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Control of leafy spurge, Euphorbia Esula L.

A. L. Bakke
Iowa State College

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Control of Leafy Spurge, *Euphorbia Esula* L.

**By A. L. Bakke**

**AGRICULTURAL EXPERIMENT STATION**  
**IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS**

**R. E. Buchanan, Director**

**BOTANY AND PLANT PATHOLOGY SECTION**

AMES, IOWA
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Sodium chlorate has proved the most effective herbicide for the eradication of leafy spurge. The following formula is effective when applied as a spray: Sodium chlorate, 1 pound; animal glue, 4 grams; sulfuric acid, 3 cubic centimeters; water, 1 gallon.

The best kill was obtained when the chlorate solution was sprayed on actively growing plants in full foliage.

In northwestern Iowa, sodium chlorate sprayed on the aerial parts has given better and more consistent results than when applied dry, directly to the soil.

The highest percentage of kill of leafy spurge through sodium chlorate was produced when the spray was applied the latter part of May or when the plant was about to come into blossom. The second spray, applied the latter part of August or before killing frost, usually completed the eradication of leafy spurge.

Sodium chlorate has proved more effective in killing leafy spurge when treated in small grain or millet than where growing alone.

Leafy spurge was eliminated in a large pasture by spraying with sodium chlorate, the first application being made the latter part of May and the second the latter part of August.

Pound for pound, the old Atlacide on the market in 1930-33 apparently was not as effective in killing leafy spurge as sodium chlorate.

Dilute sulfuric acid and C.-K. (creosote-kerosene) killed the tops of leafy spurge with little injury to the roots.

Heavy applications of ammonium thiocyanate may prove valuable as a herbicide for leafy spurge.

Potassium chlorate was about as effective in eradicating leafy spurge as sodium chlorate. Residual soil effect was greater for potassium chlorate than for sodium chlorate.

To insure complete elimination of leafy spurge by spraying with sodium chlorate, 2 years are necessary. Two applications the first year will destroy most of the spurge. Remaining plants must be given two treatments the second year.

Kainite, a fertilizer, will exterminate leafy spurge when heavy applications are made.
Applications of well rotted manure (3 tons to the square rod) were effective against leafy spurge. Straw had no effect.

Plowing leafy spurge deeply (7-8 inches) in the fall and again in the spring materially reduced the amount of leafy spurge.

Millet, sorghum and soybeans drilled in heavily about the middle of June after the ground had been plowed and fallowed proved to be good crops for infested areas of leafy spurge. Reduction in leafy spurge population is greater if the land is plowed the preceding fall and again the following spring, and cultivated until the smother crop is planted.

Fallowing for 2 years, by cultivating 30 times each year from June 1 until Oct. 1, completely destroyed leafy spurge.

A program of eradication with growing competitive crops may be shortened by giving leafy spurge one application of sodium chlorate the previous fall, shortly before killing frost.

Leafy spurge population in corn was not reduced by four cultivations. Surface cultivation in corn following regular cultivation did not prove to be an effective procedure in eradicating leafy spurge.

Alfalfa did not compete successfully with leafy spurge.

Alfalfa was tolerant to sodium chlorate and may be used on ground where the leafy spurge has been killed with sodium chlorate or Atlacide. Barley was sensitive to sodium chlorate in the soil; soybeans are less tolerant than barley or oats.
Control of Leafy Spurge,
Euphorbia Esula L.

By A. L. Bakke

Control of perennial weeds, such as leafy spurge (Euphorbia Esula L.), constitutes a serious problem on many Iowa farms. Little experimental data on control through eradication have been published. Methods of control may be placed in two categories: 1. Herbicides, and 2. cultural practices. Herbicides were introduced into weed control methods when Bolley (10) of North Dakota treated annual weeds with iron sulfate. In 1911, Rebate (27) in France, and Korsmo (22) in Norway used sulfuric acid to destroy weeds. Gray (17) employed a spray solution of sodium arsenite in combating the spread of European bindweed (Convolvulus arvensis L.). Recently Crafts (14) has recommended the “acid arsenical” method for certain perennial weeds such as the European bindweed and Russian knapweed (Centaurea repens L.). After Aslander in 1926 showed the effectiveness of sodium chlorate in killing Canada thistle, (Cirsium arvense (L.) Scop.), this material came into general use as a herbicide for perennial weeds. Rogers (28) has recommended carbon disulfide. Harvey (18) has found that ammonium thiocyanate is a satisfactory herbicide. Other chemicals (25) such as sodium chloride, copper sulfate, zinc sulfate and various petroleum oils have been used in killing weeds.

Intensive cultivation is one of the oldest and most widely practiced methods of weed eradication. In the growing of most intertilled crops, cultivation is of minor importance except to eliminate weeds (16). Such crops as millet, cane and alfalfa compete with weeds for soil moisture, nutrients and light (33). Control of weeds through grazing is effective when new growth is continually grazed off so that it finally exhausts stored material in the underground parts.

1Project 304, of the Iowa Agricultural Experiment Station.
2Thanks are due Mr. Walter Scott of Hawarden on whose farm much of the experimental work was done. He not only allowed free use of all the land desired, but furnished the equipment necessary to perform much of the work. Mr. Sherman French of Hawarden was kind enough to provide a building for conducting the laboratory experiments and housing the supplies and equipment. The Board of Education extended the facilities of its science laboratories, and the Hawarden City Council provided a room in the City Hall. Mr. Rex B. Conn, Mr. H. C. Asberg and Mr. H. S. Nicol, county agricultural agents of Sioux County since 1930, have given material assistance in conducting the experimental work involved in the studies on the control of leafy spurge. During the seasons of 1932 and 1934, Mr. Ben C. Helmick assisted with the experimental work up to the time of his death, Sept. 5, 1934.
3The author is grateful to Dr. I. E. Melhus for his interest in the work and his help in preparing the manuscript.
Comparatively little work has been done on the control of leafy spurge, a serious pest particularly on the Missouri loess soils of northwestern Iowa. Studies reported in this bulletin deal chiefly with the leafy spurge problem in that part of the state. The purpose of this investigation was to determine, by chemical and cultural methods, effective means of eradicating leafy spurge on farm lands.

MATERIALS AND METHODS

Experimental work reported in this bulletin was conducted on the Walter Scott farm of 240 acres about 4 miles northeast of Hawarden in Sioux County. The farm is gently rolling, and some portions of it are subject to erosion. A fairly deep ditch traverses the center of the farm and another crosses the pasture. The rotation practiced has usually been 2 years of corn and 1 of small grain. Although approximately 40 acres of alfalfa are grown each year, no regular rotation with alfalfa has been practiced. The state of fertility of much of the farm is rather low. There were about 60 acres of leafy spurge on the farm in patches ranging from a few plants to 12 acres.

The area selected for the experiments was located in the central part of the farm where the noxious weed infestation was heavier and more uniform than on any other part of the farm. Eradication and control of leafy spurge were largely confined to this area. The herbicidal experiments upon leafy spurge, 71 1-square-rod plots, were in corn or planted to corn during 1930-32. The ground received the usual preparation incidental to the planting of corn. Each plot the first 2 years was separated from the adjoining plot by a border row 3½ feet wide. The border rows were kept clean by hoeing in 1930 and 1931, but in 1932 the treatments were extended to include one-half the border row.

Six herbicides were used in the leafy spurge eradication experiments during 1930-32: 1930, sodium chlorate, Atlacide, C.-K. (10-90) and sulfuric acid; 1931, sodium chlorate, Atlacide, C.-K., sulfuric acid and ammonium thiocyanate; 1932, sodium chlorate, Atlacide, C.-K., sulfuric acid, ammonium thiocyanate and potassium chlorate. Weeds in the square rod plots were sprayed with the aid of a wheelbarrow spray pump and the larger areas with a power sprayer. Concentration of the solutions used is given in the experimental part of this publication.

It was realized from the outset that chemicals would be too expensive to use in eradicating leafy spurge on large areas. A number of cultural experiments involving cultivation, double plowing and fallowing were consequently inaugurated. Cropping infested ground with millet, sudan grass, soybeans and
alfalfa was also tested. Large quantities of barnyard manure and of kainite were used on certain plots. Grazing experiments with sheep and hogs were a part of the eradication program.

EXPERIMENTAL RESULTS

HERBICIDAL TREATMENTS

SODIUM CHLORATE

Sodium chlorate has been used extensively as a herbicide since 1926 (4). Latshaw and Zahnley (23), Schafer, Lee and Neller (30) and Hulburt, Bristol and Benjamin (20) have demonstrated the value of sodium chlorate in destroying such weeds as the European bindweed. Arny (1) and Barnett and Hanson (8) have recommended sodium chlorate as practical in killing small areas of leafy spurge.

SPRAY

Nineteen 1-square-rod plots with varying degrees of leafy spurge infestation were sprayed with sodium chlorate during 1930-32. Results have been tabulated in table 1.

Leafy spurge in plots 84, 96, 97 and 98 was given two sprays in 1930. In June, 1931, the number of plants varied from two to "scattered." Spraying the surviving plants twice in 1931 and in 1932 along with the preparation of the ground for the seeding of alfalfa the following August killed the remaining plants. It was found that the "heavy" infestation of leafy spurge was as readily eradicated as the "light" infestation.

Plot 44 was given three treatments of sodium chlorate in 1930, two in the form of a spray and the third by distributing the dry salt over the soil surface. In 1931 only three plants survived.

Plots 147 and 212 were sprayed once in 1931 and once in 1932. The cultivation incident to seeding of barley and alfalfa in 1933 completed the extermination of the spurge.

Eleven of the twelve plots, 326, 327, 328, 330, 331, 332, 333, 334, 335, 336, 337 and 339, were heavily infested with leafy spurge. In 1932 they were sprayed in August and in October. Plot 337 had "some" leafy spurge. In all cases, the spurge population was reduced to "few" the next year. By spraying the few plants remaining the second year, the plots were cleaned.

Plots 327, 328, 330 and 331 were seeded to buckwheat in 1934. Plants grew poorly, and many of the leaves became yellow and dropped off the stem. Sudan grass seeded on plots 332-339 grew much better than the buckwheat.
TABLE 1. THE RECORD OF THE EXPERIMENT OF SPRAYING SODIUM CHLORATE* UPON LEAFY SPURGE.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>1930 Treatment</th>
<th>Amount of spurge**</th>
<th>1931 Treatment</th>
<th>Amount of spurge</th>
<th>1932 Treatment</th>
<th>Amount of spurge</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>NaClO₃(2)**</td>
<td>heavy light</td>
<td>Hoed (4)</td>
<td>scattered</td>
<td>NaClO₃(2)</td>
<td>2 seedlings</td>
</tr>
<tr>
<td>84</td>
<td>(2) dry</td>
<td>heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>(2) light</td>
<td>heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>(2) scattered</td>
<td>heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>98</td>
<td>(2) heavy</td>
<td>scattered</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Check</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>147</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>212</td>
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</tr>
<tr>
<td>326</td>
<td>NaClO₃(2)</td>
<td>light</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>327</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>328</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>330</td>
<td>(2) heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>331</td>
<td>(2) heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>332</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>333</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>334</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>335</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>336</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>337</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>339</td>
<td>(2)† heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Check</td>
<td></td>
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</tr>
</tbody>
</table>

*The usual concentration of the sodium chlorate spray solution is made by dissolving 1 pound of sodium chlorate in 1 gallon of water. The amount of spray used is such as to make the leaves dripping wet. A heavy infestation of leafy spurge will require from 2½ to 3 gallons of spray to the square rod.

After 1931 the regular sodium chlorate spray was made by dissolving 1 pound of sodium chlorate in 1 gallon of water. To such gallon of solution, 4 grams of powdered animal glue (Armour 2 C) and 3 c.c. of sulfuric acid were added. The glue is made into a uniform paste by thorough stirring with a small amount of water. It is later diluted with hot water.

**When the exact number of plants is not given the following terms are used: Heavy, ground covered; light, ground partially covered; medium, between heavy and light; some, more than 50 plants per square rod; scattered, between 25 and 50 plants per square rod; few, less than 25 plants per square rod.

***The number placed in parentheses shows that the spurge was given that many treatments; where no number is present, it is understood that only one treatment was made.

†—Acid added—no glue.
††—Glue added—no acid.

Two applications of sodium chlorate in one season killed nearly all the leafy spurge. Only in exceptional cases were all the plants killed. Extermination of the few that remained required two applications the following year.

The greatest reduction in the leafy spurge population took place after the first spray application. Plots 44, 97, 327, 332 and 339 did not show any leafy spurge at the time of the second applications, but as there was considerable European bindweed, the plots were sprayed. Leafy spurge of plots 84, 328, 330,
333, 334 and 335 was reduced from "heavy" to "few." Plots 331, 333, 334 and 335 had a heavy infestation on Aug. 19 and 20, 1932. By Oct. 4 of that year "some" spurge was present. Plots 336 and 337, "heavy" when the first spray was applied, showed "scattered" leafy spurge at the time of the second spray.

SPRAYING LEAFY SPURGE IN SMALL GRAIN

In 1930 leafy spurge growing in small grain was as a rule taller, more vigorous, had larger leaves, blossomed later and was more succulent than the plants growing in corn fields, pastures and in fence rows. The more succulent tissue of the leafy spurge was apparently a response to a decreased evaporating environment. Sodium chlorate applied in the form of a spray would then be retained on the leaf and stem surfaces for a longer time. If all the aerial surface was thoroughly wetted in spraying, the increased leaf surface should make for increased absorption. To determine the validity of this supposition, 13 leafy spurge areas in oats and barley, varying from 2 square rods to 1/2 acre, were sprayed in 1931. Concentration of the sodium chlorate spray was 1 pound per gallon of water, and the spray was applied so that all of the vegetation was thoroughly wetted. The sprays were applied on June 8 and 9 and on Aug. 28. On Oct. 16 the sprayed areas were practically devoid of plant growth. Less than 1 percent of leafy spurge appeared the second year. In 1932 the ground was again in small grain. To exterminate the remaining spurge plants, two sodium chlorate sprays were used at about the same time as on the previous year. The oats, however, did not grow on the ground which had been sprayed the year before. No residual chlorate effect on the soil was evidenced in 1933 when corn was grown.

SPRAYING LEAFY SPURGE GROWING IN PASTURES

Beginning the last week in May and extending through a portion of the first week in June, 1933, about 10 acres of leafy spurge growing in the pasture on the Scott farm were sprayed with sodium chlorate. During the third week in August, the second application was made. In 1934 this pasture, heavily infested with leafy spurge, was practically free of this weed. The bluegrass did not appear to have been materially affected. Many of the fence rows were cleared of leafy spurge through two spray applications of sodium chlorate in one season. The first spraying was made the latter part of May or the early part of June and the second some time before killing frost.

Spraying in the latter part of May or early June of leafy spurge growing in small grain and in pasture land has been done a number of times since 1931, all with consistent results.
Leafy spurge growing in small grain, brome grass, alfalfa or other vegetation has been practically eliminated in one season by two spray applications of sodium chlorate.

**ADDITION OF GLUE AND SULFURIC ACID TO SODIUM CHLORATE SPRAY SOLUTIONS**

Some attention has been given to increasing the toxicity of sodium chlorate solutions, either by chemical means or by enhancing the physical contact between leaf surface and the spray solution. Offord and Urbal (26) found that sodium chlorate is decreasingly toxic to *Nitella* at pH values of 4.8, 5.2, 5.8, 6.6, 7.4 and 8.2. Crafts (12) has obtained better results with acidified sodium chlorate solutions. It is known that Atlacide contains a small amount of glue. The efficiency of a sodium chlorate solution might be increased by adding glue and sulfuric acid to the solution.

In 1931 a preliminary test was made on the leafy spurge in plot 212, which had a heavy infestation. On Aug. 31, the plants were sprayed with a 12 percent solution to which the glue and the sulfuric acid had been added. In 1932, as a result of the one spray, there were only a "few" leafy spurge. The plot was hoed twice in 1932 and, about 3 weeks after the second hoeing, was sprayed again with the same mixture. No spurge has been found since August, 1932. Barley, seeded on the plot in 1933, developed fairly well. Plot 147, treated with acidified sodium chlorate in 1931, was given two applications of sodium chlorate containing the acid and glue in 1932. Barley seeded in 1933 did not develop satisfactorily.

In 1932 good results were obtained in the extermination of leafy spurge from two sodium chlorate sprays applied in August and October. The leafy spurge in plots 326, 330 and 331 ranged from 0 to "few" in 1933. Plot 326, however, had a light infestation of leafy spurge when the first spray was applied. Plots 327, 328, 332 and 333 were given two sprays with acidified sodium chlorate. The number of spurge plants ranged from one to "few" the next year. Plots 334, 335, 336, 337 and 339, sprayed with sodium chlorate with only glue added, had, respectively, four, two, three, four, and four leafy spurge plants the year after spraying.

The number of leafy spurge plots tested with acid and glue was not sufficient in themselves to justify the addition of these materials to sodium chlorate spray. But if the results obtained from spraying plots 327, 328, 332, 333, 334, 335, 336, 337 and 339 are compared to those from plots 84-98 it is seen that the reduction in the leafy spurge population was such, when acid or glue
was added, as to make it unnecessary to spray the second year. The few remaining plants could have been exterminated through cultivation.

EFFECT OF GLUE ON TRANSPERSION

In spraying the leafy spurge on plot 212, it was noticed that the sodium chlorate solution to which the glue was added did not collect in drops on the leaf surface to as great an extent as when the glue was absent. As a result, a greater film covering would have to take place. This in turn would reduce transpiration. To determine whether reduced transpiration takes place, three series of experiments were made in 1932.

Wild sunflowers, growing along the ditch bank near the field laboratory, were cut off under water and transferred into 1-liter Erlenmeyer flasks, filled with water. A hole was bored through each of the cork stoppers of such size that, when inserted in the opening of the flask, each stopper fitted firmly about the stem of the sunflower plant. All openings were sealed with a paraffin-wax mixture. The plants were placed in the open and allowed to remain there for an hour before they were sprayed.

Three plants were sprayed with sodium chlorate solution of a concentration of 1 pound per gallon; three plants were sprayed with the same concentration of sodium chlorate with glue added; three plants were used as controls. Plants were weighed at hourly intervals throughout the day. On the basis of a square meter of leaf surface, the average transpiration for the period was as follows: Sodium chlorate plus glue (4 grams per gallon of solution), 206 grams; sodium chlorate, 243 grams; control, 284 grams. This indicates that the sodium chlorate spray retarded the transpiration of sunflower plants, but the effect was more marked when glue was added.

DRY SODIUM CHLORATE

If sodium chlorate, in a dry state, could be applied directly to the soil and be as effective as the spray, many advantages would accrue to the farmer. It would make spray machinery unnecessary, reduce the cost of application and reduce the fire hazard. Some effort already has been made in this direction. Aslander (4) and Loomis, Smith, Bissey and Arnold (24) report that applications of the dry salt were effective against Canada thistle. Kiesselbach, Petersen and Burr (21) found that the dry salt materially reduced the population of European bindweed when applied with a grain drill at the rate of 400 pounds per acre. Killing action of the dry salt was equal to the chlorate in solution. Lack of evidence bearing on the use of the dry salt as a leafy spurge herbicide led to trials in 1930-34.
Plot 10, dressed with three applications of dry sodium chlorate at the rate of 4 pounds to the square rod, did not show any appreciable spurge reduction throughout the 1930 season. On July 19 of the following year, there were still “some” leafy spurge and on Sept. 8, a “few” plants occupied the plot. The two sodium chlorate sprayings in 1932 killed the remaining plants. A heavy infestation of leafy spurge was present on plot 86 in 1931 after having 2, 1½-pound treatments of the dry sodium chlorate, on Aug. 26 and on Sept. 18. Spraying the spurge with a 10 percent solution of sulfuric acid and with sodium chlorate reduced the number of plants to “scattered.”

Plots 347, 348, 361 and 362 were each treated with 2 pounds of the dry sodium chlorate during the early part of October, 1932. In 1933 the plots were sprayed twice with sodium chlorate of the usual concentration before the leafy spurge was eliminated.

Results obtained from using the dry sodium chlorate to eradicate leafy spurge have not been as consistent as when the sodium chlorate was used as a spray. The dry sodium chlorate, distributed over the soil surface, must come into solution before it can percolate into the soil and come in contact with the underground parts of the plant. To have the sodium chlorate go into solution there must be sufficient soil moisture. It is known, too, that sodium chlorate, exposed to high temperatures, will decompose.

During the summer of 1930, temperatures were rather high, but rainfall was fairly well distributed, except for the month of July. There was a heavy rain on June 25; on Aug. 18, 1.75

TABLE 2. THE RECORD OF AN EXPERIMENT WITH DRY SODIUM CHLORATE.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>1930 Treatment</th>
<th>Amount of spurge</th>
<th>1931 Treatment</th>
<th>Amount of spurge</th>
<th>1932 Treatment</th>
<th>Amount of spurge</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>NaClO₃(dry)(3)</td>
<td>some</td>
<td>Hoed (5)</td>
<td>few</td>
<td>NaClO₃(spray)(2)</td>
<td>scattered</td>
</tr>
<tr>
<td>86</td>
<td>NaClO₃(dry)(2)</td>
<td>heavy</td>
<td>Na₂SO₄</td>
<td>heavy</td>
<td>NaClO₃(spray)(2)</td>
<td>scattered</td>
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<td>heavy</td>
<td>--</td>
<td>heavy</td>
<td>--</td>
<td>heavy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>1932 Treatment</th>
<th>1933 Treatment</th>
<th>1934 Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>347</td>
<td>NaClO₃(dry)</td>
<td>NaClO₃(spray)(2)</td>
<td>millet*, alfalfa</td>
</tr>
<tr>
<td>348</td>
<td>NaClO₃(dry)</td>
<td>NaClO₃(spray)(2)</td>
<td>millet alfalfa</td>
</tr>
<tr>
<td>361</td>
<td>NaClO₃(dry)</td>
<td>NaClO₃(spray)(2)</td>
<td>cane, alfalfa</td>
</tr>
<tr>
<td>362</td>
<td>NaClO₃(dry)</td>
<td>NaClO₃(spray) scattered</td>
<td>soybeans**, alfalfa</td>
</tr>
<tr>
<td>Check</td>
<td>-- medium</td>
<td>-- heavy</td>
<td>sudan, few</td>
</tr>
</tbody>
</table>

*Millet and alfalfa in plots 347-361 poor.
**Soybeans very poor.
inches fell. There was a heavy rain on Aug. 30 and a fairly heavy rain on Sept. 6. Plot 10 was treated on June 28, July 9 and Aug. 12, while the sodium chlorate was distributed over plot 86 on Aug. 26 and Sept. 18.

In 1932 the dry sodium chlorate was added during the early part of October. The next year the amount of leafy spurge varied from “few” to “some.” When there is a deficiency in rainfall, the dry sodium chlorate is not able to percolate into the soil. If the dry sodium chlorate were inserted into the ground of the infested leafy spurge area with a grain drill, or directly in the plow furrow, more consistent results might be obtained.

**ATLACIDE**

Herbicidal action of the commercial product “Atlacide” on leafy spurge was studied. Material used from 1930-1932 contained, in addition to sodium chlorate, principally calcium chloride. Calcium chloride, a hygroscopic salt, was used to reduce the fire hazard. Concentration of the Atlacide solution, unless otherwise stated, was the same as of sodium chlorate—1 pound per gallon of water. Eight plots were treated in 1930 and two in 1931. Plots 87 and 92 were each given two dry treatments in 1930. Data have been summarized in table 3.

The 1930 plots sprayed once and those sprayed twice with Atlacide showed leafy spurge infestations in 1931 ranging from “few” to “some” in all cases except plot 58, where two sprays killed all the spurge in one season. After two applications of Atlacide sprays in 1931, there was still enough leafy spurge for reinestation in 1932. Cultivation incident to seeding of alfalfa in 1933 completed the eradication.

The two spray applications of Atlacide given plots 140 and 141 in 1931 and 1932 reduced the vigor and number of leafy spurge so that it was possible to eliminate the remaining plants with alfalfa.

Dry Atlacide treatments in 1930 used on plots 87 and 92 reduced the number of leafy spurge from “heavy” to “some.” The Atlacide spray and the one sulfuric acid (10 percent) treatment given plot 87 in 1931 apparently did not have much effect as “some” spurge was found on July 31 of that year. Two sprayings of sodium chlorate in 1932 eliminated the remaining spurge plants. Alfalfa seeded in August, 1933, was in good condition at the time the last readings were made.

Two dry Atlacide applications given plot 92 reduced the heavy spurge population to “some,” while two Atlacide sprays in 1931 cut the number of spurge to four. One sodium chlorate spray and the cultivation necessary to seed alfalfa killed the remaining four plants.
**TABLE 3. THE RECORD OF AN EXPERIMENT ON APPLYING ATLACIDE TO LEAFY SPURGE.**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>1930 Treatment</th>
<th>Amount of spurge</th>
<th>1931 Treatment</th>
<th>Amount of spurge</th>
<th>1932 Treatment</th>
<th>Amount of spurge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spraying</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spray</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Atlacide</td>
<td>some</td>
<td>NaClO₃(2)</td>
<td>some</td>
<td>NaClO₃(2)</td>
<td>13</td>
</tr>
<tr>
<td>58</td>
<td>Atlacide</td>
<td>heavy</td>
<td>NaClO₃(2)</td>
<td>0</td>
<td>NaClO₃(2)</td>
<td>1</td>
</tr>
<tr>
<td>59</td>
<td>Atlacide</td>
<td>light</td>
<td>NaClO₃(2)</td>
<td>scattered</td>
<td>NaClO₃(2)</td>
<td>30</td>
</tr>
<tr>
<td>88</td>
<td>Atlacide (2)</td>
<td>heavy</td>
<td>NaClO₃(2) H₂SO₄ (10%)</td>
<td>some</td>
<td>NaClO₃(2)</td>
<td>12</td>
</tr>
<tr>
<td>89</td>
<td>Atlacide (2)</td>
<td>heavy</td>
<td>NaClO₃(2) H₂SO₄ (10%)</td>
<td>some</td>
<td>NaClO₃(2)</td>
<td>some</td>
</tr>
<tr>
<td>91</td>
<td>Atlacide (2)</td>
<td>some</td>
<td>Atlacide</td>
<td>light</td>
<td>NaClO₃(2)</td>
<td>few</td>
</tr>
<tr>
<td>95</td>
<td>Atlacide</td>
<td>heavy</td>
<td>Atlacide NaClO₃</td>
<td>some</td>
<td>NaClO₃(2)</td>
<td>6</td>
</tr>
<tr>
<td>102</td>
<td>Atlacide</td>
<td>heavy</td>
<td>Atlacide</td>
<td>few</td>
<td>NaClO₃(2)</td>
<td>2</td>
</tr>
<tr>
<td>Check</td>
<td>……</td>
<td>heavy</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>heavy</td>
</tr>
<tr>
<td>140</td>
<td>……</td>
<td>heavy</td>
<td>……</td>
<td>……</td>
<td>……</td>
<td>scattered</td>
</tr>
<tr>
<td>141</td>
<td>……</td>
<td>……</td>
<td>……</td>
<td>……</td>
<td>……</td>
<td>21</td>
</tr>
</tbody>
</table>

**Spraying Leafy Spurge Growing in Small Grain with Atlacide**

It is not possible to make an accurate comparison of the effectiveness of sodium chlorate and Atlacide in the destruction of leafy spurge as there was not a sufficiently large number of plots treated in the same way (tables 1, 2 and 3). In August, 1933, all the plots treated with sodium chlorate and with Atlacide were seeded to alfalfa. No leafy spurge has been found in these plots since 1932.

**Spraying Leafy Spurge Growing in Small Grain with Atlacide**

In 1931 Atlacide was applied on five different leafy spurge areas in barley and oats, ranging in size from 5 square feet to 1/4 acre. Spray was applied on June 9, 1931, with a power sprayer, the same as that used for the sodium chlorate spray. Spray was applied so that all the aerial parts were wetted. The second spray was made on Aug. 28. On Oct. 16 approximately 80 percent of the leafy spurge was killed. Oats were seeded on the area in 1932 but soon became yellow and died, leaving the ground
bare. Leafy spurge surviving the Atlacide treatment in 1931 was sprayed twice in 1932. No leafy spurge was found in 1933 and 1934.

Results obtained from spraying leafy spurge growing in small grain showed that it was possible to exterminate the weed by two sprayings for two seasons. Data are not sufficient nor accurate enough, however, to conclude that sodium chlorate is a better herbicide for leafy spurge than Atlacide.

**CREOSOTE-KEROSENE**

The solution "C.-K." (creosote, 10 parts, kerosene, 90 parts) has been used along railroad rights-of-way. Leafy spurge of plots 33, 63, 65, 73, 107 and 118 was sprayed with C.-K. (10-90) in 1930, at a rate varying between 250 to 500 gallons per acre. Tops were killed shortly after the spray application, but within 4-6 weeks the ground was covered with new growth. It soon became evident that this spray was not effective in eradicating leafy spurge.

**SULFURIC ACID**

Åslander (35) employed sulfuric acid in eradicating weeds. Brown and Street (12), Skilbeck and Coles (31) have recommended sulfuric acid for the control of annual and perennial weeds. These findings suggested the possibility that sulfuric acid might be important as an initial spray and in this way reduce the amount of sodium chlorate required. To test the value of sulfuric acid, plots 32, 45, 150, 151 and 152 were

**TABLE 4. RECORD OF THE EXPERIMENT WITH 10 PERCENT SULFURIC ACID.**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>Amount of spurge</th>
<th>Treatment</th>
<th>Amount of spurge</th>
<th>Treatment</th>
<th>Amount of spurge</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>H₂SO₄</td>
<td>heavy</td>
<td>Atlacide</td>
<td>heavy</td>
<td>Hoed(2)</td>
<td>6 (a)</td>
</tr>
<tr>
<td></td>
<td>(2 gallons)</td>
<td></td>
<td></td>
<td></td>
<td>NaClO₃(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NaClO₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>H₂SO₄</td>
<td>heavy</td>
<td>NaClO₃(2)</td>
<td>few</td>
<td>Hoed (9)</td>
<td>2 (b)</td>
</tr>
<tr>
<td></td>
<td>(4 gallons)</td>
<td></td>
<td></td>
<td></td>
<td>NaClO₃(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NaClO₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>H₂SO₄</td>
<td>heavy</td>
<td>NaClO₃(dry)</td>
<td>heavy</td>
<td>Hoed NaClO₃(2)</td>
<td>some (c)</td>
</tr>
<tr>
<td></td>
<td>(2 lbs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>151</td>
<td>H₂SO₄</td>
<td>heavy</td>
<td>NaClO₃(dry)</td>
<td>heavy</td>
<td>Hoed NaClO₃(2)</td>
<td>some (d)</td>
</tr>
<tr>
<td></td>
<td>(2 lbs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>H₂SO₄</td>
<td>heavy</td>
<td>NaClO₃(3)</td>
<td>light</td>
<td>NaClO₃(3)</td>
<td>light (e)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td>heavy</td>
<td></td>
<td></td>
<td></td>
<td>heavy</td>
<td>heavy (f)</td>
</tr>
</tbody>
</table>

(a) No spurge after June 28, 1932; barley poor; alfalfa good, Sept. 27, 1933.
(b) Barley very poor; alfalfa good; one bare spot (8'x8') 1933.
(c) Barley fair; alfalfa good; ½ of plot bare, 1933; two spurge, Aug. 6, 1934.
(d) Barley very poor; alfalfa light, 1933; 10 spurge, Aug. 6, 1934.
(e) Barley gone; alfalfa fair, 1933; six spurge, Aug. 6, 1934.
(f) Heavy infestation spurge, 1933 and 1934.
sprayed with 10 percent sulfuric acid. Results are given in table 4.

Plot 32, having a heavy infestation of leafy spurge, was sprayed on July 3, 1930. The acid killed all the above-ground vegetation, and the spurge did not come up until July 16; on Sept. 9 the spurge population was as dense as ever. Two Atlacide sprayings in 1931 reduced the number of spurge to six by June 1, 1932. With hoeings on June 1 and June 28, the leafy spurge was eliminated.

Plot 45 received 4 gallons of sulfuric acid in 1930 and one spray of sodium chlorate. By May 31, 1931, the leafy spurge population had been reduced to a "few" plants.

The effect of subsequent addition of dry sodium chlorate to areas treated with sulfuric acid was tested on plots 150 and 151 in 1931. On July 18, 1932, there was still a small amount of leafy spurge on these plots. One hoeing and two sprays of sodium chlorate, one on July 18 and the other on Oct. 5, 1932, eradicated the leafy spurge plants. No spurge was found in 1933. The few leafy spurge plants found in 1934 were in all probability seedlings developed from dormant seeds.

One sulfuric acid treatment given to the leafy spurge in plot 152 in 1931 reduced the stand from "heavy" to "light" the following year. Only one spurge plant survived three applications of sodium chlorate in 1932. Six spurge plants found on Aug. 6, 1934, in all probability were seedlings developed from buried seeds.

Sulfuric acid was also used on an area of approximately 1/8 acre of leafy spurge growing in corn in 1931. Two applications with a knapsack sprayer were made during the growing season. It was not possible to note any reduction in the number of leafy spurge plants the following year.

From the limited data at hand, it is clear that a 10 percent sulfuric acid spray reduced the leafy spurge population somewhat, but not enough to warrant its use as a substitute for one of the two sodium chlorate sprays of the season. Sulfuric acid, however, may be of a considerable value in killing seedlings.

AMMONIUM THIOCYANATE

Ammonium thiocyanate has a twofold action: as a herbicide and as a fertilizer (18). It does not embody a fire hazard as does sodium chlorate. Ammonium thiocyanate crystals deliquesce, but manufacturers now furnish the material in a solution of 3 pounds per gallon. At the present time the supply is limited, and the price is high. Aston, Bruce and Thompson (6) have used ammonium thiocyanate in eradicating ragwort (Senecio jacobea L.) in New Zealand. Barnett and Hanson (8) did not obtain complete eradication of leafy spurge in any of their trials.
TABLE 5. THE RECORD OF THE EXPERIMENT WITH AMMONIUM THIOCYANATE.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>1931</th>
<th>1932</th>
<th>1933</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment</td>
<td>Amount of spurge</td>
<td>Treatment</td>
</tr>
<tr>
<td>230</td>
<td>NH₄CNS</td>
<td>medium</td>
<td>NH₄CNS(3)</td>
</tr>
<tr>
<td>231</td>
<td>NH₄CNS</td>
<td>medium</td>
<td>-</td>
</tr>
<tr>
<td>233</td>
<td>NH₄CNS</td>
<td>light</td>
<td>NH₄CNS</td>
</tr>
<tr>
<td>234</td>
<td>NH₄CNS</td>
<td>light</td>
<td>NH₄CNS</td>
</tr>
<tr>
<td>235</td>
<td>NH₄CNS</td>
<td>light</td>
<td>NH₄CNS</td>
</tr>
<tr>
<td>Check</td>
<td>No treatment</td>
<td>heavy</td>
<td>No treatment</td>
</tr>
<tr>
<td>315</td>
<td>NH₄CNS + H.CHO(3)</td>
<td>light</td>
<td>No treatment</td>
</tr>
<tr>
<td>316</td>
<td>NH₄CNS + H.CHO(3)</td>
<td>some</td>
<td>No treatment</td>
</tr>
</tbody>
</table>

Seven different leafy spurge plots, with varying degrees of infestation from "scattered" to "some," were treated with ammonium thiocyanate. Results are given in table 5. Plots 230, 231, 233-235, 315 and 316, in corn in 1931 and 1932, were given the usual cultivation throughout the growing season. In August, 1933, the first five plots were seeded to alfalfa, while buckwheat was seeded on plots 315 and 316 in 1934.

Plots 230, 231, 233, 234 and 235 were sprayed once on Sept. 1, 1932, and showed a marked reduction in the leafy spurge population. Plot 230, given three applications in 1932, did not have any leafy spurge in 1933. No spurge was found in plot 231 in 1933 following two sprays of ammonium thiocyanate in 1931. Plots 233-235 were given one spray in 1931; the following year there was only one plant in plot 234. Plots 315 and 316 were sprayed three times with ammonium thiocyanate mixed with formaldehyde (1 ounce per gallon of solution). In 1933 there were, respectively, three and a "few" leafy spurge. These plants were killed when the ground was prepared for buckwheat the next year.

Results obtained during 1931 and 1932 on seven plots using ammonium thiocyanate indicate that this chemical has some merit.

POTASSIUM CHLORATE

According to its composition, potassium chlorate should be as effective an herbicide as sodium chlorate and should have the advantage over sodium chlorate of containing the element potassium, necessary in plant metabolism. Potassium chlorate is less soluble than sodium chlorate, so it is more difficult to handle.
TABLE 6. THE RECORD OF AN EXPERIMENT WITH POTASSIUM CHLORATE.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>1932 Treatment</th>
<th>Amount of spurge</th>
<th>1933 Treatment</th>
<th>Amount of spurge</th>
<th>1934 Treatment</th>
<th>Amount of spurge</th>
</tr>
</thead>
<tbody>
<tr>
<td>359</td>
<td>KClO₃(2) (2 lbs.)</td>
<td>heavy</td>
<td>NaClO₃</td>
<td>heavy</td>
<td>Cane, alfalfa</td>
<td>few</td>
</tr>
<tr>
<td>360</td>
<td>KClO₃(2) (2 lbs.)</td>
<td>heavy</td>
<td>NaClO₃</td>
<td>light</td>
<td>Cane, alfalfa</td>
<td>few</td>
</tr>
<tr>
<td>365</td>
<td>KClO₃(2) (6 lbs.)</td>
<td>some</td>
<td>KClO₃ NaClO₃</td>
<td>scattered</td>
<td>Soybeans, alfalfa</td>
<td>2</td>
</tr>
<tr>
<td>366</td>
<td>KClO₃(2) (6 lbs.)</td>
<td>some</td>
<td>KClO₃ NaClO₃</td>
<td>some</td>
<td>Soybeans, alfalfa</td>
<td>4</td>
</tr>
<tr>
<td>367</td>
<td>KClO₃(2) (2 lbs.)</td>
<td>some</td>
<td>NaClO₃(2)</td>
<td>light</td>
<td>Soybeans, alfalfa</td>
<td>2</td>
</tr>
<tr>
<td>373</td>
<td>KClO₃(2) (3 lbs.)</td>
<td>light</td>
<td>KClO₃ NaClO₃</td>
<td>few</td>
<td>Soybeans, alfalfa</td>
<td>0</td>
</tr>
<tr>
<td>377</td>
<td>KClO₃(2) (2 lbs.)</td>
<td>scattered</td>
<td>NaClO₃(2)</td>
<td>few</td>
<td>Soybeans, alfalfa</td>
<td>0</td>
</tr>
<tr>
<td>380</td>
<td>KClO₃(2) (6 lbs.)</td>
<td>light</td>
<td>NaClO₃(2)</td>
<td>few</td>
<td>Soybeans, alfalfa</td>
<td>0</td>
</tr>
<tr>
<td>Check</td>
<td>No treatment</td>
<td>heavy</td>
<td>No treatment</td>
<td>heavy</td>
<td>Soybeans, alfalfa</td>
<td>some</td>
</tr>
</tbody>
</table>

*Aggregate amount used on plot.

At the present time potassium chlorate is higher in price than sodium chlorate. Eight 1-square-rod plots were sprayed with potassium chlorate in 1932. Data have been tabulated in table 6.

Application of potassium chlorate, concentration 1/2 pound per gallon, to the leafy spurge of plots 359, 360 and 367 on Aug. 23, 1932, did not produce a material reduction in the number of spurge. Plot 359, which carried a heavy infestation of leafy spurge, had at the time of the second spraying (Oct. 6) a "medium" amount of this weed. The number of leafy spurge in plot 360 was the same on this date as at the time of the initial spray. On June 15, 1933, there was still a heavy infestation of spurge. One spraying of sodium chlorate in 1933 reduced the number but did not kill all the plants. Although the ground was plowed for the seeding of cane and alfalfa in 1934, there were a "few" leafy spurge plants in plot 359 and "scattered" plants in 360 and four plants in 367.

Two applications of potassium chlorate, concentration 3/4 pound per gallon, on the leafy spurge of plots 365 and 366 produced results somewhat better than where 1/2 pound of the salt was used. Preparation of the ground incidental to the seeding of alfalfa in 1934 killed the remaining spurge plants.

Plot 373, carrying a light infestation of leafy spurge, had 15 plants on June 22, 1933, after the two sprayings of potassium chlorate (3/4 pound per gallon) in 1932. In 1933 the "few" leafy spurge plants were given one spray treatment of potassium chlorate of the same concentration as the year before and one sodium chlorate spray. Two small spurge were found in the alfalfa in 1934, but in 1935 the plot was clean.
Leafy spurge plants in plots 377 and 380 were, respectively, "scattered" and "light." In both cases the number of plants was reduced to "few" in 1933 as a result of the two sprayings of potassium chlorate in 1932. Two sprayings with sodium chlorate of the "few" plants in 1933 completed the eradication. Results obtained from using potassium chlorate upon leafy spurge in the eight plots justify the substitution of potassium chlorate for sodium chlorate in the killing of leafy spurge.

In 1935 alfalfa on the eight potassium chlorate plots was generally poor. In four of the plots the alfalfa was completely killed. The average yield of corn per plot in 1933 was 11.1 pounds in plots treated with potassium chlorate, 18.2 in plots treated with sodium chlorate and 20 pounds in the controls.

CULTURAL TREATMENTS

CULTIVATION

Cultivation is primarily intended to control weeds (16). Small grain production does not offer as good an opportunity for eradication of weeds as corn. Where a specific weed such as leafy spurge is present, it may be necessary to modify the usual practice or even to introduce new methods of culture.

SMALL GRAIN

Seeding of an area infested with leafy spurge to spring-seeded small grain is a useless procedure. Preparation of ground through diskin (usually practiced) serves only to retard the development of leafy spurge. Since it is one of the first plants to appear in the spring, it has the advantage over the small grain of having well-established roots. Roots of leafy spurge may penetrate to a depth of 15½ feet (7). Deeply penetrating roots, provided with large amounts of food material, are able to extract the soil moisture to a depth not attained by the roots of our small grains.

CORN

Corn, as it is usually grown, is cultivated three or four times during the growing season. During much of August and September there is ordinarily no cultivation. Such a system at best does not offer much interference with the growth of such a plant as leafy spurge. The aerial shoots are cut off at the time the ground is prepared in the spring. New shoots soon appear and cover the ground before the corn seedlings are established. When the corn is cultivated, the majority of the stems of the spurge are injured, and others are only covered with soil. Shoots appearing in the corn hill are not molested. When the corn be-
comes too tall to be cultivated, the leafy spurge grows rapidly and may cover all of the space between the corn rows. During the latter part of July and throughout August, great quantities of the fruit are ordinarily produced. On July 29, 1932, 11 leafy spurge plants were arbitrarily chosen from a heavily infested area in a corn field and found to possess the following numbers of fruits: 74, 17, 37, 34, 81, 9, 21, 53, 32, 39 and 35, averaging 39. As there are usually three seeds in each fruit, the average number of seeds per plant was 117. Since leafy spurge plants may produce fruit throughout the entire growing season, a single count would not give the full number produced.

During 1931 and 1932 considerable attention was given to surface cultivation of infested leafy spurge areas in corn, using a one-horse cultivator after the usual cultivation had been discontinued. Where regular cultivation was supplemented by surface cultivation for 2 consecutive years, the decrease in the amount of leafy spurge was small.

In 1931 a portion of a cornfield, badly infested with leafy spurge, approximately ½ acre in extent, was kept clean throughout the season by hoeing. Spurge in another infested area in a corn field of about the same size was pulled. In both cases there was approximately a 50 percent reduction in the number of leafy spurge the following spring. Expense involved in such operations necessitated the discontinuance of the experiment.

If eradication measures are practiced before the leafy spurge plant has become firmly rooted, it is a simple matter to kill plants through cultivation. The use of the hoe and the pulling of perennial weeds such as leafy spurge will be of material assistance in preventing further spread. A continued removal of the tops will eventually kill the plant.

DOUBLE PLOWING

During September, 1931, a tract of about 8 acres, badly infested with leafy spurge, was plowed. During the latter part of April and the first part of May, 1932, the area was plowed again, disked, harrowed and planted to corn. A good crop was raised. It was estimated that fully 75 percent of the leafy spurge was killed. Plowing, 7 to 8 inches deep, severed the feeding roots and rhizomes from the deeply penetrating roots.

FALLOWING

Fallowing or clean cultivation has been used extensively in eradicating weeds. Gates and Cox (16), Call and Getty (13), Barnum (9), Stewart and Pittman (32), Kiesselbach, Petersen and Burr (21) and Zahnley and Pickett (35) have recommended clean fallow for the eradication of bindweed. Barnett and
Hanson (8) found that frequent and thorough hoeing of leafy spurge reduced the number. Brenchley (11) has stated that fallowing may reduce considerably the number of weeds if the process can be carried on long enough to exhaust the underground reserves.

Welton, Morris and Hartzler (34) have stated that in Canada thistle the organice food reserve of the rootstocks gradually decline during the early part of the year while vegetative growth goes forward. The food reserves are at a minimum about the first of June, after which they increase until the end of the season. Arny (2) found that the total readily available carbohydrates in the storage roots of leafy spurge reached the low point for the season by the middle of May. At this time the plants were beginning to blossom. Rapid storage of readily available carbohydrates followed for a time and continued at more moderate rates until the close of the season. There was a marked decrease in the percentage of true starch and an increase in sugars in the underground storage organs of leafy spurge as the temperature became lower in the fall. A decline occurred in the total organic nitrogen of the underground storage organs during the early part of the season. This decline continued at more moderate rates until August, after which increases occurred.

During 1933 and 1934, about 2 acres of leafy spurge and European bindweed were subjected to clean tillage from the first of June until killing frost. From observations made upon the effect of cultivating corn in spurge areas, it has been found that new shoots are rapidly formed. Rhizomes in large numbers grew from the numerous buds of the injured roots. In 3 to 4 days, the ground was covered with leafy shoots. In the formation of the rhizomes, the material of construction had to come from food material stored in the roots. To prevent an increase in the food material through photosynthesis, cultivations should be made twice a week.

As a spring-tooth harrow was the only implement available throughout the season, it was used. Where aerial shoots were not pulled off, they were cut off with a hoe. No measurements were made on the number of spurge shoots present from time to time as emphasis was placed on the time necessary to produce eradication. There was, of course, a decrease in the number of shoots as the season advanced, particularly in the second year. Rhizomes became smaller in diameter and finally appeared as fine threads before the plants were killed. After 30 cultivations in 1933 and an equal number in 1934, the leafy spurge was eradicated. In 1935 the area was planted to corn, but no spurge was present.

Clean tillage will kill leafy spurge, but it entails a great amount of labor; using a tractor involves considerable expense. Under
general farming practices, the twice-a-week clean cultivation program is difficult to follow.

FERTILIZERS

There is a definite physiological limit to the application of fertilizers. If the applications are heavy enough, toxicity occurs (29). On this basis, it should be possible to add enough fertilizer material to kill all plant growth.

KAINITE

Kainite, a potassium chlorosulfate fertilizer, being available at the time, was used in 1932. Forty pounds of kainite were added to each of the square rod plots 313 and 314. Plot 313 was cultivated three times in 1932, while plot 314 was not given any cultivation. Both plots were cultivated twice in 1933. In 1934 the plots were seeded to buckwheat. On July 29, 1934, there were three leafy spurge plants in plot 313 and a "few" in plot 314. There was a marked reduction in the number of leafy spurge, particularly in plot 313 which had been given the cultivation. Perhaps the three cultivations given plot 313 in 1932 served to distribute the fertilizer so that a larger amount of underground plant tissue was killed than in plot 314.

Application of such a fertilizer as kainite in large quantities to eradicate such perennial weeds as leafy spurge is suitable only where the infested area is small.

BARNYARD MANURE

As barnyard manure is available on practically all farms, it was logical to determine the effect of adding large quantities of barnyard manure upon one of the plots. On Aug. 13, 1931, well-rotted manure at the rate of 480 tons per acre was added to plot 205, heavily infested with leafy spurge. At the time of the application of the manure, the ground was spaded. On April 21, 1932, the plot was plowed and seeded to sweet clover. At that time, there were "scattered" leafy spurge plants. On Sept. 6, 1932, the ground was seeded to winter rye. On that date, no leafy spurge was present, and there has been none since. Results suggest the possibility of using this method to eradicate leafy spurge in small areas. Using large quantities of barnyard manure to eradicate leafy spurge produced the same results at Cherokee on the Nestor Stiles and George Nelson farms in 1932 and 1933. Using large quantities of straw has not been successful.

COMPETITIVE CROPS

Competition occurs where two or more plants make demands for light, nutrients or water in excess of the supply. It in-
creases with the increase in population (33). According to Russel (29), one of the most effective ways of suppressing weeds is to grow a heavy crop which "smothers" them by excluding light and by exerting certain root effects. Call and Getty (13) consider sorghum or cane as the best annual smother crop to use in controlling European bindweed in Kansas.

An infested area of about 5 acres was plowed in the fall of 1932 and again in the spring of 1933. The field was fallowed until the middle of June when it was divided into three parts, and drilled separately to millet, sorghum and soybeans. Rates of seeding were: Millet, 50 lbs., sorghum, 30 lbs. and soybeans, 120 lbs. In September, 1933, when the area was plowed, only "scattering" spurge plants were seen in the portion seeded to millet and sorghum, and a "few" leafy spurge plants were present in the soybeans. In 1934 soybeans were planted again on a portion of this area. At the end of the season the leafy spurge was eliminated.

In 1934 a ½-acre piece of ground was seeded to soybeans. In this area were several heavily infested patches of leafy spurge. In early October when the ground was plowed there were only a "few" leafy spurge plants remaining. This ground was again seeded to soybeans in 1935. At the end of the 1935 season no leafy spurge was present. It is evident that competitive crops such as millet, cane and soybeans will reduce the amount of leafy spurge.

SPRAYING PLUS SMOOTHER CROPS

Approximately 5 acres of leafy spurge and European bindweed were sprayed with sodium chlorate in the fall of 1932. The ground was plowed the following spring, fallowed until the middle of June and then seeded to millet and cane. There was a heavy growth of both the cane and millet and no spurge was found. As soybeans are extremely sensitive to small amounts of sodium chlorate, they can not be recommended to follow, for at least 3 years, on ground which has been sprayed with sodium chlorate.

ALFALFA

Barnum (9) has stated that alfalfa is the best and most profitable crop to grow on ground infested with European bindweed. Call and Getty (13) found that alfalfa is the best crop to use on European bindweed land, provided the growing conditions are satisfactory for alfalfa. No experimental work on the effect of alfalfa on leafy spurge is recorded in the literature. In growing alfalfa in northwestern Iowa, the limiting factor usually is lack of moisture. In the experimental program for the eradication of leafy spurge, an effort was made to determine
whether alfalfa could be of assistance in exterminating leafy spurge.

In the summer of 1931, 10 acres of ground infested with leafy spurge and European bindweed were plowed and prepared for alfalfa which was seeded that year on Aug. 31. Seed germinated readily, and the plants made considerable growth and withstood the winter. The next spring a heavy rain weakened the stand materially by pounding many of the plants out of the ground. Since 1932 the alfalfa plants have increased in number so that the stand in 1933 and 1934 was good. In this alfalfa field, spurge plants have been found, but the plants are smaller than those growing undisturbed in the fence row and normally are later in their development. No noticeable reduction in the number of leafy spurge plants has been found.

In another alfalfa field on the same farm, the spurge had gained considerable headway and in 1934 had to be sprayed. Of course, much is contingent upon the age of the infestation. However, the seeding to alfalfa of an area infested with leafy spurge in order to eradicate the weed is not to be recommended.

**ALFALFA ON SODIUM CHLORATE OR ATLACIDE-TREATED GROUND**

Plots 44, 34, 96, 97 and 98 were seeded to alfalfa in August, 1933. With the exception of plot 44, the alfalfa on Sept. 27, 1933, was rather poor. In 1934 the crop improved considerably, and a good yield was produced. Barley seeded on these plots in the spring of 1933 failed to develop. Plot 44 was not treated with sodium chlorate in 1931 and only lightly in 1932, but the other plots were given heavier applications of sodium chlorate during 1930-32.

The alfalfa seeding on the Atlacide plots, 14, 58, 59, 87, 89 and 92 was good in 1934.

It is evident that alfalfa may be used advantageously as a crop on ground where weeds such as leafy spurge have been killed with sodium chlorate or Atlacide.

**GRAZING**

The grazing experiment was carried on during 1931-33. In 1931 a 2-acre enclosure, heavily infested with European bindweed and containing "some" leafy spurge, was separated into two parts. Sheep were placed in the east half and hogs in the west lot. Sheep avoided the spurge until practically all the other vegetation had been consumed, no doubt due to the bitter acrid taste of the latex. In 1934 the experiment was discontinued as there was a larger number of both bindweed and leafy spurge than was present in 1931.

Esser (15) has reported that leafy spurge is poisonous to livestock, but none of the sheep in the enclosure showed any signs
TABLE 7. DEVELOPMENT OF LEAFY SPURGE* UPON PLOTS GIVEN THE TREATMENTS EMPLOYED IN GENERAL FARMING.

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>1932 Treatment</th>
<th>Amount of spurge</th>
<th>1933 Treatment</th>
<th>Amount of spurge</th>
</tr>
</thead>
<tbody>
<tr>
<td>346</td>
<td>Corn, cultivated (3)</td>
<td>medium</td>
<td>Barley</td>
<td>heavy</td>
</tr>
<tr>
<td>370</td>
<td>Corn, cultivated (3)</td>
<td>heavy</td>
<td>Barley</td>
<td>heavy</td>
</tr>
</tbody>
</table>

*The ground was covered with leafy spurge shoots when it was plowed the latter part of April.

of poisoning. During 1930-33 the regular pasture, containing about 9 acres of leafy spurge, supplied feed for a number of cattle on the Scott farm. As there was a moisture deficiency throughout the summers of these years, the pasture was overgrazed. Cattle and sheep consumed a small amount of spurge, but none of the animals showed any signs of poisoning.

NO SPECIAL TREATMENTS MADE

To determine whether the regular farm practices would increase the infestation of leafy spurge, comparisons with the leafy spurge contiguous to the plots were made during 1930 and 1931. Areas became larger and more heavily infested. To make definite measurements, plots 346 and 370 received only the treatments which are generally used in farm practice. Data for these two plots are given in table 7.

Plot 346, planted to corn in 1932, had a "medium" stand of leafy spurge. Although the corn was cultivated three times, there was a heavy growth of leafy spurge in September. The plot was seeded to barley in 1933, but the grain was poor. By Aug. 15 there was enough spurge on the plot to be designated as "heavy." Plot 370 with a "heavy" infestation of leafy spurge in the spring of 1932 had a "medium" amount on Aug. 23. The next year the population was reduced, through plowing, from "heavy" to "medium." On Sept. 28, there was again a "heavy" infestation of leafy spurge. Barley seeded on this plot did not produce a profitable crop.

Data given above show that when leafy spurge becomes established in a given place it can not be eradicated through practices generally given corn or small grain crops.
LITERATURE CITED


(2) Arny, A. C. Variations in the organic reserves in the underground parts of five perennial weeds from late April to November. Minn. Agr. Exp. Sta., Bul. 84. 1932.


