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Screening Conventional Fungicides . . .

control of blister rust

on sugar pine in California

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ABSTRACT: After 5 years, 4 of 14 fungicides tested showed varying promise of development into satisfactory direct control of blister rust. Little promise of systemic control was found. Trees treated were second-growth sugar pine in a mixed conifer forest in eastern Shasta County, California, where blister rust has been intensifying for many years. Most trees received basal-stem treatment. Tree mortality after treatment--from all causes other than obvious accidents--varied from zero to 60 percent. No antifungal antibiotics were included in these tests.

RETRIEVAL TERMS: screening tests; fungicides; *Cronartium ribicola; Pinus lambertiana;* Shasta County, Calif.; systemic action; 2-norcamphane methanol; dyrene; biphenyl; cyprex.

OXFORD: 443--414.26[--172.8 *Cronartium ribicola* + 174.7 *Pinus lambertiana* + 172.8 *Cronartium ribicola*]

Experimental work on direct control of blister rust (*Cronartium ribicola* Fischer) on sugar pine (*Pinus lambertiana* Dougl.) in California is largely centered on chemical treatments. Since 1959, this Station has been screening antibiotic and conventional fungicides for promise of development into effective control measures. For purposes of this report, conventional fungicides are described as customary, long-used or experimental, antifungal chemicals other than antibiotics.

On July 12, 1961, we began a series of 23 tests in which 350 trees were treated with 14 different conventional fungicides.[1] Trees were checked annually through 1966. Five years after application, the following fungicides showed varying promise of development into satisfactory direct control: 2-norcamphane methanol, Dyrene (a *sym.*-triazine compound), biphenyl, and Cyprex (dodine).

Materials and Methods

Area and Trees. Plots are located on the westerly slope of Hatchet Mountain, on lands owned by the Scott Lumber Company, near Burney, Shasta County, California.[2] They lie on various southerly and westerly subslopes just east of Little Hatchet Creek, at altitudes from 4,000 to 4,500 feet. The area--an old cutover about a mile due east of the Old Buffam Cutover, from which test results have been reported previously[3]--has been salvage-logged lightly in recent years.

Treated sugar pines, mainly saplings and small poles, varied widely in crown class and vigor, and in number, age, and extent of blister rust infections. Blister rust has been in evidence here for a long time--perhaps a quarter of a century. The test area is not within a blister rust control unit. The disease is irregularly increasing in the mosaic of ecologic niches--the system of small localized differences in physical habitat and forest vegetation--found on the test area.

Purple mold (*Tuberculina maxima* Rost.), a fungus hyper-parasite of

[1] Clifford H. Lamoureaux, graduate student in the Department of Botany, University of California, Berkeley, assisted me in all aspects of the program during field seasons 1962 through 1966.

[2] The cooperation of Irvin E. Toler, chief forester, Scott Lumber Company, in making trees and area available for experimental use, is gratefully acknowledged.

[3] Quick, Clarence R. *Chemical control of blister rust on sugar pine...two fungicides show promise in California tests.* U.S. Forest Serv. Res. Note PSW-147. Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 8 pp., illus. 1967.

blister rust has been variably abundant over the trees, niches, and years of the tests. Its presence has caused some uncertainties in assessing effectiveness of treatments.

This paper reports results of 17 tests on 243 diseased trees (table 1). Average crown-class of test trees was relatively low--indicating that they were relatively poor in vigor and somewhat older than sizes otherwise indicate. Smaller trees appear in general to have had a greater proportion of bole treated with chemicals than larger trees. This tendency was unfortunate.

Chemicals, Carriers, and Treatments. The 14 fungicidal materials used in the tests were as follows:[4]

BENZOIC ACID, U.S.P. (Dissolved in isopropanol.)

BIPHENYL, PRACT. Diphenyl. (Dissolved in isopropanol.)

CRESATIN. *m*-Cresyl acetate. *m*-Tolyl acetate.

CYPREX 65-W. Dodine, 65 percent wettable powder. *n*-Dodecylguanidine acetate, tech. American Cyanamid Co.

CYPREX, TECH. Dodine, tech. American Cyanamid Co.

DOWICIDE 1. *o*-Phenylphenol, tech. Dow Chemical Co.

DYRENE, TECH. 2,4-Dichloro-6-(*o*-chloroaniline)-*s*-triazine, tech. Chemagro Corp.

EC#1182. (Experimental Chemotherapeutant #1182.) 4-chloro-3,5-dimethylphenoxyethanol, tech. Union Carbide Chemicals Co.

EC#1207. (Experimental Chemotherapeutant #1207.) 2-Norcamphane methanol, tech. Union Carbide Chemicals Co.

EF#28720. (Experimental Fungicide #28720.) Copper^{II} complex of 1,2-naphthoquinone-2-oxime, 25 percent wettable powder. American Cyanamid Co.

EF#35429. (Experimental Fungicide #35429.) Manganese^{II} complex of 1, 2-naphthoquinone-2-oxime, 25 percent wettable powder. American Cyanamid Co.

GLYOXIDE DRY. 2-Heptadecylimidazoline, tech., as 70 percent wettable powder. Pittsburgh Plate Glass Co.

MERTAX. 2-Mercaptobenzothiazole, pract. (MBT. Thiotax.)

TERRACLOR, TECH. Pentachloronitrobenzene, tech. (PCNB.) Olin Mathieson Chemical Corp.

One promising material--EC#1207--may now be unavailable as experimental fungicide. A 5-percent solution of this material in propylene glycol was reported[5] as causing severe damage when applied to the cornea of rabbits' eyes. Small amounts of mist of another promising material--Dyrene--which accidently drifted onto a wrist and forearm on one operator may have caused a severe dermatitis resembling that from poison oak. Most fungicides are relatively innocuous to human beings, and exacting precautions are seldom necessary. But all unfamiliar materials, especially experimental materials, should be handled with the care commonly accorded poisonous chemicals in general.

Solid fungicidal chemicals commonly were dissolved in appropriate solvents in the laboratory and carried to the field as single-test stock solutions. Stove oil (Pacific Specification #100) was used in all tests as spray diluent and carrier. Liquid chemicals and proprietary liquid formulations were simply diluted in the field with stove oil to planned concentrations. Wettable powders were applied as suspensions in the stove oil. Two liters of spray solution were used to establish each test.

[4]Companies listed furnished samples of materials shown. Trade names and commercial products or enterprises are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied. Unnamed products of comparable chemical content are not assumed to be inferior.

[5]Martin, Hubert. *Guide to the chemicals used in crop protection.* Ed. 3. Can. Dep. Agr., Research Branch. 306 pp. 1957.

About 85 percent of the trees in these tests were given basal-stem or bole-band treatment. Other trees were given an "infection only" treatment in which obviously rust-infected areas and a surrounding zone of apparently healthy bark were sprayed to the point of run and drip. For each of these trees, an equivalent length of bole treatment was estimated. Treated portions of boles commonly were pruned before treatment. In most cases this preparation amounted to little more than removal of dead and decadent limbs from the lower fifth to third of the bole.

Excessive tree mortality or inadequate effectiveness, or both, developed in tests with two chemicals (benzoic acid in isopropanol, at 0.9 and 1.5 percent; Terraclor, tech. at 1.5 percent). Inspection records for these tests are incomplete. Three test materials (Cyprex 65-W at 1.5 percent active; EF#28720 and EF#35429, both at 1.5 percent active) were applied to trees in a dense second-growth stand on a rocky ridge. Low site-class and relative abundance of *Atropellis pinicola* Zeller & Goodding probably put tests with these three materials into a different tree population.

Inspections. I applied all treatments and made all reported inspection readings. Application records and other notes were read at each formal inspection following treatment; the treatment description was visually reapplied to the tree at hand; tree damage and treatment effectiveness were then assessed and recorded.

Effectiveness on each inspected tree was classed by a 5-unit code: 5 (excellent); 4(good); 3(fair); 2(poor); or 1(no apparent effect of treatment). The code is explained in more detail in a previous report.[6] Bole infection only is considered in this report. "Readable trees," a term used later in graphs, refers to live treated trees in which effectiveness could be read with reasonable certainty. Mean effectiveness is the arithmetic average of code classifications for the trees of a test or group of tests. Tree mortality includes trees dead from all causes after treatment except obvious accidents.

Results

Tree Mortality. Because treatment effectiveness data are based on reliably readable trees alive at time of inspection, and because many trees died after treatment, tree mortality data are reported before treatment effectiveness data.

No close over-all correlation between chemical concentration and tree mortality 5 years after treatment with selected conventional fungicides was found (fig. 1). This lack of consistent relationship presumably indicates that factors other than chemical toxicities *per se* often determine degree of damage and mortality. Dyrene was severely damaging to sugar pines, and biphenyl relatively innocuous. Two tests (biphenyl at 1.5 percent and Cyprex, tech. at 2.0 percent) showed no tree mortality.

No close correlation of tree mortality data with the previous effectiveness rating, or with years after treatment, was found. Table 2 segregates number of dead treated trees in 20 tests (305 trees) into groups by year of death, and by treatment effectiveness class assigned each tree 1 year previous to being found dead. Slightly more than half the tabulated trees were classified 4 (good) or 5 (excellent) 1 year before finding them dead. But a quarter of the dead trees were rated 1 (no apparent effectiveness of treatment) 1 year previously.

A table of data from single tests with several fungicides, presented later under treatment effectiveness, contains a few more data on tree mortality.

Treatment effectiveness tended to increase as concentration of applied

[6] See footnote 3.

fungicides was increased. This relationship suggests promise of satisfactory direct canker control by a few materials, notably biphenyl and Cyprex (fig. 2). But little promise of systemic effectiveness was shown. Individual effectiveness readings varied all the way from 1.0 (no apparent effect of treatment) to 4.5 (halfway between "good" and "excellent"). There were marked differences between the general level of direct and systemic effect. There also were marked differences between direct and systemic levels of effectiveness among the several fungicides.

Tree mortality as well as treatment effectiveness, must be kept in mind whenever assessing the promise of treatments.

Table 3 compares direct and systemic effectiveness means from one test each with six fungicides. Only two of the tests equaled or exceeded an apparent direct effect of 4.0, 5 years after treatment. No promising systemic effect is apparent, but benzoic acid in isopropanol shows a slightly higher systemic than direct mean effectiveness. Tree mortality in 1966 is tabulated for the six tests.

Graphs of direct effectiveness of chemical treatments from a group of individual tests can often be classified into one of two types. Figure 3A illustrates tests which apprently stabilized at rather high levels of direct effectiveness 2 to 4 years after treatment. A test with Cyprex 65-W at 2.5 percent active gave a similar reaction. These tests seem to demonstrate fungicidal action. Figure 3B illustrates tests which rose to a peak of apparent effectiveness 3 years after treatment, then sharply declined. Dowicide 1 at 2.5 percent and Cyprex, tech. at 2.0 percent produced results very similar in configuration to those of Mertax and Glyoxide Dry. These tests suggest only fungistatic action.

Maximization of treatment effectiveness by propitious choice of chemical concentration, solvents, spray carrier, season, and other variables might well upgrade the apparent fungistatic action to fungicidal effect.

Discussion

The major purpose of the reported tests was to select for further testing one or more fungicides that offered promise of development into satisfactory field control of blister rust, not to prove conclusively that any tested material had in fact produced effective control. Fine points of statistics were deemed inappropriate, perhaps impossible, considering the state of knowledge of the problem in 1960 and 1961 when the work was begun.

Decisions on experimental plans concerned with early screening efforts of this sort are not easy to make, but at least two alternatives are evident. It is possible to build up a mass of knowledge of reactions of trees, the disease, chemicals, and methods, with results from various types of tests. Alternately it is possible to estimate, choose among, or ignore a diversity of variables and immediately design what purports to be a statistically definitive field experiment. The first method may take much time, but the second may prove little except that one or more essential points of chemistry or of biology/ecology were unknown, ignored, or inaccurately assessed.

The full range of tree sizes and crown classes in the population of young sugar pines on the old cutover was included in the tests, except that severely suppressed trees and severely diseased trees were not treated. This range approximates one type of sugar pine population to which operational control of blister rust might well be applied if successful fungicidal methods can be developed. Sequence of treating pre-selected trees on the test area was largely determined by contiguity--a criterion distinctly not likely to produce the small variances needed in definitive tests. Small differences in effectiveness and tree damage after treatment are not considered significant, but large or general differences

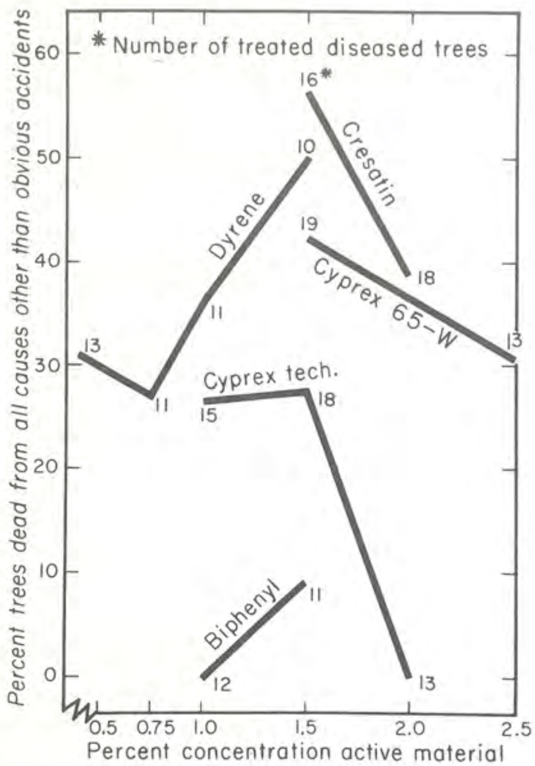

Figure 1.--*No consistent correlation is shown between concentration of applied conventional fungicides and percent of dead trees 5 years after treatment.*

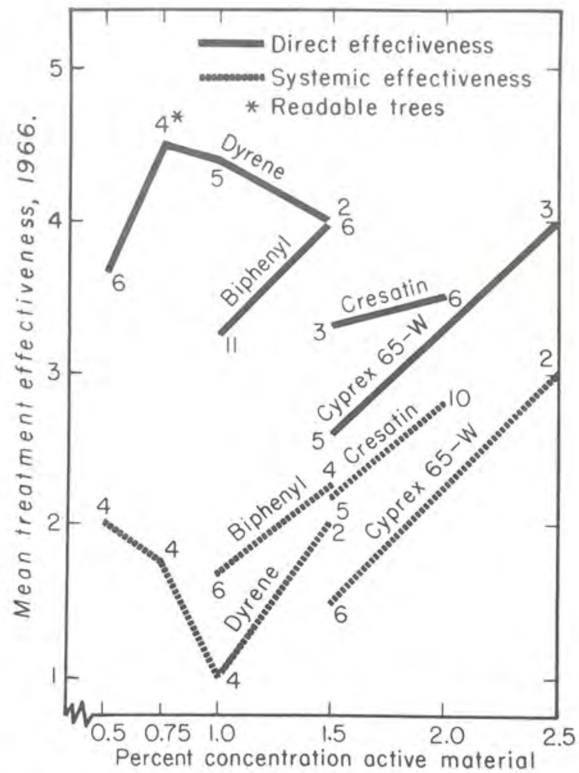

Figure 2.--*Effectiveness of blister rust control of promising conventional fungicides increased as applied concentrations were increased.*

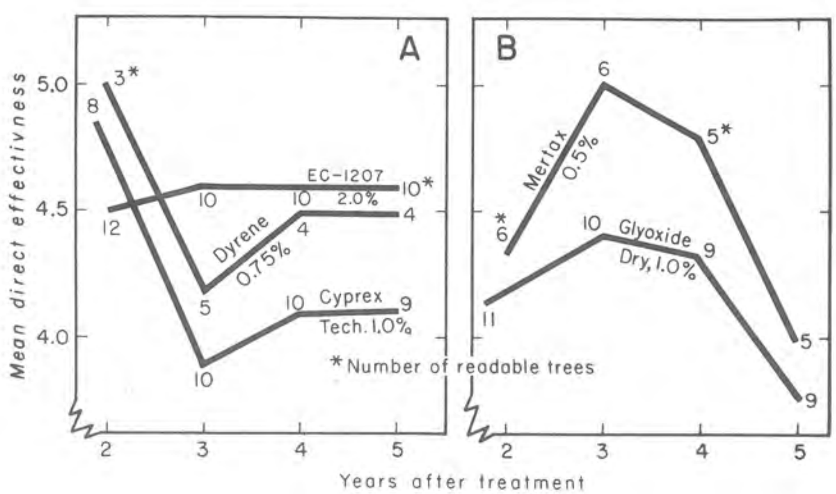

Figure 3.--*In single tests with conventional fungicides, results were mixed. Some materials showed promise of direct control* (A); *others appeared to be ineffective* (B).

are considered to be reliable bases for further experimentation.

Sizeable numbers of trees in the 23 tests died within 5 years of chemical treatment. This high mortality is explained in part by the inclusion in the tests of moderate numbers of small trees under the ecologic hazards to which young sugar pines commonly are exposed on old cutover in mixed-conifer forest. To this background of habitat pressures are added the effects of number and age of rust cankers, toxicities of fungicides, and possible damage from solvents and spray carriers. In general, the different types of hazards are additive and more or less cumulative. Comparable degrees of tree mortality have been encountered in previous work.[7]

Principal causes of treatment effectiveness, or the lack of such, also are hard to separate. Fungicides are of many chemical natures. It is unreasonable to expect that all trees of a species at any one time and place will react identically to treatment with a specific concentration of a fungicide. Significant differences in tree reaction are caused by tree vigor, tree size, bark type, and other genotypic and ecotypic variations.

A mean rating of 4.0 ("good") from a particular treatment probably could be improved if effectiveness could be maximized and tree damage minimized by making the best choice among the many factors involved in treatment and effect. But such a selection depends upon more knowledge of pertinent factors and their interrelations than is now available. For example, we know too little about the action and effects of solvents and carriers in treatment of blister rust. Sugar pine bark at a somewhat variable age becomes thick, hard, and scaly, and then appears much less permeable to chemicals. Does an applied fungicide then penetrate intact dense, corky bark, or does it penetrate only rust-damaged bark and then spread into the edges of cankers--where rust mycelium is most likely to persist? Do fungicides have greater over-all effectiveness, or could greater over-all effectiveness be developed, on "smooth-barked" trees than upon older "scaly-barked" trees?

Two or more general patterns can be drawn from the data on effectiveness of treatment. The "peaked" or "domed" configuration (fig. 3B) suggests fungistatic effects rather than fungicidal effects, and is obviously unpromising. Effectiveness of other fungicides (fig. 3A) apparently stabilizes at promising levels 2 to 4 years after application. Such a pattern holds much more promise. Chemical nature and concentration of applied fungicides presumably are the principal determinants of effectiveness pattern. But here again spray adjuvants and carriers--and possibly biologic/ecologic factors, such as crown class, type of bark, age and extent of infection--may well cause variations in pattern of results.

Possibilities for development of fungicidal control of blister rust in particular, and of conifer bark diseases in general, are far from exhausted. And experimentation should continue.

[7]See footnote 3.

The Author

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Table 1.--*Trees and fungicidal treatments in 17 tests started in 1961, Shasta County, California*

Fungicide material	Conc., percent active	Treated trees: Number	Mean ht., feet	Mean crown class[1]	Percent bole treated[2]
Biphenyl	1.0	13	14.9	3.2	28.2
Biphenyl	1.5	12	17.1	3.3	25.2
Cresatin	1.5	18	11.6	2.7	33.6
Cresatin	2.0	19	11.5	2.7	37.5
Cyprex 65-W	1.5	22	8.3	2.4	37.2
Cyprex 65-W	2.5	13	16.2	3.3	27.8
Cyprex, Tech.	1.0	15	14.2	3.0	29.7
Cyprex, Tech.	1.5	18	12.4	2.9	32.4
Cyprex, Tech.	2.0	13	16.0	3.5	24.8
Dowicide 1	2.5	18	15.4	3.0	24.9
Dyrene	.5	13	13.1	3.0	33.1
Dyrene	.75	11	13.9	3.1	34.2
Dyrene	1.0	11	14.9	3.2	29.4
Dyrene	1.5	11	12.8	3.0	30.7
Glyoxide Dry	1.0	14	17.4	3.3	22.0
Mertax	.5	15	14.2	2.9	32.6
E.C. #1207	2.0	15	17.8	3.4	20.8

[1]Crown class code: 5-Dominant; 4-Codominant; 3-Intermediate, 2-Suppressed; 1-Severely suppressed.

[2]Includes estimates for trees given 'Infection only' treatment.

Table 2.--*Trees in 20 tests found dead at annual inspections after treatment, by effectiveness ratings of the previous year's inspections, Shasta County, California*

Treatment effectiveness, previous year[1,2]	Trees found dead at inspection — Trees, by years after treatment: 1	2	3	4	5	Total dead trees, 2-5 years
	Number					*Percent*
0	[3]21	0	1	1	0	3.4
1	--	2	4	4	5	25.4
2	--	3	1	1	1	10.2
3	--	1	0	0	2	5.1
4	--	8	3	7	1	32.2
5	--	5	0	6	3	23.7

[1]Effectiveness code: 0-Not reliably readable; 1-No apparent effect; 2-Poor; 3-Fair; 4-Good effectiveness; 5-Excellent (infection apparently dead).

[2]Direct treatment effectiveness was used whenever available; otherwise systemic effectiveness if available.

[3]Died following treatment, but before first (1962) check of effectiveness. These 21 trees are not included in the percentages of last column.

Table 3.--*Mean direct and systemic effectiveness in single tests 5 years after treatment with selected fungicides, Shasta County, California*

Fungicide material	Conc., active	Trees treated 1961	Trees dead 1966	Treatment effectiveness, 1966: Direct — Trees read	Direct — Mean	Systemic — Trees read	Systemic — Mean
	Percent	*Number*	*Percent*				
E.C. #1207	2.0	14	14	10	4.6	3	2.7
Mertax	.5	11	9	5	4.0	5	2.6
Glyoxide Dry	1.0	14	21	9	3.8	2	2.0
Dowicide 1	2.5	17	12	11	3.5	8	2.5
E.F. #28720	1.5	21	38	6	3.5	8	2.1
Benzoic acid	1.5	16	38	7	2.7	5	3.2