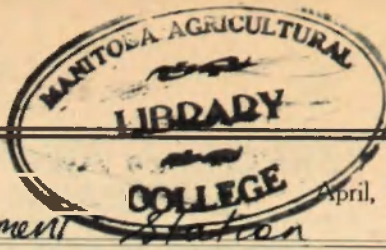


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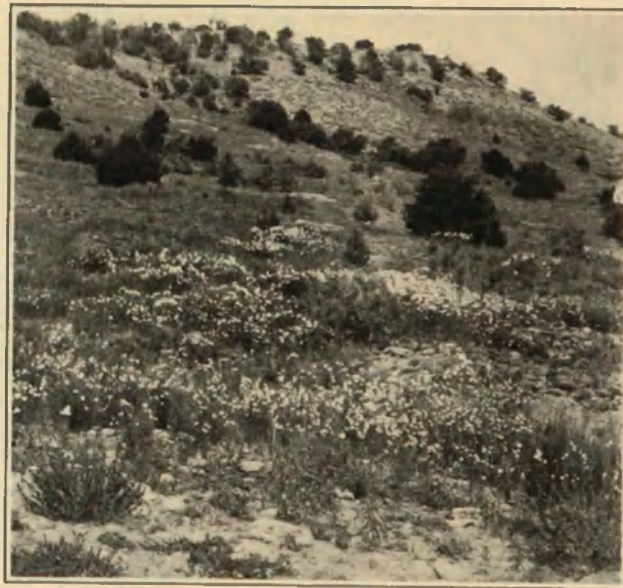
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The Colorado Experiment Station

AGRICULTURAL DIVISION

CONTROL OF THE WHORLED MILKWEED IN COLORADO

By W. L. MAY
Deputy State Entomologist



Location of Plots for Chemical Eradication Experiments near Paonia, Colorado.

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CONTROL OF THE WHORLED MILKWEED IN COLORADO

By W. L. MAY, Deputy State Entomologist

When it had been conclusively established in 1918¹ that the whorled milkweed (*Asclepias galioides* H. B. K.) had been responsible for previously unexplained heavy losses of livestock in Southwestern Colorado, it became imperative that control measures be determined to put a stop to these losses. This work was turned over to the author in 1918, who, at that time, was assistant botanist for the Experiment Station, and during that year the work was carried on entirely as a project of the botanical section of the Experiment Station. In 1919, the work was carried on jointly between the botanical section and the State Entomologist's office. Finally, in 1920, under the provisions of the Pest Act and the State Entomologist's Law, the work was transferred to the office of the State Entomologist.

At the time of the transfer of the work, the only project in mind for the writer was the whorled-milkweed problem. Since that time, however, the investigational work on this problem has been completed, and the weed problem of the State is being viewed on a broader basis. There are other pernicious weeds in the State which do not poison livestock, but which probably cause a greater financial loss yearly than does the milkweed, due to the reduction in yield of farm crops and tillable acreage. With the increased value of agricultural land and the rapidly diminishing amount of new land that is available, the weed problem is being viewed with more and more apprehension. Especially is this true where valuable land is being entirely taken by such pernicious weeds as the wild morning glory, perennial peppergrass, poverty weed and Canada thistle. When an acre of valuable land is made valueless by the encroachment of such weeds, the owner realizes his loss, and a demand is made for some means of reclaiming such land, and of preventing more acres from being infested.

The policy of this office has been to take up the investigation of control measures for these worst weed pests as fast as the available funds will allow. We find that there is a remarkable paucity of information as to successful methods to be used against our worst weeds. We find, also that methods highly recommended for other sections, are not always applicable to Colorado conditions, so that it seems we are faced with the necessity of working out control methods applicable to our particular conditions, and in this work, oftentimes, we can merely be guided by the work of others under dissimilar conditions. At the present time, this office is centering its attention on the wild morning glory (*Convolvulus arvensis*) and the perennial pepper-

grass (*Lepidum draba*). Two seasons' work on the former has given us some rather valuable information, but it has not placed us in a position to make any definite recommendations. The work on the latter was just begun the past season.

The weed work of this office has been entirely empirical, that is, a number of methods of attack were outlined and tried out in the field, and conclusions based on the results of this "cut and try" method. The plans are, of course, influenced by the knowledge available of the life history and the physiological activity of the plant attacked, but the writer feels that such knowledge has been altogether too limited, and that the proper control of our worst weed pests will resolve itself into a joint problem for the plant physiologist and the chemist. Particularly is this true of chemical eradication of weeds, where the reaction of chemicals on the soil will also enter in.

In the work on the whorled milkweed it early became evident that the problem naturally divided itself into three parts. The first part of the work was to determine the distribution of the plant, its life history and habits, and to acquaint the livestock owners with the plant so they could recognize it and know it as poisonous. This constituted the major portion of the work in 1918. The results from this educational work were exceedingly gratifying, and since the livestock men have been made acquainted with the plant and the conditions under which poisoning occurs, few heavy losses have been recorded, and the losses of individual animals have been greatly reduced.

The second part of the problem was to determine practicable methods of killing out the plant on tillable land, and the third part was to work out a chemical treatment that could be applied on waste land of little value, where cultivation methods could not be applied, where the milkweed was a constant menace to stock, and where seed was produced which became a source of infestation on tilled lands.

ERADICATION OF MILKWEED² ON TILLABLE LAND

At the beginning of the investigation on the whorled milkweed, many farmers reported extreme difficulty in trying to rid their land of this pest. The plant is extremely persistent by means of very fine, lateral rootstocks and, because of this feature, has proved itself to be in a class with Canada thistle and wild morning glory, although subsequent experimentation has proved that it is not equal to these plants in persistence. Farmers reported that years of hoeing and ordinary cultivation methods had proved of no avail against the plant. The writer at the beginning of the work was imbued with the old established idea that the proper method of attack for all such weeds was to start early in the year and to continually keep the tops cut

off, with the object of starving the roots out. At the end of the experimental work, the writer does not have so much faith in this procedure as a practical method of eradicating such perennial weeds; and in the case of the whorled milkweed, this method is not only a very expensive one to apply, but it is entirely impractical for killing the plant.

Following is an extract from Bulletin 255 of the Colorado Experiment Station:

Plot IV. Summer Fallow 1918, followed by a Cultivated Crop in 1919. During 1918 this plot was given the following treatment: Plowed June 15, with a double-disc plow to a depth of 3 or 4 inches. Double disced June 26. Double disced July 8. Plowed with tractor 3 inches to 10 inches deep July 23. Double disced August 26. Double disced September 20. Double disced October 15.

The principle followed in this treatment was to keep the plant from having any green leaves during the season; at no time was the milkweed allowed to form any green leaves. As soon as a very few showed through the surface the plot was double disced. The persistence with which the roots continued to send up stalks through the soil was remarkable. It must be remembered that no rains fell during the period from June 1 to September 1, and that by the latter date the upper 8 inches of soil were as dry and as porous as an ash heap. Every bit of milkweed in this upper layer was dried up and dead but the roots below the furrow slice continued to send shoots to the top of the soil through the dry dirt until fall. (Fig. 1). In most cases these roots were about the size of ordinary binding twine or smaller, and yet enough shoots were sent up to make the stand as thick as it was originally.

From May 16 to May 20, 1919, this plot was double disced and harrowed. On May 20 part of the plot was planted to potatoes and part to corn. These two crops were treated as follows during the season:

Hoed June 10.

Hoed June 26.

Cultivated three times over July 25.

Cultivated August 10.

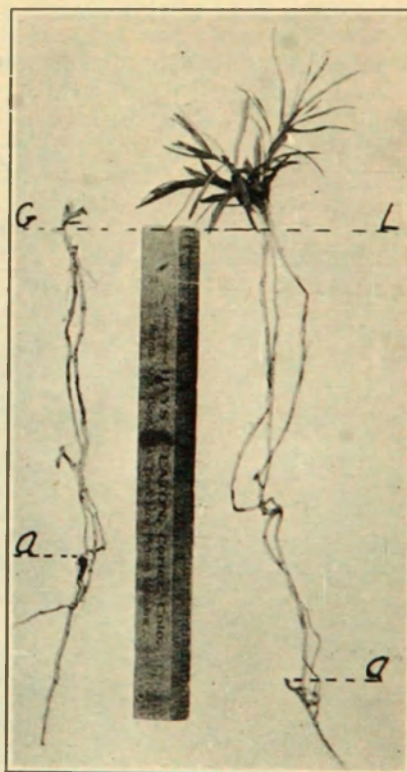


FIG. 1.—Growth made on Plot IV at Cortez from July 20th to August 20th, 1918. A and A are the points at which the old plants were cut off. G D is the ground line. The growth was made after the treatment outlined in text.

The crop was given the treatment of an ordinary farm crop, with the exception that a little more care was given.

The rainfall during the 1919 season was considerably greater than in 1918, but the corn and potatoes were not irrigated. Despite this treatment the milkweed was thicker in 1919 than it had been at the beginning of the experiment in 1918. The potato and corn crops were not in any way held back by the milkweed. In fact, due to the summer fallow the previous year, the crops were very good. (Fig. 2). The experiment was a good demonstration, proving conclusively that thorough work, begun early and continued throughout the season, and followed the next year by a hoed crop, is inefficient as a means of eradicating milkweed.

The conclusions from the above are obvious, and these results have been substantiated numerous times by the experience of farmers who have followed a similar method in attempting to rid their land of this pest.



FIG. 2.—Corn crop in Plot IV, August, 1919.
Note small milkweed in foreground.

Two other plots, in which the work was based on the principle of attacking the plant just before the maturing of the seed, at which time the roots are most completely sapped of their stored food, gave much more encouraging results. One of these plots was grubbed with a grub hoe just as the plants were beginning to form pods on July 15, 1918. By "grubbing" is not meant just the digging up of that portion of the soil immediately surrounding the shoots

which are visible above ground. All the soil was moved to a depth of eight inches, entirely across the plot, and extending for at least a foot beyond any visible green shoots on all sides

of the patch. A second such grubbing was given on August 23, when it was estimated that the plot was showing 3 percent of the original stand. The following year twelve spindling shoots of milkweed made their appearance on a plot 50 feet long by 8 feet wide, where the previous year the ground had been entirely covered with milkweed. This is almost 100 percent control. In 1919 the ground was completely covered by a stand of horsemint which came from seed from a neighboring patch.

Almost identical results were obtained on a plot which was plowed on August 1 and again on September 2. In this case the control was not so good as where thorough grubbing was done, but at least 90 percent of the original stand was killed.

Based on the conclusions from the above experimental work, it was recommended to farmers that they try a late summer plowing followed by an early fall plowing and seeding to winter wheat where practicable. Those who tried this plan have in every case reported successful control. In bad infestations it was necessary to continue the treatment another year. Some farmers have reported excellent results by late fall plowing after seeding time, even as late as October, this treatment being repeated for another year. This method was followed by some men in an effort to cover up the milkweed in their pastures before turning sheep in, and much to their surprise, two years of the treatment killed out practically all of the milkweed, and this in some cases on patches where previously a very careful and painstaking job of summer cultivation had been followed and the killing of the plant given up.

RECOMMENDATIONS FOR ERADICATION ON TILLABLE LAND

From the four years of experimental work, and the observations made on the work of farmers on their own farms, the following recommendations are made to be applied on lands that are tillable:

(1) Do not attempt to kill out whorled milkweed by beginning early in the season and cutting off the tops continuously throughout the season. It is work wasted.

(2) Leave the milkweed entirely alone in the early part of the season and begin eradication work just before seeding time.

(3) On large patches, plow thoroughly just before seeding time, and again in early fall and, where possible, establish a good stand of winter wheat. It is rather important that the soil be occupied as soon as possible by a crop that shades the ground. Avoid a cultivated crop the next year. It will usually be necessary to repeat the late summer or fall plowing the following year.

(4) For small patches where plowing is not practical, a treatment based on the same principle may be given, a grub hoe or a spade being substituted for the plow. (Fig. 3.) Remember that in plowing, all the soil is moved, and in grubbing or



FIG. 3.—Method of grubbing small patches. Note bank to be worked to.

spading, every portion of the soil must be moved, if desirable results are obtained. A second treatment may be given if green shoots make their appearance.

EXPERIMENTS WITH CHEMICAL SPRAYS

It was found that there are many acres of whorled milkweed growing on hillsides which cannot be cultivated, and where the nature of the soil will not permit of any grubbing work. Particularly is this true of rocky hillsides below irrigation ditches in Western Colorado (Fig. 4). The only method which seemed to offer any hope of success in eradicating such areas was the use of a herbicide. Letters of inquiry to various experiment stations revealed the fact that very little of a definite nature was known as to the successful use of herbicides against perennials.

Perhaps the most successful general use of any herbicide is that of iron sulphate against the mustards, particularly in grain fields. This had its beginning in the work of H. L. Bolley in North Dakota. Other chemicals which have been given a trial as herbicides, with more or less variable results, are copper sulphate, common salt, crude oil, sulphuric acid, carbon bisulphide and sodium arsenite.



FIG. 4.--The type of milkweed patch that can be eradicated only by chemical treatment.

Of all these, the latter is probably the most potent. It has been used to a considerable degree in Hawaii⁴, especially where the rainfall is excessive and working of the soil would result in puddling. Considerable experimentation was carried out in California by George P. Gray on the use of sodium arsenite in the eradication of wild morning glory⁵. His results were very good in the fog belt, but he could not duplicate these in the arid section⁶.

Practically all the commercial weed-killers on the market are composed either entirely or in large part of sodium arsenite. The use of this chemical is attended with the undesirable feature that when applied in appreciable quantities it poisons the soil and makes it sterile, and there is always the danger of poisoning livestock where foliage is sprayed with an arsenical. These features will limit the use of arsenical weed-killers to untilled land or land of little value, or, in extreme cases, to tilled lands which are made valueless because of being totally occupied by pernicious weeds and where it is desired to kill out the weed at any cost to prevent further spreading. They may also be used on roadsides, rights-of-way or other places where no vegetation is desired.

Much of the milkweed which it is desired to eradicate occurs on rocky hillsides (Fig. 4) along stock driveways where it is a constant menace to stock being driven down to the lower valleys in the fall. Furthermore, these areas are in the lower

valleys where there is no loose stock during the summer months when there is the most danger of poisoning from the sprayed foliage. It was found that the foliage which had been sprayed was so dried up by the time the stock came down in the fall that there was none of it eaten. In addition, these areas have been responsible for so much loss, and are still such a menace to stock, that any sure method of eradication would be a paying investment even though the cost was apparently rather excessive.

SPRAYING EXPERIMENTS OF 1920

General Plan:—During 1920 the plan of the work was to try out a number of different herbicides with a view to determining the one which gave the most promise of success. With this in mind the following chemicals were used at the beginning of the season:—Iron sulphate, copper, sulphate, crude oil, common salt, sodium arsenite and two commercial weed-killers, whose active ingredient is sodium arsenite.

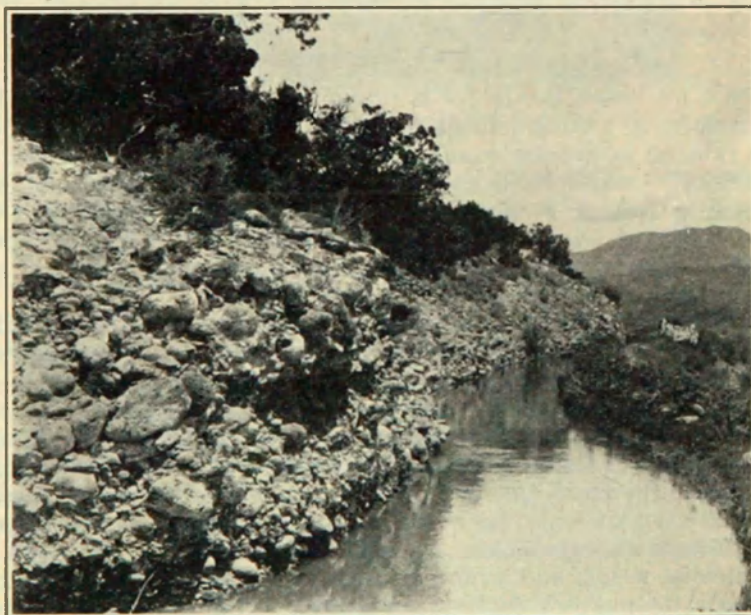


FIG. 5.—Type of soil in which much milkweed occurs in Western Colorado, and where eradication by cultivation cannot be applied.

Plots one square rod in area were laid out on a hillside two and a half miles west of Paonia, where the occurrence of the milkweed was typical of the areas which cannot be successfully

eradicated by cultivation methods. The soil there is very rocky, as shown in Fig. 5.

All chemicals were applied in the form of a fine spray, a Meyers hand spray pump being used. No attempt was made to soak the soil and kill the plants by the root absorption method, but the tops only were completely covered. Because of the smooth epidermis of the milkweed leaves and stems, one-eighth pound of linseed-oil-jelly soap per 5 gallons of solution was added to all the sprays, except the sulphate and the commercial weed-killers. In the case of the sulphates the soap forms a very sticky precipitate which clogs up the machinery. Furthermore, the sulphate is broken down by the chemical reaction between it and the soap which would make it inefficient as a herbicide.

Iron Sulphate.—To each square-rod plot treated with this chemical a solution of 10 pounds of ferrous sulphate to 5 gallons of water was applied. In all, three plots were treated with this chemical, and in no case were the tops even completely killed. The killing was so small as to cause it to be discarded early in the season.

Copper Sulphate.—The solution for each square rod was 5 pounds of the copper sulphate to 5 gallons of water. The results were identical with those obtained from the use of the iron sulphate.

Crude Oil.—Each square-rod plot was treated with three-fourths of a gallon of oil, two and a fourth gallons of water and one-eighth pound of linseed-oil-jelly soap to make a good emulsion. This application killed all the tops of the plants, but there was no absorption into the below-ground portions, the killing being limited to the portions covered with the oil. Growth was immediately resumed from the roots. While the use of this material was continued through most of the season and a number of plots were treated, the results would not warrant even the continuation of experimental work for another season.

Common Salt.—Several applications were made using ten pounds in five gallons of water. In no case was there any appreciable killing of the milkweed plants.

Sodium Arsenite.—A stock solution of sodium arsenite was made as follows: Three pounds of sal soda (sodium carbonate) were dissolved in boiling water and one pound of white arsenic was added and boiled from twenty minutes to half an hour. Enough water was used to make two gallons. From this stock solution, dilutions were made for application upon the various plots. There were four series of plots based on the amounts of white arsenic per acre used in the applications. The application on Series 1 was equivalent to 8 pounds of white arsenic per acre; on Series 2, 12 pounds per acre; and on Series 3, 16 pounds per

acre. In these three series, 5 gallons of the diluted solution were applied to each plot. On Series 4, 10 gallons of material containing 1 pound of white arsenic were applied per square rod.

In every case the tops of the plants on the plots were entirely killed, but in the case of the lighter solutions, there was practically no absorption into the roots, even though on some plots as many as three applications were made during the season. The amount of absorption did not seem to increase at all as the season advanced. In case of Series 4, however, both with single applications and with two applications during the season, practically all the roots were killed, and, as late as the fall of 1922 two of the plots in this series had no more than four or five plants of milkweed on them, where previously the ground had been entirely covered. These few plants are showing no signs of spreading, and in every case they are coming up from under large rocks where the roots were evidently not reached by the applications.

The killing of the tops by this chemical was very quick and very thorough, but there was no absorption into the underground parts of the plant where small quantities were used as reported by Mr. Gray in his work on the morning glory in California. Where the large quantities were used, however, the roots were killed as far as any roots could be found in the soil, some of these going to a depth of about 14 inches, and in many cases lateral roots eight or ten inches beneath the surface were killed for a distance horizontally of 18 inches from the clump of stems to which the material was applied.

Commercial Weed-Killers.—Two commercial weed-killers were used. One of these, according to analysis by the chemistry department of the Colorado Experiment Station, contained approximately three and one-fourth pounds of white arsenic per gallon, the other contained almost four pounds white arsenic per gallon. The first of these was diluted at the rate of one-fourth gallon of the weed killer to four and three-fourths gallons of water, the second at the rate of one-half gallon to nine and one-half gallons water. These were the dilutions advised by the manufacturers. The ten-gallon application was heavier than was really necessary to cover the plants, but the five-gallon application did not allow of any appreciable amount of material getting onto the soil. These applications correspond to applications of 125 and 300 pounds of white arsenic per acre. The excessive amount did not give any better results than did the application of the prepared sodium arsenite corresponding to 160 pounds of white arsenic per acre. The applications at the rate of 125 pounds of white arsenic per acre did not give as good results as the 160 pounds per acre.

The roots on the plots treated with the commercial weed-killers were killed to a depth of six inches to a foot into the ground. The plots treated with the weaker weed-killer showed no appreciable control in 1921, but the plots sprayed with the stronger weed-killer showed from 50 to 85 percent killing in 1921.

Conclusions.—At the beginning of the work for the 1920 season, there was very little information to guide the planning of the work. It was necessary to do a good deal of guessing as to the methods of attack that would be likely to produce results. As a result, the season's work only served to clear the field to a certain extent and to serve as an indicator of what line of procedure followed in 1921 would give the most promise of success. It was clearly demonstrated that, of all the chemicals tried, only one, sodium arsenite, was giving results that would warrant the continuance of its use in 1921. It was shown also that applications of more than 16 pounds of white arsenic per acre would be necessary to accomplish the desired results, while such excessive amounts as 300 pounds of white arsenic per acre were apparently no more effective than 160 pounds. The optimum strength seemingly lay between 16 pounds and 160 pounds of white arsenic per acre.

SPRAYING EXPERIMENTS OF 1921

In accordance with the results of the 1920 experiments, the only chemical retained for use for the 1921 season was sodium arsenite. This material was bought in the form of a thick, sirupy solution, which is a by-product of the smelting industry, the white arsenic from the smelting being combined with a solution of sodium hydroxide. The sodium-arsenite solution bought was guaranteed to contain eight pounds of white arsenic per gallon.

General Plan of Work.—The objects sought in the season's work were to determine, first, the most efficient strength of solution to use; second, the best time in the development of the plant to make the applications; and third, the comparative efficiency of dilute solutions begun early and repeated through the season, and of heavy solutions made late in the season.

With these objects in mind, the following method was pursued:

Stock Solution: A stock solution was prepared by adding to one gallon of the sodium-arsenite solution as purchased, seven gallons of water, making eight gallons of a stock solution containing one pound of white arsenic per gallon.

Strengths of Solutions Used.—Square-rod plots were grouped into seven series, lettered A to G, respectively, and the applications for these plots made according to the following table:

Series A—1½ gal. stock solution plus 4½ gal. water
Series B—1 gal. stock solution plus 4 gal. water

Series C—1	1	gal. stock solution plus	3 $\frac{3}{4}$	gal. water
Series D—1	$\frac{1}{2}$	gal. stock solution plus	3 $\frac{1}{2}$	gal. water
Series E—2		gal. stock solution plus	3	gal. water
Series F—3		gal. stock solution plus	3	gal. water
Series G—1		gal. stock solution plus	4	gal. water

It will be noted that in series F and G the dilutions are the same, but that the amounts applied are not the same. Those two series were begun on July 28, when the plants were in the pod stage, and were made for the purpose of testing the efficiency of copious applications made only once, late in the season.

To each five gallons of solution applied, a lump of linseed-oil-jelly soap was added to act as a spreader and sticker. This soap served very well to bring about even spreading and sticking to the smooth surface of the milkweed plants.

Method of Application.—All applications were made with a small, hand, spray pump mounted in a twelve-gallon galvanized can, which in turn was mounted on handles and a wheel so that it could be moved as a wheelbarrow. A Bean Majestic nozzle of the whirlpool type was used with a six-foot rod made from a



FIG. 6.—The outfit illustrated in use on wild morning glory is the same one used in the experiments on the whorled milkweed.

piece of three-eighths-inch pipe. The nozzle was angled so that the spray was directed downward. With this outfit, a very fine spray could be made, one man operating the pump and the other using the rod. (Fig. 6). A special effort was made to keep the spray in the form of a fine mist that would evenly cover the plants. No effort was made to wet the soil, the tops only being sprayed. A certain amount of the material, of course, got to the

soil, especially in series F and G, but in no case was the soil appreciably wetted.

Numbering of Plots.—Each plot was designated by its series letter, and the number representing its consecutive place in the series as shown by the date of the first application to the plot. For example, the first plot in Series A received its first application on June 9, and it was designated as Plot A1; the second plot in this series was sprayed for the first time June 25, and was designated A2, and so on.

Location of the Plots.—The plots for the 1921 work were laid out on the same hillside as were those for 1920.

Weather as a factor.—It is thought that rainfall and relative humidity have an important effect upon the action of chemicals upon plants. Following is a summary of these two factors for Paonia for the 1921 season.

There was an exceptionally large amount of rainfall for this section in 1921. In June there were eight rainy days; in July, 9; in August, 9; and in September, 4. In June, July and August, the rainfall was considerably above the normal, while in September it was below the normal for the section. In June there were 1.79 inches rainfall; in July, 1.97 inches; in August, 1.95 inches; and in September, 1.06 inches. The normal rainfall for Paonia over a 29-year period up to 1921 was as follows: June, 0.54 inches; July, 1.03 inches; August, 1.25 inches; September, 1.33 inches.

Following is the rainfall as it occurred at Paonia during the four months:

June	July	August	September
4—.40 inches	1—.37 inches	1—.27 inches	1—.93 inches
5—.02 inches	9—.08 inches	3—Trace	15—Trace
6—.13 inches	12—.14 inches	10—.30 inches	17—.10 inches
7—.61 inches	13—.04 inches	14—.10 inches	28—.03 inches
9—.03 inches	15—.13 inches	16—.08 inches	
13—Trace	18—.26 inches	21—Trace	
14—Trace	22—.30 inches	22—.60 inches	
15—.60 inches	26—.56 inches	24—.55 inches	
	31—.12 inches	25—.05 inches	

The relative humidity for this section is always low. In 1922 the relative humidity for Grand Junction compared very closely with relative humidity records kept at Paonia. It is probably safe, for comparison of Paonia with other general sections of the country, to assume that the relative humidity at Paonia is very close to that at Grand Junction, it probably being a little higher at Paonia. The monthly relative humidity for Grand Junction was as follows: June, 40, or 8 percent above normal; July, 47, or 11 percent above normal; August, 56, or 16 percent

above normal; September, 36, or 6 percent below normal. Despite the fact that the rainfall and relative humidity for 1921 were above the average for Paonia, it must be borne in mind that this section would be considered as arid, especially during the summer months, as the heavy precipitation comes during the winter months. At all times the relative humidity is always low enough to cause rapid evaporation of spray from the plants.

Development of Plants as a Factor.—It is indicated that this will be an important factor in the killing of plants by the use of chemical sprays. In order to prevent the repetition of the same information applicable to a number of plots, a summary of the development of the milkweed plants on the different dates of spray applications is given at this point.

On June 9 a small percent of the plants were showing buds, others were just about an inch high or just breaking through the ground, and some shoots had not reached the surface.

On June 25 the plants were in the budding stage, a very few umbels beginning to show open blossoms. The plants were thrifty and growing rapidly.

On July 15 the late-blossoming stage had been reached, practically all the flowers being open, and in a few cases the petals of the lower flowers had fallen.

On July 28 a few of the lower pods were about two inches long and not yet filled out. The last of the upper buds had opened.

On August 11 the pods were two to three inches long, a very few beginning to burst. Vegetative activity had practically ceased.

On September 3 the pods were shedding seed. About 50 percent of the pods had burst.

RESULTS BY PLOTS

Plot A1.—First application, June 9; 100 percent of tops killed and dried up June 11.

Second application, July 15; 90 percent of original stand returning at time of application; all tops killed July 17.

Third application, August 16; 90 percent of original stand returning; new growth three inches to six inches high; all tops killed August 18.

On September 29, 1921, it was estimated that there was 90 percent of the original stand returning. The older roots, especially the larger and woodier ones, had been killed to a depth of three to four inches, and in some few cases of tap-rooted specimens, plants were killed completely. In most cases, digging revealed new growth coming from the point where the roots branched horizontally.

During the 1922 season the plot showed 80 percent of the original stand. Individual plants showed from one to three healthy stalks. The seeding was normal. Grass (*Hilaria jamesii*) and horehound (*Marrubium vulgare*) plants were apparently uninjured.

Plot A2.—First application June 25; 100 percent of tops killed June 28.

Second application on August 16; 60 percent of original stand returning; new growth six inches to eight inches high; all tops killed August 18. On September 29, 1921, digging showed that spray had killed the roots to a depth of two to six inches, but growth was resumed from below these points. A few tap-rooted plants were killed. On October 16, 1922, it was estimated that the plot had 80 percent of the original stand of milkweed.

Plot A3.—First application July 15; all tops killed July 18.

Second application on August 16; new growth 100 percent of original stand about 3 inches high; all tops killed August 19. During the 1921 season, about 50 percent of the original stand returned, and in 1922, 55 or 60 percent of the original stand returned.

Plot B1.—First application June 9; all tops killed June 11.

Second application August 16; 60 percent of original stand returning, mostly from horizontal roots between the old crowns; returning growth six inches to eight inches high; all tops killed August 18.

On September 29, about 5 percent of the original stand was returning, and this mostly from between the old crowns, only four or five of the latter showing any green shoots. Digging showed that all new growth was returning from at least 6 inches under ground; that is, all old roots had been killed to at least this depth.

On October 16, 1922, not over 5 percent of the original stand was present on the plot. Eleven shoots on the plot made seed in 1922. A few plants of *Hilaria jamesii* and horehound were growing normally on the plot.

Plot B2.—First application, June 25; all tops killed June 28

Second application, Sept. 3; all tops killed. There is what would seem to be a discrepancy in the notes on this plot. At the time of the second application, the returning growth was estimated at 40 percent of the original stand. On September 29, the returning growth was estimated at 90 percent of the original, and it was very clear that the second application had done no root killing. During the 1922 season, it was estimated that there was 60 percent of the original stand in 1921.

Plot B3.—First application, July 15; all tops killed July 18.

Second application, September 3. The returning growth was

two to seven inches high and estimated at 50 percent of the original. All tops killed September 5. It was estimated in 1921 that 80 percent of the plants had been killed, but on October 16, 1922, it was estimated that 60 percent of the original stand had returned.

Plot B4.—First application July 28; all tops killed August 1.

No second application. The roots on this plot were in no case killed to more than two inches below the surface. In 1922 the stand was entirely uninjured.

Plot B5.—Application made August 11; all tops killed August 14.

In 1922 the stand showed no injury, 100 percent of a stand being present on October 16, 1922.

NOTE:—For this plot and for all plots sprayed on or after this date, it was impossible to make any estimate of root killing in 1921, as it was so late in the development of the plants, that even though the roots were not killed, very little returning growth was made in 1921. The estimates of control for this and plots sprayed later were based entirely on growth that returned in 1922.

Plot B6.—Application made September 3; all tops killed.

On August 2, 1922, the stand showed no injury.

Plot C1.—First application, June 9; all tops killed June 11.

Second application, August 16; returning growth was estimated at 50 percent of original stand.

On September 29, there were only six green shoots of milkweed on the plot, and all but one of these were coming from small, horizontal roots between the old crowns. During 1922, the plot remained totally bare except for seven weak shoots of milkweed, and a half dozen small clumps of *Hilaria jamesii*. The killing was at least 98 percent.

Plot C2.—First application, June 25; all tops killed June 28.

Second application, September 3; all tops killed. On September 29, the plot showed 85 per cent of the original stand. Roots were killed two to four inches into the ground. During 1922, it was estimated that 50 percent of the original stand was present.

Plot C3.—First application, July 15; all tops killed July 18.

Second application, September 3; 40 percent of original stand returning; new growth two inches to seven inches high, larger plants just budding; all tops killed September 5.

On October 16, 1922, the control was estimated at 80 percent.

Plot D1.—First application, June 9; all tops killed June 11.

Second application, August 16; two percent of original stand returning; new growth in early blossom stage; all tops killed August 18. On September 29, only two green shoots were showing on the plot. Rotted roots were dug up to a depth of a foot and to a distance of 18 inches horizontally.

In 1922, the plot remained entirely bare except for two small

shoots of milkweed and a small amount of grass (*Hilaria jamesii*) at the bases of rocks where it was difficult to reach with the spray. Control was almost 100 percent. (Fig. 7).

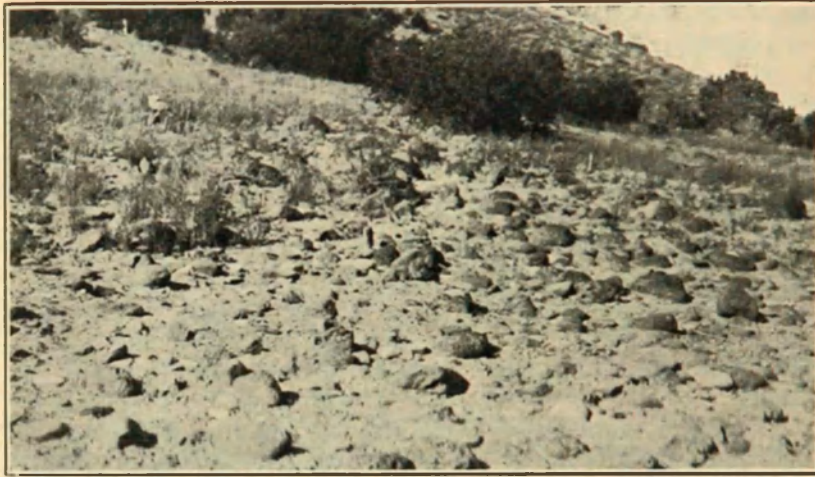


FIG. 7.—In the foreground, Plots D 1 and E 1 sprayed in 1921. Picture taken late August, 1922, showing no returning growth as against heavy growth on check in background.

Plot D2.—First application June 25; all tops killed June 28.

Second application, September 3; new growth estimated at 50 percent of original stand; three inches to eight inches high; all tops were killed.

During 1922, the estimated control was 85 percent.

Plot D3.—Application made July 16; all tops killed. On September 29, digging showed that the roots had been killed to the horizontal branches, and that the killing had extended for a few inches along the latter, but enough new sprouts were coming from the unkilld portions to make 50 percent of the original.

Plot D4.—Application made July 28; all tops killed. Roots were killed to a depth of two to four inches below the surface, but growth from below this point was resumed very quickly. During 1922, the stand was apparently uninjured.

Plot D5.—Application made August 11; all tops killed. During 1922, about 80 percent of original stand returned.

Plot D6.—Application made September 3; all tops killed. This plot showed no returning growth worth while spraying in 1921, but in 1922 the stand was apparently uninjured.

Plot E1.—First Application made in June 9; all tops killed June 11.

Second application August 16; 50 percent of original stand returning; new growth in early blossom. During September,

1921, there were four new shoots on the plot. These apparently had begun growth but were below the surface at the time of the second application. During 1922, no milkweed or other weeds grew on this plot. It remained entirely bare during the entire year.

Plot E2.—First application June 25; all tops killed June 28.

Second application September 3; returning plants 60 percent of original stand; new growth 3 inches to eight inches high; some blossoming. The control on this plot in 1921 was estimated at not more than five percent, but in 1922 only twelve plants showed up on the plot and the control was estimated at 95 percent.

Plot E3.—First application July 15; all tops killed July 18. The growth which returned on this plot was very slow in starting, and it was estimated in 1921 that 90 percent of the roots were killed. In 1922, however, about 50 percent of the original stand returned from small horizontal roots between the old crowns.

Plot E4.—Application made July 28; all tops killed August 1. It was estimated that the returning growth on this plot on October 8, 1921, was 90 percent of the original stand. In 1922, the killing was estimated at 40 percent.

Plot E5.—Application made August 11; all tops killed August 14; practically no returning growth in 1921. Control was in 1922 estimated at 50 percent.

Plot E6.—Application made September 3; all tops killed September 5. The stand in 1922 was 100 percent of the original.

Plot F1.—Application made July 28; all tops killed August 1.

In 1921, the estimated returning growth was 15 percent of the original. In 1922, the control was estimated at 75 percent.

Plot F2.—Application made August 11; all tops killed August 14.

Control estimated in 1922 at 95 percent.

Plot F3.—Application made September 3; all tops killed. Control in 1922 estimated at 50 percent.

Plot G1.—Application made July 28; all tops killed August 1.

Digging of roots in 1921 showed all roots rotted. In 1922 three small plants showed up on the plot, a control of at least 99 percent.

Plot G2.—Application made August 11; all tops killed August 14.

Control estimated in 1922 at 95 percent.

Plot G3.—Application made September 3. All tops killed September 6.

Control estimated in 1922 at 95 percent.

DISCUSSION OF RESULTS

While a study of the foregoing notes on the individual plots treated shows some discrepancies in results on some of the plots, there are apparently some rather general conclusions that may be drawn as to the efficient strength of solution to be used, and the time of application.

It is not worth while considering any application which does not show practically 100 percent killing. A checking over of the results on the various plots shows that there are ten of the thirty plots treated which show a control of 90 to 100 percent. These plots are B1, C1, D1, D2, E1, E2, F2, G1, G2 and G3. The solution in Series A, which was equivalent to an application of 80 pounds of white arsenic per acre was entirely too weak to give any worth-while control. From an examination of the data on these plots certain conclusions are obvious:

First.—Stronger applications of sodium arsenite are required as the season advances to kill even the tops of the milkweed. This is evidenced by the fact that only in the series receiving very heavy applications was there appreciable control where the first application was made after the plants had reached the blossoming time. In all the series, except Series A, very good control was obtained where the first application was made on June 9, when only the very first shoots to come up were beginning to show buds, and the second application was made from the middle of August to early in September, when the returning growth was just beginning to blossom. It is rather strange that the same control was not obtained where the applications were made to plants previously unsprayed and which were in the same stage of development as were the returning plants on plots previously sprayed once. This might be partly explained by the fact that the new growth on plots sprayed once came back largely from horizontal rootstocks between the first crowns which were killed back. This growth may have sapped the horizontal under-ground portions so that the second application completed the killing and the absorption through the new growth was sufficient to reach the remaining horizontal rootstocks.

Second.—The most economical single application, which gave 95 percent control, was made on Plot F2 on August 11, when the plants had practically ceased vegetative activity and the pods were two to three inches long with some of them beginning to burst. The same application made on Plot F1 on July 28, gave a 75 percent control, while an application made to F3 on September 3, when the plants were practically through all activity and most of the seeds were shed and all matured, killed only 50 percent of the plants. The single applications in Series G, each of which is equivalent to the application of 640 pounds of

white arsenic per acre, killed the milkweed practically completely, but such an application is out of the question to be used in a practical way, except in the case of a very small patch which is a menace to agricultural land and which it would be desired to kill at any cost. In such a case this treatment might be used, but the results on other plots show that it is not necessary to use such drastic measures.

Third.—It would seem that the best chemical method to use in attacking the whorled milkweed, as indicated by the results of the spraying at Paonia, is to start with the first application early in the growth of the plants at about the time the earliest plants are beginning to form flower buds. At this time there will be quite a number of shoots not yet through the ground. The new growth may then be allowed to get to the early blossoming stage and a second application made.

This second application probably need not be so heavy as the first, as in making all applications the effort is made to wet only the above-ground parts and not to soak the soil, and the second growth will probably not be over the entire plot. With this method of treatment, the dilution made in Series B was very efficient, but a stronger solution is recommended. Where five gallons of solution was applied to a square rod, which amount thoroughly wetted a heavy 100-percent stand of the milkweed, the application in Series B was equivalent to 160 pounds of white arsenic per acre. A stronger solution is more certain of results. It would probably pay to use as a minimum the strength of solution used in Series C, which was equivalent to 200 pounds of white arsenic per acre. In making applications over a large area there would probably not be five gallons used per square rod, so that this would reduce the amount per acre. The dilution used in Series C is a dilution of 1 to 32 of the original commercial weed-killer, containing 8 pounds of white arsenic per gallon.

Fourth.—The method outlined above should give good results in killing the whorled milkweed in the arid sections, but it is recommended for use only on such areas as are causing losses of livestock, or on patches along ditch banks which are a source of seed to be carried down onto agricultural land. **In no case should it be used on tillable land, as the cultivation method of control is far the cheaper, and there is not the danger of poisoning the soil.** Even though serious poisoning of the soil did not take place, the cultivation method will leave the soil in much better tilth. It must be borne in mind that the expense of applying the above treatment will be greater than the value of the land, and the only consideration which justifies its use is the prevention of livestock losses, or the prevention of seeding of agricultural land which might finally result in livestock losses.

SOME GENERAL OBSERVATIONS

Growing out of the work on the whorled milkweed there are some indications of general application with reference to the use of sodium arsenite as a herbicide.

First:—It is evidenced that in our arid sections much stronger solutions of the sodium arsenite are necessary to obtain desired results than are required in the moist sections where the relative humidity is high. This is probably due to the fact that the evaporation of the solutions from the plant is much more rapid in the arid sections so that the chemical does not stay in solution so long. Arguing from this premise, it would seem that if an application were made late in the evening, or during a damp period of weather, the results would be better. This might explain the difference in results between the plots receiving the first applications on June 9, and those receiving the first applications on June 25. The former date was during a rainy spell, while the latter was about in the middle of the longest dry spell of the season. There was no difference, however, in the weather conditions at the time of the second applications to the above groups of plots, nor did plots sprayed during rainy periods later in the season show any appreciable advantage over those sprayed with the same strengths of solution during dry periods. This would indicate that the development of the plants is probably as potent a factor as is the relative humidity.

Second:—The good herbicidal value of sodium arsenite should warrant its use on annuals along fence rows, ditch banks, roadways, rights-of-way, and such places, which are commonly breeding places of weed seed, which later infest agricultural land. For young annuals a very dilute solution could be used. The strength used in Series A in these experiments should be very efficient. This solution contained one pound of white arsenic in ten gallons of water. An application would require only enough to thoroughly wet the tops of the plants.

Third:—From the results on the different types of plants on the whorled milkweed plots, it is indicated that these weaker solutions might be very efficient against tap-rooted and woody-rooted types of perennials. Occasionally the milkweed grows as a tap-rooted plant. All such individuals were readily killed by all the different strengths of solution used. Where especial effort was made to thoroughly wet the plants of horehound (*Marrubium vulgare*) which were present on practically all the plots, all solutions used killed the plants in almost every case. The greatest difficulty experienced was in killing the finer roots and rootstocks which run horizontally through the ground and which are characteristic of the milkweed. It was from these roots between the old crowns that most of the returning growth

came after an application. Little difficulty was experienced in killing the roots down to the point of horizontal branching, but the poison did not follow the horizontal branches readily.

Caution:—In the use of sodium arsenite it must never be forgotten that it is extremely poisonous, and it must be used with all the care possible. Livestock seem to show a preference for arsenical-sprayed foliage, so care must be used to keep them away from it. It must also be remembered that large amounts of this chemical are toxic to the soil.

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