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Experimental Fungicidal Control of Blister Rust on Sugar Pine in California

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ABSTRACT: Parallel series of exploratory experiments with antifungal antibiotics and conventional chemical fungicides for control of blister rust on sugar pine were started in northern California in 1959. Several fungicides, both antibiotic and conventional, appear slightly systemic, but all tested materials are more effective when sprayed directly on infected tissues. Conventional fungicides appear as effective as antibiotics for direct control of blister rust. Large differences in effectiveness appear due to concentration of fungicide and to season of application.

This paper reports on the progress of exploratory studies seeking to define an effective, safe chemical method for controlling blister rust (Cronartium ribicola Fischer) on sugar pine (Pinus lambertiana Dougl.) in California. Although certain results show some promise, no control program based on the findings of these exploratory experiments can be recommended at the present time.

Methods developed for controlling blister rust on individual white pine trees include excising cankers from infected trees, and treating infected trees with chemical fungicides. A canker excision method for eastern white pine (Pinus strobus L.) proposed by Martin and Gravatt[1] is applicable to high-value horticultural trees. But their technique is hardly feasible under forest conditions.

Other workers have investigated the use of antifungal antibiotics. Cycloheximide (Acti-dione, Upjohn),[2] isolated in 1946, was found to inhibit many plant pathogenic fungi in vitro. This material was first used on blister rust infections on sugar pine in 1952 in

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[1] Martin, J. F., and Gravatt, G. F. Saving white pines by removing blister rust cankers. U. S. Dept. Agr. Circ. 948, 22 pp., illus. 1954.

[2] Trade names are used in this report for convenience and precision. Such usage is not to be considered endorsement by the U. S. Forest Service of particular products or brands. Products of comparable chemical content, not specifically named, are not assumed to be inferior.

southern Oregon. Antifungal antibiotics, especially cycloheximide and later, phytoactin (Phytoactin, Pabst)--both presumed to move systemically in plants--were tested and recommended during the late 1950's for treating western white pines (Pinus monticola Dougl.) infected with blister rust. [3]

In 1959 the Pacific Southwest Station started a study to develop an effective and safe chemical method for controlling blister rust on sugar pine in California, or to rule out the immediate possibility of such direct chemical control. Numerous tests were started on the west slope of Hatchet Mountain, near Burney, Shasta County, in 1960, 1961, and 1962; along Cottonwood Creek, southwest of Humbug Valley and Lake Almanor, Plumas County, in 1959, 1961, and 1963; along upper Concow Creek near Flea Valley, north of Jarbo Gap, Butte County, in 1961, 1962, and 1963; and along Wildcat Creek, east of Pulga and the Feather River Canyon, Butte County, in 1959 and 1962. Since 1959, some 140 tests have been conducted on about 1,860 sugar pine trees.

Paralleling these studies have been an integrated and complementary series of pilot tests established by the Klamath National Forest staff. From the start of this twin program, parallel experiments have compared conventional chemical fungicides and antifungal antibiotics.

The fungicides tested were:

Fungicide	Source	Common chemical names
Acti-dione BR Aerosol	Upjohn	Cycloheximide
Acti-dione BR Concentrate	Upjohn	Cycloheximide
Biphenyl	Eastman Organic	Diphenyl; phenylbenzene
Cresatin	Eastman Organic	m-Cresyl acetate; m-Tolyl acetate
Cyprex 65-W	American Cyanamid	Dodine (n-dodecylguanidine acetate) as 65 percent wettable powder
Cyprex, Technical	American Cyanamid	Dodine as technical chemical
Dowicide 1	Dow Chemical	o-Phenylphenol
EC #1182	Union Carbide	4-Chloro-3, 5-dimethylphenoxyethanol
EC #1207	Union Carbide	Norcamphane methanol

[3] Moss, V. D., Viche, H. J., and Klomparens, W. Antibiotic treatment of western white pine infected with blister rust. Jour. Forestry 58:691-695. 1960.

Fungicide	Source	Common chemical names
Glyoxide 70-W	Corona Chemical	2-Heptadecyl-3-imidazoline as 70 percent wettable powder
Mertax	Eastman Organic	2-Mercaptobenzothiazole
Phytoactin L-340	Pabst Laboratories	Phytoactin
Phytoactin L-341	Pabst Laboratories	Phytoactin
Phytoactin L-342	Pabst Laboratories	Phytoactin
Quinolinol-Benzoic Acid	Laboratory (Eastman Organic)	8-Quinolinol and benzoic acid in molecular equivalent amounts
Terraclor 2#/E	Olin Mathieson	PCNB (pentachloronitrobenzene) in liquid formulation
Terraclor, Technical	Olin Mathieson	PCNB as technical chemical

METHODS AND MATERIALS

Application methods. --With few exceptions, all materials have been applied as coarse sprays from small pump-up garden sprayers equipped with simple disc nozzles with "M" (medium-sized) apertures. Treated parts and areas on trees were sprayed to the point of run and drip. Spray carrier most commonly used was stove oil, but sometimes was diesel oil or kerosene--rarely water. Treated trees have varied a great deal as to size, crown class, and vigor, and intensity and age of rust infection. Unless seriously suppressed or excessively diseased, most infected sapling and pole trees on selected test areas were treated.

Most 1959 and 1960 tests were applied as basal-stem treatments to determine systemic effects of materials--effects on unsprayed blister rust infection beyond limits of direct treatment. In the basal-stem treatment, all sides of the main stem of the treated tree were sprayed from ground level to a recorded height. Tests in 1961 were mixed direct and systemic treatments. Almost all tests in 1962 and 1963 were direct treatments of infection.

Recording results. --Insofar as rust infections and applied fungicidal treatments permit, each treated tree is read for treatment effectiveness on sprayed bole infection (SBI), unsprayed bole infection (USBI), sprayed limb infection (SLI), and unsprayed limb infection (USLI). For example, if a tree with a trunk canker at 4 feet and a limb canker at 9 feet off the ground is treated basal-stem to 6 feet, the tree can be read for SBI and USLI, but not for USBI or SLI. A more or less subjective effectiveness scale of five steps has been used to record results of treatments:

Result:	Treatment effectiveness Rating	Code
Infection apparently dead	Excellent	5
Infection looks dead, but may be only dormant	Good	4
Infection seriously affected, but obviously alive	Fair	3
Infection affected, but not seriously so	Poor	2
No apparent effect on infection	None	1

The average effectiveness rating is simply the arithmetic mean of effectiveness readings on one type of infection and treatment from the several trees of a test.

TEST RESULTS

It is difficult to tell by field inspection whether a treated blister rust canker is or is not dead. We decided on effect of treatment from ocular inspections. Sometimes we shaved off scaly bark and used hand lenses to check treated infections. But we have no positive way of telling just when a rust infection is actually dead.

1959 tests. --Most tests started in 1959 (August 11-14, and 18-19) were made with materials that proved inadequate, or with ineffective concentrations of promising materials. Except for some encouraging leads, these tests did little to define satisfactory control.

1960 tests. --In 1960 (August 11-18), parallel series of tests were started to compare effectiveness on blister rust of two formulations of cycloheximide, three formulations of phytoactin, and formulations of several conventional chemical fungicides. Table 1 summarizes average effects of these tests at Hatchet Mountain, Shasta County, California. All materials tested--except the five best conventional fungicides and Acti-dione BR Aerosol--killed more than 20 percent of treated trees. The manufacturer suggested using cyclohexanone as a carrier additive with the Acti-dione BR Concentrate. This combination would have been outstanding in the tests if tree damage had been less serious. Weir[4] reported similar percentages of dead trees after basal-stem treatment with Acti-dione of Douglas-fir infected with Rhabdocline needle cast.

1961 tests. --The most promising of the 1961 tests reached satisfactory control of blister rust. The July series (Hatchet Mountain) was reasonably effective (table 2), but the August series (Cottonwood Creek) and September series (Concow Creek) were largely inadequate--presumably because of host and disease phenology. Individual tests with nine conventional fungicides had mean effectiveness ratings better than

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[4]Weir, L. C. Control of needle-cast of Douglas-fir by antibiotics. Forestry Chron. 39:205-211. 1963.

Table 1. --Comparative effectiveness of fungicides applied to bole infections of blister rust on sugar pine, Hatchet Mountain, Shasta County, California[1]

Fungicide	Mean concentration	Tests	Trees treated	Trees dead 1963	Average effectiveness rating[2]		Treatment effectiveness rated "5" (excellent)[2]	
					Sprayed bole	Unsprayed bole	Sprayed bole	Unsprayed bole
	Percent	Number	Number	Percent	Mean	Mean	Percent	Percent
Acti-dione BR Concentrate	0.04	5	61	46	4.9	3.0	88	26
Acti-dione BR Aerosol	.03	2	10	20	4.0	2.0	0	0
Phytoactin L-340	.02	4	39	33	4.4	3.5	86	50
Phytoactin L-341	.04	4	38	39	3.8	[3] 5.0	31	[3] 100
Phytoactin L-342	.07	4	41	37	3.4	2.0	18	0
Best conventionals[4]	.90	5	56	20	4.3	2.2	27	0
Other conventionals	.75	6	73	36	3.2	2.5	0	0

[1]Fungicides applied August 11-18, 1960; checked June 17-18, 1963.

[2]Effectiveness code: 5 is excellent, 4 is good, 3 is fair, 2 is poor, and 1 indicates no apparent effectiveness.

[3]Applies only to four trees. There is some indication that phytoactin is more effective systemically than many other materials tested.

[4]One test each with Cresatin, Dowicide 1, Mertax, Quinolinol-Benzoic Acid, and Terraclor 2#/E.

Table 2. --Relative effectiveness of some fungicides in individual tests on blister rust on sugar pine, Hatchet Mountain, Shasta County, California[1]

Fungicide	Fungicide concentration	Trees treated	Trees dead 1963	Effectiveness of treatment on sprayed bole infection		
				Trees rated	Effectiveness rating[2]	Treatments rated "5" (excellent)[2]
	Percent	Number	Percent	Number	Mean	Percent
Cyprex, Technical[3]	1.0	15	13	8	4.8	75
Union Carbide EC #1182	2.0	13	23	6	4.5	50
Dowicide 1	2.5	18	6	9	4.4	44
Union Carbide EC #1207	2.0	15	7	12	4.3	67
Cresatin	2.0	19	16	6	4.3	33
Glyoxide 70-W	1.0	14	7	10	4.3	30
Cyprex 65-W	2.5	13	8	4	4.3	50
Biphenyl, Technical	1.0	13	0	9	4.2	22
Mertax	.5	15	0	5	4.2	20
Terraclor, Technical	1.5	12	42	6	3.7	0

[1]Fungicides applied July 12-20, 1961; checked June 14-15, 1963.

[2]Effectiveness code: 5 is excellent, 4 is good, 3 is fair, 2 is poor, and 1 indicates no apparent effectiveness.

[3]Cyprex, Technical was difficult to dissolve in common solvents. Effectiveness of this test may be due in part to solvents used.

4.0 (good) in 1963. Dowicide 1 at 2.5 percent in stove oil apparently killed only 6 percent of treated trees, had a mean effectiveness of 4.4; and 44 percent of sprayed bole infections were rated "5" (excellent apparent control). Union Carbide EC #1182 at 2.0 percent in stove oil and Cyprex, Technical, at 1.0 percent in laboratory solvents and stove oil appeared slightly more effective.

1962 tests. --Results from 1962 tests are strictly tentative. But some previously untested materials appeared to have fair effectiveness against blister rust on sugar pine in 1963, notably (a) Acti-dione BR New Formulation, (b) benzoic acid plus isopropanol, (c) cyclohexanone, (d) Phytoactin L-440, and (e) thymol.

1963 tests. --1963 tests also consisted largely of additional experiments with the more promising materials, concentrations, and carriers of previous series. As the two sets of 1963 tests mature, some of the uncertainties of present analyses of data should be reduced.

CONCLUSIONS

1. To date several tested materials have shown some systemic effectiveness. But all applied materials have been more effective when sprayed directly on infected areas. Fungicidally effective amounts of most materials apparently do not move within the sugar pine tree.

2. The most important controllable variables for any one material appeared to be (a) date of application (seasonal phenology of host and disease); (b) concentration of active ingredient; and (c) choice of field diluent and carrier additive. Results from comparable tests show that effectiveness of treatment and tree damage both drop drastically with advance of season (table 3). These changes are presumed to be due largely to phenologic changes in the tree host, but probably are conditioned also by a changing physiologic state of the disease. In many cases, only a small margin of safety exists between elimination of disease and damage to tree host by fungicide treatment.

3. Concentration of active ingredient in general had a moderate effect on mean effectiveness rating, but a marked effect on percent of treated trees rated "5" (excellent apparent effectiveness of control) (table 4). In the five pairs of tests, one test of each pair was applied with a more concentrated solution of fungicide than the other.

4. Little or no difference in effectiveness of the three materials commonly used as carriers was discernible in the data. Principal field diluents and spray carriers have been Pearl Oil (water-clear kerosene), stove oil (PS-100), and diesel oil (truck fuel). Diesel oil may have been slightly more effective as a carrier and also slightly more damaging to the trees. In general, stove oil is the preferred carrier. It is a satisfactory solvent and spray carrier for most materials, and during hot weather is less hazardous to the operator than diesel oil.

Table 3. --Influence of season on effectiveness of some fungicides applied to blister rust on sugar pine, north central California

Fungicide	Fungicide concentration	When applied (1961)	Trees treated	Trees dead 1963	Effectiveness of treatment on sprayed bole infection in 1963		
					Trees rated	Effectiveness rating[1]	Treatments rated "5" (excellent)[1]
	Percent	Date	Number	Percent	Number	Mean	Percent
Union Carbide EC #1182	2.0	7/14	12	25	6	4.5	50
Union Carbide EC #1182	2.5	8/18	21	10	4	2.0	25
Mertax	2.0	7/14	11	0	5	4.2	20
Mertax	2.0	9/21	19	0	11	1.3	0
Terraclor 2#/E	1.5	7/14	12	42	6	3.7	0
Terraclor 2#/E	3.0	8/21	22	5	2	1.0	0
Dowicide 1[2]	2.5	7/18	17	6	5	2.4	0
Dowicide 1[2]	2.0	8/23	19	0	8	1.0	0
Early season	2.0	7/15	52	17	21	3.8	19
Late season	2.4	8/29	81	4	25	1.6	4

[1]Effectiveness code: 5 is excellent, 4 is good, 3 is fair, 2 is poor, and 1 indicates no apparent effectiveness.

[2]Data for Dowicide 1 pertain to sprayed limb infection; all other tests to sprayed bole infection.

Table 4. --Influence of concentration on effectiveness of some fungicides applied to blister rust on sugar pine, north central California

Fungicide	Fungicide concentration	When applied	Trees treated	Trees dead 1963	Effectiveness of treatment on sprayed bole infection in 1963		
					Trees rated	Effectiveness rating[1]	Treatments rated "5" (excellent)[1]
	Percent	Date	Number	Percent	Number	Mean	Percent
Cresatin	1.5	7/18	16	6	3	4.3	33
Cresatin	2.0	7/18	18	11	6	4.3	33
Cyprex 65-W	1.5	7/19	20	15	7	1.3	0
Cyprex 65-W	2.5	7/20	13	8	4	4.3	50
Terraclor 2#/E	2.5	8/18 [2]	7	0	7	2.1	0
Terraclor 2#/E	5.0	8/21	13 [3]	0	13	2.9	8
Cresatin	2.5	8/18 [2]	5	0	4	2.3	0
Cresatin	5.0	8/21	15 [3]	0	15	2.6	0
Union Carbide EC #1182	1.5	9/22	9	0	2	1.0	0
Union Carbide EC #1182	2.5	8/18	21	10	4	2.0	25
Lower concentrations	1.9	8/13	59	6.8	23	2.1	4
Higher concentrations	3.4	8/8	80	6.3	42	3.0	14

[1] Effectiveness code: 5 is excellent, 4 is good, 3 is fair, 2 is poor, and 1 indicates no apparent effectiveness.

[2] Tests applied in 1962; all other tests applied in 1961.

[3] Field diluent was diesel oil; all other tests were in stoveoil carrier.

5. Based on results to date, we have considerable hope that a moderately successful direct chemical control of blister rust in California can be developed.

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