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Chemical Control of Blister Rust on Sugar Pine . . .

two fungicides show promise in California tests

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ABSTRACT: Among several fungicides tested, Phytoactin L-340 and Dowicide 1 (o-phenylphenol) showed the most promise for systemic chemical control of blister rust on sugar pine in northern California. The trials included 22 tests on 224 sugar pines: five with Acti-dione BR (cycloheximide), one each with five common chemical fungicides, and 12 with phytoactin. Apparent effectiveness of the antibiotics rose to marked maximums 2 to 3 years after application, then declined.

RETRIEVAL TERMS: Antifungal antibiotics; blister rust control; *Cronartium ribicola*; cycloheximide; fungicide control; fungicide screening; phytoactin; *Pinus lambertiana*; sugar pine.

OXFORD: 443--414.1:172.8 *Cronartium ribicola*: 174.7 *Pinus lambertiana*: (794)

Since 1959, the Pacific Southwest Station has held field tests designed to find safe, effective chemical methods of controlling blister rust (*Cronartium ribicola* Fischer) on sugar pine (*Pinus lambertiana* Dougl.) in California. The experimental approach has largely been that of screening selected fungicides for promise of becoming an effective field control. Preliminary results have previously been reported.[1]

During the week of August 11, 1960, we started 32 tests on 354 trees in northern California. Treatments were checked annually, 1961-65.[2] We tried to determine if cycloheximide and phytoactin showed promise of developing into an effective control method. We also compared selected conventional fungicides with antibiotics in parallel tests.

On the basis of results from 22 tests on 224 sugar pines, it appears that Phytoactin L-340 and selected conventional fungicides offer the greatest promise for chemical control of blister rust on sugar pine.

Preliminary results with cycloheximide on sugar pine in tests that H. R. Offord and I started in 1952 raised doubts that this antibiotic could be developed into successful control for blister rust. Methods for treating this fungus on western white pine (*P. monticola* Don.) with cycloheximide and phytoactin were developed in northern Idaho and adjacent areas in the late 1950's.[3]

In the current tests, one formulation of cycloheximide (Acti-dione BR Concentrate[4]) and three formulations of phytoactin (Phytoactin L-340, L-341, and L-342) were tested by applying a series of four or five concentrations to blister rust infection on sugar pine. One or two tests each with 10 conventional fungicides also were started.

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[1] Quick, Clarence R. *Experimental fungicidal control of blister rust on sugar pine in California.* U.S. Forest Serv. Res. Note PSW-48. Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 10 pp. 1964.

[2] 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, 1962-66.

[3] Viche, Henry J., Moss, V.D., and Hartman, H.J. *Developments in aerial application of antibiotics to control blister rust on western white pine.* J. Forestry 60:782-784. 1962.

[4] Trade names and commercial products and 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.

For the purposes of this report, conventional fungicides are defined as customary, long-used or experimental, antifungal chemicals other than antibiotics.

METHODS

Study plots were set up on land owned by the Scott Lumber Company, near Burney, California.[5] This area lies on the westerly slope of Hatchet Mountain on a moderate easterly subslope at altitudes of 3,900 to 4,300 feet. Site quality varies between I (high) and III (medium). Second-growth on the old cutover is moderately dense.

Tuberculina maxima Rost., a fungus hyperparasite of blister rust, was variably common to abundant over the area during the test period, and it caused some uncertainties in assessing effectiveness of fungidical treatments.

About 80 percent of trees treated in 1960 were given the basal-stem treatment--in which all sides of treated tree trunks are sprayed from ground level to a recorded height. The remaining trees were given the bole-band treatment--in which all sides of the trunks are sprayed between two recorded heights. Length of treated bole in both cases averaged about one-third of tree height. Each test was made with a given volume--2 liters--of spray solution. Number of trees per test, therefore, tended to vary inversely with mean size of trees.

The test chemicals consisted of the following:[6]

A-D. Acti-dione BR Concentrate. Cycloheximide, in a 4 percent proprietary liquid formulation miscible with most fuel oils, was applied at 200,300,400,500, and 600 p.p.m. in stove oil. Cyclohexanone, tech. was added as cosolvent to the stove oil carrier at the rate of 3.9 ml. per liter per 100 p.p.m. Acti-dione. At 200 p.p.m. conc. this rate (7.8 ml./1) equals 1 fluid ounce per gallon.

CONV. Five selected conventional fungicides, often carried to the field in laboratory-prepared stock solutions, were applied in stove oil carrier. Concentration of applied active fungicide was 1 percent, except that mercaptobenzothiazole was applied in 0.5 percent solution.

CRES. Cresatin. m-cresyl acetate. m-tolyl acetate. A liquid chemical miscible with fuel oils.

DOW. Dowicide 1. o-phenylphenol, tech. Stock solution in isopropanol. Also soluble in fuel oils.

MBT. Mertax. Thiotax. 2-mercaptobenzothiazole, tech. Solvents in the stock solution were isopropanol (45 percent) and petroleum aromatics (12 percent of final field solution).

PCNB. Terraclor. Pentachloronitrobenzene, tech., in a proprietary liquid formulation miscible with fuel oils.

Q-BA. 8-Quinolinol (8-hydroxyquinoline) and benzoic acid in equimolar amounts. Stock solution in isopropanol.

PHYTO. Phytoactin. Three proprietary formulations were tested. All were dilute solutions of one antibiotic material--phytoactin --in isopropanol, and all were miscible with fuel-oil carriers. Some spray solutions at the higher applied concentrations of phytoactin contained more isopropanol than fuel oil. In such cases, agricultural spray oil often was added to the

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

[6]Companies that furnished samples of test chemicals were the Chevron Chemical Co., Dow Chemical Co., Olin Mathieson Chemical Corp., P-L Biochemicals Inc., Union Carbide Chemicals Co., and Upjohn Co.

Table 1.--*Fungicides tested, and characteristics of sugar pines treated, Shasta County, California, 1960*

Fungicide	Mean concentration	Tests	Trees	Description of treated trees, 1960 means				Length of lower bole	
				Height	D.b.h.	Crown[1] class	Vegetative[2] vigor	Pruned[3]	Sprayed
	Percent	*No.*	*No.*	*Feet*	*Inches*			*Feet*	*Feet*
Acti-Dione BR	0.04	5	58	14.5	2.9	1.6	1.5	6.3	4.8
Conventionals	.90	5	56	14.1	3.1	2.0	1.9	5.8	4.7
Phytoactin L-340	.07	4	34	15.8	3.9	2.0	1.6	7.0	5.3
Phytoactin L-341	.04	4	36	15.6	3.3	1.9	1.7	6.6	5.5
Phytoactin L-342	.07	4	40	12.6	2.6	2.7	2.4	5.0	4.9
Totals and means	--	22	224	14.4	3.1	2.0	1.8	6.1	4.9

[1]Crown class: 5 (dominant); 4 (codominant); 3 (intermediate); 2(suppressed); 1 (severely suppressed).

[2]Vegetative vigor (visual estimate): 5 (excellent); 4 (good); 3 (fair); 2 (poor); 1 (very poor).

[3]Includes bole naturally devoid of live limbs.

alcoholic solutions to slow evaporation from the trees after application. Applied concentrations of the Phytoactin formulation were: L-340 at 100, 200 (with and without 10 percent spray-oil emulsion), and 300 p.p.m.; L-341 at 200, 400 (with and without 10 percent spray-oil), and 600 p.p.m.; L-342 at 400, 600, 800, and 1,000 p.p.m.

Trees within each test varied considerably in characteristics (table 1). The low average crown class indicated that treated trees were older than heights suggested. Tree age rather than size commonly determines corkiness and scaliness of trunk bark in sugar pine, and mature corky bark presumably reduces speed and degree of penetration of spray solutions.

Apparent control of blister rust after treatment was recorded on a five-point scale:

5: Excellent--infection is apparently dead.
4: Good--infection looks dead, but control is doubtful.
3: Fair--infection seriously affected, but obviously alive.
2: Poor--infection affected, but not seriously so.
1: None--no apparent effect on infection.

Effectiveness readings were subjective; all were made by me. Mean effectiveness is the arithmetic average of the 5-point scale readings for one type of treatment from trees of a test, or a group of tests. Only trunk infections are considered in this report.

RESULTS

TREE MORTALITY

The term "readable trees" refers to number of live trees in a test or a group of tests in which direct or systemic effectiveness can be read with reasonable certainty at time of inspection. Mortality is death of trees due to all causes after treatment, except for obvious accidents, and commonly includes severely damaged trees as well as dead trees. In well stocked regeneration on old cutover, severely damaged trees seldom survive. Diseased trees, concurrently subjected to the usual ecologic hazards of mixed-conifer cutover forest, are easily killed. There are many aspects of cause-effect relations in damage to trees due to combinations of ecologic pressures, blister rust infections, and treatment with chemicals.

Acti-dione BR and the three formulations of phytoactin were each applied in a four- or five-test series of concentrations. The planned method of comparison among concentrations of a series was by regression analysis, and among materials by comparison of regression characteristics. Unexpectedly high tree mortality caused difficulties with this type of analysis, and the data are presented in tables and simple line graphs.

Our experience with sugar pine mortality is similar to that of Weir[7] with basal-stem treatment of Douglas-fir with Acti-dione. If damage to treated trees had been more accurately forecast, number of trees per test would have been increased.

The three phytoactin formulations showed comparable degrees of tree mortality (fig. 1). Tree damage and mortality from treatment with cycloheximide was more and treatment with conventional fungicides considerably less than damage resulting from phytoactin. Although individual tests within each group of figure 1 varied considerably, we believe the graphs accurately reflect damaging effects of the three types of materials on the treated trees.

Data reported on treatment effectiveness are based on ratings from annual inspections of all trees that could be reliably classified. Many trees died within 5 years after treatment. We considered the possibility that tree mortality was closely correlated with treatment effectiveness. If effectively treated trees were always damaged or killed, nothing would be gained because no undamaged cured trees would result. Table 2 was compiled to estimate the degree of correlation between tree damage and treatment effectiveness. In the 22 summarized tests, 40 trees died before the first annual inspection and 66 trees died in the 4 years between the first annual inspection and the fifth. After first annual inspection, tree mortality occurred most often in the previous year's high-effectiveness classes, but was by no means restricted to them.

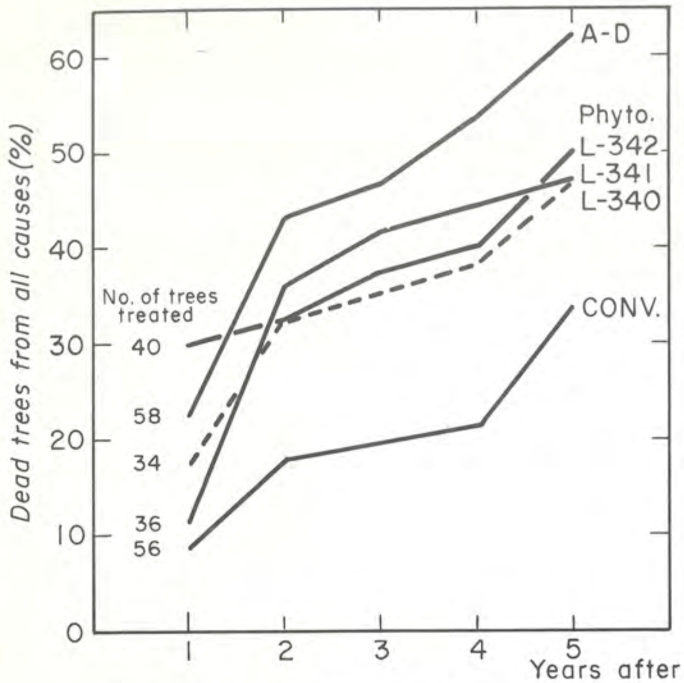
The complex array of ecological factors that adversely affects sugar pine regeneration on old cutover in mixed-conifer forests, plus the weakening effects of blister rust infection, are believed largely responsible for mortality of treated trees. But chemical damage from fungicides and spray carriers presumably accentuated the harmful effects.

Individual tests with the five conventional fungicides showed considerable variation in tree mortality (fig.2).

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

Table 2.--*Treated trees found dead at annual inspections, 1962-1965, segregated by treatment-effectiveness ratings for the inspection previous to tree death*

Fungicidal material	Number: Tests	Number: Treated trees	Trees found dead 1961	Trees found dead, 1962-1965, tabulated by effectiveness rating of previous year: 1	2	3	4	5	Total
			Number						
Acti-dione BR	5	59	16	2	5	4	6	3	20
Conventionals	5	55	5	3	1	3	3	4	14
Phytoactin L-340	4	34	6	2	0	1	5	2	10
Phytoactin L-341	4	35	3	0	2	2	6	3	13
Phytoactin L-342	4	40	10	2	1	2	1	3	9
Totals	22	223	40	9	9	12	21	15	66
Percent trees found dead, 1962-1965	--	--	--	13.6	13.6	18.2	31.8	22.7	100



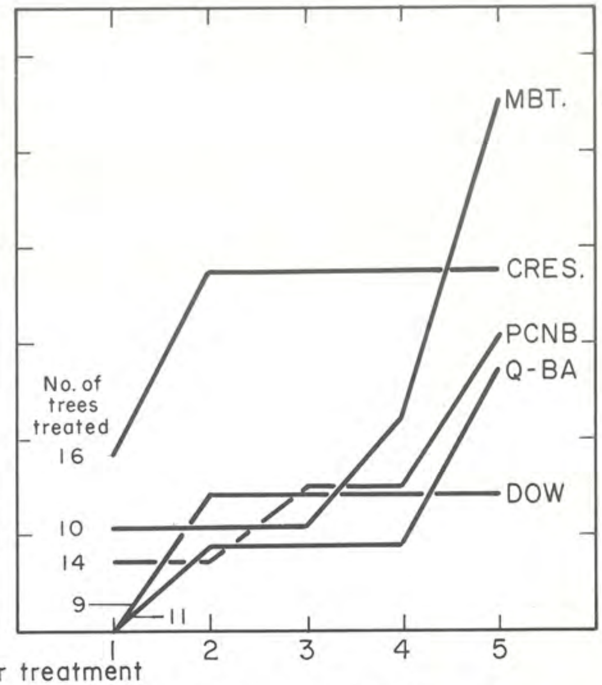
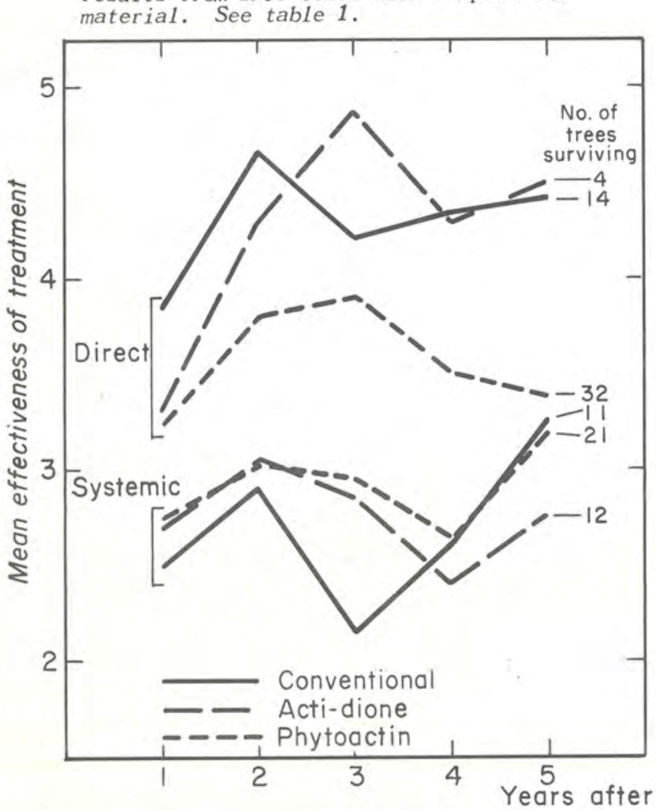


Figure 1.--*Percent dead sugar pines from all causes following fungicidal treatment for control of blister rust. Each graph averages results from 1960 tests with a specified material. See table 1.*

Figure 2.--*Tree mortality after treatment of sugar pines with conventional fungicides.*



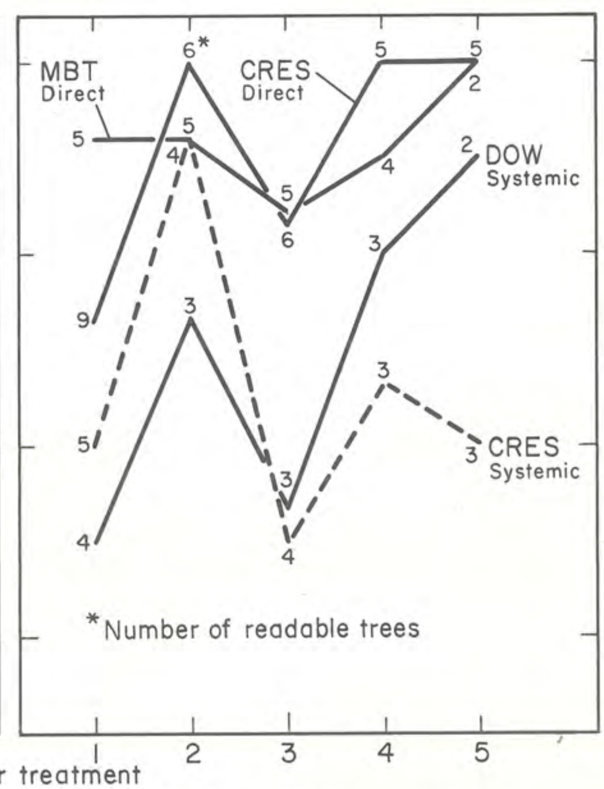


Figure 3.--*Mean effectiveness of direct and systemic treatments of blister rust on sugar pines with a group of five conventional fungicides and with two antifungal antibiotics (Acti-dione and Phytoactin).*

Figure 4.--*Mean effectiveness of treatment with selected conventional fungicides. Each line represents a single test.*

In addition to stove oil, spray carriers for Mertax, Cresatin, and quinolinol-benzoic acid contained 20 percent by volume of a petroleum fraction with an aromatic content of about 60 percent. The final content of petroleum aromatics thus was about 12 percent. All mortality from the two simple phenolic compounds (Dowicide 1, Cresatin) occurred within 2 years of treatment. We presumed that increase of slope in graphs with time indicates continuing damage from chemical treatment.

Four undiseased sugar pines were treated with antibiotics--two with Acti-dione BR (300 and 400 p.p.m.) and two with Phytoactin L-341 (400 and 600 p.p.m.). They all survived unharmed.

Twelve diseased sugar pines were treated with 600 p.p.m. Acti-dione BR--a severe chemical treatment. Average values for trunk diameter, tree height, and tree vigor, derived from the tree description data collected in 1960 at test initiation, were progressively higher for the trees that survived in 1961 (10 trees), 1963 (6 trees), and 1965 (3 trees). Tree mortality probably would have been much less if all treatments had been restricted to dominant and codominant trees, but too few of such vigorous, ecologically favored trees to meet our test needs grew on available areas.

TREATMENT EFFECTIVENESS

We compared average direct and systemic effectiveness readings from three main groups of tests: (a) five conventional fungicides, (b) five concentrations of Acti-dione BR, and (c) four tests each with three formulations of phytoactin (fig. 3). Direct effectiveness concerns trunk infections actually sprayed. Systemic effectiveness concerns unsprayed trunk infections on treated trees, without consideration of how far the infection was from sprayed parts of the bark. Therefore, we presumed that systemic effects were the result of translocation of material within the tree.

Both antibiotics show markedly domed or peaked graph lines between 1961 and 1964 (fig. 3). Their apparent direct effectiveness reached a peak in 1963--3 years after treatment. And their apparent systemic effects were highest in 1962. Mean effectiveness of conventional fungicides shows trends that resemble those of the antibiotics except for a strong but unexplained downward trend in 1962-1963. Apparent direct effectiveness below 4.00 to 4.25, and systemic effect below 3.00 to 3.25 are considered too low to be promising.

Encouraging results were obtained from tests with individual conventional fungicides (figs. 2,4). Readable trees at times of inspection are indicated on graphs by small numerals close to plot points. Reduction of these numbers with time is due to tree mortality and sometimes to other causes.

Apparently agricultural spray oil and spray-oil emulsion should not have been added to the alcoholic phytoactin formulations (table 3). Two out of three direct treatments, and all three systemic treatments, were more effective without spray-oil additions.

Contents of the three proprietary phytoactin formulations, except for concentration of the antibiotic, were not specified. Phytoactin L-342, applied at the high concentrations of 400, 600, 800, and 1,000 p.p.m., resulted in excessive tree mortality in three out of four tests. There were wide differences in effectiveness of treatment between Phytoactin L-340 and L-341 (fig. 5). Results from L-340 were most promising. I believe that phytoactin should be retested on dominant and codominant sugar pines in a series of concentrations and carriers. If further tests with this antibiotic are made, Phytoactin L-340--the precise formulation furnished by the manufacturer for our 1960 tests--should be included for comparison.

Possibilities in the successful use of conventional fungicides for control of blister rust are far from exhausted. Additional tests are in progress.

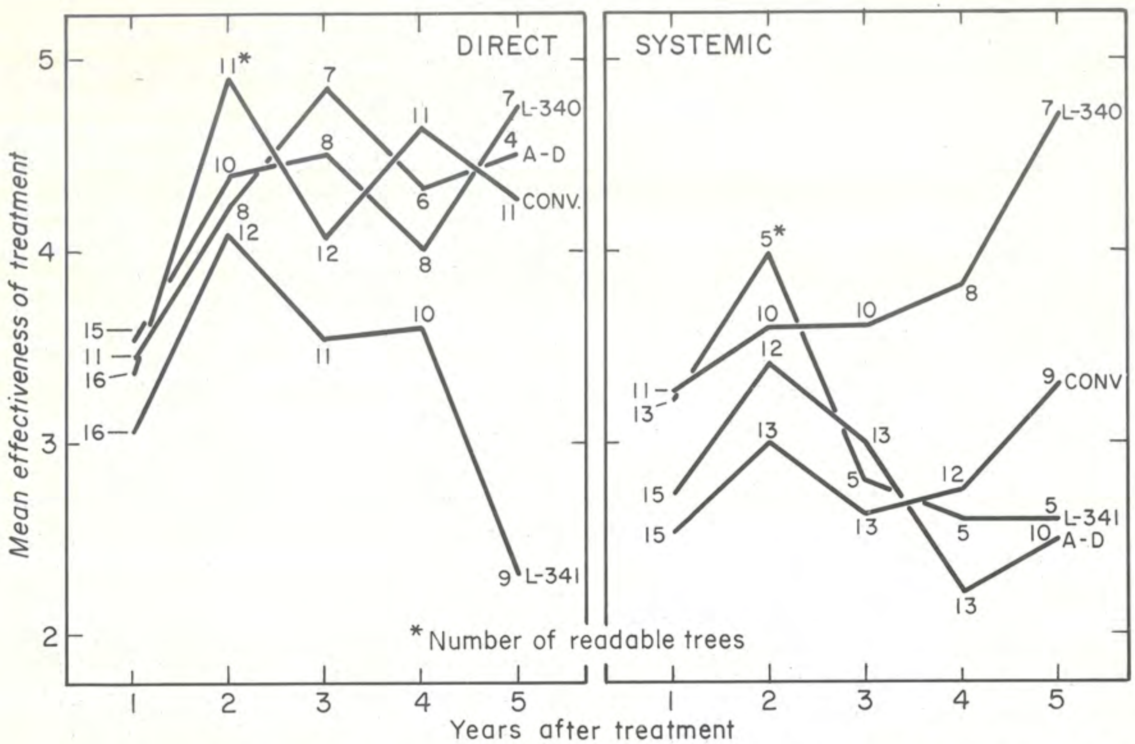


Figure 5.--*Mean effectiveness of direct and systemic treatment with antibiotic and conventional fungicides. Each line averages three selected tests.*

Table 3.--*Apparent effect of spray carrier on mean effectiveness of treatment with phytoactin*

Phytoactin		Test batch contents, percent v/v			Tree mortal-ity	Mean test effectiveness	
Formu-lation	Concen-tration p.p.m.	Formu-lation[1]	Stove oil	Spray oil	1965	SBI[2]	USBI[2]
					Percent		
L-340	200	42.3	47.7	[3]10.0	71	4.54	1.33
L-340	200	42.3	57.7	([4])	36	3.75	3.62
L-341	400	58.1	31.9	[5]10.0	60	2.96	2.86
L-341	400	58.1	[6]41.9	([4])	50	4.11	4.33
L-342	800	79.7	([4])	[7]20.3	33	2.86	1.55
L-342	1,000	99.5	.5	([4])	83	4.63	4.33

[1]Reported to be largely isopropanol.
[2]Sprayed bole infection, and unsprayed bole infection.
[3]Orthol-K Flowable Medium.
[4]None.
[5]Volck Supreme Oil Spray.
[6]Diesel oil (truck fuel) in this one test.
[7]Orthol-K Ready-Mix Light Medium.

Two tests with Acti-dione BR aerosol gave results similar to those in tests with Acti-dione BR concentrate. Two tests with a combination of benzoic acid and 2,4-dichlorophenoxy-acetic acid killed almost all treated trees.

DISCUSSION

Fuel-oil spray carriers may have contributed directly or indirectly to the mortality of pruned treated trees. Petroleum oils, especially "asphaltic-base" oils, contain a variety of aromatics (benzene-ring chemicals). Aromatic petroleum hydrocarbons and their oxidation and substitution products are well known as solvents. And some are strongly phytotoxic and fungitoxic as well. Sugar pines are surprisingly tolerant of fuel oils. Prudent choice of petroleum oils for solvents and spray carriers in therapeutic treatment of conifers may both minimize tree damage and add significantly to effectiveness of fungicidal treatment. The function and choice of fuel-oil carriers should be further explored.

In the over-all comparisons of fungicide groups (fig. 3), no obvious advantage resulted from use of antifungal antibiotics, when compared with the five selected conventional fungicides, for either direct or systemic control of blister rust on sugar pine. In this figure the rise of apparent effectiveness maximums 2 to 3 years after treatment and the subsequent decline suggest fungistatic inactivation of blister rust infection rather than fungicidal elimination.

Moderate differences in treatment effectiveness appeared among tests in the conventional fungicides group, among formulations in the phytoactin group, and among concentrations in the Acti-dione BR group. Five years after some tests were started, there were inadequate data for analysis, mainly because of excessive tree mortality.

A more useful comparison of relative effectiveness of specific materials might be shown by effectiveness means from those three tests of each type of material that contained most surviving trees in 1965 (fig. 5). Phytoactin L-340 showed much greater effectiveness, both direct and systemic, than Phytoactin L-341; in fact, Phytoactin L-340 was the most promising material. The three tests included in the direct-effect graph for L-340 are 100 p.p.m. and 200 p.p.m. in stove oil only, and 200 p.p.m. in stove oil plus 10 percent agricultural spray-oil emulsion. The three tests included in the systemic-effect graph for L-340 are 100 and 200 p.p.m. in stove oil only, and 300 p.p.m. in diesel oil only.

The three conventional fungicides as a group showed more promise of systemic control of blister rust than either Acti-dione BR or Phytoactin L-341. The three conventionals were (a) Cresatin at 1.0 percent, in stove oil plus 12 percent petroleum aromatics, (b) Dowicide 1 at 1.0 percent, in stove oil plus 8.5 percent isopropanol, and (c) quinolinol-benzoic acid at 1.0 percent (computed as the ester), in stove oil plus 30 percent isopropanol and 12 percent petroleum aromatics.

The Author

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