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OFFORD, H R VAN ATTA, G R SWANSON, H E 1 OF 1

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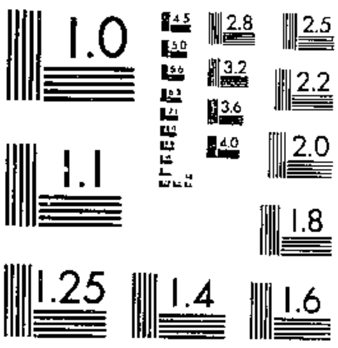

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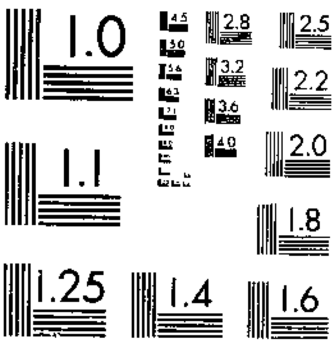

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UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D. C.

CHEMICAL AND MECHANICAL METHODS OF RIBES ERADICATION IN THE WHITE PINE AREAS OF THE WESTERN STATES[1,2]

By H. R. Offord, *pathologist*, G. R. Van Atta,[3] *assistant pathologist*, and H. E. Swanson, *senior pathologist, Division of Plant Disease Control, Bureau of Entomology and Plant Quarantine*

CONTENTS

INTRODUCTION

The development of chemical and mechanical methods of ribes[4] eradication has been an important part of the work undertaken in

[1] Submitted for publication December 30, 1938.

[2] The chemical methods described in this bulletin are based on studies undertaken by the authors at the College of Agriculture, University of California, and the University of Idaho, where facilities were made available for this cooperative work through the immediate interest of the departments of forestry. The authors were assisted in the chemical studies by R. P. d'Urbal, and in the studies on the morphology and ecology of ribes by C. R. Quick. The mechanical methods and special spraying equipment were developed in conjunction with practical control operations in northern Idaho. The use of a power-driven machine for the eradication of ribes and brush from alluvial bottom land was first proposed by C. H. Johnson. J. F. Breakey was responsible for the adaptation of the special brush rake for the bulldozer and the development of the spraying equipment. F. O. Walters made many major improvements in the use of mechanical methods in the field. H. J. Hartman and F. J. Heinrich directed and improved crew methods used in the large-scale spraying work. C. P. Wessela, supervisor for blister rust control work in Oregon, designed and tested the special hook plow for uprooting large *Ribes cereum*. T. H. Harris and R. M. Riley, of the California operation, first advised the use of stumping powder for breaking up clumps of ribes and brush. Photographs used in this bulletin were taken by Miller Cowling. Blister rust control work was directed by the Bureau of Plant Industry from 1916 to 1933, and was taken over by the Bureau of Entomology in December 1933. All personnel named in these acknowledgments are (or were at the time the work was performed) employees of the Division of Plant Disease Control.

[3] Resigned January 7, 1937.

[4] The generic name *Ribes* and the common name "ribes" are used in this bulletin to indicate both currants and gooseberries.

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the control of white pine blister rust (*Cronartium ribicola* Fischer) throughout the Western States since 1924. In this region the blister rust menaces about 5 million acres of western white pine (*Pinus monticola* Dougl.) and sugar pine (*P. lambertiana* Dougl.) (pl. 1) having a stumpage value of about $250,000,000. Other species affected are northern white pine (*P. strobus* L.), limber pine (*P. flexilis* James), whitebark pine (*P. albicaulis* Engelm.), Mexican

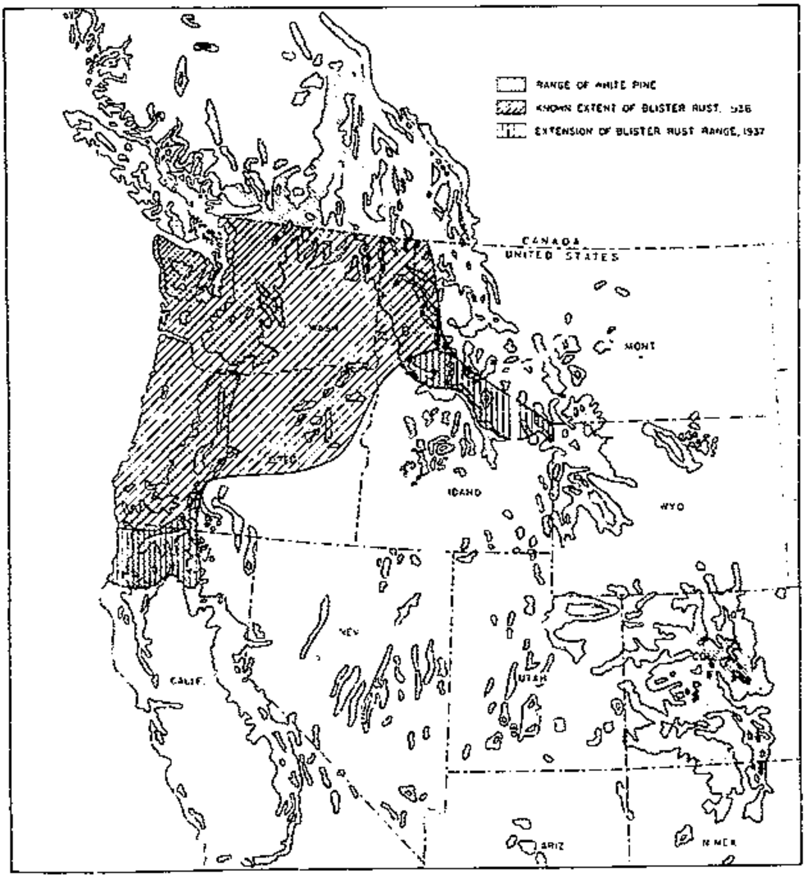
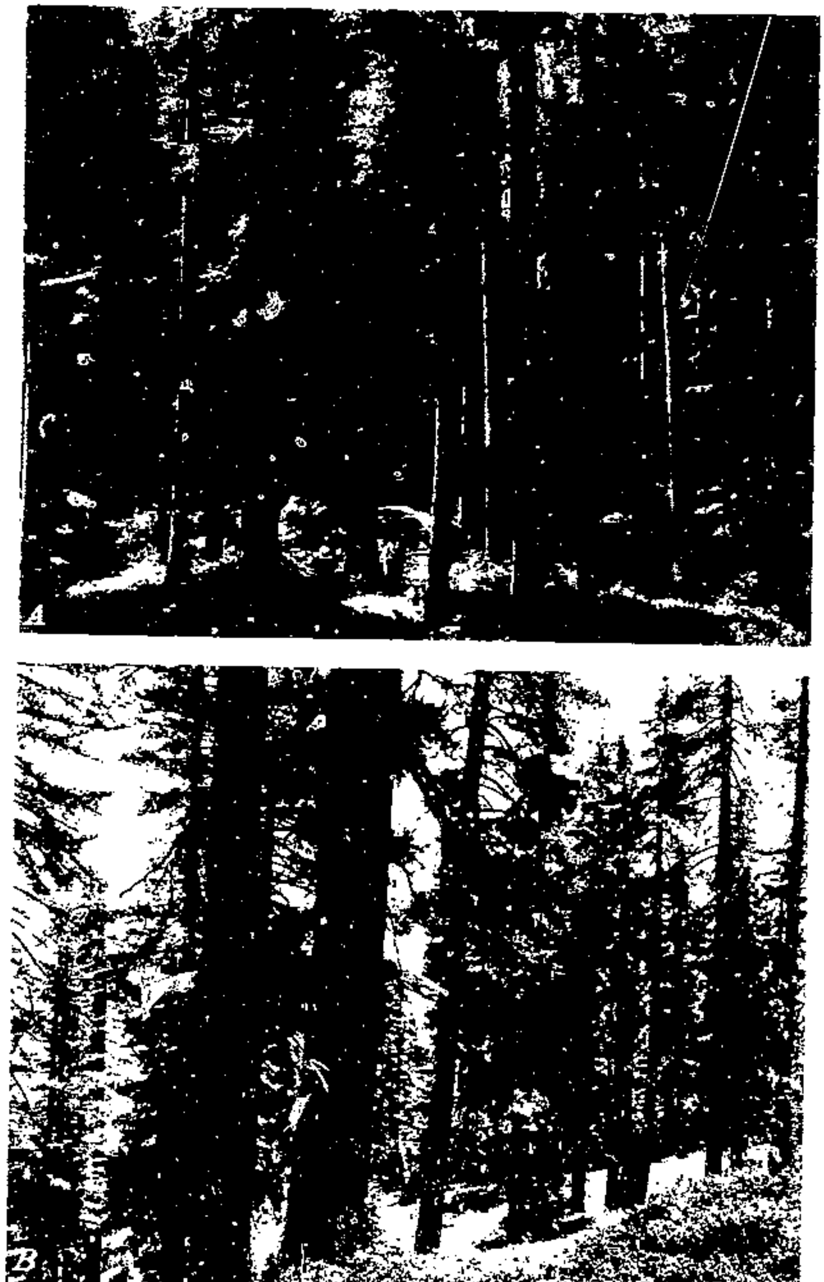


FIGURE 1.—Range of white pines and known extent of blister rust in the Western States.

white pine (*P. ayacahuite* Ehrenb.), foxtail pine (*P. balfouriana* Murray), and bristlecone pine (*P. aristata* Engelm.).

Although the disease is widely distributed in some of the most valuable white pine areas of the Western States (fig. 1), serious losses can be prevented by vigorous application of control methods. It has been possible to develop effective methods for blister rust control, because the disease cannot spread directly from one pine tree to another, but must go through a developmental stage on ribes, the alternate host plant (*5, 6, 18*),[5] and because the wind-blown spores

[5] Italic numbers in parentheses refer to Literature Cited, p. 58.



Typical stands of mature white pine: *A*, Western white pine in an old homestead area, Coeur d'Alene National Forest, Idaho; *B*, sugar pine in the Eldorado National Forest, Calif.

that spread the disease from ribes to pine are delicate and short-lived. Most species of *Ribes* grow under conditions that limit the range at which they can cause severe damage to white pine to about 900 feet. Important exceptions are *R. petiolare* Dougl. and *R. bracteosum* Dougl. (wild black currants), and *R. nigrum* L. (cultivated black currant). These species produce such large volumes of viable spores that damage to white pine may occur for distances up to about a mile. Effective and economical control of the disease can thus be accomplished by the removal of ribes from any designated pine area and from a surrounding safety zone 900 feet to a mile or more wide, depending upon the species and population of ribes and the topography (*3, 15*). Studies on pine damage in this region subsequent to ribes eradication show that a high degree of protection is obtained by the control methods now being used (*21*)[6].

Hand pulling and grubbing are the principal methods employed by ribes-eradication crews in all regions where blister rust control work is undertaken in the Eastern, the Lake, and the Western States. These methods were developed in the East and have been entirely successful in the protection of *Pinu. strobus* (*8*). For a time they were the only methods used in the control program in the West, but here ribes conditions presented special probems that were not encountered in the Eastern States, and it soon became apparent that some of the western ribes could not be economically removed in that way. Such plants as *Ribes petiolare* and *R. inerme* Rydb., found in the alluvial bottom land along streams in eastern Washington, northern Idaho, and western Montana, could not be hand pulled or grubbed at a reasonable cost because of their great numbers and the proliferation of their layering stems and roots. Although these stream-type areas represented somewhat less than 10 percent of the forest land requiring protection, the rapid removal of *R. petiolare* was of vital importance to the control program because it is the most susceptible and dangerous of the native wild ribes in the spread of blister rust in that region (*7*).

In upland areas ribes do not usually occur in the dense concentrations typical of stream type, and hand methods have been successfully used for the major portion of upland work. In these areas, however, difficulties have been encountered in the removal of large ribes and those rooted under logs or in rocky soil. In order to destroy these plants, more economical and effective methods had to be developed.

To devise cheaper and more effective methods than hand pulling or grubbing, a program of experimental work in the chemical eradication of ribes was begun in northern Idaho in 1924. By 1927 the effectiveness of aqueous sodium chlorate for the destruction of *Ribes petiolare* had been established, and the following year the first large-scale chemical work on this species was undertaken by regular eradication crews. In 1931 a report was published (*9*) on the results of experiments in the chemical eradication of ribes for the period 1924–28. In that report it was stated that *R. petiolare* could be eradicated more cheaply with a 10-percent aqueous solution of sodium chlorate than by hand pulling and, further, that *R. inerme* and *R. lacustre* (Pers.) Poir. were much more resistant than *R. petiolare* to all the chemicals tested. For example, an application of 10-percent sodium

[6] FRACKER, S. B. THE STATUS OF WHITE PINE BLISTER RUST CONTROL. U. S. Bur. Ent. and Pl. Quarantine, mimeographed report presented at a conference in Washington, D. C., Dec. 3, 1934.

chlorate gave 100-percent bush kill on *R. petiolare* and only 10 to 25 percent on *R. inerme* and *R. lacustre*. Fortunately it was possible to take advantage of the high susceptibility of *R. petiolare* and to destroy this species by chemical means, because it was found most frequently in solid patches or clumps in areas where *R. inerme* did not occur.

In the continuation of this work since 1928 tests have been made to develop methods and equipment for the chemical eradication of *Ribes petiolare* and certain upland-type species, and to establish the scope and limitations of chemicals for the destruction of more resistant species, especially *R. inerme*. The development of mechanical methods of ribes eradication has also been undertaken. Progress in this work is reported in this bulletin.

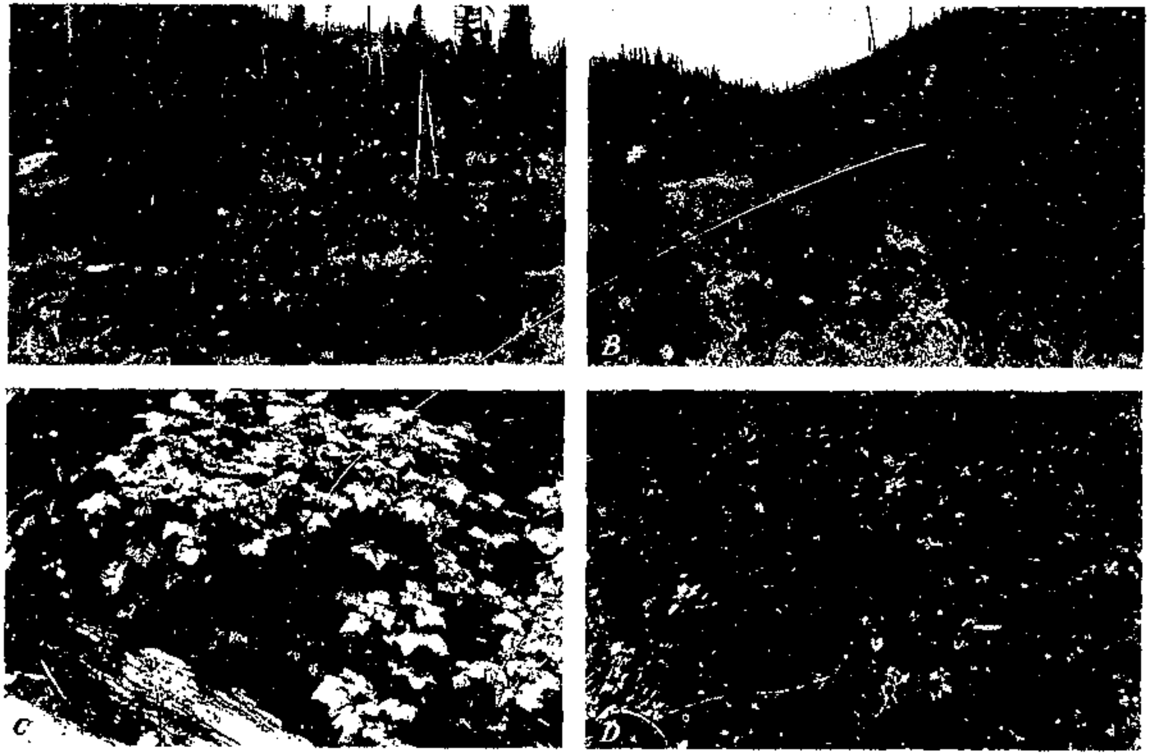
SPECIES OF RIBES INCLUDED IN THE TESTS

The species of *Ribes* found in the Western States may be divided into two classes according to habitat. Species that are found on flat or gently sloping land contiguous to a watercourse are known as stream-type ribes, and their habitat is designated as stream type (pl. 2). In such areas ribes, brush, and herbaceous vegetation occur in great abundance, and the typical soil consists of a surface horizon of alluvial silt, with underlying strata of sandy silt, coarse sand, and gravel in the order named.

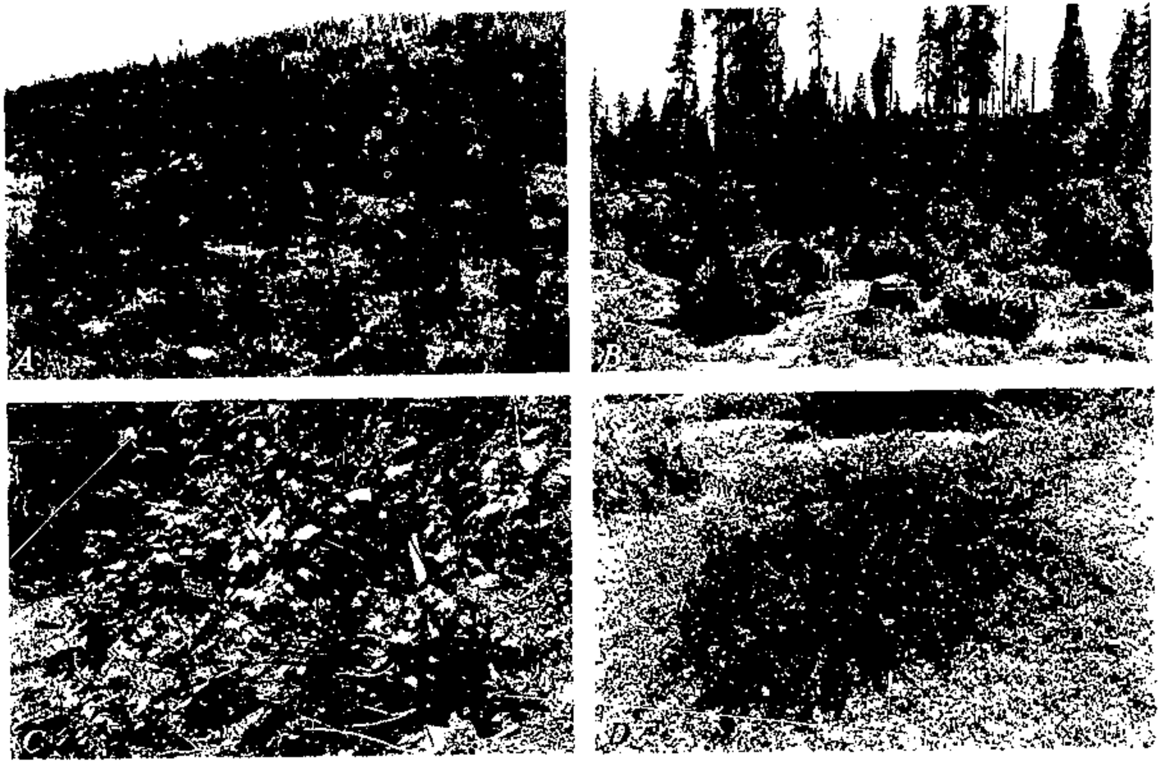
Stream-type ribes are prevalent throughout the white pine areas of eastern Washington, northern Idaho, and western Montana, where numerous watercourses provide ideal conditions for their growth and for the spread of the rust. The species found in this region include *petiolare*, *inerme*, *lacustre*, and *triste*. Less extensive areas of this type occur in the sugar pine sections of Oregon and California, the Plumas National Forest being the southern boundary of the area in which stream-type ribes are an important factor in blister rust control. The principal species of this type in Oregon are *bracteosum* and *lacustre*, whereas in California they are *nevadense* and *inerme*. *Ribes petiolare* occurs in Oregon in some parts of the Blue Mountains and along the eastern slope of the Cascades, and to a very limited extent in northeastern California.

Species of *Ribes* growing in mature timber, reproduction, cut-over land, and burned, logged, or brushy areas—in fact, in all areas not designated as stream type—are classified as upland-type ribes (pl. 3). Species of this type, which include *viscosissimum* and *irriguum* (Idaho), *cereum*, *erythrocarpum*, *lobbii*, *sanguineum*, and *watsonianum* (Oregon), and *roezli* and *cereum* (California), ordinarily grow as separate bushes or in well-defined clumps, in contrast to the large patches growing along streams.

A list of the species of *Ribes* that have been included in these studies, together with information as to their distribution, habitat, and growth form, is given in table 1.



Stream-type areas in northern Idaho: *A*, Where *Ribes petiolare* occurs abundantly; *B*, where *R. inerme* predominates; *C*, detail of *R. petiolare*; *D*, detail of *R. inerme*. Note the greater brush density in *R. inerme*, and the open, grassy areas in *R. petiolare* type.



Cut-over upland areas: *A*, White pine in northern Idaho; *B*, sugar pine in California; *C*, *Ribes viscosissimum*, the species most common in site *A*; *D*, *R. roezli*, the most abundant species in site *B*. The white pine in *A* is coming back almost to a pure stand. An understory of young sugar pine is seen in *B*.

TABLE 1.—*Ribes of the Western States included in eradication studies*

Botanical and common names [1]	Distribution in western North America	Typical habitat and growth form
Ribes bracteosum Dougl. (stink currant).	Coastal region from eastern Alaska to northern California.	Stream type. Along stream banks or in moist, boggy areas. Erect or semierect, usually growing in clumps.
R. cereum Dougl. (squaw currant).	Central and eastern British Columbia, Washington, and Oregon, and the Sierra Nevada of California. Also western Montana, Idaho, Nevada, southwestern Utah, and northwestern Arizona.	Upland type. Usually on rocky slopes and ridges. Erect, shrubby plant, usually with multiple crown.
R. erythrocarpum Coville and Leiberg (Crater Lake currant).	Southern Oregon in Rogue River National Forest and Crater Lake National Park, within Hudsonian Life Zone.	Upland type. On open slopes and ridges. Trailing, usually in patches.
R. inerme Rydb. (white-stemmed gooseberry).	From Montana to central British Columbia, especially abundant on Kaniksu, Coeur d'Alene, and St. Joe National Forests in the white pine area of northern Idaho. Also the Cascade Mountains of Oregon and the Sierra Nevada of California, Utah, and New Mexico.	Stream type. On alluvial stream bottoms, swampy areas, or open grassy areas where soil moisture is high. Semierect in open locations. Inclined to trail when associated with alder and willow in swampy areas.
R. irriguum Dougl. (inland black gooseberry).	Central British Columbia, Washington, Idaho, western Montana, and eastern Oregon.	Upland type. Along talus slopes or rocky locations where moisture and some shade are available. Semierect to trailing. Forms composite clumps with trailing underground stems.
R. lacustre (Pers.) Poir. (prickly currant).	Alaska to northern California. Widespread distribution in British Columbia, Washington, Idaho, Montana, and Oregon.[2]	Stream type. Along stream banks or in moist areas on hillsides. Semierect, with long underground stems connecting many root centers into clumps of bushes.
R. lobbii A. Gray (gummy gooseberry).	From southern British Columbia to northern California, especially in the Cascade Mountains of central Oregon.	Upland type. On open or brushy hillsides. Low shrub, semierect. Usually found as a single bush.
R. nevadense Kell. (Sierra Nevada currant).	Southern Oregon, the Sierra Nevada of California, and western Nevada.	Stream type. Along stream banks and in moist draws, also in mountain meadows. Erect plant, usually growing as a single bush.
R. petiolare Dougl. (wild black currant, western black currant).	Central British Columbia to western Montana, northern Idaho, especially the Clearwater and St. Joe National Forests, Utah, east of the summit of the Cascades in Oregon, and the Warner Mountains in Oregon and northeastern California.	Stream type. Along the banks of streams and in moist, swampy areas. Semierect, shrubby plant, tending to grow in large clumps or patches.
R. roezli Regel. (Sierra gooseberry).	California throughout the Sierra Nevada and the Sierra Madre.	Upland type. On burned-over and cut-over hillsides, frequently in association with brush. Semierect or erect, usually growing as a single bush.
R. sanguineum Pursh (red flowering currant).	From British Columbia to northern California, chiefly on western slopes of the Coast and Cascade ranges.	Upland type. Most common on burned-over or cut-over hillsides. Erect plant, usually growing as a single bush.
R. triste Pall. (wild red currant).	Alaska, British Columbia, Washington, Idaho, Montana, and Oregon.[2]	Stream type. Along edges of streams, frequently in rocky locations. Prostrate or semierect, growing most frequently in small patches.
R. viscosissimum Pursh (sticky currant).	Central British Columbia, eastern Washington, north Idaho, western Montana, Oregon, and California.	Upland type. On burned-over or cut-over hillsides. Erect shrubby plant, usually growing as a single bush.
R. watsonianum Koehne (Mount Adams gooseberry).	Southwestern Washington and the Cascade Mountains of Oregon.	Upland type. On hillside draws or moist areas in upland. Erect or semierect plant, occurring most frequently as a single bush.

[1] Common names are those accepted and commonly used by blister rust workers in the western region.
[2] Also occurs in the Eastern States.

OUTLINE OF TESTS IN CHEMICAL ERADICATION

The studies in the chemical eradication of ribes have included laboratory and greenhouse experiments, small-scale tests in the field, and large-scale methods tests in the field. Only a brief résumé of laboratory and greenhouse investigations is given in this bulletin, as reports on this phase of the work have already been published (*4, 9, 10, 11, 12, 13, 14, 16, 17, 19*). A full discussion is given of the technique used in the small-scale field tests, and the large-scale methods tests are described only insofar as they differ from those on a small scale.

LABORATORY, GREENHOUSE, AND SMALL-SCALE TESTS IN THE FIELD

The testing of new herbicides has been the major objective of the laboratory, greenhouse, and small-scale field experiments. Since the publication of the last report on the chemical eradication of ribes (*9*), many new herbicides have been tested and a number of the old ones have been further studied in critical dosage tests. The herbicides were selected on the basis of the writers' previous experience or from literature on chemical weed killers,[7] or were synthesized in the laboratory (*14*).

The first step in testing the toxicity of a chemical was to apply it at various dosages to ribes grown in the greenhouse, either in soil or in culture solution. A practical technique had been developed for the propagation of ribes plants from rootstock, from stem cuttings, and from seed (*16*).[8] At least five plants were used for each test, and the plants were subjected to soil treatment, top treatment, or soil and top treatment combined. These tests usually determined whether the chemical was to be used the next season on small field plots. A chemical that was sufficiently toxic to kill the plants in the small-scale field trials was again subjected to careful laboratory study on the basis of safety to operator, cost and availability, poison hazard to stock, fire hazard (*13*), and corrosiveness to equipment. Specifications on chemicals and equipment were worked out and special technical procedures developed to aid in recording the field data (*19*).

The chemicals recommended for general crew use were studied in the laboratory to determine their stability in soils typical of the white pine areas (*4*) and to establish the influence of temperature and moisture on the power of these soils to fix or alter the toxic agent. Investigations were also made of the effect of such chemicals on seed germination and the survival of ribes seedlings.

Concurrent with the aforementioned work, a separate investigation was pursued on the histology of ribes, the purpose being to correlate biometric data for the various species with their susceptibility to chemical injury. At intervals throughout the growing season roots, stems, and leaves of ribes were analyzed quantitatively for starch, reducing sugars, tannins, suberin, cutin, and other plant constituents to determine the period during which stored food and protective materials occur in the smallest quantities. Plants other than ribes were occasionally used as biological material to expedite studies on the herbicidal action of chemicals (*11*), and analytical procedures required in control tests were investigated (*4, 10, 11*). Special field studies were made on the gross morphology of roots, including the depth and lateral spread of underground parts capable of vegetative regeneration.

Many chemicals were taken to the field for testing after they had

[7] A bibliography of 650 references on chemical weed killers is contained in a recent publication (*2*).

[8] OFFORD, H. R., VAN ATTA, G. R., and QUICK, C. R. METHODS OF PROPAGATING RIBES IN NUTRIENT SOLUTION FOR USE AS TEST PLANTS. U. S. Bur. Ent. and Pl. Quarantine, ET 106. 1937. Mimeographed.

shown marked toxicity to greenhouse-grown ribes, but only a few of these chemicals proved to be successful herbicides under field conditions. Results of these unsuccessful field tests are given only when they are pertinent to the development of practical field methods, or when they are needed to define the status of chemical methods on various species of ribes. All chemicals tested in the greenhouse and small-scale field plots, and the species of ribes on which these tests were made, are given in the following list. In this list the chemicals marked with a small circle (degree mark) failed to pass the greenhouse tests. Of the remaining chemicals, all of which were applied to small field plots, those indicated by an asterisk were the only ones that merited further consideration as herbicides, and as such they may be called to the attention of those interested in the chemical eradication of noxious plants.

CHEMICALS AND CHEMICAL MIXTURES TESTED AS HERBICIDES FOR THE ERADICATION OF RIBES, 1929-35

SPRAYS

Chemical	Species of *Ribes*
Chlorates:	
Atlacide*	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense, bracteosum, lobbii, erythrocarpum, triste*
Atlacide plus zinc chloride*	*inerme, petiolare, lacustre*
Barium chlorate°	*inerme, petiolare*
Calcium chlorate	Do.
Copper chlorate°	Do.
Iron chlorate°	Do.
Magnesium chlorate	Do.
Potassium chlorate	*inerme, petiolare, lacustre*
Potassium chlorate plus—	
Acetic acid	*inerme, lacustre*
Ammonium chloride	Do.
Ammonium nitrate	Do.
Glycerin	Do.
Zinc chloride	*inerme*
Sodium chlorate*	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense, cereum, bracteosum, erythrocarpum, irriguum, sanguineum, triste, watsonianum*
Sodium chlorate plus—	
Acetic acid*	*inerme, lacustre*
Ammonium chloride	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense*
Borax*	*inerme, lacustre, nevadense, roezli*
Calcium carbonate°	*inerme, petiolare*
Calcium chloride*	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense, bracteosum*
Copper complex X [1]	*inerme*
Furfural*	*inerme, lacustre, roezli, nevadense*
Glycerin°	*inerme, petiolare*
Glycol°	Do.
Magnesium chloride	*inerme, petiolare, roezli, cereum, bracteosum*
Osmic acid°	*inerme*
Phenol	Do.
Potassium bicarbonate	Do.
Potassium permanganate	*inerme, petiolare, lacustre, nevadense*
Selenic acid°	*inerme*
Sodium arsenite*	*inerme, petiolare*
Sodium bicarbonate*	Do.
Sodium carbonate°	*inerme*
Sodium chloride*	*inerme, bracteosum*

[1] Sodium tetrathiosulfatocyanocuprite.

SPRAYS—continued

Chemical	Species of *Ribes*
Chlorates—Continued.	
Sodium chlorate plus—Continued.	
Sodium dichromate	*inerme, petiolare, lacustre, nevadense*
Sodium fluosilicate°	*inerme, petiolare*
Sodium hypochlorite	*inerme, lacustre*
Hydrochloric acid	Do.
Sodium hydroxide	*inerme, lacustre, nevadense, bracteosum, sanguineum, triste, watsonianum*
Sulfuric acid	*inerme, petiolare, lacustre*
Tannic acid°	*inerme, petiolare*
Urea°	*inerme*
Zinc chloride*	*inerme, petiolare*
Sodium chlorate plus traces of—	
Ethylene°	*inerme*
Iron	*inerme, lacustre*
Manganese	Do.
Nickel°	*inerme*
Perchloric acid	*inerme, lacustre*
Tin°	*inerme*
Zinc°	Do.
Heavy-metal complexes:	
Aquapentamine cobaltichloride°	*inerme*
Chloropentamine cobaltichloride°	Do.
Copper aniline sulfate°	Do.
Copper chlorodithiourea°	Do.
Copper citrate°	Do.
Copper complex X* [1]	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense, cereum, bracteosum, sanguineum, triste, watsonianum*
Copper complex X [1] plus—	
Ammonium chloride	*inerme*
Magnesium chloride	*inerme, roezli, cereum*
Copper cyanamide°	*inerme*
Copper oxalate°	Do.
Copper sulfanilate°	Do.
Copper tetraminesulfate°	Do.
Copper thiosulfate°	Do.
Dimetatolyl selenide°	Do.
Dimetatolylselenium hydroxychloride°.	Do.
Dinitrotetramine cobaltichloride°	Do.
Dipyridinomanganous chloride°	Do.
Hexaminochromichloride°	Do.
Potassium chromihexathiocyanate°	Do.
Selenocuprocyanide°	Do.
Sodium thioselenate°	Do.
Trinitrotriamine cobalt°	Do.
Trithiourea cuprochloride°	Do.
Miscellaneous:	
Aluminum sulfate	*inerme, lacustre*
Ammonium chloride*	*inerme, roezli, nevadense*
Ammonium chloride plus—	
Acetic acid	*roezli*
Ammonium persulfate	Do.
Borax	*roezli, nevadense*
Sodium dichromate	Do.
Ammonium persulfate	*inerme, roezli, nevadense*
Ammonium thiocyanate*	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense, cereum*
Ammonium thiocyanate plus sodium chloride.	*viscosissimum*
Arsenious chloride	*inerme*
Barium chloride	Do.
Barium thiocyanate°	*inerme, petiolare, lacustre*

[1] Sodium tetrathiosulfatocyanocuprite.

SPRAYS—continued

Chemical	Species of *Ribes*
Miscellaneous—Continued.	
Borax	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense*
Borax plus hydrochloric acid	*roezli*
Cadmium chloride	*inerme, viscosissimum*
Cadmium sulfate	Do.
Calcium hypochlorite	*inerme*
Copper carbonate colloidal°	Do.
Copper sulfate	*inerme, viscosissimum*
Cresol	*inerme*
Ethylene thiocyanate in alcohol°	*petiolare*
Formaldehyde°	*inerme*
Furfural*	*inerme, petiolare, roezli, nevadense*
Oxalic acid	*inerme, lacustre*
Perchloric acid	Do.
Potassium permanganate plus—	
Acetic acid	*roezli, nevadense*
Borax	*nevadense*
Hydrochloric acid	Do.
Sodium dichromate	*roezli, nevadense*
Sodium arsenate (monobasic)	*inerme*
Sodium arsenite*	*inerme, petiolare*
Sodium chloride*	*inerme, lacustre, viscosissimum*
Sodium dichromate	*viscosissimum, roezli, nevadense*
Sodium dichromate plus—	
Sodium hydroxide	*roezli, nevadense*
Sulfuric acid	*roezli*
Sodium fluoride	*viscosissimum, roezli*
Sodium fluoride (colloidal)°	*inerme*
Sodium hypochlorite	*roezli, nevadense*
Sodium selenate°	*inerme*
Sodium selenite°	Do.
Sodium sulfide	Do.
Sodium sulfite*	*inerme, lacustre*
Sodium thiosulfate	*inerme*
Zinc ammonium chloride*	*inerme, petiolare, roezli*
Zinc carbonate (colloidal)°	*inerme*
Oils:	
Diesel*	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense, cereum, bracteosum, erythrocarpum*
Diesel plus—	
Benzene	*inerme*
Cresol	*inerme, nevadense*
Furfural*	*inerme, roezli, nevadense*
Kerosene	Do.
Naphthalene	*inerme*
Pitch oil	*inerme, petiolare, nevadense*
Pyridine	*inerme, roezli, nevadense*
Toluene	*inerme, roezli*
Kerosene plus trichloroethylene°	*petiolare*
Pitch oil*	*petiolare, lacustre, roezli, nevadense*
Pitch oil plus—	
Benzene	*inerme, roezli, nevadense*
Cresol	Do.
Furfural	Do.
Naphthalene	*inerme, roezli*
Phenol	Do.
Pyridine	*inerme, roezli, nevadense*
Toluene	*inerme, roezli*
Pitch oil emulsified with—	
Copper cyanide°	*inerme*
Copper complex X°[1]	Do.
Sodium chlorate°	Do.

[1] Sodium tetrathiosulfatocyanocuprite.

CROWN APPLICATIONS

Chemical	Species of *Ribes*
Ammonium thiocyanate*	*inerme, petiolare, lacustre, viscosissimum, roezli, bracteosum*
Atlacide*	*inerme, petiolare, lacustre, roezli*
Borax*	*lacustre, viscosissimum, roezli*
Calcium chloride	*lacustre*
Carbon disulfide*	*inerme, lacustre*
Carbon disulfide plus sodium hydroxide.	*lacustre*
Chloral hydrate°	Do.
Chloroacetamide°	Do.
Chloropicrin*	*cereum*
Chloropicrin plus kerosene	Do.
Copper complex X[1]	*inerme, petiolare, lacustre, viscosissimum, roezli*
Diesel oil*	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense*
Ethylene chlorohydrin°	*lacustre*
Ethylene oxide	*inerme, petiolare, lacustre*
Ethylene thiocyanate°	*lacustre*
Gasoline	*roezli, nevadense*
Kerosene*	*inerme, petiolare*
Pitch oil	*inerme, roezli*
Sodium arsenite*	*inerme*
Sodium chlorate*	*inerme, petiolare, lacustre, viscosissimum, roezli, nevadense*
Sodium chlorate plus—	
Borax*	*inerme, petiolare, lacustre, viscosissimum, roezli, cereum, irriguum*
Sodium bicarbonate*	*inerme, petiolare, viscosissimum, roezli*
Sodium chloride*	*inerme, viscosissimum, roezli*
Sodium sulfite*	*lacustre*
Sodium thiocyanate*	*bracteosum*
Sulfur°	*inerme, roezli*
Zinc ammonium chloride*	*inerme, petiolare, lacustre*

DUSTS

Calcium chloride anhydrous plus gypsum.	*inerme*
Calcium chloride anhydrous plus kaolin-limestone and copper cyanide (cuprous).	Do.
Copper complex X[1] (anhydrous)	Do.
Copper complex X[1] plus calcium chloride (anhydrous).	Do.
Sodium chlorate plus calcium chloride (anhydrous).	Do.

[1] Sodium tetrathiosulfatocyanocuprite.

For ribes-eradication work considerations of toxicity,[9] cost, ease of handling, and hazard to the operator, the woods, and game reduced this list of herbicides to the following: Ammonium thiocyanate, Atlacide, Atlacide in mixture with zinc chloride, borax, Diesel oil, sodium chloride, sodium chlorate, sodium chlorate in mixture with borax, sodium chlorate in mixture with sodium bicarbonate, and sodium thiocyanate. Arsenical compounds, generally recognized as the cheap-

[9] A discussion of the physiological factors affecting the toxicity of the well-known herbicides listed is beyond the scope of this bulletin. Valuable data of this sort will be found in the following publications: A. Åslander, Jour. Agr. Research 36:915–934, 1928; 34:1065–1091, 1927; W. H. Cook, Canad. Jour. Research 15:380–390, 1937; A. S. Crafts et al., Hilgardia 9:437–457, 461–498, 1935; 10:343–374, [377]–413, 1936; Plant Physiol. 10:699–711, 1935; W. E. Loomis et al., Jour. Amer. Soc. Agron. 25:724–739, 1932; W. C. Muenscher, N. Y. (Cornell) Agr. Expt. Sta. Bull. 542, 8 pp., 1932; J. R. Neller, Jour. Agr. Research 43:183–189, 1931.

est and most effective of weed killers, were not more toxic to ribes than the chlorate mixtures, and because of their poisonous nature have not been considered desirable for extensive use over forest watersheds where blister rust control is undertaken. The plot technique used in evaluating these herbicides depended on the type of ribes to be eradicated.

TECHNIQUE USED FOR SMALL-SCALE TESTS

Two procedures have been employed for the treatment of ribes; they may be described as selective and broadcast. The selective method was used on stream-type and upland-type ribes in the preliminary testing of a large number of spray formulas over the period 1924–30 and for recent work on the decapitation and treatment of troublesome ribes in upland areas. The broadcast method was adopted in 1931 for conducting dosage studies with effective herbicides.

SELECTIVE TREATMENT

In the selective treatment of stream-type ribes the spray is applied to the aerial parts and to the soil contiguous to the root centers. No attempt is made to measure dosage for individual bushes except to treat as uniformly as possible by a predetermined criterion such as—Spray until the foliage drips and the ground about the crown begins to puddle. Dosage is controlled empirically by increasing or decreasing the concentration of the spray solution. After the plot has been treated, the average dosage per bush is calculated from data on the number of bushes treated and the quantity of chemical used.

Where upland ribes in great numbers occur close to water or to a road, they may be sprayed with chemical in aqueous solution or with Diesel oil. In such areas plot technique for preliminary tests of chemicals has been the same as that of selective work on stream-type ribes.

Although selective treatment involves certain disadvantages in accuracy of plot technique under brushy conditions in stream type, it is held to be satisfactory for preliminary testing of a large number of chemicals because of the saving in labor and chemical. The disadvantages lie in possible variations in the quantity of chemical applied per bush, and in the tendency to choose plots amenable to selective application whether or not they are most typical of that particular species.

In the records of the selective tests on stream-type ribes dosage is expressed on the basis of quantity of chemical per bush or per 100 feet of live stem. In the treatment of these plots the following data are recorded: Plot number; location and size of plot; date of treatment; average height, feet of live stem and feet of dead stem by individual bushes for each species; concentration and quantity of chemical applied per plot; method of application; weather at time of application, including relative humidity and soil temperature taken early in the morning, at noon, and late in the afternoon; and general notes on soil character, presence of brush, windfall, and ground litter. The plots are systematically checked 1 year after treatment, and the effectiveness of the chemical is measured by the percentage of live stem and bushes killed.

Selective treatment has also been used in upland areas for the eradication of individual large bushes, or those rooted under fallen logs, in impacted soil, in rock crevices, or thick brush. Experimentation on this problem has comprised decapitation of the ribes at ground level followed by an application of chemical to the scarified crown. The combination of chemical treatment and some preliminary cutting has been considered since the work of Regan [10] in the Eastern States in 1918. Stream-type ribes could not be satisfactorily treated in this manner because of an intimate association with other brush, but it was readily apparent that this technique could be used on upland-type ribes with excellent effect. The chief advantages of decapitating ribes before treatment lie in the certainty of obtaining kill and in saving on cost of materials and labor.

Experiments on the decapitation of ribes have been established according to the following procedure: An area containing a large number of bushes is marked off with permanent stakes into rectangular plots containing from 50 to 100 large bushes. Decapitation is accomplished by means of a Pulaski tool (a combination ax and mattock) or by long-handled pruning shears (pl. 11, *D*), and then the chemical is applied to individual bush crowns. Each bush, as it is treated, is marked with a stake bearing a number corresponding to one on a mimeographed field form, upon which are recorded the following data: Average height, total length of live stem, mean basal diameter of canes, number of canes having a basal diameter greater than mean, total number of canes, diameter of crown, soil moisture, ground slope to within 15°, quantity of chemical used and amount of water (if any), hours of rain within 24 hours of treatment, and notes on plot site. The dosage of chemical is expressed per unit area of crown spread for the decapitated ribes. Data on plot location, date of treatment, and ribes species are also taken.

BROADCAST TREATMENT

In the broadcast method of treatment the chemical is applied over the entire plot area so that each square foot of soil surface receives the same quantity. According to this scheme each plant is treated at a uniform rate in proportion to its size. Treatment may be confined to the soil alone, or it may be applied to the aerial portions of the brush and ribes as well as to the soil. It is customary to spray all brush shoulder high and, of course, to cover thoroughly all ribes present on the area. An even treatment is obtained by cross-hatching the area with string lines and applying a small, known volume of chemical to each subplot. The size of the plot is usually about one-half of a square chain, or some other convenient fraction or multiple of the square chain, thus allowing for the division of the area into milacres. In power spraying the quantity for each subplot is apportioned by having the pump operator signal the spray man as each unit volume is delivered. Where the standard blister rust knapsack sprayer (pl. 11, *A*) is used, a definite number of calibrated, full pump strokes is allowed for each milacre subplot.

Dosage studies made on upland ribes, however, have not been applied over the entire ground area within plot boundaries because of the scattered distribution of the bushes. Instead, measured areas of

[10] REGAN, W. S. PROGRESS OF EXPERIMENTS FOR DESTROYING RIBES WITH CHEMICALS. 1918. Unpublished manuscript from the Bureau of Plant Industry, now in the files of the Division of Plant Disease Control, Bureau of Entomology and Plant Quarantine.

ground about a bush or clump usually corresponding to the bush spread are treated with chemical at a definite dosage. Even application is facilitated by the use of a rectangular wooden measuring frame with cross wires to allow for smaller measurements of ground area. All these experiments have been concerned with sprays and soil-drench treatments of intact plants.

In recording the results of all broadcast treatments, plots are marked off with string lines into milacre subplots to facilitate the recording and analysis of field data, which are essentially those described for selective treatment of stream-type ribes. Sketch maps of the plots are also made to permit subsequent analyses of data on the basis of soil type, soil moisture, windfall, and character of duff and surface litter.

SIGNIFICANCE OF TERMS USED TO DEFINE DOSAGE

In setting up practical criteria for evaluating a herbicide for ribes eradication, recognition must be given to factors of both cost and toxicity. Besides establishment of the fact that a chemical will kill any one species, data must also be obtained showing the amount of chemical needed to perform eradication work of acceptable efficiency.

The broadcast type of treatment just described has been designed primarily for such dosage studies, and it has been shown that the following three critical dosages must be determined before the effectiveness of a herbicide can be properly shown:

(1) The quantity of chemical that must be just exceeded before any bush kill results, which has been defined as the "minimum toxic dosage." This dosage has no significance to actual eradication work, but it is necessary for correct definition of the toxicity curve.

(2) The quantity that will kill the highest percentage of bushes per unit weight of chemical, which has been defined as the "dosage of maximum efficiency."

(3) The quantity needed to accomplish a practical clean-up job in one treatment, which has been defined as the "practical lethal dosage." The question of whether a practical clean-up job has been accomplished is a somewhat arbitrary one and involves a decision by workers experienced in ribes eradication. Usually it means a bush kill of 99 percent or more.

The dosage of maximum efficiency and the practical lethal dosage may differ substantially for a highly resistant species such as *Ribes inerme* and thus justify an eradication practice comprising two or more treatments. For *R. petiolare*, a species readily killed by chemicals, these two dosages may approximate one another so closely that greatest economy is attained by aiming at a thorough clean-up job on the first treatment. The application of these dosage criteria will be given in discussing the tests made on *R. petiolare* and *R. inerme*.

In tables and discussion set forth in this bulletin the toxicity of a chemical is measured by the percentage of live stem or bushes killed by a certain weight or volume of chemical. When dosages are expressed on the basis of an individual bush or 100 feet of live stem, they are self-explanatory. It should be clearly understood, however, that the per-acre dosage figures refer to theoretical areas completely covered by ribes, and since ribes have a scattered distribution in patches, clumps, or single bushes, these dosages are much higher than those actually needed for the practical working of 1 acre of stream type. Since in practice chemical is applied selectively to ribes, the dosage actually used per acre of stream type may vary from zero to the practical lethal dosage for the particular species under treatment. The greatest brush density encountered in the white pine areas of the West is that of *R. inerme* and associated plants. For this brush type the best information available showed a ribes density of 70 percent on approximately one-fourth of an acre. This means that on this particular quarter-acre the quantity of chemical needed for complete eradication of all ribes on the ground would be 70 percent of the prorated acre dosage. Twenty-five percent is considered to be a generous estimate of the average density of *R. inerme*. The quantity of chemical actually used for the large-scale eradication of *R. petiolare* has been based on an average density of about 5 percent.

LARGE-SCALE METHODS TESTS IN THE FIELD

If a herbicide has proved its effectiveness in the small field trials and is satisfactory on the score of cost and safety, it may then be included in a series of methods experiments to establish its practicability when used under conditions equivalent to those of large-scale operations. An important part of these experiments is the testing of the apparatus and equipment recommended for the application of a particular chemical. The completion of investigative work relative to the use of a new chemical, or modification in method of application, frequently necessitates the design and construction of special equipment.

Most of the large-scale tests already undertaken have been directed toward the eradication of *Ribes petiolare*, *R. lacustre*, and *R. inerme* in northern Idaho. Emphasis has been placed on the cost of operations, which is determined by such factors as spraying equipment, size of crew, area of ground to be covered by one worker, methods of distributing and preparing the chemical for crew use, and general effectiveness of the dosage recommended by the small-scale plot work. Observations on the last factor indicate the margin that must be added to allow for variations in the skill and dependability of workers. In comparison with small-scale plot work, methods tests involve treatment of a much larger ground area, a partial or less accurate recording of data on number of bushes and size of plants, less detailed information on ecologic factors, more temporary location and establishment of plot areas, and greater attention to costs and general practicability of the proposed method.

In recording and interpreting field data from methods tests several pertinent factors must be kept clearly in mind. In the first place, plots are treated more in accordance with the tenets of operations work than with those of controlled experimentation. Variations in site conditions throughout the large plots introduce further complications, and make it difficult to obtain strictly comparable data for a series of tests. Finally, stream-type ribes are so intimately associated with other brush that it is difficult to separate dead ribes bushes from dead brush, and still more difficult to determine the number of ribes bushes or root centers, in order to calculate bush kill. For these reasons no significance has been attached to numerical differences among the various tests unless they amounted to 10 percent or more.

CHEMICAL ERADICATION OF STREAM-TYPE RIBES

RIBES PETIOLARE

PRELIMINARY TESTS

In the Western States *Ribes petiolare* (table 1) is the most dangerous of the wild varieties of currants and gooseberries in the spread of blister rust disease. The presence of large bodies of this highly susceptible species in close proximity to some of the best white pine has accelerated the rapid spread of rust in the timbered areas of this region. For this reason the results of the earlier investigations on the chemical eradication of *R. petiolare* were rapidly applied in practical eradication work, with the understanding that improvements in field methods might be made by the continuation of developmental work. Studies on the effectiveness of new herbicides and on the toxicity of chlorate mixtures have therefore been in progress throughout the course of the large-scale control work on *R. petiolare*. The objectives of these later tests have been to continue comparative tests on the effectiveness of various herbicides, to explain occasional anomalies in the results of field work, and to bring about a saving in labor and quantity of chemical necessary for complete kill. To this end new herbicides were tested in greenhouse and small-scale field plots (tabulation pp. 7–10), and dosage studies were undertaken on chemicals of proved toxicity (table 2). With the exception of ammonium thiocyanate none of the new herbicides were sufficiently toxic to warrant more than preliminary field trials; all subsequent field work has been concerned with ammonium thiocyanate and with chlorate mixtures.

PROBLEMS AS TO PROPER USE OF CHLORATE MIXTURES

At the beginning of the 1929 field season chlorate sprays were already in use at dosages based on preliminary tests. Several problems then arose relative to the proper use of sodium chlorate for the eradication of *Ribes petiolare*. They concerned:

(1) The reduction of the fire hazard involved in the use of the chlorate spray. It was early recognized that the use of sodium chlorate involved a serious fire hazard, which could probably be lessened by the addition of hygroscopic substances. The laboratory and field tests had shown calcium chloride ($CaCl_2$) to be one of the cheapest and most effective of these hygroscopic materials, and a proprietary compound known as Atlacide,[11] containing about 1 part of calcium chloride and 2 parts of sodium chlorate as its chief ingredients, was already on the market. The same tests had indicated, however, that the effectiveness of the sodium chlorate was reduced by the addition of calcium chloride. Other hygroscopic agents, such as magnesium chloride, zinc chloride, and glycerin, had been tested, although they were less desirable than calcium chloride either because of their greater corrosiveness to equipment or because of higher costs.

(2) The influence of time of year on the effectiveness of chlorate mixtures. Previous observations had indicated that the effectiveness of chlorate mixtures decreased after the middle of the growing season,

[11] The Department does not recommend this or other proprietary materials in preference to others of similar composition. Reference to them by name in this bulletin is designed merely to inform the reader as to what materials were used. The Department cannot control or assure the constancy of composition of materials offered by private manufacturers.

and that the decrease became appreciable early in September. This point was obviously one of considerable importance in the regular spray work.

(3) The influence of acidity or alkalinity of chlorate sprays on their toxicity. Investigations by Offord and d'Urbal (*11*) on *Nitella clavata* (Bertero) A. Br. had shown that slightly acid solutions of sodium chlorate were more toxic to this plant than alkaline solutions of equivalent strength. Small-scale field trials on *Ribes petiolare* had shown that solutions of sodium chlorate made strongly alkaline by the addition of sodium hydroxide were less effective than a neutral or slightly acid solution of the same chemical. It was proposed, therefore, to test, under field conditions, the comparative toxicity of acid, neutral, and alkaline chlorate sprays.

(4) The variation in effectiveness resulting from changes in the concentration of a chlorate spray. On a number of occasions when the concentration of a spray had been changed during the course of eradication work, it had been observed that the strongest solutions did not always give the highest percentage of bush kill, although all sprays were presumably being applied at approximately the same rate.

(5) Critical dosages. Over the period 1930–32 observations of large-scale crew work and results of that work showed the necessity of providing more specific recommendations on the amount of spray solution to be applied.

LARGE-SCALE METHODS TESTS

In 1929, at Merry Creek, St. Joe National Forest, sodium chlorate and Atlacide sprays were tested at concentrations of 0.45, 0.89, and 2.7 pounds of chlorate (or equivalent chlorate for Atlacide) per gallon of water. The pH values of these sprays were adjusted to 4.0, 6.5, and 8.0, and a series of 18 plots were treated at 3-week intervals during June, July, and August. A total of 72 half-acre plots were sprayed in the course of this work. In 1931, at Orogrande Creek, Clearwater National Forest, 12 plots, ranging in size from 0.8 to 5.9 acres, were established for extending and confirming data on the comparative effectiveness of early, midseason, and late-season work with Atlacide and sodium chlorate. Chlorate concentrations of 0.50, 0.75, and 1.0 pound per gallon were used in these tests. In 1933, 12 half-acre plots in a stream-type location along the St. Maries River, Clarkia, Idaho, were treated for the purpose of comparing zinc chloride and calcium chloride as hygroscopic agents in mixture with sodium chlorate.

Results of these methods tests showed that it would be satisfactory to substitute the relatively safe hygroscopic mixture of sodium chlorate and calcium chloride for the sodium chlorate alone, provided that the dosage was based on the sodium chlorate content of the mixture. In the practice of large-scale ribes eradication no consistent indications have been obtained of the inhibiting action of the calcium ion on the toxicity of the chlorate ion, as noted by Offord and d'Urbal in their work on *Nitella* (*11*). Highest efficiency for all sprays was obtained about the middle of July, and, since there was a consistent reduction in bush kill late in the season, recommendations have been made to

Chemical eradication of *Ribes petiolare* in northern Idaho white pine section: *A*, Crew at work, with strings marking off crew lanes; *B*, man with knapsack unit operating trombone-type pump; *C*, clump of *R. petiolare* before spraying; *D*, same clump 1 year after treatment. Atlacide in a concentration of 1 pound per gallon of water was applied at the rate of 900 pounds per acre.

complete all spray work on *Ribes petiolare* by the middle of August. Insofar as camp organization has permitted, this recommendation has been uniformly adopted

Data on effect of pH value and spray concentration showed less than 10 percent variation; and so these factors were judged relatively unimportant to field practice. In subsequent large-scale work no attempt was made to adjust the pH value of the dissolved chlorates, except to specify that the calcium chloride used in the manufacture of Atlacide should be of sufficiently high grade to make an approximately neutral spray when dissolved in water. Although the concentration of chlorate spray appears to have no ultimate effect on work efficiency, there is, of course, a minimum which must be maintained in field operations, and for *R. petiolare* this should not drop below 0.5 pound of sodium chlorate per gallon.

CRITICAL DOSAGE TESTS

Prior to 1931 the quantity of chemical applied to *Ribes petiolare* in experimental plot work had been governed empirically by varying the concentration of chemical in the spray solution. Sprays were applied uniformly to aerial parts of the plants, and treated bushes were examined to see that coverage was complete; otherwise no attempt was made to provide a quantitative measurement of the spray solution. Recommendations for crew work were made on the same basis; thus, workers were instructed to spray all stems and leaves to the point of dripping. This procedure resulted in satisfactory kill of *R. petiolare*, and while operations were limited to small crews it appeared to furnish an adequate basis for conduct of the spray work. When the scope of the operations had increased to the point where supervisors could no longer give immediate attention to the work, inconsistencies in results sometimes appeared. In examining sprayed areas a year after treatment, it was often difficult to determine whether the poor results had been caused by the application of insufficient chemical or by uncontrollable factors such as heavy brush or high water.

To supply the eradication crews with more accurate recommendations on dosage, experiments were undertaken in 1933 and 1934 comparing the effectiveness of ammonium thiocyanate and a mixture of sodium chlorate and sodium bicarbonate [12] with the effectiveness of sodium chlorate or its equivalent of Atlacide. The 1933 plots were located on St. Maries River, St. Joe National Forest, Idaho, and the 1934 plots on Ann Creek, Soda Creek, and Washington Creek, Clearwater National Forest, Idaho. For comparing several of the heavy dosages of sodium chlorate with the other chemicals, 1 pound of Atlacide was used as the equivalent of two-thirds of a pound of sodium chlorate. This relationship, insofar as practical field work was concerned, had been clearly established by previous tests. It was considered advisable to minimize fire risks by using Atlacide in place of sodium chlorate for dosages of sodium chlorate in excess of 600 pounds per acre. A summary of treatment data and effectiveness of the chemicals is set forth in table 2.

[12] This mixture had been suggested by S. B. Detwiler, formerly in charge of the Division of Blister Rust Control, Bureau of Plant Industry, and appeared to have excellent possibilities as a herbicide.

TABLE 2.—*Relative effectiveness on Ribes petiolare of ammonium thiocyanate, sodium chlorate (or Atlacide), and a mixture of sodium chlorate and sodium bicarbonate on the basis of practical lethal dosage*

Chemical used	Date of treatment	Dosage	Bushes treated	Bushes killed
	1933	*Pounds per acre*	*Number*	*Percent*
Ammonium thiocyanate	July 29	3,500	150	95
	July 15	2,000	134	95
	Aug. 11	1,000	8	87
	July 12	500	15	67
Atlacide [1] [2]	July 15	3,000	392	100
	Aug. 12	1,500	203	100
	July 31	1,125	154	99
	July 12	750	241	100
	1934			
Sodium chlorate	July 30	600	80	100
	July 31	500	64	97
	Aug. 2	400	71	96
	do	250	71	90
	1933			
Sodium chlorate (a) and sodium bicarbonate (b)	Aug. 9	[3] 1,600	80	100
	Aug. 8	(a) 1,600, (b) 800	80	100
	Aug. 7	(a) 800, (b) 1,600	40	100
	1934			
	July 28	[3] 600	80	100
	July 31	[3] 500	82	99
	Aug. 1	[3] 400	50	95
	do	[3] 250	53	95

[1] Atlacide plots, in order named, were 1.04, 0.58, 0.65, and 0.77 acres in size. All other plots were 0.05 acre.
[2] Sodium chlorate equivalent=2/3 weight of Atlacide.
[3] Pounds per acre of each chemical.

Data in table 2 clearly show that, on the score of practical lethal dosage, ammonium thiocyanate is much inferior to sodium chlorate for work on *Ribes petiolare.* If compared on the basis of their chlorate content, the mixture of sodium chlorate and sodium bicarbonate, Atlacide, and sodium chlorate appear to be equally effective. Data in table 2 also show that 500 pounds of sodium chlorate, or its Atlacide equivalent, is enough chemical to accomplish practically complete eradication of *R. petiolare.* An occasional plant may survive treatment, but this may also occur after application of much larger dosages, as in the 1,125-pound Atlacide treatment.

After 750 pounds had been established as the satisfactory practical lethal dosage of Atlacide, it became necessary to determine how closely the operations work could conform to the recommendations of the experimental unit. A substantial margin over the practical lethal dosage was indicated, and after subsequent field observations had been made 960 pounds per acre was considered to be, in practice, an economical dosage from which approximately 99-percent ribes mortality might be expected (pl. 4). This quantity of chemical is adequate to take care of variations in efficiency of employees assigned to spraying.

Large-scale field tests were also made with a mixture consisting of 0.6 pound of sodium chlorate and 0.4 pound of sodium bicarbonate per gallon of water. This mixture furnishes approximately the same quantity of sodium chlorate per gallon of water as Atlacide, and was used with excellent results at the dosage rate of 960 pounds.

During the period 1927–36 about 80 percent of the *Ribes petiolare* bushes occurring within the valuable white pine stands of northern Idaho were eradicated with chlorate sprays. In this work 507 tons of chemical were used on 20,488 acres, or an average of about 50 pounds of chemical per acre of stream type.

FIRE HAZARDS OF SODIUM CHLORATE

Sodium chlorate, in common with other chlorates, has the ability to form dangerously explosive and highly inflammable mixtures with many combustible substances. Organic materials, such as cloth, leather, wood, and leaves, are easily ignited when impregnated with sodium chlorate. If dry, they burn with extreme violence.

To minimize this fire hazard in ribes eradication, Atlacide has been largely substituted for sodium chlorate. Although the hygroscopic calcium chloride reduces the fire hazard of sodium chlorate by retarding combustion, it does not entirely eliminate it. If mixtures of calcium chloride, sodium chlorate, and organic material are placed in very dry, warm air for a sufficient time, they may be ignited easily and will burn rapidly.

Since sodium chlorate itself does not burn but only furnishes oxygen for the combustion of other materials, it can be safely shipped and stored in light iron drums. This type of container has been used exclusively in blister rust control work for transporting the chemical in the field.

The gravest personal risk accompanying the use of sodium chlorate or Atlacide in ribes eradication arises from the possibility that clothes contaminated by the chemical may dry out before they can be washed. The humid atmospheric conditions that prevail along the streams where Atlacide is used normally prevent it from becoming dry either on clothing or on sprayed vegetation. Being soluble in water, the chemical is easily washed out of cloth, and a moderately heavy rain is sufficient to remove most of it from sprayed plants.

To guard against accident, certain safety regulations are rigidly enforced wherever the chemical is stored or handled. The following outline gives the substance of these regulations:

RULES FOR THE STORAGE AND HANDLING OF SODIUM CHLORATE

(1) Smoking is prohibited wherever the chemical is stored or handled.

(2) If stored in the open, sodium chlorate must be placed upon bare ground free from litter and at least 200 feet from the nearest building.

(3) Every precaution must be taken at all times to prevent accidental spillage of the solid chemical or its solution.

(4) If any of the solid chemical is spilled and thus contaminated with organic matter, it must be discarded by burial in mineral soil or by being thrown into running water. It must not be returned to the original container.

(5) Stations where the solutions are mixed must be located on mineral soil, preferably beside streams.

(6) The ground around the mixing stations must be kept wet during the conduct of spraying operations, and the stations must be thoroughly cleaned up before they are left.

(7) Areas on which ribes has been recently sprayed must be patrolled for a period of 10 days during hot, dry weather.

(8) Clothing worn while handling these solutions must be left on the job. Other apparel must be worn when traveling between camp and work.

(9) Spraying clothes must never be allowed to become completely dry while they are being worn. When wet with sodium chlorate solutions they must never be hung near a stove or a fire to dry. They must be frequently washed.

(10) Boots or shoes worn while spraying must be frequently greased to prevent absorption of the chemical solution.

(11) Matches must never be carried in spraying clothes.

Without doubt enforcement of the foregoing regulations has materially assisted in preventing accidents connected with the use of sodium chlorate in ribes eradication. No record exists of any injury to a worker through the use of sodium chlorate or Atlacide when the safety rules were being completely obeyed, although injury has occurred as a result of neglect of these precautions.

Recognition of the fact that safety depends on the constant vigilance of employees has prompted numerous efforts to devise means for lessening the hazards involved in the use of sodium chlorate. Solution of the problem has been sought through three avenues of approach, which may be classified as follows: (1) Attempts to develop a suitable fireproofing treatment for cloth and thus lessen the probability of clothing fires; (2) search for more effective fire retardants to take the place of calcium chloride; and (3) studies of the mechanism of combustion of chlorate mixtures and the conditions necessary for combustion, for the purpose of developing more dependable safety measures than those now in force.

The first work on fireproofing fabrics resulted in the development of a process for impregnating cloth with finely divided stannic oxide and subsequently coating it with gilsonite (*13*). The gilsonite was applied for the purpose of cementing the particles of stannic oxide to the fibers, and improving the water-repellent qualities of the cloth. The freshly treated cloth was fire-resistant and had only a slight tendency to absorb spray solutions, but these properties lacked permanence. Repeated washing removed significant proportions of both gilsonite and stannic oxide. Numerous attempts were made to replace gilsonite with some more satisfactory material, but they met with only partial success. Among the classes of substances tested were solid chlorinated hydrocarbons, synthetic resins, rubber, and synthetic rubber. Various combinations of materials belonging to these classes were also tried. Some of the substances tested were combustible, and thus partially nullified the fire-resistant property contributed by the tin oxide. Others, notably the solid chlorinated hydrocarbons, were noncombustible, but no binding agent was found which satisfactorily preserved the fire-resistant qualities of the cloth after repeated washing with soap.

Fabrics that had been coated by spraying with atomized tin, aluminum, and zinc were also examined. Only the zinc-coated cloth was fire-resistant, and the coating was entirely too heavy and stiff to be of practical value.

Numerous materials have been tried as fire retardants in comparison with calcium chloride, but none of them have been accepted for use. Most of these substances were rejected because they were less effective than calcium chloride. Some, such as zinc chloride, could not be used because of their corrosive character.

Such soluble fillers as sodium chloride are mostly without effect upon the combustibility of chlorate-impregnated material unless they are present in prohibitively large proportions. Insoluble or sparingly soluble fillers are impractical to use in spray solutions.

Borax is a sparingly soluble salt. It may, however, be used successfully as a solid when mixed with sodium chlorate and applied in powder form to individual decapitated ribes crowns. Strictly speaking, borax cannot be regarded only as a filler, since it is itself an herbicide. It may be used in much larger proportion in mixture with sodium chlorate than would be permissible if it functioned only as a diluent. Successful treatments have been made with nonhazardous mixtures composed of 1 part of sodium chlorate and 5 parts of borax.

Of all fire retardants tried so far, sodium bicarbonate is the most satisfactory substitute for calcium chloride in dilute spray solutions. A solution containing 0.4 pound of sodium bicarbonate and 0.6 pound of sodium chlorate per gallon is fully effective upon *Ribes petiolare* and quite as safe to use as the corresponding solution containing 1 pound of Atlacide per gallon. Because of the low solubility of sodium bicarbonate, it cannot be added in sufficient quantities to reduce effectively the fire risk of solutions containing more than 0.6 pound of sodium chlorate per gallon.

In June 1929, in California, several small fires were observed to start on a plot that had been treated the previous day with a spray containing sodium chlorate and magnesium chloride. The origin of these fires was not at once apparent. They all started in a thin crust of dead leaves which covered the ground. The surface of the soil itself was wet, and the leaves were at least damp. The magnesium chloride had, in fact, been used to prevent the sprayed vegetation from becoming dry. All the fires started between 10:30 and 11:15 a. m., and the ground area had been in shade until about 10 o'clock. The air temperature at the time the fires started was 78° F. and the relative humidity was 37 percent. It was positively known that these fires were not caused by such common agencies as flame, sparks, friction, or sudden compression. Previous to this time, spot fires in sprayed vegetation had been occasionally reported, but their origin had always been attributed to one of these common agencies.

In July of the same year several more fires of apparently spontaneous origin broke out in Idaho, on plots that had been sprayed with hygroscopic mixtures containing sodium chlorate. The conditions existing at the time of ignition were the same as those that prevailed in California when the fires of the previous month occurred.

Absence of an obvious cause for these fires prompted an inquiry into the temperature necessary for ignition of mixtures of chlorates and organic matter. The first fact brought forth in the study was that, when heat is the only agency concerned, the temperature necessary for the ignition of leaves impregnated with sodium chlorate is much higher than it was formerly believed to be. Subsequent work performed by other investigators confirmed this fact, and it is now known that when heat alone is concerned the ignition temperature for dry leaf material impregnated with sodium chlorate is from 291° F. to as high as 627°.

Field tests conducted in Washington in 1931, and in California in 1933, confirmed the observations made in 1929, and furnished a basis for the belief that ignition of chlorate-organic material mixtures can be initiated at low temperatures through the agency of short-wavelength light in combination with other factors. Obviously, the infrequency of such fires must be attributed to the fact that the conditions necessary to their incidence are of rare occurrence. If complete knowledge were at hand concerning the mechanism of spontaneous ignition of chlorate-organic material mixtures, it might be possible to reduce further, or even entirely eliminate, the hazard of this type of fire. Methods and apparatus have been developed for ascertaining the part that light and certain other factors may play in this kind of spontaneous ignition, but opportunity to put them to use has not yet been presented.

It should be pointed out that fires established in vegetation treated with Atlacide are easily extinguished. Their speed of propagation is ordinarily low, and if not disturbed they usually die out rather quickly of their own accord.

RECOMMENDATIONS FOR THE CHEMICAL ERADICATION OF RIBES PETIOLARE

On the basis of data obtained from all investigative work, it is apparent that effective eradication of *Ribes petiolare* can be accomplished by the use of sodium chlorate, Atlacide, or a mixture of sodium chlorate and sodium bicarbonate. Sodium chlorate alone is slightly cheaper than the two mixtures but involves an appreciably greater fire hazard to the workmen. Atlacide and the chlorate-bicarbonate mixture are equally safe in dilute solutions containing comparable amounts of sodium chlorate, but the latter is more expensive. At present, therefore, Atlacide is generally recognized as the most satisfactory material to use in large-scale work.

The correct procedure for preparing the spray solution and applying it is as follows: To 10 gallons of water add (as a sticker and spreader) one-half pint of stock glue solution,[13] or 1 teaspoonful of Tergitol 7.[14] Stir thoroughly until the glue is dissolved, then add 10 pounds of Atlacide and again stir until the chemical is completely dissolved. Apply this solution as an aerial spray and soil drench at the rate of 968 gallons[15] per acre of ribes. This dosage is equivalent to one-fifth of a gallon per square yard, which is delivered by 26 full pump strokes of the knapsack sprayer shown in plate 11, *A*. A full pump stroke is one complete stroke of the plunger either in or out. Shorter strokes may be more satisfactory for certain individuals. Operators should check the number of strokes which they customarily use to deliver one-fifth of a gallon, as a guide for applying the proper quantity of solution.

First spray the central crown of the bush, or the central portion of a clump, applying the spray vertically downward into the soil and horizontally (for clumps) across the basal portion of the stems. This treatment should moisten the ground area shaded by the bush or clump. Then work upward along the stems of individual bushes and radially toward the outer edges of clumps, wetting all stems and turning the nozzle upward to moisten the undersurface of the leaves. Finish with a top application to leaves and stems. The importance of getting ground coverage for subsidiary crowns as well as the central crown should be stressed. Insofar as is practical, drain off the water from areas in which *Ribes petiolare* plants are partially submerged. It may

[13] The stock solution of glue is prepared as follows: Soak one-half pound of glue in a small volume of cold water overnight; the next day add slowly enough hot water to make up the solution to a volume of 3 gallons; mix the solution thoroughly while the hot water is being added. If glue is desired for immediate use, add 1 quart of water to one-half pound of glue and warm the mixture with constant stirring until a homogeneous solution results. Make up to volume and use as recommended above. Best results are obtained from the use of the better grades of glue; thus, the purchaser should specify a clear, amber-colored animal flake glue.

[14] In 1938 Tergitol 7 (a mixture of several aqueous sodium secondary alcohol sulfates) was used as a spreader instead of glue in a rework program on *Ribes petiolare*. Since rework involves considerable travel and searching time, the small weight and bulk of Tergitol has increased the efficiency of the crews. According to Wilkes and Wickert (*20*) the Tergitol products may be represented by the formula R_2CHSO_4Na, where R is any primary or secondary nonfatty alkyl group. In this bulletin the concentration of Tergitol 7 refers to the aqueous product as marketed in June 1938. The Department has no control over any changes that may be made by the manufacturers of proprietary compounds, nor does it recommend this or other proprietary materials in preference to others of similar composition.

[15] Allowance has been made for the molecular volume of the dissolved chemical. This rate is equivalent to a dosage of 960 pounds of chemical per acre

involve breaking down beaver dams, although this should be done only as a last resort. If possible, all spray work should be completed by the middle of August. If it is extended beyond this date, particular care should be taken to drench the soil thoroughly.

RIBES INERME

PRELIMINARY TESTS

The eradication of *Ribes inerme* (table 1) has been recognized as high-cost work ever since the early tests were made with hand-pulling and chemical methods (*9*). Because of the urgent need for a practical eradication method, chemical investigations on this species were continued during the period 1928–34.

Tests were undertaken to devise a more toxic and safer herbicide than sodium chlorate. To this end substances were employed as fillers and hygroscopic agents to lower the fire hazard, other chemicals were used to render the chlorate more stable in the soil, and still others were added to promote more rapid decomposition. Chemicals having in themselves a recognized and distinct herbicidal value were mixed in various proportions with sodium chlorate. Many of these chlorate spray formulas were tested at several pH values.

A new type of herbicide, the heavy-metal complex,[16] was devised especially for work on *Ribes inerme*. In greenhouse tests a number of these heavy-metal complexes proved to be highly toxic to this species; copper complex X (sodium tetrathiosulfatocyanocuprite) in particular, a complex formed by the fusion of copper cyanide and sodium thiosulfate, appeared to have possibilities as a field herbicide. Subsequent experience with this compound in the field showed that it was highly effective when applied directly to crown tissue, and that rapid and extensive translocation through aerial plant parts was obtained following injection of the chemical into basal portions of stems. Stem injection, however, did not result in a sufficiently high percentage of root kill, and direct treatment of *R. inerme* crowns did not prove to be practical for general crew use. Although heavy-metal complexes have not proved to be suitable for ribes eradication work, they have potential value in the destruction of woody plants when direct injection is practicable.

Of the herbicides that were tested on *Ribes inerme*, ammonium thiocyanate was the only one that proved to be both as effective and as practical to handle as sodium chlorate or Atlacide. Although ammonium thiocyanate is too expensive to be used in large-scale eradication work, it is likely that its present cost will be substantially reduced.[17] For this reason it was included, together with sodium chlorate and Atlacide, in subsequent methods and dosage tests.

[16] It has been recognized for some time that heavy metals are extremely toxic to plant life when added to nutrient cultures in excess of the quantities needed for food. Heavy-metal compounds, however, have not proved to be effective herbicides for the destruction of woody, deep-rooted perennials. This apparent anomaly was tentatively explained by the writers as due to the fixation of the heavy-metal ions in the soil, and the precipitating action of tanninlike substances within plant tissue, chiefly in the vascular elements of the plant. A convincing demonstration of the latter point was obtained in physiological tests, in which it was shown that a complex compound of copper moved much more rapidly and extensively throughout the vascular system of ribes than did copper ion.

[17] Ammonium thiocyanate (also called ammonium sulfocyanate) is recovered from the purification liquor obtained from gas scrubbers at byproduct coke plants. The recovery process is not commercially feasible unless the coal gas contains sufficient ammonia and hydrocyanic acid gas to produce daily a quantity of ammonium thiocyanate large enough to justify the installation of recovery equipment. High-grade coking coal, as found in the eastern bituminous coal fields, seems to be well adapted for producing a gas rich in these constituents. There are at present in this country 90 byproduct coke ovens located in 21 States. About 30 of these plants could each recover daily about 800 pounds of hydrocyanic acid, the equivalent of 1 ton of ammonium thiocyanate. Several of these larger coke plants have a potential daily recovery of at least 5 to 8 tons of ammonium thiocyanate. It can be seen, therefore, that an adequate supply of a technical grade of this chemical could be furnished for weed eradication.

During 1931 and 1932 different methods of applying sodium chlorate and ammonium thiocyanate were tested for effectiveness. These methods comprised spraying the plant foliage and ground surface and drenching the soil beneath the surface. Coincidentally studies of the gross morphology of several species of *Ribes* were begun. Although the pertinent facts derived from the latter investigations did not begin to become available until the close of the 1932 season, their relation to the rest of the work is such that they will be presented before results of the dosage tests are reviewed.

Morphological work on *Ribes inerme* comprised examination of representative specimens growing in habitats typical for the species. Particular attention was given root systems to discover what relation their extent and distribution might bear to the effectiveness of different kinds of chemical treatment. Table 3 gives a summary of the biometric data obtained in a study of 12 specimens.

TABLE 3.—*Biometric data for 12 specimens of Ribes inerme*

Character measured	Range	Average
	Inches	*Inches*
Height	24–56	42
Stem spread	21–118	51
Root spread in top 3 inches of soil	42–110	72
Ratio of stem spread to top root spread [1]	.9–2.8	1.33
Distribution of fine roots by depth levels:	*Percent*	*Percent*
0–2.5 inches	30–88	60
3–5.5 inches	7–37	18
Distribution of fine roots by depth levels—Continued.	*Percent*	*Percent*
6–8.5 inches	1.4–19	8
9–11.5 inches	2–8	5
12–23.5 inches	0–17	8
24–35.5 inches	0–7	1
36–47.5 inches	0–1.1	0

[1] Range and average are shown for the 12 individuals; since the bush with the smallest stem spread did not necessarily have the smallest root spread, these figures cannot be obtained directly from those given in the preceding two lines.

The figures given in table 3 for distribution of fine roots were based on measurements of the total length of fine roots occurring in each soil horizon specified, and provide an approximate index of the vertical distribution of absorbing root surface. The table shows that *Ribes inerme* is characterized by a very shallow and widespreading root system.

Results of plot tests showed that root character has a definite bearing upon the relative merits of various methods for applying chemicals. In the subsurface-drench tests only about 30 percent of the chemical used was applied to the top 6 inches of soil; the remaining 70 percent was distributed throughout the next 14 inches of depth. These treatments were found to be only about half as effective as those in which the same total quantities of chemicals were sprayed on the plant foliage and soil surface, where the chemical not only came into direct contact with the aerial plant parts, but also reached the largest part of the absorbing root system.

LARGE-SCALE METHODS TESTS

Large-scale methods tests on *Ribes inerme* were conducted in the same areas concurrently with those described for *R. petiolare*. The tests with the chlorate mixtures covered the same essential points of fire-hazard reduction, seasonal effect, variation in pH value, and concentration of the spray that have been outlined for the *R. petiolare* work, and the results were essentially the same. In toxicity tests ammonium thiocyanate had proved to be fully as effective as the chlorate mixtures, and this chemical was included in the methods tests at Orogrande Creek in 1932 and 1933 and at St. Maries River in in 1933. No attempt was made to add a filler, since there was no fire risk with this chemical. Owing to the instability of ammonium thiocyanate in strongly alkaline or acid solution, no acid or alkali was added to the sprays.

It was early recognized that the high resistance of *Ribes inerme* to chemical kill could be attributed as much to the growth habit of the species as to its physiological character. The dense thickets of brush typical of *R. inerme* areas made crew work especially difficult and afforded such effective protection to the plant that it could not be readily treated with chemicals. For this reason large-scale methods work on *R. inerme* consisted primarily of studies of crew methods and spray equipment. From these studies it was learned (1) that the 5-gallon knapsack sprayer (pl. 11, *A*) was the most serviceable unit for work in most areas of *R. inerme*, (2) that the portable power sprayer (pl. 11, *B*) was more practical than the knapsack sprayer for treating broad areas of alluvial stream bottom, (3) that selective application to ribes was more economical than a broadcast treatment of brush and ribes, (4) that best results followed application of the chemical as a combination aerial spray and soil drench, (5) that the most practical method of accomplishing 100-percent bush kill was to treat the bushes in two successive seasons, and (6) that sodium chlorate could be effectively used in solutions containing 0.5 pound per gallon but ammonium thiocyanate lost considerable of its killing power below a concentration of 1.5 pounds per gallon.

CRITICAL DOSAGE TESTS

Although crew methods and equipment have been developed for work on *Ribes inerme*, the scope of chemical work on this species has been limited by the heavy dosages required for a practical eradication job. Critical dosage tests were performed during 1931, 1932, and 1933 by the broadcast method of application. The first 2 years' work was conducted in the Wenatchee National Forest, Wash., with sodium chlorate and ammonium thiocyanate. In 1933 further work with ammonium thiocyanate was undertaken at Clarkia, Idaho.

Since the spray treatments proved to be more effective than applications made by other methods, they formed the basis for calculation of critical dosages. A record of the principal results of the spray experiments is given in table 4. It was found possible to combine data taken from a great many sodium chlorate spray trials made prior to 1931 and to apply the combined figures directly to the problem in hand. These combined figures are also given in table 4. Atlacide was used in some of the applications, but in the table only the weight of the sodium chlorate contained in the Atlacide is reported.

TABLE 4.—*Relation of bush kill to dosage of sodium chlorate and of 95-percent ammonium thiocyanate applied as a spray to Ribes inerme*

SODIUM CHLORATE

Year	Dosage	Bushes treated	Bushes killed	Year	Dosage	Bushes treated	Bushes killed
	Pounds per acre	*Number*	*Percent*		*Pounds per acre*	*Number*	*Percent*
Prior to 1931	390	(1)	1	1931	1,750	80	12
	425	(1)	1		925	38	3
	515	(1)	9	1932	2,500	110	82
	625	(1)	12		3,500	71	100
1931	300	8	12		4,000	80	95
	1,350	17	35		5,000	120	97
	1,725	37	11				

95-PERCENT AMMONIUM THIOCYANATE

Year	Dosage	Bushes treated	Bushes killed	Year	Dosage	Bushes treated	Bushes killed
1931	252	37	0	1932	4,200	61	92
	462	33	0	1933	420	211	0
	489	20	0		631	120	1
	790	13	7.7		840	237	2
	775	26	19.6		1,680	41	71
	831	31	3.3		2,940	12	83
1932	2,100	84	69		4,200	109	98
	2,940	70	87				

[1] Number of bushes treated prior to 1931 not available. See text, p. 25.

The relation between dosage of chemical and the percentage of plants killed is shown graphically in figure 2. These curves summarize present knowledge regarding the effectiveness of the two chemicals when they are applied as sprays to *Ribes inerme.* Considering the many uncontrollable variables encountered in the conduct of field experiments of this type, very fair agreement in the results of the various tests is shown between the work done in Washington (1931 and 1932) and that done in Idaho (1933).

Several features of these curves are worthy of note. The curves for both chemicals intercept the horizontal axis somewhat to the right of the origin, at the point where killing of the less vigorous and smaller plants begins. At the other extreme the curves indicate that killing seldom consistently reaches 100 percent under field conditions, no matter how much chemical may be applied. A point along the asymptote of the curve close to the theoretical 100 percent is designated as the practical lethal dosage. Because of variation in plots and local conditions, this point can scarcely be determined with a high degree of precision, but it may be established accurately enough for field operations.

When the practical lethal dosage has been determined and the toxicity curve drawn, it is possible to estimate the killing caused by smaller dosages of chemical. It will be noted that there is a point in each curve at which the maximum bending occurs and beyond which the percentage of kill increases more slowly. This point represents the proposed dosage of maximum efficiency. It may be defined as the point where each additional percent of the practical lethal dosage results in 1-percent additional kill of the ribes concerned; in other words, where the slope is 1. For smaller dosages each percent increase in the quantity of chemical causes more than 1-percent mortality of the plants, whereas in the case of dosages greater than the dosage of maximum efficiency each percent increase in the quantity of

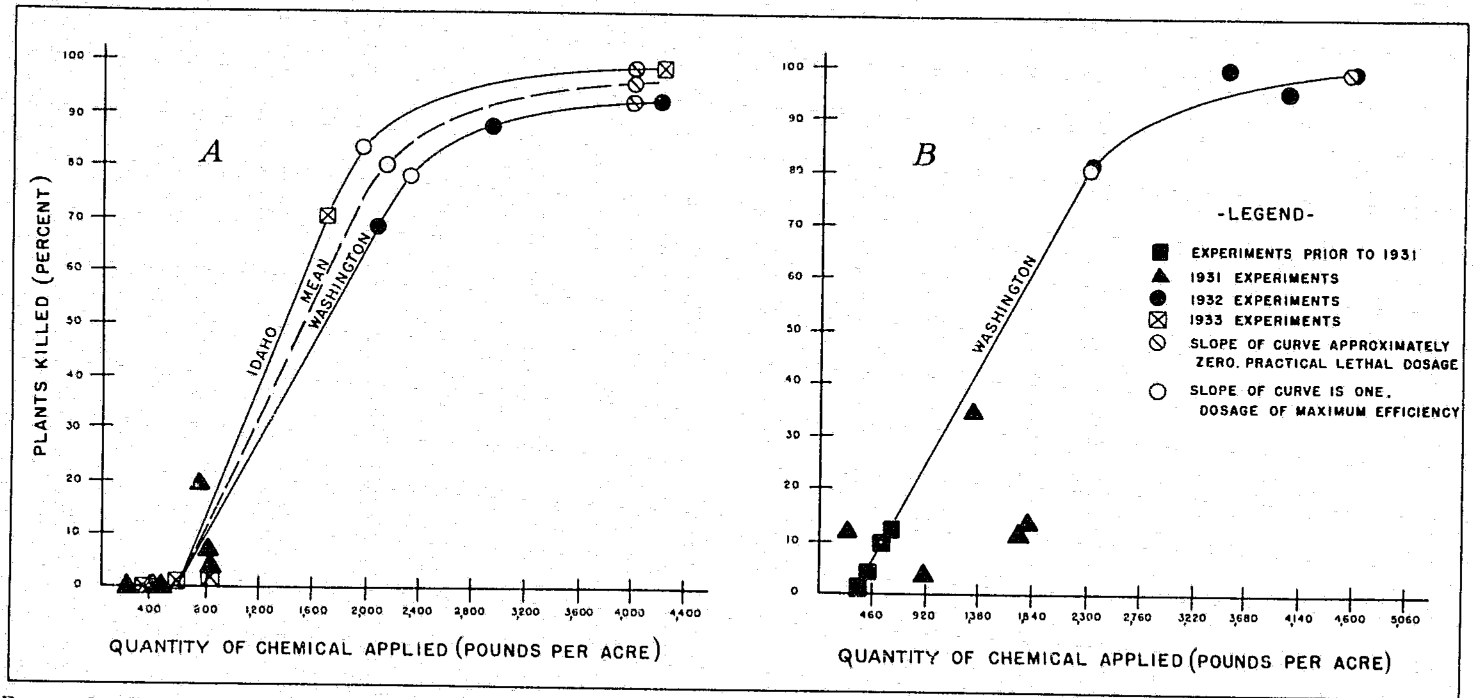


FIGURE 2.—Relation of *Ribes inerme* plant kill to dosage of chemical applied as a spray: *A*, 95-percent ammonium thiocyanate; *B*, sodium chlorate.

chemical causes less than 1-percent increase in the mortality of the plants.

Since it is evident that neither chemical is capable of yielding 100-percent eradication of *Ribes inerme* by one spray treatment, more than one working must be contemplated. As it is not possible to ascertain definitely which plants will survive a spray treatment until the following spring, rework cannot be performed until a year after the first treatment. Certain charges connected with chemical rework, such as the cost of camp establishment, etc., are virtually independent of the density of surviving ribes. Labor cost per unit of area to be reworked is determined by various factors, and doubling the number of ribes treated does not double the labor cost. It is therefore useless to attempt to lower the number of bushes that must be destroyed in rework by increasing the quantity of chemical used for first working beyond the dosage of maximum efficiency.

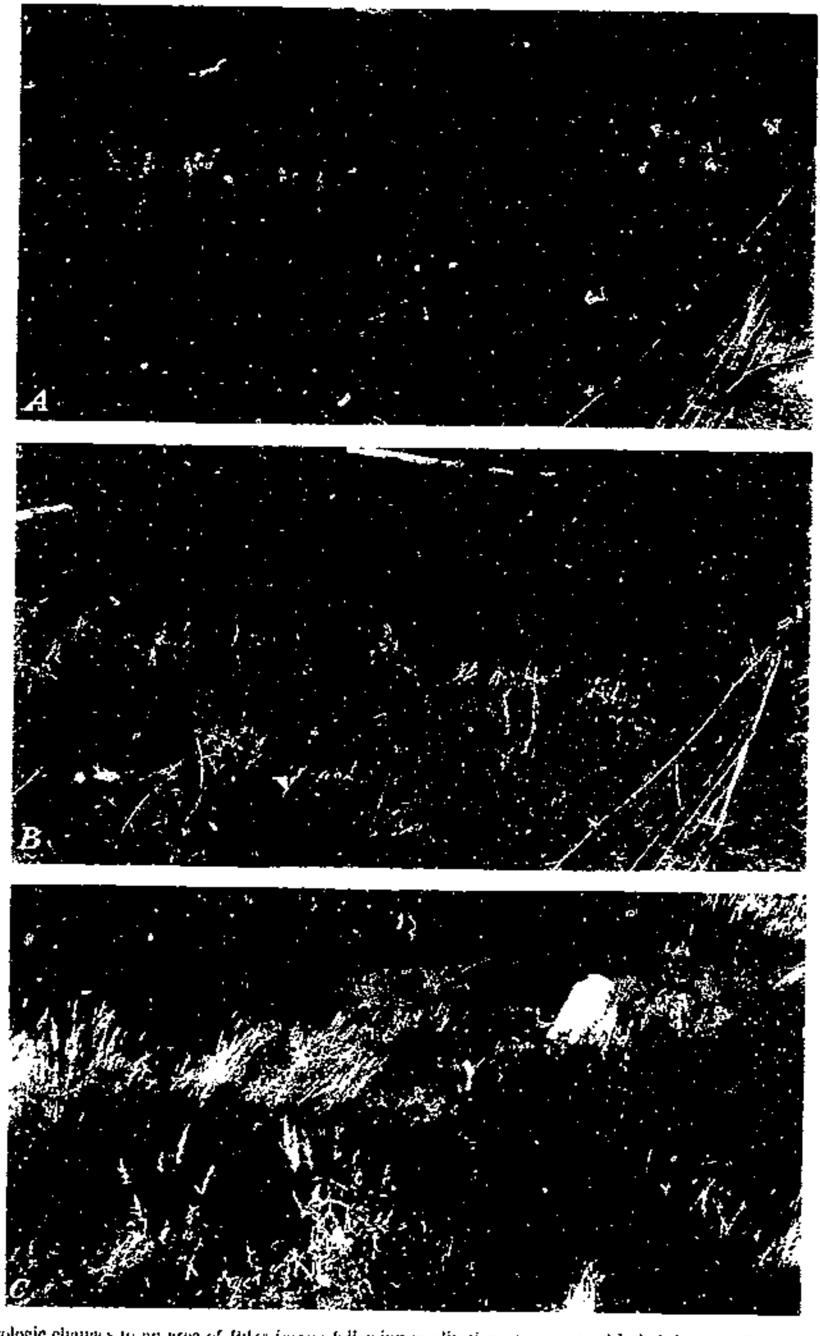
If the first treatment is properly made, nearly all the plants that survive will be in a weakened condition the following year, and rework at that time can achieve 100-percent kill of surviving plants. Although many of the survivors would succumb to a moderate dose of chemical, there will always be some that require heavy treatment. When performing rework, therefore, it is wise to apply the chemical at its practical lethal dosage, and thus make sure that all the remaining plants are killed. It should be kept in mind that, although the dosage employed in the second working is high, the quantity of chemical used per acre of stream type is only a small fraction of that necessary for the first working because the surviving ribes bushes cover such a small area. Plate 5 shows what can be accomplished by complete kill of all ribes and brush by application of the practical lethal dosage, in this case of sodium arsenite.

Values for the critical dosages taken from the curves in figure 2 are given in table 5. These figures show that a solid acre of *Ribes inerme* would require 2,160 pounds of ammonium thiocyanate, or 2,346 pounds of sodium chlorate, as a first treatment to obtain about 81-percent bush kill. The following year the surviving bushes would have to be treated with ammonium thiocyanate at the practical lethal dosage of 4,000 pounds, or sodium chlorate at 4,600 pounds.

TABLE 5.—*Critical dosages for application of 95-percent ammonium thiocyanate and sodium chlorate as sprays to Ribes inerme*

Chemical	Dosage	Chemical per acre	Bushes killed
		Pounds	*Percent*
Ammonium thiocyanate	Minimum toxic	610	0.0
	Maximum efficiency:		
	Idaho, 1933	2,000	83.5
	Washington, 1931-32	2,320	79.0
	Mean 1931-33	[1] 2,160	81.0
	Practical lethal, mean 1931-33	[2] 4,000	95.0
Sodium chlorate	Minimum toxic	322	0.0
	Maximum efficiency, mean of all trials	[1] 2,346	81.0
	Practical lethal, Washington, 1932	[2] 4,600	98.0

[1] Dosage for first treatment.
[2] Dosage for rework.



Ecologic changes in an area of *Ribes inerme* following application of a practical lethal dosage (about 3,500 pounds per acre) of sodium arsenite: *A*, Before treatment, a dense growth of *R. inerme* and brush; *B*, 1 year after treatment, all ribes, brush, and other vegetation dead; *C*, 3 years after treatment, area converted into a stand of excellent forage grasses.

A typical large clump of *Ribes cereum* near Union Creek, Rogue River National Forest, Oreg.: *A*, Before treatment; *B*, after root has been dug up by hand (note size of root and extensive digging required to remove it); *C*, remains of a bush comparable in size to the one shown in *A*, 1 year after decapitation and treatment with Diesel oil.

Local differences in field conditions will always cause some variation among the results of similar chemical treatments, but it is believed that the figures presented very closely approximate the performance for the chemicals to which they apply.

To illustrate how local conditions may influence the outcome of spray treatments applied to *Ribes inerme*, the figures given in table 6 show the relation that was found between effectiveness of chemical treatment and plant size on the 1932 plots in Washington. These records cover all the dosages employed in the 1932 plots at Swauk Creek, Wash. To extend these observations for other ribes in a different locality, similar figures covering work done on *R. roezli* in California during 1933 are also shown in the table. All the figures apply to plants that received quantities of chemical in strict proportion to the area of ground covered by the individual plants. The values reported combine the results of tests made with ammonium thiocyanate and sodium chlorate at various dosages, and by several methods of application. Each of these controllable variables is equally represented in the mean percentages. Although the two species of *Ribes* cannot be compared on the basis of these data, the values given are strictly comparable with one another within each species.

Table 6.—*Relation of bush size to effectiveness of chemical treatment of Ribes inerme and R. roezli*

Species	Length of stem	Bushes treated	Bushes killed	Species	Length of stem	Bushes treated	Bushes killed
	Feet	*Number*	*Percent*		*Feet*	*Number*	*Percent*
R. inerme	More than 200	261	71	*R. roezli*	More than 100	107	35
	50 to 200	518	62		25 to 100	729	57
	Less than 50	600	72		Less than 25	1,807	78

RIBES LACUSTRE

PRELIMINARY TESTS

Ribes lacustre usually grows on a strip of land near a stream but farther removed from the water's edge than *R. inerme* and *R. petiolare* (table 1). Frequently it is the only species of *Ribes* found in the upper stretches of a drainage, or within the narrow confines of small hillside draws. In moist sites it is shallow-rooted, and ordinarily does not offer a serious problem to hand eradication crews, though roots and layering stems may have an extensive lateral spread. Hand pulling, however, is expensive when it is found growing around and under windfalls, or in clumps or mats several square rods in extent. Conditions of the latter sort were encountered on the Still Creek planting area in the vicinity of Mount Hood, Oreg. In anticipation of the need for chemical methods on occasional areas of *R. lacustre* of this type, experiments on this species were undertaken in the greenhouse, and field tests were made at Still Creek, Oreg., and at Clarkia, Idaho.

Results of the tests with various chemicals previously listed confirmed the high resistance of *Ribes lacustre* to chemical injury. Bush kills ranging from 90 to 100 percent were obtained with sodium chlorate, sodium chlorate mixtures, and ammonium thiocyanate, when they were applied at the rate of 0.2 pound or more per bush.

Further work was undertaken with these chemicals in critical dosage tests to evaluate them for practical eradication of this species.

CRITICAL DOSAGE TESTS

Dosage tests with spray solutions of ammonium thiocyanate, Atlacide, and a mixture of Atlacide and zinc chloride were made during the 1933 field season on plots from 1¼ to 3 acres in size at St. Maries River, Clarkia, Idaho. Data from these tests, as shown in table 7, indicate that excessive quantities of chemical would have to be used to furnish a satisfactory kill on *Ribes lacustre*. Ammonium thiocyanate was shown to be more effective than Atlacide, but its present cost prohibits use in large-scale operations. The addition of zinc chloride to Atlacide, in combination with a late-season application, markedly reduced the toxicity of Atlacide on this species, as it did in similar tests on *R. petiolare*.

TABLE 7.—*Results of dosage tests of Atlacide and ammonium thiocyanate on Ribes lacustre, Clarkia, Idaho, 1933*

Chemical used	Date of treatment	Dosage	Bushes treated	Bushes killed
		Pounds per acre	*Number*	*Percent*
Ammonium thiocyanate	Aug. 15	5,000	300	96
	July 29	3,500	379	93
	July 15	2,000	105	93
Atlacide	July 31	7,500	176	94
	July 15	3,000	221	93
	July 31	2,250	213	89
Atlacide (*a*) and zinc chloride (*b*)	Sept. 7	(*a*)1,600, (*b*)300	256	40
	Sept. 14	(*a*)500, (*b*)500	129	22

DECAPITATION TESTS

In 1934 a series of decapitation tests were made on *Ribes lacustre* growing along talus slopes in the Coeur d'Alene National Forest, Idaho. In these locations *R. lacustre* often grows erect and has a well-defined central crown, thus making it amenable to treatment by the decapitation technique. Ammonium thiocyanate, 1 ounce per crown, or powdered borax, 2 ounces per crown, was 100 percent effective when applied in this manner

At present chemical eradication of *Ribes lacustre* should be confined to the decapitation and chemical treatment of single troublesome bushes. Heavy concentrations of this species must be hand-pulled or uprooted by the bulldozer.

CHEMICAL ERADICATION OF UPLAND-TYPE RIBES

RIBES CEREUM

PRELIMINARY TESTS

Ribes cereum is found throughout the sugar pine areas of southern Oregon and California, principally on open slopes and rocky points or ridges (table 1). In California the heaviest concentrations are encountered only in the upper limits of these areas, and as yet a comparatively small amount of this species has been eradicated. Within the Rogue River drainage of southern Oregon *R. cereum* is distributed throughout control areas, and it is here that this species constitutes an immediate problem to hand eradication crews. *R. cereum* exhibits a marked tendency to form composite crowns and in favorable locations grows to enormous size (pl. 6).

During the field season of 1929 experimental plots were established on *Ribes cereum* at Gooseberry Camp, Stanislaus National Forest, Calif., where the chemicals previously listed were tested by spray applications. Applications of sodium chlorate and of copper complex X failed to kill a single bush; live-stem kill did not exceed 50 percent. The need for large dosages of chemical or a change in the method of treatment was clearly indicated.

DECAPITATION TESTS

In September 1933 ammonium thiocyanate was tested as a soil drench on intact and decapitated *Ribes cereum* bushes located at Garden Springs, near Spokane, Wash. Treatment was made at the rate of 5,000 pounds per acre to 59 intact and 6 decapitated bushes. In July of the same year, at Gooseberry Camp, Calif., 40 large *R. cereum* bushes were decapitated and treated with dry sodium fluoride at dosages of 2 to 6 ounces per crown or group of crowns. Ammonium thiocyanate was 100 percent effective on decapitated bushes, but sodium fluoride killed only 30 percent. All the control bushes at Gooseberry Camp were sprouting vigorously a year after decapitation. Results from the thiocyanate soil drench on intact bushes showed 74-percent bush kill and indicated the superiority of the decapitation technique.

In June 1934 additional decapitation tests were made on *Ribes cereum* in the former experimental area at Gooseberry Camp. In these experiments 4 intact and 22 decapitated bushes or clumps were treated by injecting into the soil comparable dosages of chloropicrin, chloropicrin in mixture with kerosene, and kerosene alone, with a tool of the injector type. Dosages of chloropicrin and chloropicrin-kerosene ranged from 1⅓ ounces for the smallest bush to 17⅓ ounces for the largest of the composite clumps. Chloropicrin, alone and in mixture with kerosene, killed all but one bush. Kerosene was definitely less effective than chloropicrin. Soil injection with chloropicrin appears to be a highly effective treatment for *R. cereum*, but it is doubtful whether the method is suitable for use by inexperienced workers, because effective application cannot be made without an understanding of the gross morphology of the ribes root system.

Where the cost of chemical work is no more than that of hand pulling, the use of chemicals for the eradication of large bushes in upland areas is believed to have the following advantages:

(1) On areas of high ribes concentration, expecially on steep slopes, the possibility of soil erosion is largely eliminated by killing the ribes bush in situ.

(2) Studies in ecology show that ribes seed germinates most readily in ground that has been disturbed by fire or mechanical means. The uprooting of large bushes, with the attendant brush cutting which is frequently required when they are removed by pulling or grubbing, may create favorable conditions for the germination of seed and survival of young plants. On the other hand, decapitation, especially when it is done with pruning shears, entails little or no disturbance of the ground, and the subsequent chemical treatment tends to sterilize

the soil temporarily and thus to discourage the germination of ribes seed.

(3) The physical labor needed to decapitate and treat a large ribes bush is much less than that required for digging it. By minimizing fatigue, it should be possible to pull a larger number of the small bushes by hand. With the chemical method there is also less danger of workmen incurring injuries to back and abdominal muscles.

LARGE-SCALE METHODS TESTS

In July 1934 Diesel oil was tested on *Ribes cereum* plots located near Union Creek, Rogue River National Forest, Oreg. These tests comprised the following treatments: Sprays applied to stems and foliage, drenches sprinkled on the crowns of intact plants, and drenches sprinkled on the crowns of decapitated plants. The oil was applied to the large plants only; all small plants were grubbed or hand pulled. Most of the large plants grew in clumps of four to eight, being clustered so close together that all the stems in a clump appeared to originate from a single crown 1 to 2 feet in diameter (pl. 6).

Spraying was accomplished with the usual knapsack sprayer. Sufficient oil was applied to wet the stems and foliage completely. The crown drenches were applied with a garden watering pot, at a dosage in proportion to the ground area occupied by the top of the crowns. Decapitation was effected with a Pulaski tool. The stems were cut off even with the surface of the soil, and no further effort was made to mutilate the crowns or roots.

Data pertaining to these tests are given in table 8.

TABLE 8.—*Effectiveness of Diesel oil*[1] *treatments applied to large clumps of Ribes cereum, Rogue River National Forest, Oreg., July 1934*

Treatment	Plot area	Large clumps treated	Small plants pulled	Oil used		Large clumps killed
				Total	Average per large clump	
	Acres	*Number*	*Number*	*Gallons*	*Gallons*	*Percent*
Drench on decapitated crowns	0.33	107	39	88	0.82	100
	2.72	600	673	222	.37	96
Drench on intact crowns	3.76	512	55	297	.58	88
Spray	3.64	532	837	138	.26	8
Crowns decapitated	.44	69	680	0	.00	0

[1] Specific gravity 27° B.

The spray treatment is obviously an unsatisfactory method of eradicating these plants. Decapitation without the use of oil is also of no value. Crown drenching without decapitation is fairly satisfactory if rework can be undertaken. Decapitation followed by crown drenching with oil is entirely effective when properly done. In the light of subsequent observations, it now seems probable that 100-percent eradication of large clumps of *Ribes cereum* can be obtained by application of one-third of a gallon of oil to each decapitated crown. The improvement in method contemplated would involve merely spreading the oil over a slightly larger area of ground than that occupied by the stumps of the stems. The effectiveness of crown drenching without decapitation could also be improved by the same procedure, but in this instance a larger quantity of oil would be required, and the physical difficulties make 100-percent kill somewhat doubtful.

A comparison between hand grubbing and the chemical method can be made on the basis of the following time records: To decapitate a large clump required an average of 1½ man-minutes; to drench a decapitated crown with oil, 1⅓ man-minutes; and to dig out a large clump, 5 man-minutes. On the basis of labor at $6 per effective man-day and Diesel oil at 7½ cents per gallon on the job, the cost of eradicating a clump of *Ribes cereum* by hand grubbing is 23.0 cents as compared with 18.9 cents by the chemical method at an average dosage of 0.58 gallon of Diesel oil per crown. Improvements in decapitation and oiling technique should result in a still more favorable balance for the chemical work.

During 1937 and 1938 practical use was made of the method of plowing for the eradication of *Ribes cereum* (p. 44).

RIBES ROEZLI

PRELIMINARY TESTS

Ribes roezli is widely distributed and abundant at elevations of 3,500 to 7,000 feet throughout the sugar pine section of the Sierra Nevada of California (table 1). This species has been of major importance in the California control program; according to Benedict and Harris (*1*) it comprised 80.8 percent of the total ribes bushes eradicated from the Stanislaus National Forest during experimental work of 1926, 1927, and 1930. Typical site conditions and general characteristics of this species are shown in plate 3.

In 1927 plots were located at Leland Meadow and South Fork of the Stanislaus River near Strawberry, Stanislaus National Forest, for preliminary tests of chemicals on areas containing numerous *Ribes roezli* bushes. Additional plots were established for the same purpose at Leland Meadow, Cow Creek, and Punch Bowl, Stanislaus National Forest, over the period 1928 to 1934. These experiments showed that *R. roezli* was markedly resistant to chemicals. Of the various herbicides tested, those given in tables 9 and 10 were the only ones offering sufficient promise to justify their use in critical dosage and decapitation tests.

CRITICAL DOSAGE TESTS

Field plots of *Ribes roezli* were established in 1933 on the Stanislaus National Forest, to determine the practical lethal dosage of Diesel oil, sodium chlorate, and ammonium thiocyanate. These chemicals were applied in aqueous or liquid form to intact bushes according to the technique previously described. The plots treated with Diesel oil were located at Cow Creek and the other plots at Fiddlers Green. In the same areas the gross morphology of the underground parts of *R. roezli* was studied to furnish data on the influence of root development on the effectiveness of the various dosages of chemical. The biometrical data for *R. roezli* are not given here, because they add nothing to the previous discussion on this topic for *R. inerme* (table 3). Results of the chemical tests are given in table 9.

TABLE 9.—*Results of chemical treatments of Ribes roezli, Stanislaus National Forest, Calif., 1938*

Chemical used	Date of treatment	Dosage	Bushes treated	Bushes killed
		Pounds per acre	*Number*	*Percent*
Ammonium thiocyanate	Aug. 15	8,467	555	93
	Aug. 11–14	4,948	639	62
	Aug. 10	3,358	290	52
Diesel oil (27°+B.)	Aug. 17–18	36,400	325	98
	Aug. 21	11,150	365	70
Sodium chlorate	Aug. 4	8,703	210	67
Sodium chlotate (a) and sodium bicarbonate (b)	Aug. 3	(a) 8,540, (b) 4,271	390	85
	Aug. 2	(a) 5,257, (b) 2,644	187	74
	Aug. 4–7	(a) 4,493, (b) 6,734	273	50
	Aug. 2	(a) 2,428, (b) 3,612	103	39

On a combined basis of cost,[18] safety in handling, and effectiveness, Diesel oil proved to be more effective than any other material. Applied to intact bushes at the rate of 1.73 pints per bush (36,400 pounds per acre), it killed 100 percent of live stem and 98 percent of bushes.

This dosage may be taken as the practical lethal dosage of Diesel oil for the eradication of *Ribes roezli*. The plants treated ranged from the largest normally encountered in sugar pine areas to very young plants. The soil was dry for the first 6 inches but moist at greater depths. The results of these treatments, together with those from the decapitation work, are in complete agreement with previous experiments on this species, and attest the high effectiveness of Diesel oil on *R. roezli* in all sugar pine-yellow pine areas.

Since 1936 oil companies have been refining Diesel oils in response to the demand for a higher grade fuel for Diesel motors. The commercially available Diesel oils now contain fewer aromatics and sulfur compounds than formerly. As a result they are less effective than the old "black type" Diesel oils when used as sprays or soil drenches on intact plants. In recent field tests on intact *Ribes roezli* the Bureau of Entomology and Plant Quarantine has increased the toxicity of standard Diesel fuel oil by blending it with crude oil or with one of the sulfur dioxide extracts of lubricating oil. For the direct treatment of decapitated ribes crowns, the present grades of Diesel oil are fully as effective as the older type.

Ammonium thiocyanate applied at an average rate of 0.29 pound per bush (8,467 pounds per acre) killed 93 percent of the bushes, whereas sodium chlorate at approximately the same rate (0.26 pound per bush or 8,703 pounds per acre) killed only 67 percent. Soil conditions and vigor of ribes on the respective plots should be considered in comparing the toxicity of the two chemicals. On the thiocyanate plots the bushes were smaller and less vigorous and the soil was drier and somewhat lighter than on the chlorate plots. Moreover, there was more ground litter and humus on the area treated with chlorate. All these factors favor a higher kill with the thiocyanate. Ammonium thiocyanate, however, is at least as effective on *R. roezli* as sodium chlorate, and because of its freedom from fire hazard is preferred for work in the dry, upland locations where this species normally occurs.

The greater effectiveness of the sodium chlorate-sodium bicarbonate mixture over the sodium chlorate alone is important, since this mixture

[18] At the time of these tests Diesel oil cost about ½ cent, ammonium thiocyanate 10 cents, sodium chlorate 8 cents, and the mixture of sodium chorate and sodium bicarbonate 6 cents per pound.

is much safer than the sodium chlorate on the score of fire hazard. In the experience of the authors sodium bicarbonate is one of the few substances that does not lower the toxicity of sodium chlorate. Corroboration of this point has been obtained from dosage studies on *Ribes petiolare* (table 2).

Data for individual milacres (not given in table 9) showed that *Ribes roezli* bushes on moist land were more susceptible to both sodium chlorate and the sodium chlorate-sodium bicarbonate mixture than those of dry habitat. In the Fiddlers Green area *R. roezli* did not occur to any great extent on wet, boggy ground, but a high efficiency was invariably obtained for the occasional bush that did occur under such conditions. Most of the plants grew on moist, well-drained soil. The presence of ground litter and thick duff appeared to be more effective in reducing the toxicity of the applied chemical than variation of soil character and soil moisture.

For ammonium thiocyanate, sodium chlorate, and sodium chlorate mixed with sodium bicarbonate the practical lethal dosage exceeds 8,000 pounds per acre. Since the cost of these chemicals would prohibit their use in such amounts, no practical purpose would have been served in extending dosage studies. Further developmental work is planned with Diesel oil.

DECAPITATION TESTS

Experimental plots for decapitation tests on *Ribes roezli* were established at Fiddlers Green and Cow Creek, Stanislaus National Forest, in 1933, and at Greens Flat, Plumas National Forest, and Fiddlers Green, Stanislaus National Forest, in 1934. Results of the experiments are given in table 10.

TABLE 10.—*Results of decapitation and chemical treatment of Ribes roezli in California, 1933 and 1934*

Chemical used	Location of plots	Date of treatment	Chemical per crown	Water per crown	Bushes treated	Bushes killed
			Ounces	*Ounces*	*Number*	*Percent*
Diesel oil (27°+B)	Cow Creek, Stanislaus National Forest.	Aug. 18, 1933	1	0.0	42	95
		Aug. 21, 1933	8	0	80	100
Controls [1]	do	Aug. 18 and 21, 1933	0	0	36	17
Ammonium thiocyanate.	Fiddlers Green, Stanislaus National Forest.	Aug. 15 and 16, 1933	.9	.7	35	100
Sodium fluoride	do	Aug. 16, 1933	.5	.5	27	85
		July 24 and 31, 1933	1	1	72	97
		Aug. 16, 1933	2	2	21	100
Controls [1]	do	July 12 to Aug. 10, 1933.	0	0	35	26
Borax	do	June 27, 1934	2	0	116	90
	Greens Flat, Plumas National Forest.	July 2, 1934	1	0	50	78
	do	July 1, 1934	2	2	104	80
	do	June 30, 1934	2	0	105	80
Controls [1]	do	July 2, 1934	0	0	102	56
	Fiddlers Green	June 27, 1934	0	0	50	30

[1] Decapitation only.

Sodium fluoride, ammonium thiocyanate, and Diesel oil were all fully effective. Since Diesel oil is the cheapest and the least hazardous to use, attention is being centered on the development of methods and equipment for the use of oil. Borax by itself is not sufficiently toxic under dry Sierra Nevada conditions to make a satisfactory herbicide, though it may be possible to increase its toxicity by the addition of a small quantity of sodium chlorate. Soil moisture in this area was much higher than in the usual *Ribes roezli* site, and under drier conditions the effectiveness of sodium fluoride would probably not exceed 80 percent. The mortality of the controls ranged from 17 to 56 percent. Soil moisture appeared to be the most important single factor governing the survival of these bushes. In moist, shady spots resprouting of the controls was more certain than in dry, exposed locations.

Methods tests undertaken on the Stanislaus and Sierra National Forests in 1936 showed some advantage in the decapitation and Diesel-oil treatment over hand grubbing for heavy concentrations of *Ribes roezli.* In this work a total of 11,786 large *R. roezli* plants were decapitated and treated with Diesel oil at an average dosage of 0.42 pint per crown. Data taken the following year on the five oil plots showed 99.2-, 99.6-, 99.6-, 99.0-, and 98.5-percent kill for the treated crowns. On these same plots, however, 1.9, 0.3, 5.5, 7.4, and 7.5 percent of the decapitated crowns had been overlooked by the oiler. Further methods tests are planned in which the crowns will be marked, after decapitation, with a few strands of oiler's waste.

RIBES VISCOSISSIMUM

PRELIMINARY TESTS

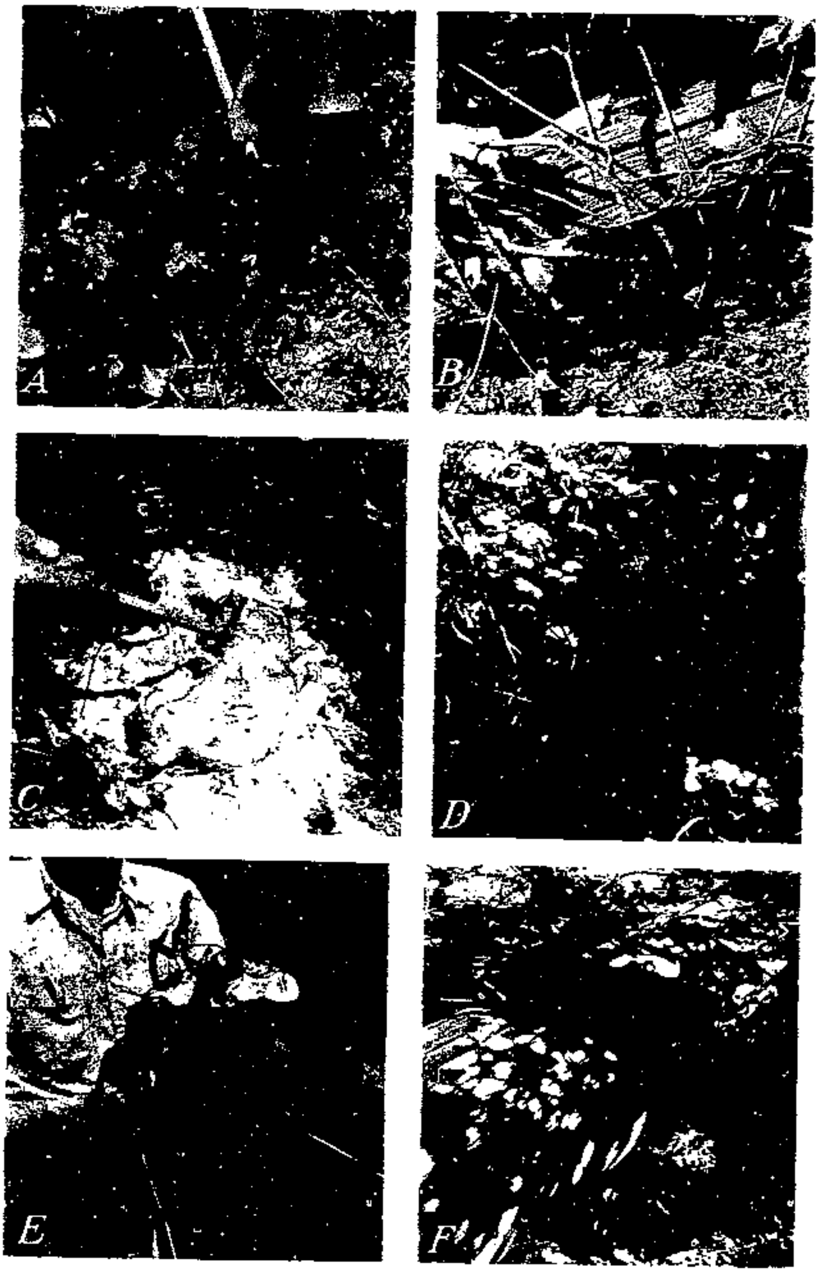
Ribes viscosissimum is the species most frequently encountered in upland eradication work in the white pine areas of northern Idaho. It also occurs within the designated control areas of the sugar pine section of southern Oregon, and to a lesser extent on some of the blister rust operations in the Sierra Nevada of California (table 1). Illustrations of bush character and site are given in plate 3.

Ribes viscosissimum has not presented a serious problem to hand eradication crews over much of the territory thus far worked, but, as previously suggested, there are special problems for which chemical methods appear to be needed. Preliminary tests of chemicals indicated that sodium chlorate and its mixtures were the only satisfactory herbicides for the spray treatment of intact *R. viscosissimum*. Table 11 shows the results of a few of these tests undertaken at Santa, Idaho, in 1928, which are typical of the general effectiveness of this chemical.

TABLE 11.—*Results of spray tests with sodium chlorate and its mixtures on Ribes viscosissimum at Santa, Idaho, 1928*

Chemical used	Date of treatment	Chemical used per bush	Bushes treated	Bushes killed
		Pound	*Number*	*Percent*
Sodium chlorate	June 27	0.14	131	96
	July 16	.14	167	100
Sodium chlorate (*a*) and ammonium chloride (*b*)	July 21	(*a*) .26, (*b*) .10	55	100
Sodium chlorate (*a*) and calcium chloride ($CaCl_2$) (*b*)	July 16	(*a*) .20, (*b*) .15	122	92

Sodium chlorate and a mixture of sodium chlorate and ammonium chloride are fully effective on *Ribes viscosissimum* when used in dosages of 0.14 and 0.26 pound of sodium chlorate per bush, respectively. The addition of calcium chloride, as previously reported, lowers the



Technique for decapitating *Ribes viscosissimum*: *A*, *C*, *E*, With Pulaski tool; *B*, *D*, *F*, with long-handled pruning shears. In *C* cut surface of the crown and the ground have been thoroughly covered with sodium chlorate-borax mixture. *E* and *F* show the aerial part of the bushes removed by decapitation. *B* shows the difficult position of the bush crown and *D* the ease with which the crown is reached by the shears.

killing power of the chlorate. It has, however, been considered unwise to use aqueous sodium chlorate in upland areas because of the high fire hazard on these dry, exposed sites. Regular crew work has been limited to decapitation and treatment of single bushes that could not be quickly and satisfactorily removed by hand eradication. Thus chemical work is definitely supplementary to hand pulling for large-scale eradication of this species of *Ribes*.

DECAPITATION TESTS

Plot experiments on the chemical treatment of decapitated *Ribes viscosissimum* were first undertaken in northern Idaho at Johnson Creek, St. Joe National Forest, during 1933. In the same year a practical test of the method was made by working with a regular eradication crew in the vicinity of Bobs Creek, Emida, Idaho. This work strongly confirmed the belief that chemical and hand methods could be satisfactorily combined in upland work to accomplish more effective and economic eradication of ribes. Additional experimental plots were established in 1934 and 1935 to test new chemicals, to extend information on the required dosage of the various chemicals, and to establish the most effective cutting tools and carrying equipment. Data from these experiments are shown in table 12.

TABLE 12.—*Results of decapitation and chemical treatment of Ribes viscosissimum in northern Idaho, 1933–35*

Chemical used	Date of treatment	Chemical per crown	Bushes treated	Bushes killed
		Ounces	*Number*	*Percent*
Ammonium thiocyanate [1]	Aug. 17, 1933	3-4	150	100
Copper sulfate (pentahydrate) [2]	Aug. 1, 1933	3-4	92	93
Sodium fluoride [2]	Aug. 2, 1933	3-4	113	92
Ammonium thiocyanate	Aug. 10 to 23 1934	1	73	99
	Aug. 8, 1934	2	51	100
Borax [2]	Aug. 10 and 23, 1934	2	52	91
		2	63	98
Controls [4]	Aug. 8 to 23, 1934	0	61	31
Ammonium thiocyanate	July 18 to Aug. 28, 1935	1/8	217	92
	July 2 to Aug. 9, 1935	1/4	177	99
	July 3 to Oct. 5, 1935	1/2	206	99
	July 5, 1935	3/4	66	100
	July 5 to Oct. 8, 1935	1	225	99
	July 11, 1935	2	101	100
Diesel oil	July 10, 1935	1/2	21	100
	July 9 to Oct. 4, 1935	1	231	99
	July 9 to Oct. 7, 1935	2	252	96
Sodium chloride	Sept. 30 and Oct. 1 1935	1/2	75	100
Sodium chlorate and borax (1:5)	Aug. 22, 1935	1/2	51	100
	July 29 to Oct. 4, 1935	1	403	99
	July 31 to Oct. 7, 1935	2	241	98
Controls [4]	July 2 to Oct. 5, 1935	0	278	62

[1] Used in conjunction with hand pulling in the course of regular crew work.
[2] Crowns moistened with water before application of chemical.
[3] 2 to 4 cc. of a saturated solution. Other chemicals except Diesel oil applied as a powder.
[4] Decapitation only.

Two types of decapitation, which may be called a high cut and a low cut, were used in the tests summarized in table 12. The former method left the crown comparatively undamaged, whereas the latter removed all or most of the crown. Results from all the tests were so uniformly high that nothing significant can be shown by an analysis of data on the basis of dosage and type of cut. It was apparent, however, that a low cut provided the possibility of a consistently greater kill. Examination of surviving crowns showed that resprouts from high-cut bushes were much more vigorous than those from low-cut bushes, especially in the untreated controls. In 1935 the low-cut controls showed an average mortality of 71.4 percent, whereas the high cut resulted in the death of but 41.4 percent of the decapitated plants.

On the basis of all dosages tested, ammonium thiocyanate, sodium chloride, Diesel oil, and the mixture of borax and sodium chlorate were about equally effective. It may be observed that in some cases the bush kill from the 2-ounce dosages was lower than that from 1-, ½-, or ¼-ounce treatments. This may be attributed in part to the selection of experimental plants, as the larger dosages were invariably applied to the largest and most troublesome bushes.

The data also show that it is not necessary to moisten ribes crowns to insure effective results from the application of a dry, nonhygroscopic chemical, provided the material is used in finely powdered form. Sodium chlorate-borax mixture or borax alone in the finely powdered form adheres nicely to the fresh tissue of newly cut crowns, but a dry, crystalline substance such as sodium chloride has a marked tendency to roll, and is difficult to apply effectively in steep places.

The data show that *Ribes viscosissimum* can be effectively eradicated by the application of dry or liquid chemical to decapitated bushes. Of the substances tested, the mixture of borax and sodium chlorate has been accepted as the most practical for large-scale eradication work. Ammonium thiocyanate has been ruled out because of its cost and its toxicity to conifers. The scattered distribution of plants of *R. viscosissimum* has strongly favored the use of a dry chemical rather than a liquid such as Diesel oil, for a few packages of dry chemical can be carried in a cartridge belt (pl. 11, *C*) or merely slipped into the trouser pocket, whereas Diesel oil requires a heavier and more cumbersome metal or glass container. One ounce of dry chemical is sufficient to kill a crown having a diameter of 2 inches or less. For larger crowns this dosage should be increased by the amount needed to give complete coverage of all crown surface.

Sodium chloride has not been tested extensively enough to justify final conclusions as to its effectiveness. Aside from its crystalline property the chief draw-back to the use of common salt is its attractiveness to animals. All salt-treated plots had been disturbed to such an extent that there was considerable doubt as to whether the kill had been accomplished by the chemical or by the salt-hungry animals. Further tests will be made with sodium chloride.

Extensive tests with the chlorate-borax mixture have been undertaken with the assistance of the regular eradication crews. Because of the scattered distribution of the *Ribes viscosissimum* bushes, it has not been practicable to lay out plots for methods tests. Time checks taken on individual bushes clearly showed that the chemical method offered a big saving in labor. In 1935 regular eradication crews used about 1 ton of the chlorate-borax mixture in 1- and 2-ounce dosages. Examination of treated bushes in 1936 failed to show any sprouting crowns. In 1936 about 3½ tons of the chemical mixture were prepared for general crew use.

Plate 7 illustrates the method of cutting off and treating *Ribes viscosissimum*.

RIBES TESTED ONLY IN PRELIMINARY PLOT STUDIES

The following species of *Ribes* have been given a preliminary test to determine their general susceptibility to chemical treatment: *bracteosum, erythrocarpum, irriguum, lobbii, nevadense, sanguineum, triste,* and *watsonianum.* For the most part these species do not occur abundantly in the important pine-growing areas or their occurrence is spotty, and they constitute only occasional problems to hand eradication crews. Reference should be made to table 1 for descriptions of habitat and growth form of these ribes, and to the tabulation on pages 7–10 for a record of all the chemicals tested.

RIBES BRACTEOSUM

Experiments on *Ribes bracteosum* were undertaken in 1928 and 1930 at Still Creek, in the Mount Hood section of Oregon, in the hope of facilitating control work on the Still Creek planting area. Best results were obtained with the sodium chlorate in a test where 0.2 pound of the chlorate per bush of 500 feet of live stem killed 99 percent of the live stem and 63 percent of the bushes. None of the spray tests showed a sufficiently high bush kill per unit weight of chemical to justify the use of chemical sprays for large-scale eradication of this species.

Decapitation tests conducted at Duck Creek, Snoqualmie National Forest, Wash., in 1936, showed 93-percent bush kill from the treatment of cut-off crowns with 2-ounce dosages of sodium thiocyanate. In localities where *Ribes bracteosum* bushes occur in rocky ground the speed and effectiveness of eradication work may be increased by treating the decapitated central crown with dry sodium thiocyanate or aqueous ammonium thiocyanate (saturated). The crew method recommended is a combination of hand pulling and chemical treatment whereby all small bushes and lateral root centers are pulled or grubbed and the large central crown is cut off at ground level and treated with the chemical.

RIBES ERYTHROCARPUM

Plots were established on *Ribes erythrocarpum* in 1930 and 1931, near the headquarters station of Crater Lake National Park. Atlacide was used in 1930 and Diesel oil in 1931. Atlacide proved to be 100 percent effective when applied at the rate of 0.2 pound per square yard, or 968 pounds per acre. Diesel oil killed only 20 percent of the bushes. This ribes is a prostrate, trailing plant and would undoubtedly be costly to remove by grubbing. If eradication of this species becomes necessary, it can be effectively destroyed at a per-acre cost comparable with that for *R. petiolare*.

RIBES IRRIGUUM

Sodium chlorate at the rate of 0.10 pound per bush applied to intact *Ribes irriguum* plants as spray killed 80 percent of live stem and 40 percent of the bushes. This test was made near Santa, Idaho, in 1928. Decapitation tests undertaken during 1934 at several locations on the Little North Fork and the North Fork of the Coeur d'Alene River, Coeur d'Alene National Forest, showed that the decapitation technique previously described is fully effective on this species. From

1 to 2 ounces per crown of ammonium thiocyanate or the sodium chlorate-borax mixture (1:5) is recommended.

RIBES LOBBII

Atlacide at the rate of 0.08 and 0.10 pound per bush was applied as a spray to intact *Ribes lobbii* bushes. Live-stem kills were 56 and 96 percent, and bush kills 17 and 20 percent, respectively. These tests were made on plots located adjacent to the motor highway 2½ miles from the summit of Huckleberry Mountain, Oreg.

RIBES NEVADENSE

Chemical tests were made on *Ribes nevadense* at Leland Meadow and South Fork of the Stanislaus River, near Strawberry, Stanislaus National Forest, during 1927, 1928, and 1930. Spray applications of sodium chlorate-ammonium chloride and sodium chlorate-furfural mixtures were 100 percent effective when used at an average of 0.40 pound of chlorate per bush. Diesel oil was less effective than on *R. roezli* and was inferior to sodium chlorate for the treatment of intact bushes. The dosage required for 100-percent kill of *R. nevadense* is considered too high to justify adoption of chemical methods in operations work. At present chemical work on this species should be used only in conjunction with decapitation of large, single bushes.

RIBES SANGUINEUM

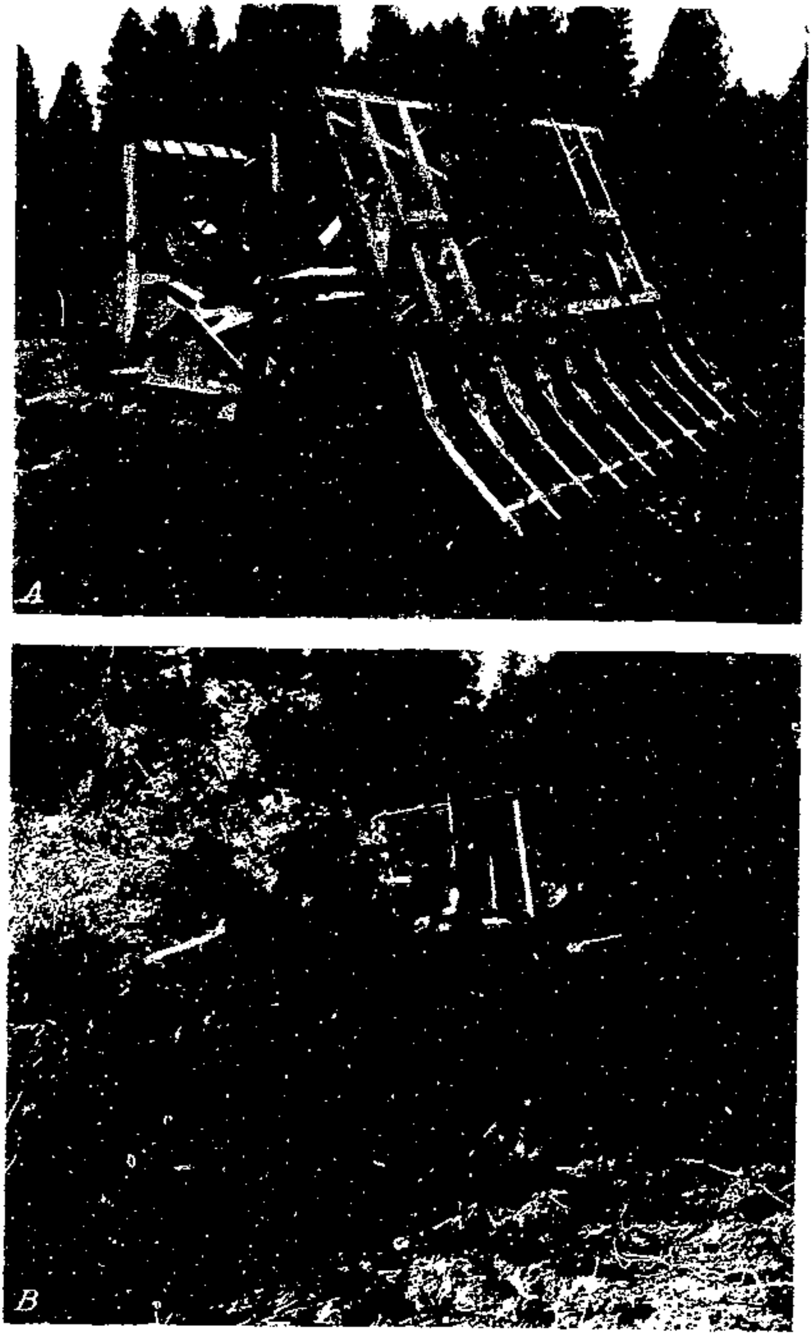
In habitat and physical character *Ribes sanguineum* resembles *R. viscosissimum* of this region. In 1929 spray tests were undertaken on this species at Santiam River, Oreg. The best result was obtained from the mixture of sodium chlorate and sodium hydroxide, which killed 94 percent of live stem and 50 percent of the bushes. Chemical work on the species should probably be confined to the decapitation treatment.

RIBES TRISTE

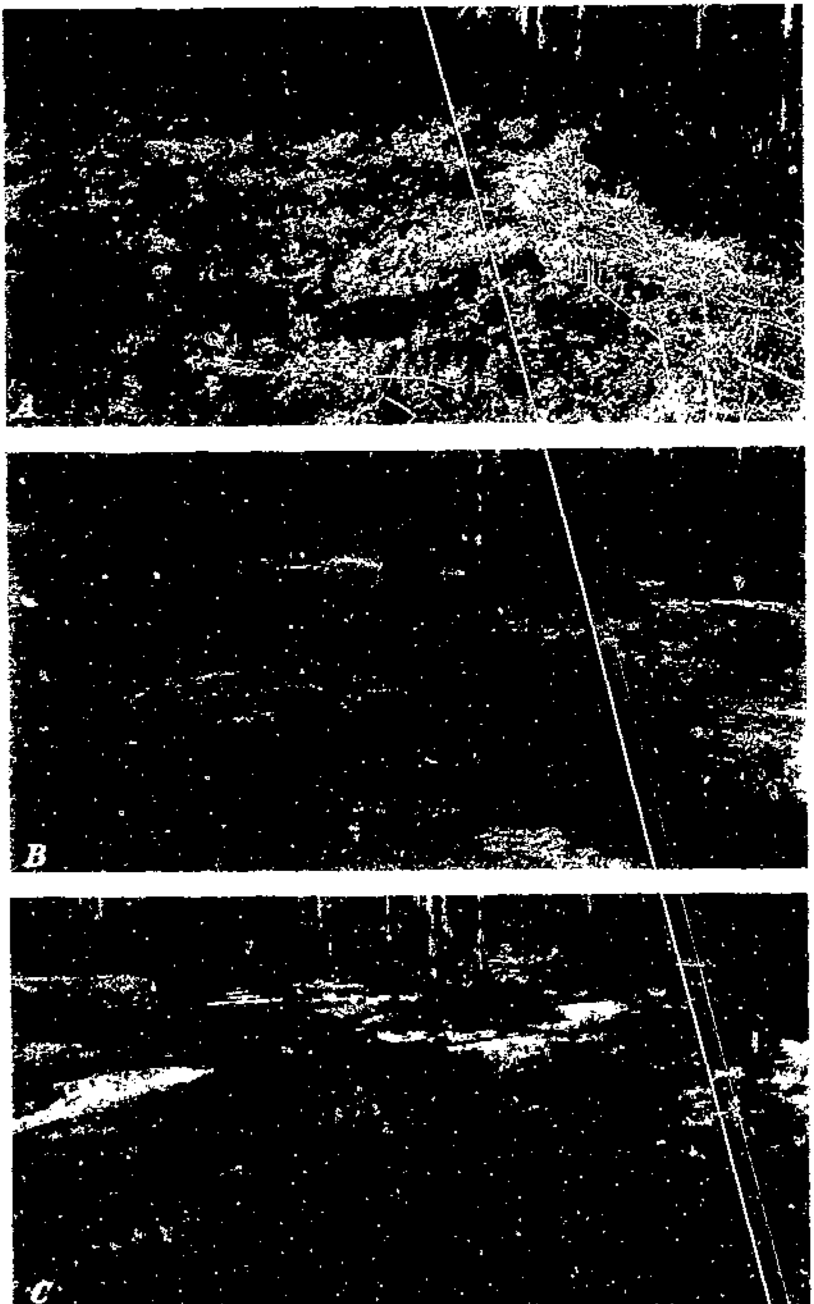
Spray experiments on *Ribes triste* undertaken at Mud Creek, Oreg., in 1929 and 1930 resulted in less than 10-percent bush kill. Additional data have been obtained from regular crew work on the St. Joe National Forest, Idaho. In the Marble Creek drainage of this area *R. triste* grows in intimate association with *R. petiolare*, and both species were sprayed with Atlacide at the rate of about 1,000 pounds per acre. The first spray killed 100 percent of the *R. petiolare* but only 25 percent of the *R. triste*. Three treatments, made in consecutive years, appear to be needed to obtain 100-percent kill. No recommendations can be made at present for a satisfactory chemical method on this species.

RIBES WATSONIANUM

In 1929 plots of *Ribes watsonianum* were located along the Mount Hood Loop Highway, a few miles from Government Camp, and were used for spray tests of sodium chlorate, alkaline sodium chlorate, and copper complex. None of these chemicals gave more than 25-percent bush kill. Chemical work on this species should at present be limited to decapitation treatment.



A, Tractor and bulldozer with brush rake for clearing ribes and brush from alluvial stream-bottom areas; *B*, machine in operation. (Northern Idaho.)



A, Area of ribes and brush prior to bulldozer work; *B*, same area worked by bulldozer, with ribes and brush piled in windrows; *C*, same area 2 years after bulldozer work and 1 year after planting to grass.

ERADICATION OF RIBES BY MECHANICAL METHODS

Mechanical methods have been developed for the suppression of brush and ribes in areas where hand pulling is ineffective and where chemical work is too costly. The most troublesome of these areas have been encountered in alluvial bottom lands within the white pine belt of the Western States, and comprise a stream-type association of *Ribes inerme* and brush. To meet the problem of ribes eradication on this type of area two mechanical methods have been used, the bulldozer method and slashing. The bulldozer method involves the use of a power-driven machine of the caterpillar type for clearing the land of all brush and ribes. The slashing method employs crews of men armed with such tools as brush hooks, axes, or Pulaskis, who cut the brush to facilitate the removal of the ribes bushes, which are pulled or dug as the work progresses. Although slashing is not mechanical in the same sense as the bulldozer method, it represents a distinct departure from hand pulling and chemical work in its use of cutting tools and in its complete removal of brush, and is therefore considered a mechanical method. In both methods brush and ribes are piled in long windrows, or individuals piles, and burned.

Either the bulldozer or the slashing method can be employed on practically all alluvial brushland, though some areas must be drained to permit the operation of the bulldozer. Of the two methods, the bulldozer is the more satisfactory from the standpoint of cost and the condition in which the area is left. For these reasons it should be used for all areas that are accessible and large enough to warrant importation of the machine. Slashing, on the other hand, is adaptable to small areas, and can be used where it is not feasible to bring in the heavy bulldozer.

Extensive areas of *Ribes inerme* on the Coeur d'Alene and Kaniksu National Forests and one large area on the St. Joe National Forest have been treated with the bulldozer. Otherwise, slashing methods have been used throughout the white pine control area of the West where hand and chemical methods were not satisfactory. Bulldozer and slashing methods have also been used in California for the eradication of *R. inerme* and brush. The slashing method was used at Meadow Valley, Plumas National Forest, in 1933-34 and the bulldozer at Miller Creek, Plumas National Forest, in 1937.

BULLDOZER WORK[19]

Experiments in the use of power-driven equipment for clearing brushy bottom land of ribes were begun in 1930 at Clarkia, Idaho. The bulldozer assembly is mounted on a tractor of the caterpillar type and is similar to the bulldozer used in road construction except that the solid blade used for removing dirt is replaced with a strongly built frame holding a series of digging teeth (pl. 8). This frame, or brush rake, was specially designed for the purpose by the Bureau of Entomology and Plant Quarantine. In the course of experimentation various types of blades were tested, including a solid blade and brush rakes with different spacing between the digging teeth. Special attachments designed to shake dirt loose from the roots of the brush

[19] With the exception of the preliminary costs attendant to the development of a special brush rake, all expenses of the operation and maintenance of the camps doing bulldozer work in region 1 have been borne by the Forest Service.

were also tested, but since they hindered the free passage of dirt between the teeth they were discarded. Two machines of the type shown in plate 8 were in operation during 1934 and 1935.

Prior to the operation of these machines the areas are surveyed and mapped to show the location of streams, beaver dams and runs, boggy ground, and any other features that would influence the method of working. Wherever necessary, areas designated for bulldozer work are drained 2 or 3 weeks ahead of the clearing work. The draining frequently involves the blowing out of beaver dams, although they are left undisturbed whenever possible. In some cases the main stream channels must be cleared to permit the standing water to run off. The removal of these water hazards allows the ground to dry sufficiently to support the machine. On these maps is also indicated the most satisfactory location for the brush piles and windrows to permit operation of the machine over hard ground, where it cannot become mired, and at the same time to reduce to a minimum the maneuvering required for clearing and piling brush. Ground conditions as they affect the maneuvering of the machine largely determine the manner in which the brush is piled.

The performance of the bulldozer is as follows: The teeth are set 3 or 4 inches into the ground, or deep enough to catch the roots, and the machine is driven ahead, uprooting the brush and ribes along the path of travel. The brush is collected in front of the rake and is pushed into a pile or windrow. The space on which the brush is piled is cleared by the machine in advance. The brush rake is raised or lowered by the driver, and a ground pilot directs him as to the correct set of the digging teeth, where the machine is to be driven, and where the brush piles are to be placed. The ground pilot also points out ditches, water holes, large rocks, or any other hazard to the machine.

SLASHING

Slashing as a method for destroying heavy concentrations of ribes and brush was first tested at Clarkia, Idaho, in 1932. The actual crew work starts with the clearing of a place to pile the brush. Crews of two men, working about 15 feet apart, slash the brush and throw it behind them onto the cleared space to form a compact pile. Care is taken not to cut off any ribes, as these plants must be taken out by the roots. Axes or Pulaskis are used for cutting heavy brush; brush hooks and scythes are more practical for work on small brush. Pulaskis, grub hoes, and trench picks are used for digging out clumps of ribes.

PILING AND BURNING BRUSH AND SUBSEQUENT CARE OF AREAS

The manner in which the brush is piled depends upon several factors, such as quantity of brush, size of area, season of year, proximity of standing timber, and, in the case of the bulldozer work, upon ground conditions as they affect the maneuvering of the machine. The windrow system is used in wide stream bottoms where the brush is very dense. This scheme is convenient because the brush does not have to be moved very far, but the windrows must be made before the middle of August, so that by the end of the fire season the brush will have dried sufficiently to burn. Individual piles are used in areas where the brush is light and scattered, or when it is slashed late in the season. This system has the advantage of furnishing sufficient fuel to burn brush that may be green. In piling brush, whether in windrows or individual piles, limbs are laid lengthwise with all the butt ends up and pointing in the same direction. This method of piling makes it easier to start a fire and to burn all the limbs.

If brush piles are to burn completely, they must be kept as free from dirt as possible. This is of special importance in bulldozer work. Although much of the dirt passes between the teeth of the brush rake, skillful coordination between driver and ground pilot is required to prevent dirt from piling in front of the digging teeth. Also, to facilitate burning, the brush piles are made as compact as possible, and while the brush in the piles is still green the overhanging limbs and loose ends are cut and all openings closed.

Brush piles are burned in the fall or the following spring. Occasionally it may be difficult to obtain a satisfactory burn because of insufficient fuel of a readily combustible nature or because of excessive dirt. Under such conditions the use of additional fuel, such as Diesel oil or wood charcoal soaked in Diesel oil, has been found helpful (*12*).

In both bulldozer and slashing work the burned area is planted to grass to establish a ground cover for discouraging the germination of ribes seed and the consequent growth of seedlings. This procedure does not suppress all ribes seedlings, and until a thick sod is well established it is necessary to examine the area occasionally for new ribes. More seedlings generally appear following slashing than after bulldozer work, but in the absence of interfering brush they can be easily located and eradicated. If the ribes seedlings appear in large numbers, they are treated with chemical; otherwise they are pulled out by hand. The reworking of these areas is usually undertaken the second or third year after the clearing operations.

Many of the areas cleared by the bulldozer have been converted into pasture land; some are even under regular cultivation. On these areas ribes seedlings present no problem whatsoever.

Plate 9 shows an area before and after clearing with the bulldozer, and plate 10 shows an area treated by the slashing method.

COMPARISON OF COSTS OF BULLDOZER, SLASHING, AND CHEMICAL WORK ON RIBES INERME

By the bulldozer method 905 acres have been cleared at an average cost of $49 per acre. This amount includes all items involved in the clearing and burning operations, the principal of which are labor, material, and depreciation on the machine. From 5 to 6 hours of operating time are required to clear an acre of ground by machine. On the basis of operating time the cost of the machine is charged to the work over a period of 3 to 4 years. The depreciation charge is set at $2.50 per hour, being based on a figure established by the Engineering Division of the Forest Service in region 1.

By the slashing method 1,577 acres have been cleared at an average cost of $58 per acre. The principal item of cost in this work is labor. On an average 9 to 10 man-days is required to slash and burn the brush on an acre of ground. Labor costs for the slashing method have been figured on the basis of $6 per effective man-day.

The cost of chemical eradication of *Ribes inerme* varies directly with the amount of ribes present. There is not the uniformity in costs found in bulldozer and slashing work, where the entire area is cleared. By chemical methods 137 acres have been worked in the course of experimentation on *R. inerme* areas at costs ranging from $50 to $300 per acre. By employing the most approved chemical method, areas comparable to the type worked by bulldozer and slashing methods can be worked at an average cost of $96 per acre. The principal items of cost are labor and chemicals. The labor item in the cost of chemical work has also been taken as $6 per man-day. On an average 7 man-days and 600 pounds of chemical are required to treat and destroy the *R. inerme* on an acre of alluvial bottom land.

From the standpoint of costs the bulldozer method is the most satisfactory for working areas of *Ribes inerme* and brush. It also leaves an area in such shape that very little maintenance work is required to keep out future ribes growth. The cost is not excessive, when it is remembered that the eradication of ribes on 1 acre of stream type may protect many acres of pine on adjacent slopes where ribes may either be absent or present in small numbers. This method also partly repays its cost by converting brushy jungles into good meadow from which hay crops can be cut in future years.

COMMENTS ON OTHER METHODS OF RIBES SUPPRESSION

PLOWING

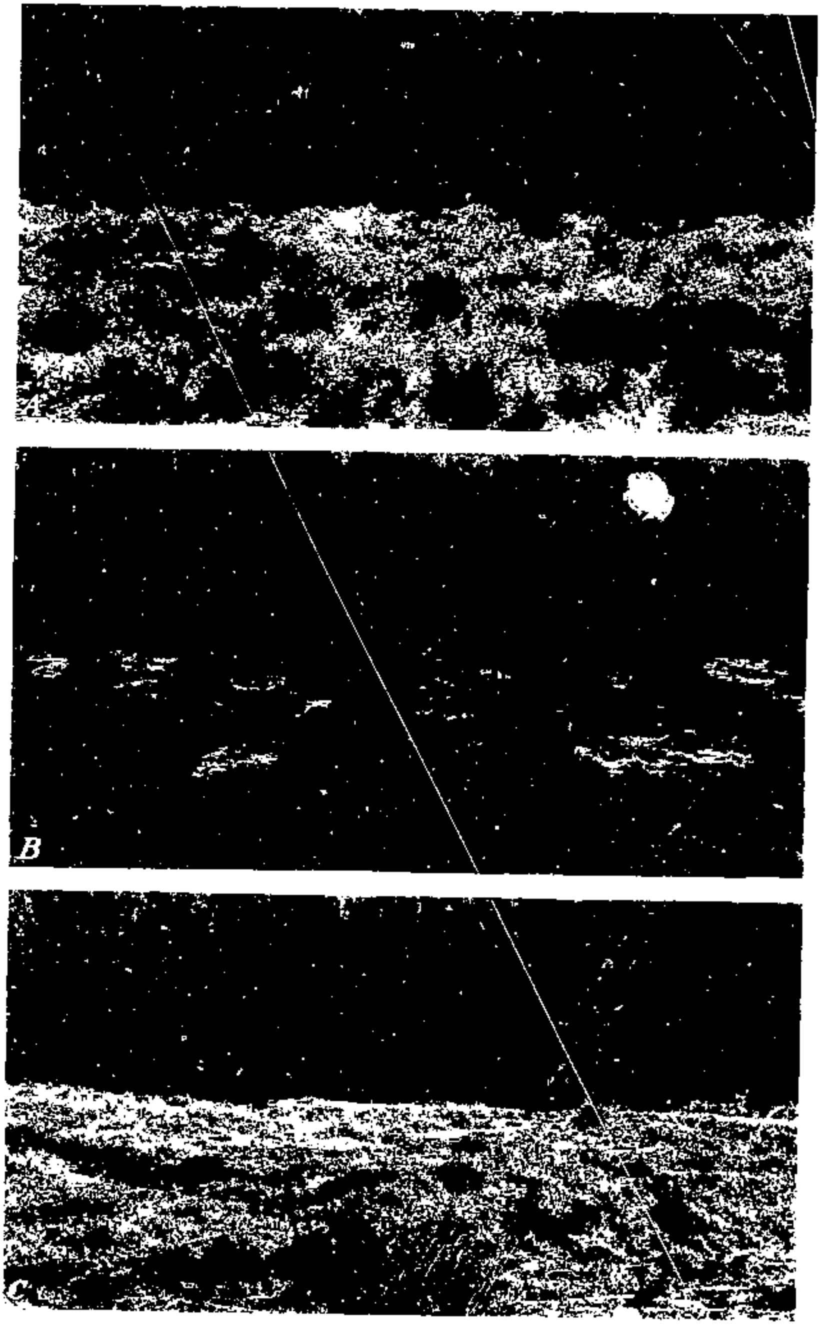
A special hook plow for uprooting large *Ribes cereum* bushes has been designed and tested in Oregon. The plow comprises two heavy iron prongs, forming a V-shaped hook fastened to an iron drag beam; ordinary plow handles are bolted to the hook and drag-beam assembly to aid in guiding the equipment, which is pulled by a team of horses. In August 1934, 507 large bushes were uprooted by this technique from an area adjacent to the Crater Lake Highway, 3 miles above Union Creek, Oreg. Bush-kill efficiency of this treatment was 95.9 percent. Further development and testing of this method are planned.

BLASTING

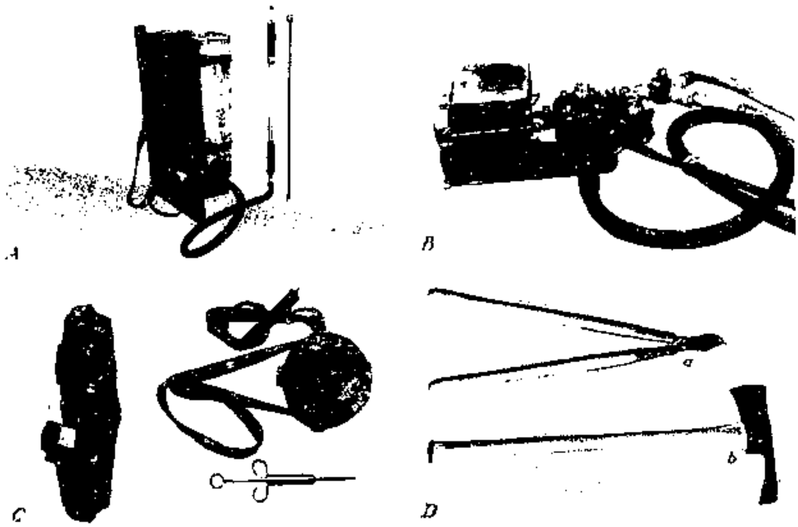
Twenty-percent stumping powder has been used successfully to aid in the eradication of *Ribes inerme* entangled with large masses of willow roots. This material was used on a slashing job undertaken at Meadow Valley, Plumas National Forest, Calif., during 1934. In addition to the stumping powder, the necessary equipment consisted of dry-cell batteries, 250 feet of No. 20 insulated copper wire for splicing electric cap wires, and No. 6 electric blasting caps. A wooden stick cut square at one end was used for tamping instead of an iron rod. The charge, one to three sticks of powder, was placed well under the roots of the willow-ribes clump and not too near the surface.

BURNING

Experiments in the burning of patches of heavy brush and *Ribes inerme* were conducted at Haugan, Mont., in 1928 and 1929. In some instances these patches were sprayed with sodium chlorate and fired about 2 weeks later, when the brush had been partially killed and



A, Area of ribes and brush before slashing was begun; B, same area after slashing had been completed; C, same area 2 years after slashing and 1 year after planting to grass.



Equipment for ribes eradication: A, Knapsack spray unit, showing the tank, pack board, flexible hose coupling, double-action trombone pump, and iron-pipe extension fitted with an injector-type nozzle; B, portable power spray unit, including two-cylinder gasoline engine cooled by bypass of spray solution, rotary pump, overhead gas tank, battery (concealed in base), and couplings; C, Army-style cartridge belt showing 2-ounce dose of chemical in one of the pouches, 2-quart canteen, and special 1-ounce syringe for fitting the canteen; D, long-handled pruning shears (a) and Pulaski tool (b).

desiccated. The heat generated in the center of some of these chemically treated brush piles was sufficient to kill the roots of brush and ribes. Near the edges of all such patches, however, *R. inerme* sprouted vigorously, and seedlings germinated in great numbers. Firing of brush piles, without the aid of chemicals, resulted in little or no kill of ribes. Burning may serve a useful purpose in the preliminary clearing of brushy areas, but this method alone cannot be expected to cause a high mortality of the ribes.

FLOODING

Ribes inerme cannot long withstand even partial submersion under water. At the Swauk Creek (Wash.) plots it was observed that two seasons of partial submersion killed *R. inerme* bushes that had been previously damaged by sodium chlorate. Flooding cannot be recommended as a method to be generally used for the eradication of ribes, but occasional sites are encountered where only a small amount of work is needed to flood a short stretch of stream bottom. Some such areas are already partly flooded by beaver dams, and would otherwise have to be drained before ribes eradication was undertaken. Frequently it is as easy to raise the water level as it is to lower it.

FIELD EQUIPMENT

WORK ON STREAM-TYPE RIBES

The equipment used for regular crew work in the chemical eradication of *Ribes petiolare* consists of a knapsack spray outfit for each crewman, and for each unit of four crewmen the following: Two 12-gallon galvanized-iron washtubs, two 10-quart galvanized-iron buckets, one spring balance weighing to 25 pounds, one 8-inch tin funnel, one 1-gallon tin measure, one 1-gallon can for stock glue solution, and 1 yard of cheesecloth for straining chemical solution. The knapsack spray unit (pl. 11, *A*) is the only special piece of equipment used by the crews. It consists of a 5-gallon galvanized-iron tank, a special pack board constructed of canvas over a wooden frame, and a double-action trombone-type pump attached to the tank by means of about 3 feet of flexible rubber hose. A 2-foot iron-pipe extension carrying the detachable nozzle is screwed to the head of the trombone pump. The nozzle head is of the injector type, containing an orifice 1 to 1.5 mm. in diameter, and delivers the chemical solution as a hollow-cone, fine-mist spray.

Portable power sprayers (pl. 11, *B*) have been developed for working extensive areas of brush and ribes, and have been used for several large-scale methods tests on *R. inerme*, but this equipment has never been utilized in regular operations work because of the preference now given to the use of bulldozers for this species. The essential features of the power unit are as follows: A two-cylinder gasoline engine, a rotary pump, a bypass valve adjustable to various working pressures, intake and outlet connections, and a special mounting frame. The pump may service from two to six spray nozzles, and delivers the spray at about 25 pounds' pressure at the nozzle, through several hundred feet of half- or quarter-inch hose. For power spraying an injector-type nozzle is equipped with a trigger release shut-off valve to give intermittent service. Containers of 50 gallons' capacity are necessary to provide an adequate reserve of solution. From one such container the solution is pumped to the spray nozzles. A fresh supply of chemical solution is prepared in a second tank, so that the pump intake can be quickly transferred to it without shutting off the motor. A complete set of tools is needed for repair work on the motor and pump.

WORK ON UPLAND-TYPE RIBES

Special equipment has been devised for delivering measured quantities of Diesel oil in connection with the chemical work on upland-type ribes. It consists of a standard Forest Service 2-quart canteen, into the orifice of which a special syringe is fitted by a friction taper (pl. 11, *C*). One full stroke of the syringe plunger delivers about 1 fluid ounce of Diesel oil. Two adjustable canvas straps, one fitting about the operator's belt and the other about the shoulder, permit the unit to be carried on the back while not in use and, when needed, swung about to a position high up on the left breast.

An Army-style cartridge belt (pl. 11, *C*) is convenient for carrying dry chemical where a small quantity of such chemical is being used. The belt contains 10 pouches, each of which is the correct size for carrying a 2-ounce dose of dry chemical. Each charge of chemical is wrapped in a ½-pound kraft paper bag. For the protection of a hydroscopic chemical such as ammonium thiocyanate the paper bags may be waterproofed by a patented process involving impregnation with zinc oxide and a gum, benzene being employed as the volatile vehicle.

The decapitation tools are illustrated in plate 11, *D*. The long-handled pruning shears (*a*) is a common orchard tool, and is a stock item of several manufacturers. This tool is 26 inches over-all, and has wooden handles and cutting blades of case-hardened steel. The blades are kept at the correct set for cutting by means of a bolt-and-ratchet nut. The Pulaski tool (*b*) combines the features of an ax and a mattock. It is made of ax steel, weighs 2½ to 3 pounds, and is about 39 inches from the handle tip to the head.

For chemical work on *Ribes cereum* in Oregon and California and on *R. roezli* in California, a special saddle tank has been developed for transporting oil by pack mule. This tank is constructed so that oil may be drawn from a tap into individual containers, or delivered directly on the ribes by gravity or by pump action through oil-resistant hose. An alternative scheme for transporting oil to the work area involves the use of standard 4- or 5-gallon cans, which may be loaded on the animal two to a side and then spotted over the ribes area in advance of crew work. An ordinary 2-gallon watering can has proved to be a convenient container from which Diesel oil may be applied, and is cheap, durable, and readily procurable. The regular 5-gallon knapsack tank equipped with an extension fitted with a shut-off valve (in place of the trombone-type pump) was successfully employed during 1936 methods tests in California. A rose-type disk is used in the nozzle head in place of the injector-type disk employed for spray work, and the oil is delivered by gravity flow.

SUMMARY

Chemical and mechanical methods have been developed for the eradication of troublesome ribes in places where the simpler methods of hand pulling and grubbing are ineffective and costly. This develop-

mental work has been an important phase of the control of blister rust (*Cronartium ribicola* Fischer) in the Western States, where this fungus disease menaces about 5 million acres of western white pine (*Pinus monticola* Dougl.) and sugar pine (*P. lambertiana* Dougl.).

Laboratory and greenhouse procedures for the evaluation of herbicides have been briefly outlined, and the results of small-scale and large-scale field tests have been described to show the importance of dosage of chemical in relation to the practical use of a herbicide for ribes eradication.

Methods for the chemical eradication of *Ribes petiolare* have been improved by establishing instructions on practical lethal dosage, the rate at which chemical must be applied to insure about 99-percent bush kill. In this work Atlacide (essentially a mixture of sodium chlorate and calcium chloride) is applied at the rate of 960 pounds per acre. An alternate herbicide has been developed which consists of 0.6 pound of sodium chlorate and 0.4 pound of sodium bicarbonate per gallon of water; it is applied at the same rate as Atlacide. Pound for pound, this mixture is as toxic as Atlacide, but because of slightly greater cost it cannot now be recommended for control work.

The fire hazards of sodium chlorate have been reviewed from the standpoint of its use under forest conditions. Hygroscopic mixtures, such as sodium chlorate and calcium chloride, or mixtures containing a noncombustible filler, such as sodium bicarbonate or borax, have been shown to be safer than sodium chlorate alone.

Ammonium thiocyanate and sodium chlorate were the most effective chemicals for killing *Ribes inerme*, but they are recommended only for isolated areas where it is impracticable to use a bulldozer. Greatest economy in the chemical eradication of this species is obtained by applying as a first spray the dosage of maximum efficiency (2,160 pounds per acre for ammonium thiocyanate and 2,346 pounds for sodium chlorate), which provides about 81-percent bush kill, and the following year treating the surviving ribes with the practical lethal dosage of ammonium thiocyanate (4,000 pounds) or sodium chlorate (4,600 pounds).

A method involving decapitation and chemical treatment has been developed as a substitute for hand pulling or grubbing of large or troublesome ribes of the individual bush type. About 1 ounce of liquid or dry chemical is used for a crown approximately 2 inches in diameter. The dosage is increased proportionately for larger crowns. Diesel oil is recommended for the eradication of *Ribes cereum* and *R. roezli*, a mixture of dry sodium chlorate and borax (1:5) for *R. viscosissimum*, and dry sodium thiocyanate or a saturated solution of ammonium thiocyanate for *R. bracteosum*.

The results of preliminary chemical studies have been given for *Ribes bracteosum*, *R. erythrocarpum*, *R. irriguum*, *R. lobbii*, *R. nevadense*, *R. sanguineum*, *R. triste*, and *R. watsonianum*. *R. erythrocarpum* can be economically eradicated with Atlacide spray used at a dosage of 960 pounds per acre; the others must be treated by the decapitation technique to obtain satisfactory bush kill.

A mechanical method known as bulldozing has been developed for the permanent suppression of occasional areas of dense brush and *Ribes inerme*. In this method all ribes and brush are uprooted and pushed into long windrows by a bulldozer equipped with a special rake blade. Hand slashing of brush in conjunction with the hand pulling of ribes has also been employed for clearing similar areas; this method, however, can only be used when labor costs are comparatively low. In both cases the brush is subsequently burned and the cleared area is planted to grass. Average cost figures per acre for the eradication of *R. inerme* are as follows: Bulldozer $49, slashing $58, and chemical $96.

The scope and limitations of special ribes-eradication methods, such as plowing, blasting, burning, and flooding, have also been noted.

Since 1928 improvements and innovations have been made in field equipment for the chemical and mechanical eradication of ribes. A special type of bulldozer has been developed for work on *Ribes inerme*. The knapsack tank has been improved by the use of a lighter and stronger tank and pack board, and a double-action pump. A dependable portable power sprayer has been constructed and tested both in experimental plot work and in extensive methods operations. For work on upland ribes apparatus has been developed which facilitates the transportation and application of chemical under widely varying field conditions. A special canteen and syringe has been constructed for carrying and discharging measured dosages of oil, and an Army-style cartridge belt has been adopted for carrying 2-ounce packages of dry chemical. A Pulaski and long-handled pruning shears have been found suitable for decapitation of upland ribes.

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