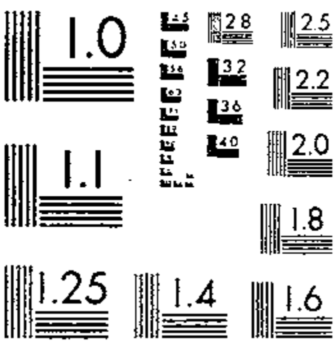
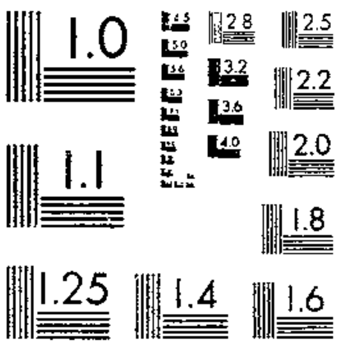
TB 240 (1931) USDA TECHNICAL BULLETINS UPDATA
THE CHEMICAL ERADICATION OF RIBES
OFFORD, H.R. 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 240 — MAY, 1931

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE CHEMICAL ERADICATION OF RIBES

By H. R. OFFORD

Agent, Office of Blister Rust Control, Bureau of Plant Industry

CONTENTS

	Page
Introduction	1
Discussion of early work	3
Tests of chemicals	5
Preliminary tests	5
Repeated application to resistant Ribes	9
Application to soil surface about the base of plants	10
Sodium-chlorate sprays	12
Large-scale tests	12
Sodium-chlorate sprays—Continued.	
Relative susceptibility of Ribes	13
Observations on killing effect	13
Factors influencing effective application	18
Inflammability	18
Field equipment and methods of spraying chemicals	19
Summary	22
Literature cited	24

INTRODUCTION

Experiments in the chemical eradication of Ribes [1] have been undertaken during the last several years to find an economical method of killing these plants in situations where simpler methods such as hand pulling and grubbing are not satisfactory.[2] The economic importance of eradication or suppression of these plants is predicated upon the fact that they are the alternate hosts of the fungus *Cronartium ribicola* Fischer, which causes the blister-rust disease of white pines.[3] Eighty or more species of wild Ribes are indigenous to the United States and are found under a wide range of site conditions. Many species occur in association with white pines, where they are noxious weeds because of their rôle in spreading the rust.

The white-pine blister rust was introduced from Europe into North America about 1898. It thrived under conditions on this continent and is now present in the New England States, New York, New Jersey, Pennsylvania, Michigan, Wisconsin, Minnesota, Montana, Idaho, Washington, and Oregon. It is also present in Canada in the Provinces of Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, and British Columbia.

White pines form a group of forest trees that are among the most valuable commercial timber species in the United States. The forests

[1] The genus name Ribes is used in this bulletin to include both currants and gooseberries.

[2] Laboratory experiments on which were based most of the field experiments herein reported were made possible through the active cooperation of the College of Agriculture of the University of California, specifically the Division of Forestry and the Division of Plant Nutrition. The writer also wishes to acknowledge the suggestions and the interest of P. R. Andrews, Seattle, Wash., R. N. Chipman, Bound Brook, N. J., and E. F. Ross, Olympia, Wash.

[3] White pines indigenous to the United States are: Northern white pine, *Pinus strobus* L.; western white pine, *P. monticola* D. Don; sugar pine, *P. lambertiana* Dougl.; limber pine, *P. flexilis* James; whitebark pine, *P. albicaulis* Engelm.; Mexican white pine, *P. ayacahuite* Ehrenb.; foxtail pine, *P. balfouriana* Murray; and bristlecone pine, *P. aristata* Engelm.

42375—31——1

of northern white pine, western white pine, and sugar pine contain standing timber which is estimated to be worth about $418,000,000. Limber pine, whitebark pine, Mexican white pine, foxtail pine, and bristlecone pine are not used extensively for timber at the present time, but are valued for watershed and scenic purposes. The blister rust is capable of attacking and destroying any tree of these species.

Blister rust spreads chiefly through the medium of wind-blown spores. Through this means it is capable of spreading long distances from diseased pines to the leaves of Ribes, where it undergoes a period of development that produces the spore stage that infects the pines. The distance of spread from Ribes to pines is short because the pine-infecting spores are very delicate and short lived. Therefore, white pines may be protected against blister-rust infection by destroying all Ribes within a comparatively short distance of the trees. This distance varies and is not definitely known for western conditions, but under forest conditions in the East it usually does not exceed 900 feet.

Control of the blister rust has been thoroughly demonstrated in New England and New York, where Ribes have been eradicated during the last 12 years on 7,757,140 acres of land. In these States the cost per acre of eradication has been low because Ribes were comparatively few over much of the area worked and white-pine sites containing very heavy stocking of these plants were not numerous. Under these conditions hand-eradication methods have been used effectively at a cost averaging about 20 cents an acre.

On the other hand, experimental control work in the commercial western white-pine region of the "Inland Empire" (northeastern Washington, northern Idaho, and northwestern Montana) has shown a higher average cost per acre because Ribes are generally more abundant and working conditions more difficult. There the most susceptible species of native Ribes occur in great profusion in the narrow strip of moist deep soil commonly found along the streams in the forested areas. Such locations are referred to as the Ribes "stream type." The two most susceptible species of Ribes in this region, *R. petiolare* Dougl. and *R. inerme* Rydb., are found in large numbers in such locations. In association with them there also occurs the less susceptible *R. lacustre* (Pers.) Poir. The great abundance of Ribes in these moist situations, where the rust finds favorable conditions for development, represents a great source of danger to the adjacent pine stands. Any plan of blister-rust control which is to assure adequate protection to the western white-pine stands of this region must include, as an immediate objective, the eradication of Ribes in these particular locations.

The eradication of Ribes along the forest streams of the "Inland Empire" (fig. 1) is difficult and costly because of the large number of these plants which grow there. Difficulties of eradication, moreover, are not manifested solely in the number of Ribes encountered; certain Ribes occurring in this region layer prolifically, and the task of removing underground stems and broken-off roots is long and arduous; others are rooted either in rock crevices or so intimately with other plants that complete eradication by mechanical means requires undue labor. Under these conditions eradication by the methods of hand pulling and grubbing which have been devised and successfully applied in the Eastern States is very costly. Accordingly, in 1924 experiments in the chemical eradication of Ribes were started in Idaho. This bulletin reports the progress of certain aspects of this work.

DISCUSSION OF EARLY WORK

The practicability of weed control by chemical methods has been demonstrated clearly by the work of a number of investigators. Brenchley (*4*).[4] Rabaté (*9*), Loyer (*8*), and Schultz (*11*) have done considerable work in Europe, and Åslander (*2*), Bolley (*3*), Long (*7*), Gray (*5*), and Thompson and Robbins (*12*) have made notable contributions from the United States. Their work may be referred to for details as to the herbicides used and for a general bibliography on chemical eradication of weeds.

Experiments in the chemical eradication of Ribes were first begun in the United States at Hobart, N. Y., in 1917, by L. W. Kephart[5] and

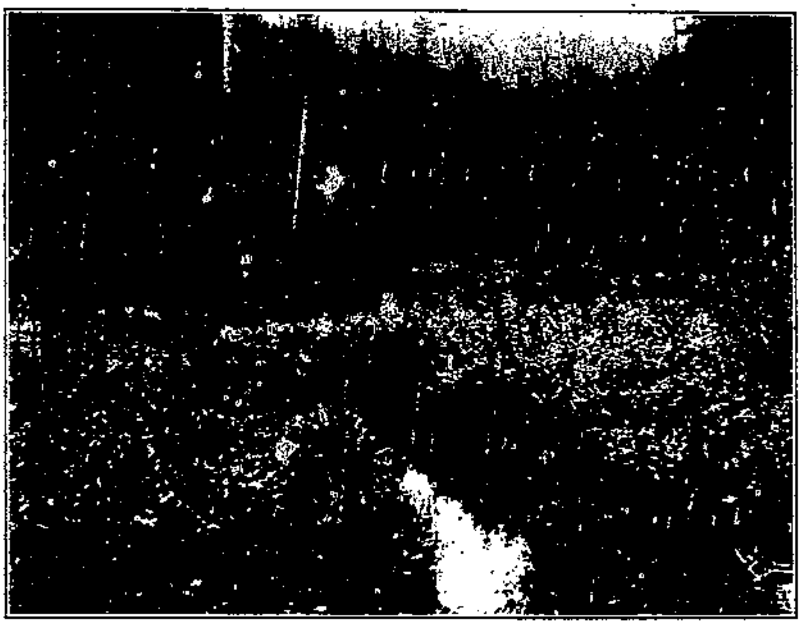


FIGURE 1.—Typical alluvial bottom land in the western white pine region of Idaho, showing *Ribes petiolare* along the edge of this slow-flowing stream. Bovill, Idaho, 1926

W. G. Wahlenberg, of the Office of Blister Rust Control. This work was continued during the period 1918–1921 by W. S. Regan, of the Office of Blister Rust Control, who conducted experiments at Hobart, N. Y., and Petersham, Mass. In the course of this work the following substances were tested: Ammonia, arsenic sulphide, arsenic trisulphide, calcium carbide, calcium chloride, calcium cyanide, carbon bisulphide, copper nitrate, copper sulphate, dip oil, formalin, fuel oil, hydrochloric acid, hydrogen cyanide, iron sulphate, kerosene, mercuric chloride, nitric acid, phenol, sodium arsenite, sodium sulphide, spirits of turpentine, sulphuric acid, and four specially prepared chemical

[4] Italic numbers in parentheses refer to Literature Cited, p. 24.

[5] Mr. Kephart was at that time an employee of the Office of Farm Management, Bureau of Plant Industry, but working under the direction of the Office of Blister Rust Control.

substances furnished by a commercial chemical company. The results of these experimental tests eliminated all of the above substances except dip oil, fuel oil, and sodium arsenite.

The following summary of Regan's[6] results with sodium arsenite has been made by the writer after a close study of the unpublished reports on his experiments with this chemical:

> Sodium-arsenite solution when sprayed on Ribes plants penetrated the leaves, buds, and stems, and one application killed varying percentages of the plants. Susceptibility of Ribes to this chemical seemed to vary with species, growth habit, and condition of the plants. Ribes with vigorous foliage appeared to be most susceptible. Two or three applications of the chemical usually killed 100 per cent of the bushy forms, while a greater number of applications was necessary to get similar results on skunk currant, *R. glandulosum* Grauer, which has a vinelike growth with many root centers developed along the trailing stems. Although sodium arsenite was fully effective, the chemical was not considered practicable for general use on account of its toxicity to livestock.

The following is a final report on dip oil and fuel oil as given by Regan (10):

> Dip oil (25 per cent cresol, 50 cents a gallon) was used straight or diluted with fuel oil. One treatment of dip oil (straight) applied to the top or crown of bushy Ribes kills in the majority of cases. Dilutions with fuel oil of 1 to 5 or 1 to 8 appear most satisfactory for the treatment of the skunk-currant areas, but two or more treatments are required for complete kill.
>
> Dip oil (straight) applied to the tops kills the Ribes foliage in from about one-half hour to a few hours, regardless of exposure to sun or shade. Crown treatment alone usually kills the plants slowly, often requiring several weeks or even months. The efficiency of dip oil appears to be little affected by rain, absence of foliage, or season of application, so long as the treatment is thorough.
>
> Fuel oil (light grade, 36.3° B., 14 cents a gallon) gives best results when applied to the entire top and crown. One treatment will frequently kill bushy species, but often two treatments, rarely three, are required. In areas of skunk currants three or more treatments will usually be required to obtain a complete kill. Dip oil and fuel oil are not poisonous to animals, and do not injure other vegetation if reasonable care is exercised. Where wild currant and gooseberry bushes are large and numerous, or grow in walls or stone piles where hand pulling is difficult, spraying with fuel oil should result in a material saving in cost, although combination with dip oil appears preferable. It does not appear to be economical to treat small plants of the bushy species, which are easily pulled by hand. One-gallon and three-gallon brass compressed-air sprayers are satisfactory for applying the oils.

Regan's work showed that bushy Ribes could be eradicated effectively with mixtures of fuel oil and dip oil. However, the cost of the material and the handling of such a bulky substance in the field limited its usefulness in Ribes eradication, particularly in view of the efficiency of the hand-pulling methods developed for removing Ribes under forest conditions in the Northeastern States. In the course of his chemical work on Ribes, Regan also made a series of tests in the use of chemicals for the destruction of barberry plants.[7]

Experimental work on the chemical eradication of Ribes was first undertaken in the Northwestern States in 1924 by W. F. Huppke.[8]

---

[6] REGAN, W. S. PROGRESS OF EXPERIMENTS FOR DESTROYING RIBES WITH CHEMICALS. 1918. (Unpublished manuscript in files, Office of Blister Rust Control.)

[7] These tests were performed in the M. A. Billings farm pasture, Millers Falls, Mass., during October and November, 1919, and August, 1920. Regan (see footnote 6) reports as follows: "Dip oil, fuel oil, salt solution, and sodium arsenite were fully effective on barberry plants. Dip oil gave the highest percentage of kill, but was more difficult to handle and more expensive than salt. Sodium arsenite is least effective and is dangerous to use in areas accessible to livestock. Salt solution (saturated solution, 3 pounds coarse-fine salt to 1 gallon water) gave 100 per cent efficiency when applied to the base, tops, or to the cut-off stumps. This appears to be the cheapest and most easily obtainable of chemicals tested and gave equally good results. Dry salt itself will kill barberry plants when placed about the base of the plants, but it usually requires a longer time and more material than where the solution is used."

[8] Employee of the Bureau of Plant Industry, U. S. Department of Agriculture, working under the direction of the Office of Blister Rust Control.

This work consisted of preliminary tests of the toxicity of numerous chemicals on Ribes occurring on small plots in the vicinity of Wallace and Priest River, Idaho. In the course of this work the following chemicals were tested: Acid sludge (50 per cent sulphuric acid), acid sludge oil, calcium chloride, calcium cyanide, calcium hypochlorite, calcium oxide, carbon bisulphide, "Carco," chromic acid, copper carbonate, copper soap in oil, copper sulphate, creosote, Du Pont Dust Disinfectant, Du Pont Weed Killer No. 3, Du Pont Weed Killer No. 4, extra-heavy fuel oil, heavy fuel oil, iron sulphate, lead acetate, light fuel oil, lye sludge oil, magnesium sulphate, manganese sulphate, mercuric chloride, oxalic acid, Paris green, phenol, potassium ferrocyanide, potassium permanganate, sodium acid sulphate, sodium arsenite, sodium chloride, tannic acid, and zinc sulphate. The work was checked over in June, 1925, by Huppke and the writer, and although the results pointed to some interesting possibilities, the evidence was not conclusive, owing to the small number of bushes to which any one chemical had been applied. The following substances had apparently produced some toxic effects on the Ribes plants: Acid sludge (50 per cent sulphuric acid), chromic acid, mercuric chloride, oxalic acid, phenol, potassium cyanide, and potassium permanganate.

After a careful check of the 1924 experiments the writer concluded that either the chemical suitable for the eradication of Ribes had not been found or that an effective chemical had been tested upon too small a scale to give convincing results. It was therefore decided to test again the seven chemicals listed above which had shown the most toxic effect in earlier experiments, and to give preliminary tests to a new list of chemicals which in the writer's opinion had potential merit.

TESTS OF CHEMICALS

PRELIMINARY TESTS

In 1925 three suitable areas for the testing of chemicals on Ribes were selected in Idaho—along Lake Creek near Wallace, along Renfrow Creek near Santa, and along Mary Creek near Clarkia. The area at Wallace represented the particularly marshy land where *Ribes petiolare* and *R. lacustre* abound and was suitable for comparative tests of the chemicals on these species. Scattered clumps of willow and alder provided both shaded and open locations for these Ribes. The plots at Santa were located in a cut-over and burned-over tract adjoining a stream and provided for comparative tests of the chemicals on *R. inerme* and *R. lacustre*. This area was comparatively free of brush and windfalls. The area at Clarkia was located in a typical "stream type" where *R. petiolare*, *R. inerme*, and *R. lacustre* occur in great numbers intermingled with alder and willow brush and provided a good basis for comparative tests of chemical on all three species. The Clarkia area, 2 acres in extent, was reserved for a test of the best ribicide as ascertained by the tests carried on at Wallace and Santa in 1925.

Both the Wallace and Santa areas were laid out in a series of rectangular 1/16-acre permanent plots. Each plot was subdivided into subplots. The majority of these plots were treated in 1925, but several plots were reserved at Wallace for use in 1926. Likewise a number of plots were reserved at Santa for use in 1926, 1927, and 1928. In order to keep all data readily available to the field observer, symbols denoting the plot number, station number, chemical used, concentration, and method of application were placed on each subplot stake as a permanent record. The uniformity of the plots at each locality, both as to size and flora, permitted a close comparison between results obtained with the various chemicals.

Before any chemicals were applied on the permanent plots the Ribes were systematically located and data were recorded for the Ribes found on each subplot. A basis for taking data by an ocular estimate of individual bushes was first established by carefully measuring a given number of each Ribes species. Data were taken by ocular estimates in the light of this established measuring stick and included height of bush (average height of erect stems), total linear feet of live stem, and total linear feet of dead stem. Summation of data then gave the total number of bushes, total linear feet of live stem, and total linear feet of dead stem by species for each subplot. The chemical to be tested was then applied over one or more subplots. Ribes data were taken again the year following treatment and compared with the data taken just before the plot was treated.

The results of chemicals tested at Wallace, Santa, and Clarkia, Idaho, between 1925 and 1928 on *Ribes petiolare* and *R. lacustre* are given in Table 1. It was fully realized that some of the chemical substances tested did not meet the necessary requirements of a killing agent for field use, such as cheapness, ready solubility, nontoxicity to men and animals, and noncorrosiveness to equipment. But in order to gain an insight into the action of numerous types of chemicals on Ribes, it was thought desirable to test all the chemical substances listed.

Table 1 arranges in three groups the chemicals tested by spray application to *Ribes petiolare* and *R. lacustre* according to the type of injury produced on these plants. While the final results for these species, which are given in terms of percentages of kill of live stem and bushes, express in a measure the toxic value of each chemical, particular attention should be paid to the grouping of the chemicals. In spite of a careful selection of experimental areas, preliminary observations showed that the age and vigor of the Ribes population varied so greatly that the live stem and bush kill could not be taken alone as the final measure of the effectiveness of the chemicals.

It was recognized that these variations in plant vigor militated against a proper evaluation of the toxic potential of any chemical if measured solely by the reduction of live stems and bushes which followed application of the chemical. Variations in plants might present an indeterminable range of vigor sufficient to account for the death of some bushes or live stem by chemicals very low in killing power, and for failure to kill other plants possessing unusual vigor by chemicals having a high toxic potential. An examination of Table 1 shows that the differences in chemical concentrations and number of bushes treated involve factors that materially influence the figures appearing under the columns headed "Live stem killed" and "Bushes killed." Also because of differences in solubility, corrosiveness, availability, and cost of materials, it was not practicable to test all chemicals in comparable concentrations.

TABLE 1.—*Chemicals tested by single application to leaves and stems of Ribes, grouped according to type of injury produced*

[Except in case of kerosene, which was applied full strength, all chemicals were applied in the form of aqueous solutions]

Chemical used: Name	Chemical used: Formula	Chemical concentration[1]	Location (in Idaho) and date of application	Ribes treated: R. petiolare: Bushes treated	R. petiolare: Live stem killed[2]	R. petiolare: Bushes killed[2]	R. lacustre: Bushes treated	R. lacustre: Live stem killed[2]	R. lacustre: Bushes killed[2]
				Number	*Per cent*	*Per cent*	*Number*	*Per cent*	*Per cent*
Group 1:[3]									
Ammonium carbonate.	$(NH_4)_2CO_3.H_2O$	20	Santa, July 21, 1926	0			119	27	0
Furfural	$C_4H_3O.CHO$	5	Santa, Aug. 9, 1928	10	25	0	14	5	0
Sodium bromide	NaBr	10	Wallace, June 28, 1925	83	4	0	32	13	0
Sodium chloride	NaCl	20	Santa, Aug. 11, 1925	0			10	27	0
Do		10	Santa, Aug. 10, 1925	0			12	36	0
Sodium fluoride	NaF	4	Santa, July 21, 1925	0			84	32	0
Sodium tetraborate	$Na_2B_4O_7.10H_2O$	[4]10	Wallace, June 29, 1925	21	4	0	40	12	0
Via Rasa[5]		4	Santa, July 22, 1925	0			92	16	0
Group 2:[6]									
Ammonium fluoride	NH_4F	4	Santa, July 21, 1926	0			9	34	11
Ammonium persulphate.	$(NH_4)_2S_2O_8$	25	Santa, July 10, 1927	23	70	4	0		
Do		15	do	34	65	3	0		
Copper sulphate	$CuSO_4.5H_2O$	10	Santa, July 18, 1927	12	12	0	9	13	0
Iron sulphate	$FeSO_4.7H_2O$	20	do	7	11	0	21	17	0
Mercuric chloride	$HgCl_2$	2	Wallace, June 29, 1925	125	6	0	15	11	0
Oxalic acid	$H_2C_2O_4.2H_2O$	4	Santa, July 18, 1925	0			18	56	11
Potassium permanganate.	$KMnO_4$	15	Santa, July 10, 1928	15	70	13	0		
Sodium bromide plus sodium hydroxide.	$NaBr+NaOH$	8 4	Santa, July 22, 1925	0			20	32	0
Sodium hydroxide	NaOH	4	Santa, July 18, 1925	0			199	57	6
Sodium hydroxide plus sodium fluoride.	$NaOH+NaF$	2 4	Santa, July 17, 1925	0			199	29	0
Sodium hypochlorite (commercial product).	NaOCl	([7])	Santa, June 26, 1928	0			48	46	4
Sulphuric acid	H_2SO_4	4	Santa, July 10, 1926	0			19	51	5
Group 3:[8]									
Ammonium chloride	NH_4Cl	30	Santa, Aug. 9, 1927	0			5	60	40
Do		25	Santa, July 20, 1926	0			143	79	19
Do		20	Santa, Aug. 28, 1925	0			15	98	7
Kerosene		([9])	Santa, Aug. 19, 1925	0			13	75	61
Potassium bromate	$KBrO_3$	5	Santa, July 22, 1925	0			26	42	19
Potassium chlorate	$KClO_3$	([4])	Wallace, June 8, 1926	113	97	68	67	97	36
Potassium chlorate plus sodium hydroxide.	$KClO_3+NaOH$	([10])	do	50	75	26	0		
Sodium chlorate	$NaClO_3$	50	Wallace, June 28, 1925	41	100	97	62	100	72
Do		25	do	166	100	99	77	98	58
Do		25	Santa, July 15, 1925	0			355	91	43
Do		25	Clarkia, Aug. 1-31, 1926.	2,710	100	99	4,700	65	24
Do		15	Santa, Aug. 29, 1925	70	100	100	424	77	14
Do		10	do	23	99	96	25	71	8

[1] Concentration expressed as percentage by weight.
[2] In these columns the closer whole number was used for fractions of 1 per cent. An even 0.5 per cent appears as the lower digit.
[3] No appreciable injury to Ribes leaves and stems; vigor of average plant remains unchanged.
[4] Supersaturated.
[5] Trade name for a mixture of ferric salts.
[6] Rapid initial injury to Ribes leaves and stems; vigor of plant temporarily affected followed by rapid reestablishment of bush.
[7] Half strength.
[8] Slow and complete killing of Ribes leaves and succulent stems, followed by slow and partial to complete death of older stem; partial to complete killing of bushes; vigor of plants permanently affected.
[9] Full strength.
[10] Potassium chlorate 5 to 6 (supersaturated), sodium hydroxide 2.

It soon became apparent, therefore, that results must be judged by two criteria: (1) The end result of whether or not death of the plant ensued, and (2) the type of injury produced, as indicated by definite symptoms shown by the treated parts of the plant. Accordingly, the complete record of each experiment included careful observations of the injury as it developed on the treated plants, as well as final data on percentage kill of live stem and of bushes, obtained the year following treatment.

The experiments reported in Table 1 have been divided into three groups, so that uniformity of results in regard to the general lowering of plant vitality is given proper consideration. If the percentages of live stem and bushes killed are then considered in the light of the characteristic injury described for the particular group in which they appear, a more accurate comparison can be made of the killing potentialities[9] of the chemicals tested. The types of injury to Ribes caused by the three groups of chemicals are as follows:

Group 1. No appreciable injury to Ribes leaves and stems. Vigor of average plant remains unchanged. *R. petiolare,* live stem killed, 4 to 25 per cent, bushes killed, none. *R. lacustre,* live stem killed, 5 to 36 per cent; bushes killed, none.

This group represents those chemicals which had little or no effect on the Ribes treated. In some cases a few leaves and some succulent stem growth were killed, but for the most part killing action was either not apparent or manifested only by a slight browning of the leaf margins where concentration of the chemical had occurred. Toxic action is primarily attributed to osmotic effects on the part of the applied sprays. Reference to Table 1, Group 1, shows that the injury produced by these chemicals was limited to the killing of comparatively low percentages of the live stem. It should be kept in mind that the figures for live-stem kill in this group for both *R. petiolare* and *R. lacustre* signify current-season stem.

Group 2. Rapid initial injury to Ribes leaves and stems. Vigor of plant temporarily affected, followed by rapid reestablishment of bush. *R. petiolare,* live stem killed, 6 to 70 per cent; bushes killed, 0 to 13 per cent. *R. lacustre,* live stem killed, 11 to 57 per cent; bushes killed, 0 to 11 per cent.

This group represents those chemicals which produced considerable initial injury, from which most of the plants recovered. The extent of injury varied greatly, as follows: Rapid and in many cases complete kill of leaves, followed by partial to complete kill of current-season stem, with partial to complete killing of old stem and an occasional bush completely killed. Partial killing was followed by rapid releafing with new leaves, green and quite normal in appearance. The highly caustic or rapidly poisonous chemicals in this group are not the substances most toxic to Ribes. The Ribes put out new leaves in almost direct ratio to the speed of defoliation. In many cases plants seemed to be stimulated to renewed growth by such treatment. Toxic action of this group of chemicals appears to consist of the caustic effect of acids and alkalies and the precipitating or coagulating power of heavy metal ions.

In general the percentages of live-stem and bush killing for the chemicals listed in Group 2 show a definite increase over those in Group 1, although it is apparent that the chemicals in Group 2 are not sufficiently toxic to make them practical for field use. In this group some 1 and 2 year old stem was killed as well as the current season's growth. If judged solely on the criterion of percentage kill of bushes,

[9] Data have been recorded only for Ribes, but observations of associated brush made by the writer suggest that the general effects described for the three groups hold good for other perennials. By arranging the experiments as shown in Table 1, it is hoped that the information therein is made more useful to those interested in the eradication of noxious weeds other than Ribes.

some of these chemicals might be called border-line compounds between Groups 2 and 3. However, in view of the quick toxic action and the rapid, vigorous releafing that followed the initial injury caused by their application, they most certainly all belong in Group 2.

Group 3. Slow and complete killing of Ribes leaves and succulent stems, followed by slow and partial to complete death of older stem. Partial to complete killing of bushes. Vigor of plants permanently affected. *R. petiolare*, live stem killed, 75 to 100 per cent; bushes killed, 26 to 100 per cent. *R. lacustre*, live stem killed, 42 to 100 per cent; bushes killed, 7 to 72 per cent.

This group represents those chemicals which tend to produce permanent injury. In contrast with the rapid and temporary injury produced by the chemicals in Group 2 was the slow sickening and dying of the plants treated with the chemicals in this group, following the slow and complete killing of the leaves. The symptoms are fairly uniform and consistent on all plants of the same species. Individual plants that do not succumb are so reduced in vitality that they recover very slowly. While the question of absorption and translocation of a poisonous chemical by a perennial is beyond the scope of this bulletin, it is certain that those chemicals which act very slowly on the leaves and succulent stems of Ribes are much more effective than those which act rapidly. Slow-acting poisons, such as sodium chlorate, appear to act in rather a fundamental fashion when sprayed on the aerial portions of plants, and it is the writer's opinion that this is characteristic of the compounds that will prove most useful in future methods of chemical suppression of weeds. Later in this bulletin some tentative suggestions are made concerning the mechanism of the toxic action of sodium chlorate.

Analysis of similar field data for *Ribes inerme* showed this species to be generally more resistant to chemicals than *R. petiolare* and *R. lacustre*; however, the three types of injury described for these species also held true for *R. inerme*. The chemicals tested by spray application[10] to *R. inerme* are arranged below in three groups on the same basis as those described for *R. petiolare* and *R. lacustre*.

Group 1. Ammonium carbonate, ammonium bromide, ammonium nitrate, calcium chloride, calcium hypochlorite, paradichlorobenzene, calcium paratoluenesulphonamide, potassium fluoride, potassium sulphate, sodium bromide, sodium chloride, sodium fluoride, sodium sulphate, sodium paratoluenesulphonamide, sodium sulphite, sodium tetraborate, Via Rasa.

Group 2. Acetic acid, aluminum sulphate, ammonium fluoride, ammonium persulphate, chromic acid, copper sulphate, hydrochloric acid, oxalic acid, perchloric acid, phenol, potassium cyanide, potassium permanganate, sodium bromide plus sodium hydroxide, sodium dichromate, sodium hydroxide, sodium hydroxide plus sodium fluoride, sodium hypochlorite, sulphuric acid, zinc chloride.

Group 3. Ammonium chloride, kerosene, potassium bromate, potassium chlorate, sodium chlorate.

REPEATED APPLICATION TO RESISTANT RIBES

The poor results obtained with sodium chlorate on *Ribes lacustre* and *R. inerme* by a single application of an aqueous spray led to some experiments dealing with the effect of two and three applications of chemicals. For these experiments sodium chlorate and ammonium chloride were selected from Group 3 on account of their relatively higher toxicity to the resistant species and were compared with sodium hydroxide, which was considered as representing Group 2. Until some chemical from Group 2 showed real promise it was felt that

[10] Kerosene was applied full strength as a spray, calcium hypochlorite was dusted on, and the other chemicals were applied in the form of aqueous solutions.

chemicals of the still lower toxicity represented by those of the Group 1 type could be ruled out as possessing no possibilities even for repeated application, and therefore no chemical from Group 1 was included in this test. In order to account for the injury that might be expected to occur by reason of repeated defoliation, the results of chemical defoliation were compared with defoliation accomplished by hand picking the leaves.

The experiments reported in Table 2 show the results of successive spray applications of sodium hydroxide, sodium chlorate, and ammonium chloride to the leaves and stems of *Ribes lacustre* and *R. inerme*, as well as the results of repeated defoliation by hand picking the leaves. These data show that three applications of a cheap defoliator such as sodium hydroxide 4 per cent are not appreciably more toxic to Ribes than the same number of defoliations accomplished by hand. Second and third applications of ammonium chloride 12½ per cent are more toxic than the same number of applications of sodium hydroxide 4 per cent, even though the concentration of ammonium chloride in this experiment was considerably lower than the one of optimum toxicity shown in Table 1. The increased effectiveness of sodium chlorate over the superficially toxic chemicals like sodium hydroxide is clearly shown and further confirms the earlier observation concerning the peculiarly fundamental action of this chemical. Three applications of a 25 per cent solution of sodium chlorate to *R. lacustre* and *R. inerme* gave from 98 to 100 per cent kill of the treated plants.

TABLE 2.—*Chemicals tested by two or more spray applications to leaves and stems of Ribes at Santa, Idaho*

Chemical used	Chemical concentration [1]	Bushes treated		Date of application	Live stem killed [2]		Bushes killed [2]	
		R. lacustre	R. inerme		R. lacustre	R. inerme	R. lacustre	R. inerme
		Number	*Number*		*Per cent*	*Per cent*	*Per cent*	*Per cent*
Sodium hydroxide	4	64	248	July 5, 1925	38	30	6	3
				July 8, 1926	41	39	8	4
				July 2, 1927	75	56	11	12
Sodium chlorate	25	175	72	July 23, 1925	83	63	40	15
				July 14, 1926	93	91	90	60
				July 12, 1927	100	98	100	98
Do	15	106	146	July 24, 1925	69	38	14	3
				July 18, 1926	89	58	18	5
Do	10	25	145	Aug. 28, 1925	63	29	8	5
				July 15, 1926	93	47	12	8
Ammonium chloride	12½	23	87	July 17, 1925	31	23	0	2
				July 12, 1926	62	53	13	7
				July 3, 1927	90	74	20	14
Leaves stripped from bushes by hand		13	165	Aug. 7, 1925	12	2	0	0
				July 14, 1926	24	35	0	0
				July 2, 1927	98	44	15	3

[1] Concentration expressed as percentage by weight.
[2] The closer whole number was used for fractions of 1 per cent. An even 0.5 per cent appears as the lower digit.

APPLICATION TO SOIL SURFACE ABOUT THE BASE OF PLANTS

The experiments reported in Table 3 were performed to obtain preliminary data concerning the practicability of killing Ribes by applying chemicals to the soil surface about the base of the plants. Regan's work had shown that the practical use of this method of treatment should be largely confined to bushy forms of Ribes that have simple root systems and that under certain conditions it was more expensive than hand pulling. The Ribes found in the "stream-type" locations of the "Inland Empire" have complex root systems as the result of profuse layering, and it was obvious that this method would be too costly on such bushes. However, areas are found in this region where *R. lacustre* and *R. inerme* occur abundantly as single bushes or are rooted in rock crevices. Such conditions render hand pulling or grubbing difficult and costly.

Data in Table 3 show the relative merits of the chemicals tested by application to the undisturbed soil surface about the base of *Ribes lacustre* and *R. inerme*. In the only two tests that included both species, *R. lacustre* appeared more susceptible to the chemicals by this method of treatment than *R. inerme*. One quart per bush of a 25 per cent aqueous solution of sodium chlorate killed 100 per cent of the *R. lacustre* bushes so treated. Eight additional chemicals were applied to *R. inerme*. Equal parts by volume of acid sludge and water, one-half pint per bush; sodium chlorate, 25 per cent aqueous solution, 1 quart per bush; ammonium chloride, one-half to 1 pound per bush; kerosene plus an equal part of acid sludge, one-half to 1 pint per bush; and sodium hydroxide 4 per cent plus sodium fluoride 5 per cent in aqueous solution, 1 quart per bush, in the order named, killed from 65 to 100 per cent of the bushes of *R. inerme* treated. All factors considered, of the chemicals listed in Table 3, sodium chlorate or the sodium hydroxide-sodium fluoride mixture are probably best adapted to the chemical eradication of Ribes by soil treatments such as used in these experiments.

TABLE 3.—*Results obtained by applying chemicals to the soil surface about the base of Ribes plants, Santa, Idaho*

Chemicals used	Quantity applied per bush	Date of experiment	Ribes treated			
			R. lacustre		R. inerme	
			Bushes killed [1]	Bushes treated	Bushes killed [1]	Bushes treated
			Per cent	*Number*	*Per cent*	*Number*
Ammonium chloride (dry)	½ to 1 pound	Aug. 15, 1925			88	26
Ammonium chloride [2] 20 per cent+; sodium hydroxide, 2 per cent.	1 pint	Aug. 4, 1925			11	8
Acid sludge,[3] 1 part; water, 1 part	½ pint	Aug. 27, 1925			65	17
Calcium chloride (dry)	½ to 1 pound	Aug. 4, 1925			15	60
Kerosene (full strength)	1 pint	Aug. 19, 1925			40	13
Kerosene, 1 part by volume; acid sludge, 1 part by volume.	½ to 1 pint	do			92	12
Sodium chlorate,[2] 25 per cent	1 quart	July 23, 1925	100	18	75	16
Sodium chloride (dry)	1 to 5 pounds	July 15, 1925	50	16	12	8
Sodium hydroxide,[2] 4 per cent; sodium fluoride, 5 per cent.	1 quart	do			100	11
Sodium tetraborate (dry)	½ to 1 pound	July 21, 1925			11	27

[1] In columns 4 and 6 the closer digit was used for fractions of 1 per cent. An even 0.5 per cent appears as the lower digit.
[2] Aqueous solution.
[3] A waste product of the oil-refining industry containing a high percentage of H_2SO_4.

It was found that in applying chemicals to the soil about the base of Ribes bushes, either in solution or in solid form, best results were obtained when the chemical was applied so that leaching or flow of solution took place across the root system of the plant. The anomalies of root distribution doubtless accounted for some of the inconsistencies obtained by the writer in these experiments. While the scope of these experiments is limited, the good results obtained in the case of several of the chemicals suggest that this method of chemical eradication may be of value on plants with simple root systems where cheaper methods are not effective. Additional experiments of this nature are now under way in the sugar-pine region where a scarcity of water renders spraying impracticable. Under these conditions a toxic hygroscopic dust applied to the aerial parts or about the base of Ribes may prove to be an effective and economical ribicide.

SODIUM-CHLORATE SPRAYS

LARGE-SCALE TESTS

It is apparent from the results obtained by the tests of chemical sprays on Ribes in 1925 and 1926 that the sodium and potassium salts of chloric and bromic acids were the only substances that gave real promise of desired results. The field tests showed these chemicals to be consistent in their effect and in the case of *R. petiolare* to give sufficient kill to merit further and more intensive experimentation. After careful consideration of these substances it was decided to test the killing effect of sodium chlorate on Ribes on a much larger scale in 1927. Potassium chlorate was eliminated because of its relative insolubility. It was also decided to discontinue experiments with the bromates because of their relatively high cost and the limited possibility of securing them in large quantities. The uniformity of results secured with these oxyhalogen compounds made it possible to eliminate all but the cheapest and most readily usable. Plans were therefore made to test the toxic effect of aqueous solutions of sodium chlorate on Ribes on a sufficiently large scale to eliminate the effect of local variations in these plants.

An area was selected on the East Fork of Potlatch Creek, several miles east of Bovill, Idaho. It consisted of the customary narrow belt of stream land, traversing in this particular case a large area of logged-off land. It contained the three Ribes species *R. petiolare*, *R. lacustre*, and *R. inerme*.

During the course of the 1927 field season the Ribes on four plots totaling 27.59 acres of "stream type" were sprayed with different solutions of sodium chlorate. Four spray solutions, representing two concentrations of the chlorate and two spreaders, were used, one to each plot, as follows: Solution No. 1, $NaClO_3$, 25 per cent; solution No. 2, $NaClO_3$, 25 per cent plus fish-oil soap; solution No. 3, $NaClO_3$, 25 per cent plus glue; solution No. 4, $NaClO_3$, 20 per cent. Results of these tests are shown in Table 4.

TABLE 4.—*Results of application of sodium-chlorate spray to the leaves and stems of Ribes, 1927, Bovill, Idaho*

Spray solution	Date of application	Area sprayed	R. petiolare				R. lacustre				R. inerme			
			Growth treated		Growth killed[1]		Growth treated		Growth killed[1]		Growth treated		Growth killed[1]	
			Live stem	Bushes	Live stem	Bushes	Live stem	Bushes	Live stem	Bushes	Live stem	Bushes	Live stem	Bushes
		Acres	*Feet*	*Number*	*Per cent*	*Per cent*	*Feet*	*Number*	*Per cent*	*Per cent*	*Feet*	*Number*	*Per cent*	*Per cent*
No. 1	July 1-15	9.16	102,150	2,043	100	[2]99+	21,150	846	99	59	48,600	1,944	93	32
No. 2	July 10-30	6.11	68,100	1,362	100	99+	15,100	604	88	14	32,400	1,296	62	(3)
No. 3	July 15-30	5.44	56,250	1,125	100	99+	10,750	403	93	42	27,000	1,080	72	(3)
No. 4	Aug. 1-7	6.88	26,000	520	100	99+	5,100	204	84	19	16,000	640	73	6

[1] The closer whole number was used for fractions of 1 per cent. An even 0.5 per cent appears as the lower digit.

[2] *Ribes petiolare* was completely susceptible. Occasionally a small plant escaped treatment in the application.

[3] Compelte data were not taken on the number of bushes killed.

Data given in Table 4 show the high kill obtained by the use of sodium-chlorate spray on *Ribes petiolare* bushes in contrast with the poorer results obtained on *R. lacustre* and *R. inerme*. The chemical was more evenly distributed over the stems and leaves and remained there much better in cases where a sticker was used. It is believed that the variation in the effectiveness of the spray on *R. lacustre* and *R. inerme*, the less susceptible species, was due to other causes than the possible reduction of toxicity by the sticker. The results of the experiments for *R. petiolare* and *R. lacustre* agree in general with those shown in Table 1. Subsequent chemical eradication work with sodium chlorate undertaken on a large scale at Bovill, Idaho, and at Haugan, Mont., in 1928 showed practically the same general differences in the susceptibility of *R. petiolare*, *R. lacustre*, and *R. inerme* to this chemical, as indicated in Table 4.

RELATIVE SUSCEPTIBILITY OF RIBES

Reference to Tables 1 and 4 show that practically 100 per cent of *Ribes petiolare* is completely killed by a single application of an aqueous solution of sodium chlorate, 10 to 50 per cent by weight, sprayed on the leaves and stems. The killing shown by Figures 2 and 3 is representative of the areas treated with sodium chlorate from which the data in Table 4 were obtained. A number of complete kills of *R. inerme* and *R. lacustre* were obtained over any area so treated, but the average effectiveness of the chemical was much lower on these species. Considerable sprouting takes place from the crown of both *R. lacustre* and *R. inerme* (fig. 4), whereas the plants are completely killed in the case of *R. petiolare*, provided the application is thorough. Data in Tables 1 and 4 show that these Ribes species are definitely arranged in an order of decreasing susceptibility to sodium chlorate as follows: *R. petiolare*, *R. lacustre*, *R. inerme*.

Recent experimental work has indicated that the concentration of sodium chlorate necessary for complete eradication of *R. petiolare* can be reduced to about 10 per cent by making the spray slightly acid (pH 5.0 to 6.5).

OBSERVATIONS ON KILLING EFFECT

Sodium chlorate has been used in Europe as a weed eradicator for a number of years. Loyer (*8*) says that work should be done in April, May, or early June. Seven to eight kilos per hectare of $NaClO_3$ are used. A mixture of $NaClO_3$ and $NaNO_3$ can be used. Rabaté (*9*) says that 250 kilos of $NaClO_3$ per hectare will destroy all vegetation. He used NH_4ClO_3 and found it to be quite effective. It had a slow action on the leaves which was not apparent for some days.

The first published report on the use of sodium chlorate as a herbicide in the United States was made by Åslander (*1*), who sprayed *Cirsium arvense* Scop. with $NaClO_3$ 10 per cent and $KClO_3$ 6.5 per cent. He observed that the epidermis and the cortex were first affected and that dilute solutions of $NaClO_3$ were selective in their action. Latshaw and Zahnley (*6*) found that a 12½ per cent solution of $NaClO_3$ was very effective when sprayed on bindweed, *Convolvulus arvensis* L. The first spray was most active if applied about the time the plants were in full bloom. They noticed, moreover, a considerable diminution of the starch content in the roots of treated plants.

When sprayed on Ribes in aqueous solution of sufficient strength to kill the live stem of the plant, the first obvious effect of sodium chlorate is a slight curling of the leaves. In hot weather this may occur a few hours after application of the chemical. Two days after treatment the leaves begin to turn brown. The succulent stems of the current year's growth show a marked darkening in color of the epidermis about the time that browning of the leaves occurs. Brown spots appear in the cambium four or five days after treatment. All succulent stem growth is usually dead at the end of the first week. The older stems show a similar effect from the action of the chemical after 12 to 14 days. Shortly after the effect of the chemical has become noticeable in the cortex of the woody stems, progress of the killing action is manifested by the appearance of a dark brown coloration in the medullary rays and pith. In the last stages of injury the bark sloughs quite easily from the woody stem. The entire plant is killed to the ground in this manner during the course of the season. In the case of *R. petiolare* the roots are, for the most part, killed during the two or three months following application. Life has been

FIGURE 2.—Dense understory of *Ribes petiolare* completely killed by one application of $NaClO_3$, 25 per cent. Sprayed on leaves and stems, August, 1926. Photographed July, 1927, Clarkia, Idaho

observed in some old *R. petiolare* crowns the ensuing spring, but no sprouting takes place, and one year from the date of treatment *R. petiolare* bushes are completely dead. The effect of the chemical on the stem as described above is slower in the case of *R. lacustre* and *R. inerme*, and in a large percentage of cases these species reestablish themselves by sprouting from crowns.

The typical action of sodium chlorate on Ribes, as described above, may be varied to a greater or less extent by certain of the individual plant's environmental factors. The rate of action of the chlorate varies considerably with the degree of exposure of the plant, although the final results seem to be the same in all cases. Ribes exposed to direct sunlight often show a curling of the leaves three or four hours after application of the spray. Shade forms, on the other hand, may only show this characteristic slight curling over periods of four to six days after application, and the subsequent manifestations of injury are similarly delayed.

Observations made on sprayed areas showed that the action of the chlorate is faster on Ribes in moist habitats than on plants occurring in drier locations.[11] It is also evident from the results of these field

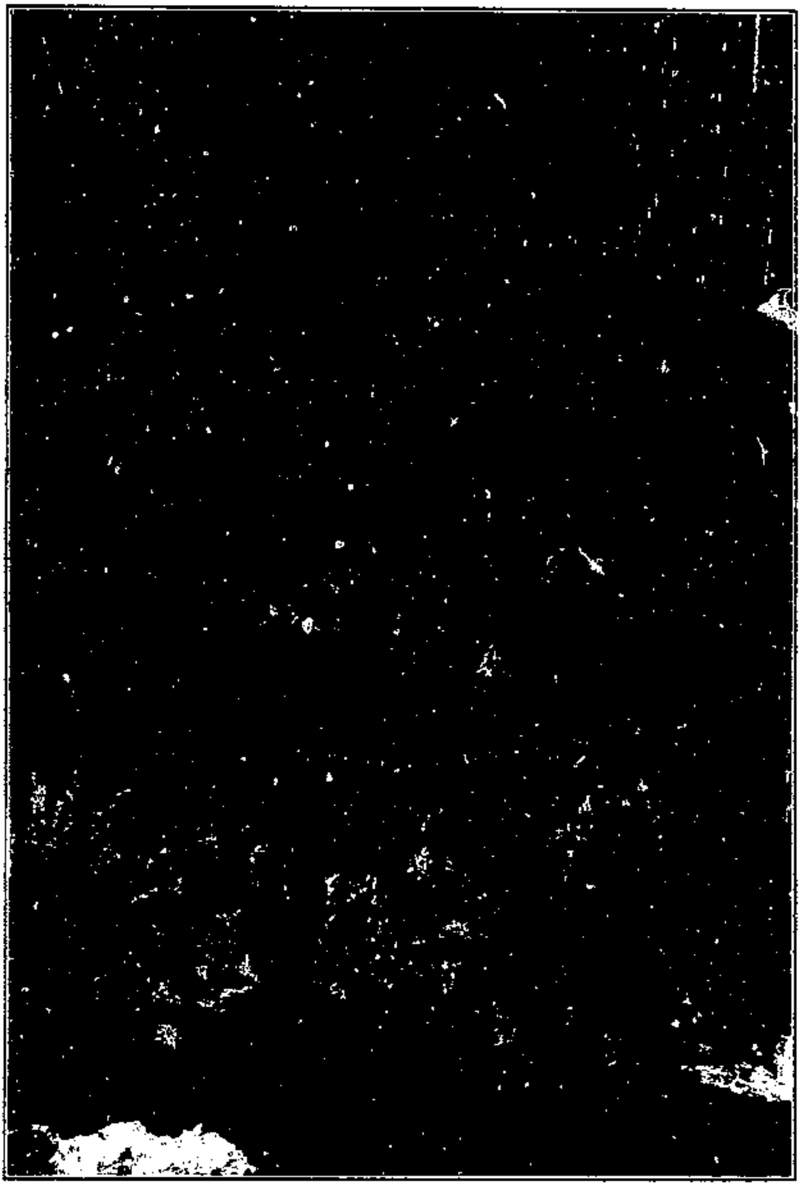


FIGURE 3.—*Ribes petiolare* with an overstory of alder and willow. Ribes are completely killed, as well as the greater portion of the brush canopy. Note the 40 to 60 year stand of white pine in the background, which is protected from blister rust by the destruction of the Ribes. Leaves and stems sprayed with sodium chlorate, August, 1926. Photographed July, 1927, Clarkia, Idaho

---

[11] The action of sodium chlorate on brush plants commonly associated with Ribes has been carefully observed during the course of experimental work. *Alnus* sp., *Salix* sp., and *Cornus* sp. apparently respond to sodium-chlorate treatment in the same manner as *R. petiolare*. These plants, essentially moisture loving, are often completely killed by a single application of sodium-chlorate spray to the aerial parts, inadvertently applied while spraying Ribes.

tests that the manner of application may vary the effectiveness of the spray. The toxic effect seems to be greater when the spray is applied to the lower leaf surface than to the upper. The significance of these facts can be determined only by detailed studies on the structure and physiology of the species concerned. Such studies are now under way.

Sodium chlorate is most effective when applied early in the growing season just after the Ribes have fully leafed out. *R. inerme* and *R. lacustre*, the most resistant species, exhibit a stronger seasonal variation than *R. petiolare*. A small amount of releafing has been observed on *R. petiolare* when the chlorate is applied late in the growing season, but the bushes do not live over the winter. *R. inerme* and *R. lacustre*, on the other hand, show less injury when the chemical is applied late in the year. Occasionally *R. inerme* and *R. lacustre* will sucker from the crown the second year after application of the

FIGURE 4.—*Ribes inerme* showing typical development of sprouts from the crown one year after spraying the leaves and stems with $NaClO_3$. The overstory is willow. Clarkia, Idaho, 1927

chlorate. In the case of *R. petiolare*, however, any tendency of the plant to reestablish itself is manifested the year following treatment.

The ideal time for application of sodium chlorate to Ribes seems to be early in the growing season during dull cloudy weather.[12] If the sun is too hot immediately after application, a certain amount of the chemical will dry on the leaf and scale off, particularly if a high wind prevails. A period of warm bright weather for a few days after

[12] It is interesting to note the observations that have been made by other investigators concerning the most favorable time for applying herbicide. Bolley (3) recommended humid weather for the application of weed sprays and found the condition favoring rapid growth to be the most satisfactory. Gray (5) states that sodium arsenite acts most vigorously on wild morning-glory if the plant is "approaching or wholly within the dormant state." Åslander (2, p. 1066) in his report on sulphuric acid as a weed killer states "* * * The mustard plants were killed under all conditions of humidity, but best results were obtained in dry air." When he used iron sulphate, however, the reverse was true, and in the same paper he states: "A solution of iron sulphate was found to be most destructive in an atmosphere containing about 100 per cent relative humidity." It seems evident that the type of inorganic salt which acts slowly is most favorably applied when the air is damp and that a film of moisture on the leaf is essential before maximum toxicity can be obtained.

the spray is applied and the presence of dew at night with comparatively high humidity during the day are favorable to the toxic action of sodium chlorate. Rain two hours after spraying does not materially reduce the toxic action of this chemical.

In the light of a widespread interest in the use of sodium chlorate as a herbicide it may be of some interest to set down a few suggestions concerning the possible mechanism of its toxic action, which have resulted from several years' field and laboratory experience with chemical eradication of Ribes. The high oxidizing potential of sodium chlorate and the readiness with which this compound gives up its oxygen when intimately associated with organic matter is a well-known chemical fact. The chlorate ion possesses another unusual property in that it contains chlorine in the pentavalent form. In the process of the decomposition of aqueous sodium chlorate in a slightly acid solution, both nascent oxygen and highly reactive chlorine might be formed, both of which would act as intense poisons to plasma proteins. The writer has recently shown, in the course of the laboratory experiments mentioned, that exposure to ultra-violet light for a few minutes brings about a decomposition of sodium chlorate as manifested by the appearance of free chlorine in the solution. Obviously the light intensity within the intercellular spaces that finally reaches the chloroplasts in the case of sprayed plants does not approach the intensity employed in the above-mentioned ultra-violet light experiment, but it is quite conceivable that a decomposition of chlorate, catalyzed by direct sunlight, would take place slowly over a long period of time under field conditions. Moreover, the slowness of this reaction is quite consistent with the slow sickening results noted following application of sodium chlorate to a plant.

Experiments carried out at Berkeley, Calif., have also shown quite conclusively that the chlorate ion is present as such in the roots of plants following the application of the aqueous spray to the aerial parts. Apparently the sodium-chlorate molecule, or the chlorate ion, is translocated within the plant during some of the processes of metabolism and by virtue of this fact exerts more than a local, superficial action. It is also certain that a rapid depletion of the stored carbohydrates occurs shortly after treatment with sodium-chlorate spray. Whether this disappearance of carbohydrate is the result of a specific reaction between sodium chlorate and the starches or sugars or merely the usual response that a plant makes to injury is unknown at the present time. So far it has not been possible to demonstrate that sodium chlorate will oxidize starches or sugars in vitro, though it is possible that direct oxidation may occur within the plant in the presence of some starch-hydrolyzing enzyme. The possibility that sodium chlorate can stimulate plant respiration to an unusual degree has also been considered, though no conclusive evidence has been obtained as yet to show that this takes place to any significant extent.

Briefly, the peculiarly fundamental toxic action exerted by sodium chlorate might be explained by (1) the fact that it is rather passive in the early stages, thus allowing movement of the poison within the plant, and (2) by the fact that over an extended period a slow decomposition with a corresponding change in the oxidizing potential of the chemical occurs in the superficial layers of the plant catalyzed by sunlight and within the plant tissue by virtue of reducing substances such as tannins or reducing sugars under the stimulus of life processes.

FACTORS INFLUENCING EFFECTIVE APPLICATION

Field experiments showed conclusively that whenever an aqueous solution of sodium chlorate 10 to 50 per cent was thoroughly sprayed on the leaves and stems of *Ribes petiolare*, a complete kill was obtained. The striking difference in susceptibility between *R. petiolare* on one hand and *R. inerme* and *R. lacustre* on the other suggested that, aside from physiological differences between species, the chemical was not being effectively applied in all cases. Several factors militate against the successful application of a spray to *R. inerme*. The screening effect of associated brush is greatest for *R. inerme*. This species, moreover, has a habit of sending out long branches which may lie prostrate on the ground or climb about the overstory of brush. Frequently parts of this plant are missed during the course of field spraying. Another factor that undoubtedly contributes to the difference in susceptibility of the aforementioned Ribes is the difference between species in area of leaf surface per foot of live stem. *R. petiolare* has a much larger area of leaf surface per foot of live stem than *R. inerme* and *R. lacustre*. Finally, *R. petiolare* has a thinner bark, is more succulent, and has a smaller amount of protective tissue than the other two species.

The tendency of the spray to run off or form large drops on the leaves of some plants has been largely overcome by the use of stickers and spreaders. Calcium caseinate, flour, fish-oil soap, glue, glycerin, linseed oil, and soap have been added in different amounts to the chlorate sprays to act as stickers and spreaders. Of these compounds, fish-oil soap or glue, 0.01 to 0.05 per cent by weight of the dry chemicals used, were found to be the most satisfactory. If soap is used, about one-third pound is shaved into a small volume of water, the temperature of which is slowly raised until the soap has completely dissolved. Water is then added to make 1 gallon of stock solution. About one-fourth to one-half pint of this stock solution is added to each 10 gallons of water in the mixing tank before adding the sodium chlorate. Careful addition of the sodium chlorate is necessary in order that the soap remain in solution. If the fish-oil soap is poured into a concentrated chlorate solution, the soap is immediately salted out and rises to the top in the form of an insoluble scum. A stock solution of glue is prepared by dissolving one-third pound of the amber-colored flake glue in 1 gallon of water. This is more readily done by soaking the glue in a small volume of cold water overnight. The following day the glue is made up to 1 gallon by adding slowly small quantities of boiling water. About one-fourth to one-half pint of stock glue solution is used for each 10 gallons of spray solution. Care is taken to avoid an excess of glue, particularly in the case of water containing appreciable suspended organic matter.

INFLAMMABILITY

An intimate mixture of sodium chlorate and any form of dry organic material in a state of fine division is very combustible. It should be noted that the results of experiments reported in this bulletin deal with a considerable range in concentration of sodium chlorate. However, solutions of this chemical stronger than 10 per cent by weight (0.89 pound per gallon of water) are not recommended for general field use, owing to the risks involved in handling it by those not familiar with its chemical properties.

Clothing is extremely inflammable if it becomes saturated with sodium chlorate and is allowed to dry out completely. Persons engaged in spraying chlorates should keep their clothing slightly damp at all times, particularly during hot weather when the humidity is low, and clothing should be carefully washed at the conclusion of the day's work.

An asphaltum waterproof paint has been applied to the lower portions of the trousers to prevent the chlorate from actually soaking into the fiber. This measure provides a margin of safety. Methods of fireproofing cloth by precipitating insoluble salts of heavy metals in the fiber are being investigated. It is proposed to combine a fireproofing and waterproofing process for treatment of clothing in order to reduce the danger.

Special care should be exercised in the handling of sodium chlorate on account of the unstable nature of the compound. Kegs of the chemical should not be dropped or rolled about needlessly and should be stored in a cool place and piled so as to allow a circulation of air.

FIELD EQUIPMENT AND METHODS OF SPRAYING CHEMICALS

The problem of spraying chemicals under field conditions falls naturally into two parts: (1) The selection of spraying equipment suitable for field use, and (2) the methods of handling men and equipment over areas to be sprayed. A careful survey of all types of spraying equipment manufactured in this country was made by the writer in 1925. This survey comprised actual inspection of equipment and an intensive study of catalogues where it was found inconvenient to visit the shop of the manufacturer.

The available power spraying units were all made for orchard or park spraying and were far too heavy and cumbersome for use under forest conditions. The portable forest-fire pump was more nearly suited than anything else to the needs of chemical eradication of Ribes along forest streams. This unit as it was originally built delivered large volumes of liquid and consequently was not suitable for spraying operations where conservation of the spray was a vital factor. However, it is possible to reduce the volume discharge of this unit and at the same time build up the pressure. Investigative work has been conducted on the construction of a small portable power sprayer specifically designed for chemical eradication work.

Experimental power units were completed in the spring of 1927 and were put through exacting field tests that summer. Experience with these units showed that it would be possible to develop economic methods based on the use of power spraying equipment for the eradication of Ribes where they occur in great profusion. Final specifications have not been reached, but it is certain that a unit weighing less than 80 pounds can do the work satisfactorily.

The essential features of the portable power sprayers that have been tested in the field consist of a small gas engine connected to a rotary pump capable of developing a working pressure of 75 to 150 pounds; a by-pass valve adjustable to any desired working pressure, which returns part or all of the spray solution to the mixing tank and takes care of the intermittent demands of the spray nozzles; and a specially designed frame made of a lightweight metal (aluminum alloy) which enables the unit to be readily transported on a man's back. Gasoline tank and battery are concealed in the base of the frame. The relative merits of air-cooled and water-cooled motors, of battery and magneto ignition, of single-stage and double-stage rotary pumps, and the question of the most convenient weight and the most efficient horsepower of the unit compatible with practicable field management are still subjects of experimentation.

Apparently, half-inch main-line hose and quarter-inch laterals connected to the main line offer the best opportunity of efficient crew management. A mechanic who is in charge of the pumper at the "filling station" can keep the supply of spray solution mixed and can start and stop the power unit according to signals given by the foreman in charge of spraying operations. Figure 5 shows a typical set-up at a "filling station."

Two types of hand sprayers have been used in experimental plot work and in the development of field methods for large-scale chemical work during the years 1925 to 1927, inclusive, namely, a 3-gallon compressed-air sprayer and a 4-gallon knapsack sprayer with pump attachment. The compressed-air type has been found most useful for

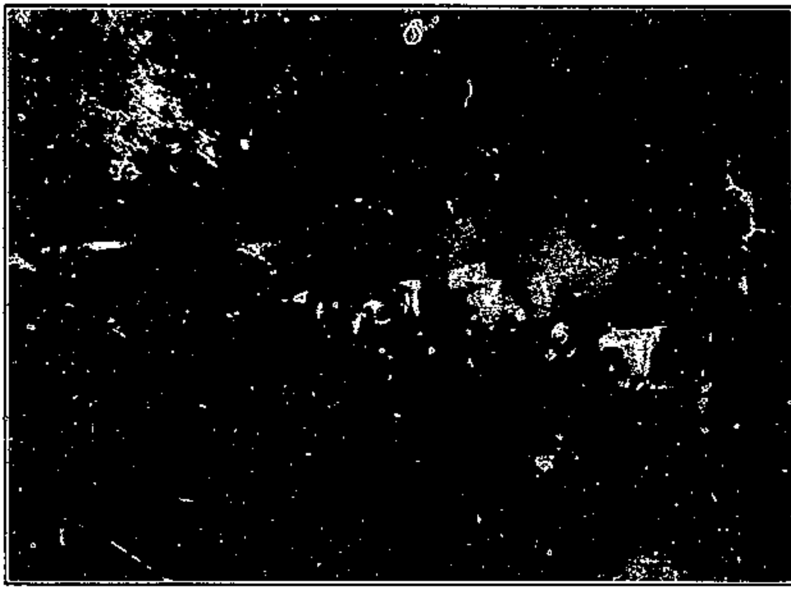


FIGURE 5.—A typical set-up of the power pumper at a so-called "filling station." The chemical is mixed in large wash boilers

plot work where small quantities of experimental sprays are applied in areas free from brush and windfall. This sprayer is the common type of compressed-air unit used for garden and orchard work and needs no further description. After preliminary field tests undertaken in 1925, 1926, and 1927, the knapsack type was recognized as being much more suitable than the compressed-air sprayer for general field work, and since 1927 it has been the subject of much experimentation designed to make it more efficient for this kind of work.

Since 1927 a knapsack unit for field use has been developed especially for chemical eradication work by J. F. Breakey, of the Office of Blister Rust Control. The complete unit, shown in Figure 6, consists of tank, pack board, and pump with hose attachment. The tank is made of 26-gauge galvanized iron and has a capacity of 5½ gallons. It is slightly curved so that it fits naturally and easily to the pack board, to which it is securely fastened by means of two leather straps. A right-angle support fastened to the pack board beneath the tank prevents vertical shifting. A tight-fitting cap of the automobile gasoline-tank type provides a water-tight seal and is readily removed by hand. A double-action brass pump with handle is attached to the tank by a short length of rubber hose. The pressure within the pump is readily adjusted so that a slow pumping motion delivers a continuous stream of spray. The extent to which the spray is atomized is regulated by the size of the hole in the spraying disk and can be further modified by the pressure that is built up

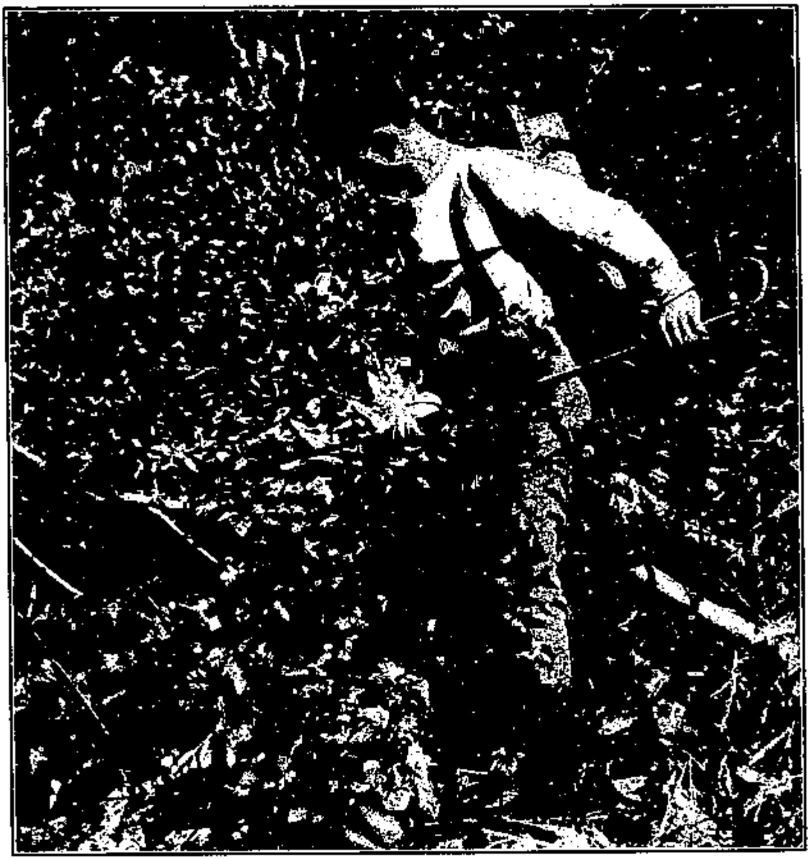


FIGURE 6.—Knapsack tank sprayer with pump attachment, showing the manner in which it is carried by the workman

within the pump by the operator. The complete unit weighs 12½ pounds when empty and about 60 pounds when filled with chlorate solution.

Initial experiments undertaken in the summer of 1928 show that where Ribes grow in very great profusion power-spraying methods have effected a saving of 56 per cent over hand-pulling methods. (Fig. 7.) Knapsack-spraying methods show a saving of 49 per cent over hand pulling in areas containing fewer Ribes. A test of knapsack and power-spraying methods over identical areas has not been made, and no comparative data on these two methods are available.

It seems certain, however, that both knapsack and power-spraying methods will have a place in any program of eradicating Ribes along forest streams in so far as effective chemicals are available, augmented, of course, by hand-pulling methods where the Ribes are few and somewhat scattered. The hand-spraying method with the knapsack sprayer and the power-spraying method employing the specially devised portable unit are now recommended as field methods for the chemical eradication of *Ribes petiolare*.

It should be observed that details of equipment and working methods for both knapsack and portable power sprayers and also the comparative costs of these methods are still the subject of experimentation. Further changes in the details of equipment and further reduction of costs are expected as the work progresses.

SUMMARY

A number of chemicals were tested on *Ribes petiolare, R. lacustre*, and *R. inerme* under varied field conditions in Idaho and Montana to find a cheap, effective chemical for the destruction of these plants in situations where other methods of eradication were unsatisfactory.

These Ribes occur in great abundance in the narrow strip of moist, deep soil found along the streams of the forested areas of the "Inland Empire," where, because of their rôle in the spread of blister rust, they constitute a source of great danger to the adjacent stands of western white pine.

Ribes petiolare, R. lacustre, and *R. inerme* layer prolifically under these conditions and thereby develop such a tangled mass of roots that it is impracticable to eradicate them economically by hand pulling or grubbing. The application of chemicals to the ground about the base of the plants growing in these locations is impracticable because the roots are often covered by water and the root systems of individual plants can not be readily located. However, tests of various chemicals applied in this manner to individual plants of *R. lacustre* and *R. inerme* growing in drier situations showed that these species could be effectively killed by such treatment. In the drier situations they develop simple root systems that can be readily located. Of the chemicals tested in these experiments, sodium chlorate 25 per cent aqueous solution applied at the rate of 1 quart per plant and an aqueous solution of sodium hydroxide 4 per cent plus sodium fluoride 5 per cent applied at the same rate gave the best results.

The application of chemicals to the aerial parts of the Ribes species occurring in the stream bottom lands appears to represent the best possibility for their practical eradication. Various concentrations of a large number of chemical sprays were tested by systematically applying them to the leaves and stems of *R. petiolare, R. lacustre*, and *R. inerme*. The results showed a wide variation in the toxicity of the different chemicals to these Ribes and indicated that those substances which acted very slowly on the leaves and stems effected more permanent injury than the chemicals that caused quick defoliation and rapid initial injury. Of the chemicals tested in these experiments, sodium chlorate was the most effective spray on the three Ribes species in the "stream-type" location. These plants were decreasingly susceptible to sodium chlorate: *R. petiolare, R. lacustre*, and *R. inerme*.

The field experiments show conclusively that one application of from 10 to 50 per cent aqueous solution of sodium chlorate to the leaves and stems of *R. petiolare* kills 96 to 100 per cent of the treated plants. It is concluded that this species of Ribes can be more cheaply and effectively eradicated by this method of treatment than by hand pulling or grubbing the plants. Both *R. lacustre* and *R. inerme* showed considerable resistance to sodium-chlorate sprays, and many of the treated plants reestablished themselves by sprouting from the crown. However, three applications of a 25 per cent solution of sodium chlorate to these species gave from 98 to 100 per cent kill of the treated plants. Fish-oil soap or flake glue, 0.01 to 0.05 per cent by weight of the dry chemical used, added to the sodium-chlorate solution, were found to be satisfactory stickers and spreaders. Best results were obtained by applying sodium chlorate early in the growing season, during dull, cloudy weather. A period of warm, bright weather for a few days after the spray is applied and the presence of

FIGURE 7.—A chemical-eradication crew spraying *Ribes petiolare* and *R. inerme*. Average brush conditions, Bovill, Idaho, 1927

dew at night with comparatively high humidity during the day are favorable for the toxic action of the chemical.

The effect of sodium-chlorate spray on Ribes is first manifested by a slight curling of the leaves. Within a few days the leaves turn brown. The succulent stems of the current year's growth show a marked darkening in color of the epidermis, and brown spots appear in the cambium four or five days after treatment. All succulent stem growth is usually dead at the end of the first week. The older stems show a similar effect from the action of the chemical after 12 to 14 days. Shortly after the effect of the chemical has become noticeable in the cortex of the woody stems, progress of the killing action is manifested by the appearance of a dark-brown coloration in the medullary rays and pith. In the last stages of injury the bark sloughs quite easily from the woody stem and the entire plant is killed to the ground.

Preliminary experiments were undertaken in which several types of spraying equipment and methods of crew spraying were tested. A

3-gallon hand sprayer of the compressed-air type was found to be satisfactory for brushless areas encountered in plot work. Large-scale spraying operations were undertaken by crews of men who used a knapsack tank sprayer with hand pump attached and a specially devised portable power sprayer. Results of large-scale tests showed that power-spraying methods effected a saving of 56 per cent over hand-pulling methods where Ribes occurred in great profusion. In areas where Ribes were less abundant, knapsack spraying was 49 per cent cheaper than hand eradication.

The inflammability of sodium chlorate necessitates extreme care on the part of persons engaged in applying the spray. Clothing should be kept slightly damp at all times and carefully washed at the end of each day's work. Fireproofing and waterproofing of the clothing to be worn by workmen while applying the chlorate spray is desirable and will give a margin of safety. Solutions of sodium chlorate stronger than 10 per cent by weight (0.89 pound per gallon of water) are not recommended for general field use, owing to the risks involved in handling this chemical by those who are not familiar with its chemical properties.

LITERATURE CITED

(1) Åslander, A.
1926. Chlorates as plant poisons. (A preliminary report.) Jour. Amer. Soc. Agron. 18:1101–1102.

(2) ———
1927. Sulphuric acid as a weed spray. Jour. Agr. Research 34:1065–1091, illus.

(3) Bolley, H. L.
1900. Studies upon weeds in 1900. N. Dak. Agr. Expt. Sta. Ann. Rpt. 11:48–56.

(4) Brenchley, W. E.
1925. Spraying for weed eradication. Jour. Bath and West and South. Counties Soc. (5) 19:1–20.

(5) Gray, G. P.
1919. Tests of chemical means for the control of weeds. Calif. Univ. Pubs., Agr. Sci. 4:67–97.

(6) Latshaw, W. L., and Zahnley, J. W.
1927. Experiments with sodium chlorate and other chemicals as herbicides for field bindweed. Jour. Agr. Research 35:757–767, illus.

(7) Long, H. C.
1911. The destruction of weeds by chemical means. An important agricultural problem. Sci. Amer. Sup. 71:76–77, 93–94, illus.

(8) Loyer, [M.]
1923. Emploi des chlorates pour la destruction des herbes dans les céréales de printemps. Compt. Rend. Acad. Agr. France 9:957–960.

(9) Rabaté, E.
[1922?] La destruction des mauvaises herbes. 170 p., illus. Paris.

(10) Regan, W. S.
1919. The destruction of ribes by chemical means. Amer. Plant Pest Com. Bul. 4, p. 12.

(11) Schultz, G.
1909. Die Bekämpfung des Unkrautes. Drittes Stück. Ackersenf und Hederich. Arb. Deut. Landw. Gesell., Heft 158, 78 p., illus.

(12) Thompson, N. F., and Robbins, W. W.
1926. Methods of eradicating the common barberry (Berberis vulgaris L.). U. S. Dept. Agr. Bul. 1451, 46 p., illus.

U. S. GOVERNMENT PRINTING OFFICE: 1931

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 10 cents

END