3. The land where these systems or crop rotations were conducted was all located on West Agronomy Farm, Brookings, and was similar in character throughout.

The plots, or small fields, occupied by the three rotations were divided each into three equal parts, as indicated by 1-a, 1-b, 1-c. One of the sub-divisions lettered a in each case was allowed to remain in the same rotation which had been conducted for years on the land, and which had evidently allowed said land to become thoroughly infested with bindweed. These rotations could all be included within a general crop system entitled: (1) corn, (2) small grain, and (3) legume.

In the third sub-column of the table under year 1934, the number of bindweed plants per square yard counted in the spring of the year in this case previous to April 7 at the outset of this experiment may be observed as fairly uniform for all the plots and sub-divisions—indicating that later differences in such infestation must have been due to the treatments accorded.

In the two lower horizontal lines of the foregoing table, it may be observed first that the percentage of survival of bindweeds in 1935 on land which had been seeded to winter rye in the fall of 1934, and thoroughly fallowed in the summer of 1935 subsequent to rye harvest was roundly 1 per cent. The corresponding percentage of survival, however, for land which was likewise seeded in winter rye fall of 1934, but thick-seeded to sudan grass for a smother crop subsequent to rye harvest was more than 79 per cent.

It seems apparent that the comparative low percentage of survival amounting almost to eradication in the former instance was due to the fallowing process, under the circumstances, which took the place of the sudan smother-crop utilized in the latter instance.

It is possible to observe, furthermore, from the right hand column of the table that the percentage of survival of bindweed was reduced in all instances where small grain or millet—of whatever kind as a smother crop—was combined with fallowing, as compared to that where the regular three-year rotations prevailed. In the latter, the bindweed infestation was always 100 per cent.

Furthermore, a comparison of the percentage of survival in the right hand column indicates the superiority of small grain over millet for the purpose of a smother crop. It is the further observation of the writers that winter rye is also superior to either oats or barley.

Conclusion—The foregoing table apparently indicates that fallow combined with winter rye for smothering, introduced into ordinary cropping systems virtually as a part thereof constitutes a successful process for controlling (if not eradicating) bindweed under the conditions of this experiment.

Practical Control, with Fallow-Winter Rye Method. On Acre 170, West Farm, Brookings, (1934-1936)—On Agronomy West Farm, Brookings, are two separate acres of land which were utilized for alternate, (1) Corn, and (2) small-grain nursery for a good many years previous to 1933. The land was thus occupied with a two-year rotation of corn followed by small grain which is practically utilized with some variations over thousands of acres in South Dakota and adjoining states.

Also important to note here is the fact that this fairly typical land, with likewise a typical succession of corn and small grain, became so increasingly infested with field bindweed that its use for experimental crops was temporarily abandoned in 1933.

The land of both these acres, 170 and 270, stood idle in 1933. It had been the object to use chemical treatment against the bindweeds over both the acres in that season, but that project was abandoned, with the outcome indicated that no treatment whatever was pursued that year.

By the beginning of 1934, when the present account starts, the infestation of bindweed plants on acre 170 was 67 plants per square yard, and on acre 270, 63 plants per square yard—approximately equal infestation on the two acres.

The treatment accorded these two separate acres amounts to a demonstration of the use of the summer fallow-winter rye succession which the writers have arrived at, through the devious methods tried out and reported herein.

In order to set forth the outline of treatment on the separate acres as succinctly as possible, the field notes outlining conditions and the treatments on the separate acres are put down in the following two columns:

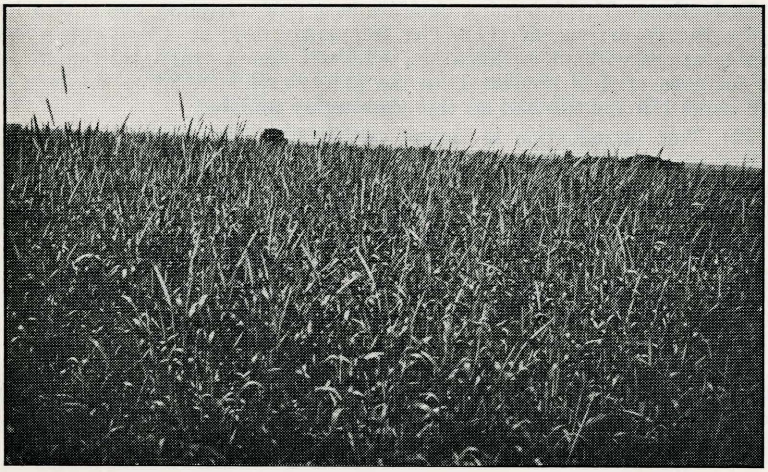
Outline of Procedure on Parallel Acres—With Fallow-Winter Rye Method of Practical Bindweed Control—(Brookings West Farm—1934-1936).

Acre 270:	Acre 170:
1933	1933
Idle. Bindweed infestation 63 plants per square yard.	Idle. Bindweed infestation 67 plants per square yard.
1934	1934
Spring plowed 5in. May 29, June 4, double disced and double harrowed, and planted **to cultivated rows of sudan grass—cultivated 4 times. Harvested** Sept. 14. Seeded to winter rye, September 15.	Mowed, June 28, **Field cultivated: Fallowed with duck-foot. (Illustration, page 21.** July 5, 10, 16, 21, 25, Aug. 3, 10, 17, 24, 31, Sept. 13. Seeded to winter rye, September 15.
1935	1935
Rye harvested—July 12, 24.8 bushels per acre. **% bindweeds killed** 20.6. Plowed 5 in. 7-19-35. Disced 8-2, Duck footed 8-6, 8-12, 8-19, 8-26, 9-3, 9-20. Winter rye seeded 9-21—came up 9-28. Harvest 7-19-36. Bindweed plants per sq. yd.=7.6, 7-10-36.	Rye harvested July 12. 43.4 bushels per acre. **% bindweeds killed 98.9.** Plowed 5 in. 7-19-35. Disced 8-2, Duck footed 8-6, 8-12, 8-19, 8-26, 9-3, 9-20. Winter rye seeded 9-21. Came up 9-28. Harvest 7-9-36. Bindweed plants per sq. yd. = .083, 7-10-36.

Observations From Foregoing Outline—The foregoing two columns may be taken to set down procedures for field bindweed eradication on two comparable separate acres, with the use of the same method (summer-fallow; winter rye), but with difference in the duration of its application.

The difference in the outcome of number of bindweed plants eradicated put down at the bottom of the outline indicates at once that the fallow-rye method against bindweed is successful, and also that it must be persisted in long enough to secure results.

Careful examination may make it appear that acre 270 has been twice seeded and cropped to winter rye—which same is true of acre 170, but acre 170 was summer-fallowed (duck-footed) previous to the first rye crop in 1935; whereas acre 270 was cultivated that same season in a row crop (sudan grass). Accordingly, on date 7/10/36, as indicated in the last line of the two columns, 7.6 bindweed plants per square yard are counted (immediately after rye harvest) on acre 270 and .083 plants per square yard as an average on acre 170.



Winter rye covers Bindweed Acre 270, West Farm, Brookings, May 8, 1936. In 1933, infested 100%. Reduction of bindweed resulted from smother crops and fallow (sudan, winter rye, fallow, winter rye). Two seasons smother crop, one season of fallow intervening, reduced bindweed to 7.6 plants per square yard.

Bindweed Control, Acre 170, West Farm, Brookings, with introduction of succession of fallow (duck-foot), winter rye, fallow, winter rye. Photo May 28, 1936. Winter rye in illustration shelters .083 bindweeds per square yard—fewer than Acre 270 above. The trace of bindweed persisting under rye **may** be eliminated by fallowing, present season.

Deductions—The foregoing constitutes a fair summary demonstration of the theory arrived at: (1). The frequently used two- and three-year crop rotations without modification, evidently create conditions that favor the increase of field bindweed. In the present demonstration the land of both acres 170 and 270 had become thoroughly infested.

(2). Tme introduction of fallow (either late summer or full season) with a succeeding crop of winter rye amounts to the introduction of an essential change in the usual cropping system or crop rotation which will make the system as a whole unfavorable instead of favorable to the growth and increase of bindweed.

(3). It may be observed that a trace of bindweed is still to be found in acre 170, now in 1936, even after the introduction of the two successive seasons of summer fallowing (duck-footing), succeeded in due course by winter rye.

The present plan is to persist in a succession of fallowing (duck-footing) and seeding to winter rye on these acres in the present season, 1936, in order to demonstrate that this pest may not only be practically, but absolutely, eradicated.

References

Aslander, Alfred
Sulphuric Acid as a Weed Spray. J. Agr. Res. Vol. 34, No. 11, pp. 1065-1091, 1927.

Aslander, Alfred
Experiments on the eradication of Canada Thistle, Cirsium arvense, with chlorates and other Herbicides. J. Agr. Res. Vol. 36, No. 11, pp. 915-34, 1928.

Aslander, Alfred
Chlorates as Plant Poisons. J. Am. Soc. Agron. Vol. 18, No. 12, pp. 1101-1102, 1926.

Arny, A. C., and others
Eradicating Perennial Weeds with Chlorates. Minn. Agr. Ext. Cir. 32, 4 p., 1930.

Ball, W. S., and W. W. Robbins
Wild Morning Glory (Convolvulus arvensis L.) Calif. Agr. Dept. B., Vol. 24, 192-4, 1935.

Barnum, C. C.
The Control of Wild Morning Glory. Calif. Cir. 256, 1923.

Bissey, Russell, and Butler, O.
Effect of Applications of Sodium Chlorate and Ammonium Thiocyanate on Subsequent Sowings of Wheat. J. Am. Soc. Agron. Vol. 26, No. 10, p. 838-846, 1934.

Call, L. E., and Getty, R. E.
The Eradication of Bindweed. Kansas Cir. 101, 1923.

Cox, H. R.
The Eradication of Bindweed, or Wild Morning-Glory. U. S. D. A. Farmers Bulletin 368, 1909.

Crafts, A. S.
Problems of Morning-Glory Control. Pacific Rural Press. 127-488, 1934.

Hansen, Albert A.
Eradicating Quack Grass with Sodium Chlorate. J. Am. Soc. Agron., Vol. 20, No. 10, p. 1120-1123, 1928.

Harper, Horace J.
The Use of Sodium Chlorate in the Control of Johnson Grass. J. Am. Soc. Agron., Vol. 22, No. 5, p. 417-422, 1930.

Harvey, R. B.
Ammonium Thiocyanate as a Weed Eradicant (Note) J. Am. Soc. Agron., Vol. 23, No. 11, p. 944-946, 1931.
Hulbert, H. W., Remsberg, J. D., and Spence, H. L.
Controlling Perennial Weeds with Chlorates. J. Am. Soc. Agron., Vol. 22, No. 5, p. 423-433, 1930.
Hulbert, H. W., Bristol, R. S., and Benjamin, L. V.
Methods Affecting the Efficiency of Chlorate Weed Killers, Idaho Agr. Expt. Sta. Bul. 189, 1931.
Kiesselbach, T. A., and others.
Bindweed Eradication. Nebr. Agr. Expt. Sta. Cir. 50, p. 1-8, 1935.
Latshaw, W. L., and Zahnley, J. W.
Killing Field Bindweed with Sodium Chlorate. Kansas Agr. Expt. Cir. 136, 1928.
Latshaw, W. L., and Zahnley, J. W.
Experiments with Sodium Chlorate and Other Chemicals as Herbicides for Field Bindweed. J. Agr. Res., Vol. 35 p. 757-767, 1927.
Latshaw, W. L., and Zahnley, J. W.
Magnesium and Calcium Chlorate as Substitutes for Sodium Chlorate for Killing Field Bindweed (note). J. Am. Soc. of Agron., Vol. 20, No. 12, p. 1329, 1928.
Loomis, W. E., et al
The Absorption and Movement of Sodium Chlorate when used as an Herbicide. J. Am. Soc. Agron., Vol. 25, No. 11, p. 724-739, 1933.
McGeorge, W. T.
Fate and Effect of Arsenic Applied as a Spray for Weeds. J. Agr. Res., Vol. 5, No. 11, p. 459-463, 1915.
Porter, R. H.
Noxious and Other Bad Weeds of Iowa. Iowa Ext. Cir. 201, 1934.
Rowley, H. K.
When to Treat Quackgrass Most Effectively With Chlorates. J. Am. Soc. Agron., Vol. 23, No. 1, p. 41-42, 1931.
Rudolfs, W.
Experiments with Common Rock Salt. II. Eradication of Weeds and Cleaning of Roadsides with Salt. J. Soil Science, Vol. 12, p. 457-70. III. After Effects of Salt. J. Soil Science, Vol. 12, p. 471-474.
Schafer, E. G.
The Bindweed. Washington Ag. Exp. Pop. Bul. 137, 1-19, 1927.
Smith, C. W.
Machinery to Control the Field Bindweed. Agr. Eng. Bul., Vol. 16, p. 142-8, 1935.
Stewart, Geo. and Pittman, D. W.
Studies in the Eradication of the Wild Morning-Glory. J. Am. Soc. Agron., Vol. 16, No. 8, 506-518, 1924.
Stewart, Geo., and Pittman, D. W.
Ridding the Land of Wild Morning-Glory. Utah Agr. Expt. Sta. Bul. 189, 1924.
Tingey, D. C.
The Comparative Cost and Effectiveness of Tillage and of Chlorates In the Control of Morning Glory, Canada Thistle, and Perennial Sow Thistle. J. Am. Soc. Agron., Vol. 26, No. 10, p. 864-876, 1934.
Tingey, D. C.
Spontaneous Combustion on Weed Plats Sprayed with a Solution of Atlacide (note) J. Am. Soc. Agron., Vol. 25, No. 4, p. 297-299, 1933.
Wiant, D. E., and Patty, R. L.
The Two-Row Cultivator Converted into a Weed Control Machine. S. Dak. Expt. Sta. Bul. 303, 1936.