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Bulletin No. 189 - Ridding the Land of Wild Morning Glory

George Stewart
D. W. Pittman

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Ridding The Land of Wild Morning Glory

GEORGE STEWART AND D. W. PITTMAN

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L. M. WINSOR, B. S ................................ Irrigation Engineer

*On leave of absence.
RIDDING THE LAND OF WILD MORNING GLORY
By GEORGE STEWART AND D. W. PITTMAN

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INTRODUCTORY

"Morning glory" is the common name for one of the worst weeds found in Utah. On account of its general resemblance to a cultivated plant spoken of as morning glory, the weed is frequently and more correctly known as the "wild morning glory." Since everyone who handles farm land knows the plant, a description of it is unnecessary. It may not be amiss, however, to mention that the name probably comes from the fact that the showy, funnel-shaped flowers are open only in the morning, being folded within the sepals after midday or earlier in hot, dry weather.

In almost every locality this weed attracts its first attention when it has taken possession of a small spot of ground that varies from a few feet to one or two rods in diameter. Its power to spread underground by means of strand-like roots or rootstocks, depending on the species, permits such a spot to enlarge gradually by pushing outward a few feet each year. Once it occupies land, it remains in firm possession unless some vigorous method of eradication is set in operation.

Neglect of these beginning spots or half-hearted attempts to destroy the colony, for such it is, serves only to infest adjacent farm land. Pieces of the brittle roots or rootstocks are carried along the field on plows, cultivators, or harvesting machinery or even floated along by irrigation water. Wherever one of these
pieces may lodge, it is not long until a rather slender weakly plant appears. Usually little attention is given to it because it does not by appearance show how dangerous it really is. In a season or two the spreading underground strands move outward in all directions. These are filled with stored-up plant-food, and another firmly established center of spread is now on the farm. Sometimes many acres are so infested in the course of two or three years.

**Nature of Injury.**—Few crop plants thrive on land infested with morning glory. Alfalfa, sugar-beets, grasses, grains, and even potatoes and corn are greatly retarded in early spring. Small-seeded crops such as alfalfa and sugar-beets are often crowded out before the seedling crop plants can become established. Fortunately morning glory does not begin growth in very early spring, and because of this it is usually possible to get an early-sown crop well started before morning glory interferes. After growth once starts, the great supply of stored plant-food then permits rapid development of the weed. In a heavy stand, the soil is filled with a network of roots and rootstocks, and the top growth soon covers the ground so thoroughly as to make a dense shade. Available plant-food, on which the seedling crop plants depend for thrifty growth, is quickly used and soil moisture is rapidly exhausted in dry weather.

Almost all field crops are held in check by a full stand of morning glory, tho sometimes the vigorously growing alfalfa may hold its own until mowing, after which time the morning glory begins to weaken. The ordinary condition, however, is for the alfalfa to remain thin and dwarfish and for the morning glory at least to retain its hold. Tho not able to occupy additional land while the alfalfa is in its prime, morning glory does so as soon the alfalfa begins to weaken from age, which it does after the fifth or sixth year. When the alfalfa field is broken, the morning glory remains ready to dispute the success of cultivated crops. Occasionally a heavy stand of alfalfa that is mowed frequently smothers out the pest or leaves its hold much weakened. For some reason these occasional successes have attracted more notice from farm operators than they deserve. Even considerable decrease in vigor on the part of the morning glory due to smothering is not a real service because only one season is required for recuperation.

Serious as is this weed in field crops, it is even more serious in truck crops, with which rapidity of growth is necessary if early markets are to be reached. Rapid reduction of soil moisture and available plant-food hinder both rapid growth and proper development of the tender vegetative parts of truck crops. In addition,
there may be an even greater injury to the quality of the crop than to its yield. Tender plants of all sorts are much dwarfed in size and made unthrifty in appearance when grown in a morning-glory bed even tho the top growth is kept rather well cut down. It is possible that dividing soil nitrates with the more vigorously growing weed brings about a condition of partial starvation in the young crop plants. Getting to market later with smaller yield of low quality produce is not a desirable predicament for the market gardener.

At harvest time still further trouble results from difficulty in harvesting such crops as grain, hay, potatoes, beets, and truck produce. Even corn for ensilage is more difficult to harvest. Seed crops are depressed in price if they bear admixtures of morning-glory seed. Quality in hay is lowered if morning glory forms any appreciable part of it.

Land infested with morning glory has a considerably smaller sale value than similar land not so infested. This, coupled with its menace to neighboring land as a source of infestation, gives to the weed a community and economic importance of unrealized magnitude. Indulgence of the pest is like playing with fire. Not only does the individual get his fingers burned but community good name is also seared.

Occurrence.—During the last fifteen years wild morning glory has spread into practically every agricultural section of Utah. Most of these infestations are light, considered from the percentage of land they occupy. From the standpoint of threat in the future, the pest has gained a position of widespread menace. There is now no large agricultural area in the state that is free. The presence of small spots should be a warning that trouble is not far distant unless farm operators and communities are aroused to the actual danger that impends.

In four areas the morning glory has occupied such a large proportion of the land that practically every farm is infested, many of them to the extent of one-third to two-thirds of the total farm acreage. The southern end of Davis County has attracted most attention on account of the intensive truck farming that is there practiced. The old fields in the vicinity of Manti are rather completely overrun; grain fields, alfalfa fields, and potato fields show heavy infestation. In central Utah County is an area less severely infested but where the pest is more widely spread. In the vicinity of Nephi, especially west of town, are areas of considerable size. In these areas and in other parts of the state the roadways and waste land in general are largely occupied. Yet in spite of the seriousness of the pest in Utah, our state is just in the first stages of morning-glory occupation.
Table 1. Number of Farms Infested and the Total Acreage of Morning Glory in the Principal Agricultural Counties of Utah (Estimated by County Agents for 1923)

<table>
<thead>
<tr>
<th>County</th>
<th>No. of Farms Infested</th>
<th>Total Acreage</th>
<th>County</th>
<th>No. of Farms Infested</th>
<th>Total Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaver</td>
<td>60</td>
<td>50</td>
<td>Millard</td>
<td>110</td>
<td>1000</td>
</tr>
<tr>
<td>Box elder</td>
<td>75</td>
<td>75</td>
<td>Morgan</td>
<td>47</td>
<td>33</td>
</tr>
<tr>
<td>Cache</td>
<td>300</td>
<td>150</td>
<td>Salt Lake</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>Carbon</td>
<td>2</td>
<td>1</td>
<td>Sanpete</td>
<td>750</td>
<td>10,000</td>
</tr>
<tr>
<td>Davis</td>
<td>180</td>
<td>200</td>
<td>Summit</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Emery</td>
<td>6</td>
<td>2</td>
<td>Tooele</td>
<td>150</td>
<td>350</td>
</tr>
<tr>
<td>Iron</td>
<td>50</td>
<td>12</td>
<td>Utah</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Juab</td>
<td>60</td>
<td>400</td>
<td>Weber</td>
<td>12</td>
<td>200</td>
</tr>
</tbody>
</table>

Great areas in California and in the older farming regions are much more completely occupied.

STATUS UP TO 1921

Previous to 1921, when the experiment here reported was begun, there had been only a few tests of an experimental nature that had for their purpose the discovery of eradication methods for morning glory. This did not indicate that the problem was considered to be settled, for in most agricultural areas of the United States there was felt great need of information in regard both to method of attack and results that might be anticipated. A brief review of the published information on morning-glory control previous to 1921 will show the status of the problem when this research was begun.

Review of Publications.—In 1908 Cox1 canvassed the situation with reference to morning-glory control. He describes a number of plants that go under the common name of bindweed, the worst of which are hedge bindweed and field bindweed, the two species of wild morning glory common in Utah. Control methods are considered briefly and the conclusion reached that top growth must be kept cut down in order to starve the roots and rootstocks. Sowing infested land to alfalfa is suggested as one means of control. He does not count the use of chemicals to be successful.

A test approaching careful experimenting was conducted at Davis, California, for two years, 1909-1911. In this test Biolletti2 found roots capable of producing new shoots at a depth of fourteen feet. Ordinary good cultivation in the surface three feet of soil did not seriously affect the vigor of the plant colony. Various tests on about ten acres of uncropped land, however,

showed that if the tops were cut back every five days during the season the roots lost about 70 per cent of their weight and allowed but little top growth the next season.

The cost of labor for the season was estimated to amount to $9 an acre.

Spraying was tried in California by Gray who conducted spray experiments from 1915 to 1919. Along the coast, where due to fogs the air was humid, he found\(^3\) that a spray solution killed 85 to 90 per cent of the roots to a depth of four feet. His spray consisted of 10 pounds of granulated caustic soda (98 per cent) and 20 pounds of white arsenic (As\(_2\)O\(_3\), 99 per cent) in 5 gallons of water, diluted at the rate of one gallon of this stock solution in 99 gallons of water. The fields seemed free for eight to twelve months, after which new shoots arose to the surface. It is stated as a belief that annual fall spraying (October preferred) would eventually eradicate the weed. Later, however, he found that spray was successful only where the air was saturated with moisture, or so nearly so, as to allow time for the absorption of the poison before evaporation removed the water from the spray solution. Only in this condition was there a downward movement of poison to the roots.

In a somewhat more extended study of the effect of chemicals


on morning glory, Gray applied various chemicals to the soil in an effort to kill by root absorption. This method failed to kill the weed at reasonable expense. Moreover, the concentration necessary to kill the roots of morning glory damaged the soil for the growing of crop plants.

Pammel and King sprayed thirty-one weeds and cultivated plants with copper sulfate (blue vitriol), sulfuric acid, sodium chloride (common salt), carbolic acid, slaked lime, formaldehyde, corrosive sublimate (mercuric bichloride), and other chemicals. Top growth was killed with all of them, but iron sulfate at the rate of 2 pounds to the gallon of water and 50 gallons of solution to the acre was recommended. Occasional change in the strength of spray and deep plowing are suggested as likely methods of control.

In Oregon spraying mustard and pigweed with 20 per cent solution of iron sulfate retarded the growth of these weeds but had no effect on morning glory. Solutions at 22, 24, 26, 28, and 35 per cent concentrations made no perceptible progress toward eradicating morning glory.

Meanwhile, sodium arsenite (Na₃AsO₃) and various patented "weed killers" in which sodium arsenite practically always occurred had come into favor as means of killing down weed growth on waste land, roadways, and in special phases of agricultural production, such as pineapples in Hawaii when spray could be applied between the rows. Much spraying was done between 1916 and 1921 in Utah, especially on vacant building lots in and around Salt Lake City. Top growth could be killed readily, and the method was used as a fire-prevention method with apparent success.

In several cases weedy roadways and railroad rights-of-way were sprayed and top growth killed. A heavy bed of morning glory south of Salt Lake City was treated a few times, but with only temporary success.

**Recommended Treatment.**—These experiments and rather wide experience permitted a reasonably successful analysis of the control tests. It had been rather established that most perennial weeds which spread by means of roots or rootstocks demanded essentially similar treatment. The treatments advocated were (1) cutting down tops, (2) smothering, (3) covering with tar

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paper, (4) pasturing, (5) digging, (6) treating with chemicals, and 7) crop rotation. The discussions were about as follows:

"Cutting.—The one sure way to get rid of these weeds is to keep the tops down so thoroughly that they cannot develop any green leaves. The roots will eventually starve if they are not fed. The leaves feed the roots; therefore, no green part is to be allowed above the ground. Constancy alone can prevent these pests from gaining strength; leaves above the ground soon become green. The chlorophyll makes food for the storehouse that must be exhausted.

A besieging fleet would not consider letting an occasional shipload of supplies pass the blockade. When a strict blockade has weakened the enemy, then is the time to strike. In control of weed pests, the course is identical.

"Smothering.—Manure or straw may be piled on small spots and spread well out beyond the edges to make sure that no stalks come up beyond the edge of the pile. The pile should be so thick and compact as to shut out both light and air. No leaves must be allowed to penetrate. This prevents the development of green leaves. Two seasons should kill the weed.

"Covering with Tar Paper.—Sometimes a weed may be overcome by covering with tar paper or with heavy, opaque building paper such as will shut out the light. Care must be taken to prevent holes being in the paper, to weigh it down thoroughly, and to have it extend well out beyond the edges. This prevents the growth of green leaves. Two seasons should kill any weed.

"Pasturing.—Very close pasturing with hogs, sheep, or goats may weaken and in some cases kill out perennial weeds. Hogs may root out the underground stems and sheep or goats may eat down the leaves so closely as to starve the rootstocks.

"Digging.—Where the spot is small control may be gained by keeping water away and by digging out the rootstocks which are thereby exposed to the hot dry sun. Let the earth be stirred up to keep it dry. If the spots are very small, a canvas may be spread to shed the rain in a storm. Sometimes a similar exposure to frost may help.

"Treating with Chemicals.—In some places it is more convenient to spray a weed patch than to use one of the other methods. A broad-leaved weed may be killed in a narrow-leaved crop. If the crop is wide-leaved, sprays are as likely to kill the crop as well as the weed, and perhaps more so, due to the fact that weeds usually have heavier leaf-coverings. Strong salt

solutions are used sometimes both on the tops and in the soil. Iron sulfate, copper sulfate, arsenite of soda, sulfuric acid, and corrosive sublimate have all been more effective. The usual strength in the middle-west where they have been tried most is to add to ten gallons of water twenty pounds of iron sulfate, two and a half pounds of copper sulfate, four ounces of sodium arsenite (sodium arsene, twenty ounces), a quart of sulfuric acid, or one and three-fourths ounces corrosive sublimate. Iron sulfate and sodium arsenite (not sodium arsene) have given best results. Some few trials in Utah seemed to indicate that our weeds are so much more resistant the solutions need to be stronger—perhaps half as strong again.

"Rotation.—Crops that develop heavy top growth such as alfalfa, sweet clover, or heavy grain may weaken rootstocks by shading. Cultivated crops such as corn or potatoes which permit a thorough hoeing may be good means of gaining control. The weeds must be taken out, even though the crop is somewhat injured by so doing."

Attitude of Farmers.—In spite of the assurance felt by specialists—that wild morning glory could be eradicated—farmers were not at all convinced. They said they had kept the pest hosed down; they had cultivated five or six times, and then had found themselves too busy to follow up the cutting. In spite of their efforts not only had the weed remained vigorous, but in many cases it had increased its hold on the land either by enlarging the patch that was its original conquest or by scattering to other parts of the farm. In some cases alfalfa had held it in check and in one or two instances had apparently killed it, but in the majority of cases it was the alfalfa that was checked. Even where there had been no spread in the alfalfa field the pest sprang into vigorous growth at once after the field was broken.

In many localities pastures, not in solid grass, were overrun; orchards were completely covered and the streets invaded. In these communities where the pest was firmly established there seemed to be no place of which possession might not be taken. In fact, the weed grew everywhere. Altho regarded as a plant limited to relatively abundant moisture, here and there it spread to dry farm lands and seemed to remain undisturbed by considerable tillage. Five or six cultivations or hoeings while the top growth was small but with an occasional larger growth allowed did not seem to be effective.

The ease and sureness with which spread took place had alarmed many. The plow, the harrow, and the cultivator seemed
to drag it to hitherto unoccupied places. It had grown up thru piles of straw and manure which spread over the weed areas, and later when this material was hauled to other land, new colonies were started. Barnyards in some cases were invaded and served as centers of spread. Rubbish dumps were observed to be covered; unpaved sidewalks and roadways bore a covering except in the trail where constant tramping kept the ground bare.

Altogether, land owners and tenants in the heavily infested communities dreaded morning glory in no uncertain way. Yields were decreasing tremendously; in a few cases what had been high-priced land was sown to less profitable crops or completely abandoned. Several infested tracts of land were offered for sale at prices that represented a mere fraction of the value of neighboring uninfested land. A strong feeling of utter hopelessness was spreading. Buyers for infested farming land were not to be found. Even city building sites that were overrun with morning glory were noticeably less attractive. The great dread in which the pest was held is partly expressed by the local name "devil gut" applied to it in Davis and Weber Counties. "Sucker weed" and "strangle hold" were also heard.

EXPERIMENTAL

So serious had the psychological attitude with respect to this pest become that the Utah Agricultural Experiment Station began to wonder what the facts might be. The literature was meager and inconclusive for this part of the country, practically all the experimental work having been done in California. Most of the evidence regarding the eradication of morning glory, for the Great Basin or Rocky Mountain region, for one reason or another, was not clear-cut. The Experiment Station obtained in the early months of 1921 possession of a 10-acre tract of land bearing a heavy stand of the weed on 2.5 acres in one bed and several smaller patches. An experiment was planned in such a way as to test all the commonly advocated remedies and also to demonstrate their relative efficiency to visitors.

The field in question is about one-half mile northwest of the central experiment farm known as the Greenville Farm at North Logan. Containing slightly over ten acres and being almost square, the field extended 42.5 rods from east to west and 40 rods from north to south. Along the north fence extending the entire 42.5 rods a solid bed of the large-leaved morning glory (Convolulus sepium) reached southward approximately 7 rods at the east fence line and 12 rods at the west. This bed was laid off in-
to twenty-one plats, each two rods wide, from east to west and extending 10 rods north to south, so as to include the edge of the infested area. Another area near the middle of the west side and about 4 rods by 8 rods in extent was made into four hog pastures, 2 rods by 4 rods.

The whole 10-acre field was sown to sugar-beets. When they first came up, the stand was a good one with the morning glory just beginning to show. About the end of May the morning glory was growing rapidly and by June 15 had completely hidden the beets. Several farmers who saw the field said it was impossible, irrespective of expense, to grow even a fair yield that season. Careful examination showed the infestation to be essentially a solid occupation. There were no bare spots and but few places where the stand was thin.

On June 15 a beet cultivator with duck foot blades was run over the land at a depth of about 4 inches, doubling so as to destroy beets and weeds alike. This cultivation was repeated several times until all surface growth was entirely removed.

**PLAN OF PLAT TREATMENTS**

The twenty-one large plats were measured carefully and corner pegs driven in securely. By July 1 a new top growth of morning glory covered the ground. The plants' branches were about 6 to 12 inches long and rapidly growing. Treatments began on July 1 and continued to October 1. The method and frequency of treatment are shown in Table 2.

<table>
<thead>
<tr>
<th>Plat</th>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 11</td>
<td>Spray, ordinary strength</td>
<td>Frequent (as soon as surface of field seemed green)</td>
</tr>
<tr>
<td>2, 12</td>
<td>Spray, ordinary strength</td>
<td>Half as often</td>
</tr>
<tr>
<td>3, 13</td>
<td>Spray, one-half strength</td>
<td>Frequent</td>
</tr>
<tr>
<td>4, 14</td>
<td>Spray, double strength</td>
<td>Frequent</td>
</tr>
<tr>
<td>5, 15</td>
<td>Spray, ordinary strength</td>
<td>Delayed till bloom</td>
</tr>
<tr>
<td>6, 16</td>
<td>Tillage—shallow</td>
<td>Frequent</td>
</tr>
<tr>
<td>7, 17</td>
<td>Tillage—shallow</td>
<td>Half as often</td>
</tr>
<tr>
<td>8, 18</td>
<td>Tillage—deep plowing</td>
<td>Whenever shoots appeared</td>
</tr>
<tr>
<td>9, 19</td>
<td>Tillage—shallow plowing</td>
<td>Once, followed by shallow cultivation</td>
</tr>
<tr>
<td>10, 20</td>
<td>Smother—Russian sunflowers</td>
<td>Hoed once when sunflowers were 4 feet tall</td>
</tr>
<tr>
<td>21</td>
<td>Check plat—untreated except on spray treatment on August 10 to prevent seeding.</td>
<td></td>
</tr>
</tbody>
</table>

Plats 1 to 5 and 11 to 15, inclusive, were sprayed with sodium arsenite (Na₃AsO₃) obtained in a liquid form in gallon cans.
Directions on the cans suggested dilution of one gallon of the chemical in 200 gallons of water. This was taken as ordinary strength and half strength or double strength made up proportionately. It was necessary to allow the tops to make sufficient growth to cause the land to appear green before applying the spray. The time required for this to happen was about a week in early season and gradually increased to two weeks as the season advanced.

Fig. 2.—Above: top growth; Below: rootstocks. Each pile was harvested from 4 square feet, the rootstocks by digging in the fall and the top growth by clipping the following June.
Plat 21—check; no treatment
1—spray ordinary strength; frequent
2—spray ordinary strength; infrequent
3—spray half strength; frequent
4—spray double strength; frequent
5—spray delayed till full bloom

Shallow cultivation treatments were at first applied by means of a beet cultivator with hoes and duck foot blades. Later on a sled knife was made by fastening a steel blade beneath a solid frame in such a way that it cut about 3 inches below the surface. As soon as any growth appeared above the surface, cultivation was applied on the frequently treated plats and on the infrequently treated plats each alternate time that the frequently treated ones were cultivated. Growth appeared in about five days during July and in about ten days in September.

Plowed plats received treatment varied slightly from this plan. The two plats receiving deep plowing were plowed July 1 about 15 inches deep and then cultivated shallow when required to keep down top growth. The plats for shallow plowing were treated whenever growth began to appear. The plowing was about 5 inches in depth and was required about every 10 days at first and later about each 15 days. There was no other tillage applied in the shallow-plowed plats. Smother plats on July 1 were sown to Mammoth Russian sunflowers in rows 20 inches
apart with plants every 3 or 4 inches in the row. When the sunflowers were about 4 feet tall, the rows were cultivated and hoed thoroly. Thereafter no treatment whatever was applied during the season until the land was fall-plowed (about November 15) The sunflowers grew to about 10 feet in height and shaded the ground thoroly except along the edges where the light came in for a few feet. No morning glory grew except where this light reached.

Fig. 3.—Above: top growth; below: rootstocks from 4 feet square
   Plat 21—check; no treatment
   6—tillage; shallow, frequent
   7—tillage; shallow, infrequent
   8—deep plowing followed by shallow tillage
   9—shallow plowing repeated frequently
   10—sunflowers as a smother crop

PLAT DATA OBTAINED

On October 1 a careful digging test was made to find the relative abundance of rootstocks, it being thot that this would at least indicate the general effect of the treatments. The holes were exactly 2 feet square (4 square feet in area). As the dirt was thrown out the rootstocks were picked out by hand and saved. Digging was continued until no more roots were found, which in this case was a depth of about 30 inches, where the water-table had stopped penetration. Care was taken to keep the holes the same size so as to make the data comparable. As soon as dug the roots were taken to the laboratory, washed clean, and weighed as soon as the water drained off and evaporated. After being thoroly air-dried the dry-weights were obtained.

During the process of digging it was observed that rootstocks obtained from frequently tilled plats were slender, watery, and brownish in color, whereas those taken from spray plats and from the check plats were plump and white. On the sunflower plats the ground was full of decaying strand-like plant tissue that seemed to be dead rootstocks.
In Table 4 are given the data obtained next spring after growth had had time to get well started. On June 8 another set of small sample plats was laid off, each 2 feet square, that is, 4 feet in area. This time the top growth was shaved off to the surface and
Table 4. Number of Plant Shoots, Green and Dry Weight of Top Growth on Spray and Tillage Plats
(From a 4-square-foot area)

<table>
<thead>
<tr>
<th>Plat Number</th>
<th>Treatment Applied</th>
<th>No. of Shoots</th>
<th>Fresh Weight (grams)</th>
<th>Air-Dry Weight (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spray—ordinary—frequent</td>
<td>89</td>
<td>79</td>
<td>14.5</td>
</tr>
<tr>
<td>2</td>
<td>Spray—ordinary—½ frequent</td>
<td>212</td>
<td>294</td>
<td>46.5</td>
</tr>
<tr>
<td>3</td>
<td>Spray—½ ordinary—frequent</td>
<td>121</td>
<td>110</td>
<td>20.5</td>
</tr>
<tr>
<td>4</td>
<td>Spray—2 ordinary—frequent</td>
<td>59</td>
<td>28</td>
<td>5.0</td>
</tr>
<tr>
<td>5</td>
<td>Spray—delayed till bloom</td>
<td>291</td>
<td>318</td>
<td>60.0</td>
</tr>
<tr>
<td>6</td>
<td>Cultivation—shallow—frequent</td>
<td>1</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>Cultivation—shallow—½ frequent</td>
<td>51*</td>
<td>26</td>
<td>4.0*</td>
</tr>
<tr>
<td>8</td>
<td>Deep plowing—then shallow tillage</td>
<td>29</td>
<td>13</td>
<td>2.0</td>
</tr>
<tr>
<td>9</td>
<td>Shallow plowing—frequent</td>
<td>15</td>
<td>9</td>
<td>1.0</td>
</tr>
<tr>
<td>10</td>
<td>Sunflowers—one hoeing</td>
<td>33</td>
<td>28</td>
<td>5.0</td>
</tr>
<tr>
<td>11</td>
<td>Spray—ordinary—frequent</td>
<td>127</td>
<td>80</td>
<td>15.0</td>
</tr>
<tr>
<td>12</td>
<td>Spray—ordinary—½ frequent</td>
<td>266</td>
<td>234</td>
<td>44.0</td>
</tr>
<tr>
<td>13</td>
<td>Spray—½ ordinary—frequent</td>
<td>185</td>
<td>136</td>
<td>27.5</td>
</tr>
<tr>
<td>14</td>
<td>Spray—2 ordinary—frequent</td>
<td>80</td>
<td>56</td>
<td>10.5</td>
</tr>
<tr>
<td>15</td>
<td>Spray—delayed till bloom</td>
<td>279</td>
<td>275</td>
<td>47.5</td>
</tr>
<tr>
<td>16</td>
<td>Cultivation—shallow—frequent</td>
<td>13</td>
<td>7</td>
<td>0.5</td>
</tr>
<tr>
<td>17</td>
<td>Cultivation—shallow—½ frequent</td>
<td>134*</td>
<td>98</td>
<td>18.5*</td>
</tr>
<tr>
<td>18</td>
<td>Deep plowing—then shallow tillage</td>
<td>23</td>
<td>9</td>
<td>1.0</td>
</tr>
<tr>
<td>19</td>
<td>Shallow plowing—frequent</td>
<td>10</td>
<td>6</td>
<td>0.5</td>
</tr>
<tr>
<td>20</td>
<td>Sunflowers—one hoeing</td>
<td>37</td>
<td>42</td>
<td>7.0</td>
</tr>
<tr>
<td>21</td>
<td>Check—no tillage—one spraying to prevent seeding</td>
<td>169</td>
<td>668</td>
<td>98.0</td>
</tr>
</tbody>
</table>

*The lack of agreement between Plats 7 and 17 is still noticeable.

The shoots counted. The fresh weight was taken immediately and the dry weight after the material had come thoroly air-dry. The small plats were now taken in what seemed to be an average area of the field plat. Rootstocks sampling in the fall could not allow for this because no top growth showed at the time. The closeness, however, with which spring growth agrees with the dry weight of rootstocks taken more or less at random is striking. It was also decidedly apparent that untreated plats gave a more vigorous and rapid spring growth. The shoots on the check plat started several days earlier, grew faster, and were about three times as long and about eight times as heavy on June 8 as were the shoots from the frequently tilled plats. The relative numbers are shown in the table.

Sugar-beets were again sown in the land in 1922. The plats were shortened two rods on the south and this strip clean-tilled with a beet cultivator thruout the season. It was decided to grow beets on all plats possible. Plats on which there remained a heavy stand were sprayed or sown to corn as a smother crop. The treatments and the yield of beets at harvest are shown in Table 5.
On account of being in front of the field entrance and isolated by spray plats and a fence, it was decided to fallow Plat 1, and hoe weeds from Plat 11, its duplicate. It did not seem possible to grow beets on Plats 2, 12, 3, 13, 5, and 15 on account of the dense weed stand yet remaining. Plats 2, 12, 3, and 13 were sprayed with a double strength spray frequently enough to kill down the top growth of morning glory. This killed the beets also except for a dozen or so beets on each plat. The smother crop of corn on Plats 5 and 15 was drilled in rows 24 inches apart, with the seed 2 or 3 inches apart in the drills. Because the corn did not grow as rapidly as had the sunflowers the season before, it was
never effective in checking the weed growth. Plats 6 to 10 and 16 to 20 all grew fair to good crops of beets with no care except two light hoeings. Plats 10, 17, and 20, however, required vigorous weeding to keep the morning glory in check. The others were given merely ordinary care such as beets receive on clean ground, with only a little more care in hoeing so as not to miss any shoots of morning glory. The beets were not delayed or disturbed in any way on the ten plats that had been given tillage in 1921, except in the cases of 10, 17, and 20 where vigorous hoeing reduced the stand and caused excessive work. The fact that Plat 7 was nearly free from weeds has been already noted. It yielded 12.54 tons an acre as compared with 10.10 tons for Plat 17 which was rather weedy.

In 1923 the entire experimental area was again sown to beets. All plats were grown successfully, but Plats 2, 3, 5, 12, 13, and 15 required vigorous weedings. Plats 4, 10, 11, 14, 17, and 20 required some extra attention to get all the shoots of morning glory, whereas Plats 6, 7, 8, 9, 16, 18, and 19 were cultivated as if on land that had always been clean. Of course, a sharp lookout was maintained for morning glory top growth, but only few shoots were found and none at all (not even one) on Plats 6, 9, 16, and 19. At the north end of the plats, along the fence line, some plants still persisted, due principally to inability to make the 1921 cultivation effective close to the fence.
As the season advanced it became apparent that the stand of beets decreased on the plats that required vigorous hoeing to hold the morning glory in check. Not long before harvest careful counts were made on six of the rows, all of which ran the entire length of the field from east to west across all the plats. The beets were no longer on the plats that had been hoed more to keep down the morning glory. The stand of beets will be a fair check on yield in 1923, the second year after the treatment was applied.

Table 6. Number of Sugar-Beet Plants on the Same Six Rows in Each Plat (2 Rods Wide) (1923)

<table>
<thead>
<tr>
<th>Original Treatment (1921)</th>
<th>Plat</th>
<th>Number of Beets</th>
<th>Plat</th>
<th>Number of Beets</th>
<th>Total No. of Beets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray—1:200, frequent</td>
<td>1</td>
<td>*</td>
<td>11</td>
<td>109</td>
<td>218*</td>
</tr>
<tr>
<td>Spray—1:200, ½ frequent</td>
<td>2</td>
<td>70</td>
<td>12</td>
<td>72</td>
<td>142</td>
</tr>
<tr>
<td>Spray—1:400, frequent</td>
<td>3</td>
<td>110</td>
<td>13</td>
<td>95</td>
<td>205</td>
</tr>
<tr>
<td>Spray—1:100, frequent</td>
<td>4</td>
<td>143</td>
<td>14</td>
<td>97</td>
<td>240</td>
</tr>
<tr>
<td>Spray—1:200, delayed till bloom</td>
<td>5</td>
<td>95</td>
<td>15</td>
<td>93</td>
<td>188</td>
</tr>
<tr>
<td>Cultivation—shallow, frequent</td>
<td>6</td>
<td>147</td>
<td>16</td>
<td>118</td>
<td>265</td>
</tr>
<tr>
<td>Cultivation—shallow, ½ frequent</td>
<td>7</td>
<td>141</td>
<td>17</td>
<td>104</td>
<td>245</td>
</tr>
<tr>
<td>Deep plowing—then shallow</td>
<td>8</td>
<td>139</td>
<td>18</td>
<td>143</td>
<td>282</td>
</tr>
<tr>
<td>Shallow plowing—frequent</td>
<td>9</td>
<td>143</td>
<td>19</td>
<td>149</td>
<td>292</td>
</tr>
<tr>
<td>Smother—Russian sunflowers</td>
<td>10</td>
<td>116</td>
<td>20</td>
<td>106</td>
<td>222</td>
</tr>
</tbody>
</table>

*Plat 1, clean cultivated; total for treatment obtained by doubling the number on Plat 11.

Pastured by Hogs

The four plats (24, 25, 26, and 27) fenced for hogs had made considerable growth. Since the morning glory was not heavy there was about a half stand of sugar-beets that were good-sized by July 27 when three hogs were turned into Plat 24. The beginning of this test had been delayed 10 days longer than was anticipated due to difficulty in obtaining hogs. By August 13 Plat 24 was well rooted up and entirely bare. The gate between Plats 24 and 25 was opened and the hogs allowed access to both plats; as the hogs were growing and needed more feed, they more quickly cleaned Plat 25, tho there was the additional growth of 17 days on it. On August 22 they broke into Plat 26 and were allowed to remain as Plats 24 and 25 were bare and the rootstocks seemed to be well rooted out. On September 3 the hogs were let into Plat 27 and allowed access to all four plats. The growth on Plat 27 lasted only a few days, but the hogs were kept in the pasture till November 1 being kept alive by small amounts of barley grain. They became extremely thin and seemed to be ravendously hungry all the time, they rooted everywhere and
seemed to have made about as thoroly a job of rooting as possible. On October 1, when the digging for rootstocks was done on the large plats, similar diggings were also made on the four hog pasture plats. The results are shown in Table 7.

**Table 7. The Weight of Fresh and Air-Dry Rootstocks Found in 4 Square Feet on Hog-Pastured Plats**

<table>
<thead>
<tr>
<th>Plat</th>
<th>Treatment</th>
<th>Fresh (grams)</th>
<th>Air-Dry (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Hogs turned in July 27</td>
<td>40</td>
<td>8.1</td>
</tr>
<tr>
<td>25</td>
<td>Hogs turned in August 13</td>
<td>51</td>
<td>9.9</td>
</tr>
<tr>
<td>26</td>
<td>Hogs turned in August 22</td>
<td>34</td>
<td>9.4</td>
</tr>
<tr>
<td>27</td>
<td>Hogs turned in September 3</td>
<td>43</td>
<td>11.5</td>
</tr>
</tbody>
</table>

During the next season hogs were again pastured on the plats. There was considerable reduction in the stand as compared with a check plat, but the hogs seemed to reduce the rootstocks beyond a point at which about one-third or one-fourth of a full stand remained. During 1922 the growth of morning glory just about maintained itself, being as thick in the fall as in the spring.

**Fig. 8.** Rootstocks from 4 square feet.
- Plat 21—check; no treatment
- 22—weed killer, scalped
- 23—weed killer, growth sprayed
- 24—hog pasture—turned in July 27
- 25—hog pasture—turned in August 13
- 26—hog pasture—turned in August 22
- 27—hog pasture—turned in September 3
- 28—spray, crude oil
- 29—spray, kerosene
- 30—spray, salt brine
- 31—spray, kerosene
- 32—shade, building paper

**Chemical Sprays and Other Treatments**

Sprays of a much-advertised patent weed killer, crude oil, kerosene, salt brine, and gasoline, and building paper, for shade
were applied to small areas of morning glory on another piece of land—on the south edge of a new 6-acre field about 40 rods south of the Greenville Farm. The sprays were applied several times throughout the season but had no important effect, except gasoline and weed-killer, which weakened the weeds. The weed-killer had with it printed directions which said to scalp the surface of top growth before applying. A plat was divided and half of it scalped before applying the spray according to directions; on the other half, the spray was applied to the growing plants. Rootstocks were dug on October 1, at the same time for other treatments.

<p>| Table 8. Weight of Fresh and Air-Dry Rootstocks on 4 Square Feet of Chemical Spray and Paper-Covered Plats (1921) |
|-------------------------------------------------|-----------------------------|---------------------------|</p>
<table>
<thead>
<tr>
<th>Plat</th>
<th>Treatment</th>
<th>Weight of Rootstocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fresh</td>
</tr>
<tr>
<td>22</td>
<td>Weed-killer—scalped</td>
<td>132</td>
</tr>
<tr>
<td>23</td>
<td>Weed-killer—growth sprayed</td>
<td>14</td>
</tr>
<tr>
<td>28</td>
<td>Spray—crude oil</td>
<td>819</td>
</tr>
<tr>
<td>29</td>
<td>Spray—kerosene</td>
<td>281</td>
</tr>
<tr>
<td>30</td>
<td>Spray—salt brine</td>
<td>194</td>
</tr>
<tr>
<td>31</td>
<td>Spray—gasoline</td>
<td>108</td>
</tr>
<tr>
<td>32</td>
<td>Shade—building paper</td>
<td>99</td>
</tr>
</tbody>
</table>

During the second season Plat 21 (the check plat) was divided into several small plats, one-half of each being hoed clean or "scalped" just ahead of treatment with kerosene, gasoline, oil, salt brine, and weed killer. One part was covered with about four or five feet of well-rotted straw. This made a much more compact mass than would ordinary straw. The edges were hoed around to prevent plants thus exposed to light from feeding the rootstocks under the straw.

There has been no appreciable effect of any sort due to spraying with these chemicals, except "weed killer" which was found by chemical analysis to contain large quantities of sodium arsenite. This killed top growth and affected the plant generally in a manner almost identical to the sodium arsenite spray. The gasoline also killed the top growth temporarily each time applied. The straw, applied in midsummer, seemed to be effective until about midsummer the next season when shoots came thru and quickly made an almost complete covering of green leaves in about two weeks.

CORROBORATIVE TRIALS

Two flaws, or what seemed to them to be flaws, in the experiment have been pointed by different men who examined the plats or who have heard the data discussed. By some it was felt
that the weed studied in this experiment—hedge bindweed (*Convolvulus sepium*)—is a much easier weed to eradicate than is field bindweed (*Convolvulus arvensis*). The other objection urged against the experiment was that the water-table was too near the surface to permit roots or rootstocks to develop as deeply in the soil as they would on well-drained land. There seems to be little doubt as to the correctness of both statements but the inferences drawn need more careful analysis.

It is probably well-established that the large-leaved species (*C. sepium*) is somewhat less difficult to eradicate than is the small-leaved type (*C. arvensis*). Conceding this point does not in any way vitiate the results of the test, for corroborative trials with the small-leaved type indicate that its hold on the land is weakened by the same methods and about as quickly as is that of the large-leaved species.

In 1920 the Experiment Station bought a piece of land just north of the Greenville Farm. The field had in it one large spot and several small ones of the small-leaved morning glory, field bindweed (*Convolvulus arvensis*). No effort was made to determine the depth of root penetration on this land. Since, however, the water-table is about 100 feet below the surface (a well was driven about 15 rods away in 1923), there was
nothing to prevent full development of the root-system. In this field neither of the objections raised against the plats hold, and yet almost perfect eradication of the large spot in one season was accomplished by clean fallowing.

During 1920 the land sown to sugar-beets was farmed in usual manner, but very little was grown on the larger spot of morning glory. In 1921 this area, about one-fourth acre in size, was summer fallowed and cultivated with a beet cultivator as often as new growth started. No record was kept as to the number or frequency of cutting, but they were applied approximately once a week throughout the earlier part of the year, becoming less and less frequent towards autumn. That fall a seedbed was prepared and the land seeded to the rod-row winter wheat nursery for plant-breeding trials. The rows were one foot apart and hand-hoed during 1922. Some morning glory top growth appeared during June, but this was promptly cut off 3 or 4 inches below the surface. At intervals of a few days the grain rows were gone over and an occasional shoot of morning glory found and cut-off. During 1923 two plants only were found and these seemed to be seedling plants, possibly from seed that had lain dormant in the land since 1919 or 1920.

Several farmers in Davis County, and probably others elsewhere, have practically eradicated the small-leaved species by means of one summer fallow and frequent cutting. On one farm a fine crop of onions was grown in 1922, on land that had been fallowed and tilled in 1920 to remove a heavy infestation of "devil gut", as the small-leaved species is called in that locality.

In 1921 the field was sown to onions and cultivated frequently and hoed as often as any morning glory appeared. This land had been drained with clay-tile drain laid about 3 feet deep. W. J. Thayne, who is county agent in Davis County, reports that Mr. Willis Perkins of Woods Cross had completely cleaned a three-fourths acre patch by clean tillage for one summer and hoeing in intertilled crops for the next two summers. About 20 others in that county have reduced the stand to such an extent that successful crops are grown with only somewhat more care than would be required on uninfested land. In these cases as cutting has not been intense enough to annihilate, the danger of increase in stand always remains and does not permit the farmers to relax in vigilance. C. O. Stott, county agent in Sanpete County, reports that five farmers have cleaned their lands of heavy infestations. All report similar results where the farmer has done the cutting before any appreciable amount of green growth appeared.
On the other hand, occasional cutting has failed to give effective control. Farmers and gardeners abound everywhere who have cut off the top growth before it “amounted to anything”. This means anytime after the shoots are well up and green until they are 5 or 6 inches long. The small spots on the newly acquired land at the Experiment Station are still there for the same reason—negligence in cutting the top growth as soon as it appeared and to keep it so well cut as to prevent the development of green leaves.

During the last few months there have appeared two new publications on eradication of morning glory, both on the small-leaved species. Barnum⁸ has summarized the California data already cited and reiterates that cutting for one season will so reduce the roots by starvation that they can be completely eradicated by a reasonable amount of cultivation and hoeing.

Call and Gettys⁹ discuss the prevalence of bindweed (morning glory) in Kansas and say that it is limited to from one to fifty farms in each county and usually to small areas in each spot (that is, only a few square rods), but that in some parts tracts of 80 to 160 acres are occupied. Heavy salting of the land (20 to 28 tons of salt to the acre) killed most of the weeds but left the land useless for several years. At Fort Hays, Kansas, about 20 cultivations in a season, consisting of two or three plowings an occasional diskling, and frequent harrowing with spring tooth harrow killed 85 to 99 per cent of the plants. Eradication was completed in the second season by about a dozen treatments. No mention is made of growing a cultivated crop and hoeing in place of fallow and tillage during the second season. Close hog pasturing and a smoother crop of alfalfa, sorghum, or Sudan grass are recommended under conditions that warrant their use.

DISCUSSION

One of the principal difficulties encountered at the outset was to find a method of measuring progress toward eradication. It was not known that digging for rootstocks would serve adequately, but trial seemed to indicate that such was the case. On fallow land the possibility of digging in a nearly bare spot or in the heart of a heavy stand had to be considered. It was found that by digging tentatively here and there about the plat a representative spot could be approximated. Actual stands during the next season were used as a check on the amount of rootstocks

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in the soil. As may be seen by comparing Tables 3 and 4, there is an almost unexpected agreement between the weight of rootstocks gathered in October and the top growth the following June.

Notable throughout, also, was the lack of ability to kill on the part of spray, whether applied as soon as there was top growth or only to plants in bloom. Comparison of the top growth, both as to number of shoots and total weight produced, shows the sprays as such to be much less effective than tillage—at least of a comparable sort, that is, when frequent tillage is compared with frequent spraying and vigorous tillage with strong sprays. Frequent tillage not only reduced the rootstocks in quantity but left them in a watery condition. After being dried these rootstocks were very thin and apparently depleted of starch. On the plats grown to a smother crop of Russian sunflowers there remained only a few rootstocks, but these few seemed plump and unexhausted. A much heavier top growth during the succeeding spring from these plants than those frequently tilled indicates that the appearance of the rootstocks was a fair indication of the stage of food exhaustion.

It has been frequently maintained that deep cultivation was essential to eradication of such pests as morning glory. The smaller amount of rootstocks obtained by fall digging and less thrifty top growth of the next spring on the plats receiving shallow frequent tillage seems to indicate that if there be any appreciable difference between plowing and surface cutting, the advantage rests with the surface cutting. A similar condition seemed to show that shallow plowing was equally as effective as deep plowing, if not slightly more so. It was felt that plowing in addition to being more expensive might delay the process of starvation by burying pieces of rootstocks and possibly seeds which would germinate later when returned near enough to the surface. Everything seemed to indicate that eradication was hastened by that treatment which permitted most rapid growth and most rapid destruction of tops.
The acre-yields obtained during the second and the third season, the proportionate stand of beets in the third season, and the amount of hoeing required to save the beets all show the spray treatment to be much less effective than tillage or even a smother crop of Russian sunflowers.

The great proportion of the stand of morning glory remaining even after two seasons of spraying leads the authors to doubt that eradication can ever be accomplished by this method—at least in a reasonable time and with reasonable expense.

This same thing might be said of the hog pasture plats. There was a reduction to a point at which only about 8 or 10 per cent of the rootstocks remained, but there was no apparent decrease beyond this. Other plats which contained similar amounts of rootstocks at the end of the first season were made to grow a successful crop of sugar-beets. In this fact there seems to be the suggestion that while hog pasturing cannot, or at least frequently does not, completely destroy the rootstocks, it could be used as a method of reducing the stand to such an extent that a cultivated crop could be grown, thereby permitting a completion of the eradication process by careful intertillage and hand-hoeing.

Smother crops probably can be utilized in a somewhat similar manner. A strict analysis of the experimental data obtained in these tests does not permit them to be applied to another smother crop than Russian sunflowers. Kansas experience with sorghum and Sudan grass suggests that corn planted close in drilled rows might be used. Alfalfa was also suggested for Kansas where the areas were too large to permit applying the frequent shallow-tillage treatment. Midsummer sowing of alfalfa on cleanly tilled land was advocated in order to obtain a full stand of alfalfa.

Various shading treatments such as covering with straw and covering with building paper were not found effective. Shoots came thru four feet of straw and developed green leaves. They also showed unexpected ability to spread horizontally but were not allowed to do this, the outside edges of the straw being kept clean by frequent hoeings. The same general result was obtained with building paper. The edges were kept clean by hoeing, but the paper was penetrated here and there in various ways. Irrigation water seemed especially likely to weaken the paper. Tar paper was not used in this case, but heavy building paper was given every chance possible save that it was allowed to come in contact with irrigation water. It was felt that this was a test it must stand on most of our infested land, for irrigation was likely to be necessary to maintain crop growth.
There is no doubt that heavy salting or that saturating the soil with thick oil or solutions containing sodium arsenite will kill not only morning glory but other plants as well. The difficulty with this method is that no plants will grow for several years after such applications, on which account it is practical only for tennis courts, roadways, yards, waste land, or at least for land not required to grow plants. Since this study related only to agricultural land, and since the salting or saturating of the soil with oil or poison was known to be effective, these treatments were not used with "weed killer" which was found to be effective. Sprays of salt solutions, of kerosene, of gasoline, and of oil were tried, but with the exception of gasoline were found to be almost entirely without effect.

Carbon bisulfid (C$_2$S) has been advocated but not tried in this test. A. E. Smith, county agent of Juab County, tried it but obtained no results even tho he followed directions with great care. Small quantities of the liquid were placed in holes which were later filled and tramped.

Finally, it must be kept in mind that sodium arsenite is soluble and therefore active as a stomach poison. Several cases have been reported where farm animals have died from eating sprayed plants. In Salt Lake County in about 1917, 1918, and 1919, there was considerable spraying of weeds of all sorts along railroad rights-of-way, canal banks, streets, and vacant city lots. It was reported that animals showed a preference for sprayed plants. No attempt has been made to verify either this increased palatability due to spraying or the killing of the animals. Veterinarians say, however, that there is little doubt as to the killing of the animals. This danger from spraying with sodium arsenite, added to its lack of efficiency as a method of eradicating morning glory, suggests at least that it be used only after careful consideration.

Fence lines, road-ways and ditch banks may warrant the use of spray, but the consequent danger must not be ignored.

CONCLUSIONS AND RECOMMENDATIONS

Several conclusions seem warranted by the results of this experiment.

When tillage treatment was begun with a season of fallow, it was much more effective than spray. It reduced the stand of weeds to a greater extent, and more rapidly. On small plats tillage was found to be less expensive than spray. On large areas the spray would be cheaper, but since tillage need not be pro-
hibitive for agricultural land it is recommended in preference to spray.

It is clearly shown by these tests that frequent treatment, either spray or tillage, is considerably more efficient than are less frequent treatments. It is recommended that tillage be applied just before top growth shows, or at latest, immediately afterward. Waiting 5 or 6 days after the first new shoots appeared was found to be only about half as injurious to morning glory as immediate cutting. Longer delays seemed practically to nullify the value of treatment.

Neither deep nor shallow plowing seemed any better than shallow cutting. What difference there was favored shallow tillage. Plowing costs about 5 times as much as cutting with beet-cultivator knives or with a blade cutter. One man and two horses can plow two acres or can cut 10 acres in a day. Deep plowing was a trifle less efficient than shallow plowing. Clean fallow of infested spots and shallow frequent cutting are recommended.

Gasoline, kerosene, oil, salt, and "weed killers" are not recommended except on land that has no agricultural value. Only the soil-saturation method is effective.

Smothering with Russian sunflowers was effective up to about 85 per cent. In Kansas sorghum and Sudan grass have helped. Alfalfa is reported in Kansas about 50 to 90 per cent effective where it gets a good start. This method is not recommended unless clean tillage is impractical. When smother crops are to be used, clean tillage should precede sowing so as to insure a good stand of the smother crop. In the case of alfalfa, either very early spring seeding or midsummer seeding after thorough tillage promises best. Midsummer sowing is best but requires late water which is not available in some areas of heaviest infestation.

Where whole farms are occupied with morning glory, clean tillage of 10 to 25 per cent of the area seems warranted with the remaining land partly in smother crop and partly in intertilled crops. After this method has run a season, the intertilled crop that comes after a frequently tilled fallow can be vigorously cultivated to keep down the weakened top growth. A regular system of summer fallow and thorough frequent cutting should go gradually over the whole farm, thereby permitting eradication to be completed.

Shading with straw, manure, or building paper is not recommended except in exceedingly rare cases.

Hog pasturing seems effective only in part. Rootstocks may be reduced to about the stage where a coarse cultivation crop
can be grown. This treatment is not recommended except as a beginning, and not then if clean tillage is at all possible.

The process of eradication seems to be essentially one of starvation by exhaustion of the food supply in the rootstocks and roots. During the process of clean tillage growth should be encouraged by irrigation or other necessary means. The stored food supply will give rise to just so much top growth and no more. The sooner, therefore, that this amount of growth can be cut off just before it emerges the sooner the job is done. Remaining idle thru a period of drouth serves only to delay the process as it in no wise reduces the stored food supply.

A few seed may remain in the soil and germinate when the land seems otherwise clean. It may be that an occasional shoot may arise from a piece of root or rootstock that had been buried too deep or that had been kept too dry. It is recommended that occasional plants on otherwise clean ground be dug up in entirety and burned. Throwing on waste land roadsides may result in new spots which will serve as sources of later spread.

Finally, eradication is difficult but not impossible in any sense of the word. Small beginning spots should be ferreted out and pounced on with all the vigor of an aroused community. Vigilance and thoroness are the only safe remedies. There are no substitutes—nothing "just as good".

SUMMARY

Since there was no clear-cut evidence as how best to kill morning glory in the interior Rocky Mountain region, a somewhat thoro test was begun in 1920. This test involved five spray treatments, five tillage treatments, and an untreated check plat. Strong and weak spray solutions of sodium arsenite were applied at frequent and infrequent intervals, and at much prolonged intervals, that is, not till the plants had reached full bloom. The tillage treatments consisted of frequent and infrequent shallow cutting, shallow frequent plowing, and deep plowing. Smothering with Russian sunflowers, hog pasturing, shading with straw and building paper, and sprays of salt brine, oil, kerosene, gasoline, and a commercial "weed killer" were all given a preliminary trial.

Effectiveness of the different treatments was measured by the amount of rootstocks left in the soil at the end of the season, by the amount of top growth the following spring, and by the ease and success with which sugar-beets were grown the first and second years after treatment. Relative cost of treatment and the relative amount of hoeing required to permit the growing of
a crop of sugar-beets the season after treatment are both noted briefly.

The conclusions reached are:

(1) Tillage is more effective than spray.
(2) Frequent tillage is required.
(3) No top growth may be allowed safely.
(4) Shallow tillage is as good as deep and is less expensive.
(5) Russian sunflowers destroyed about nine-tenths of morning glory. Corn was not nearly so effective.
(6) Hog pasturing destroyed about three-fourths of the stand.
(7) Shading with four feet of straw or with heavy building paper was not effective.
(8) Control—even eradication—of morning glory is possible.

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