TESTS TO CONTROL FUSARIUM ROOT ROT OF PONDEROSA PINE IN THE PACIFIC NORTHWEST

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Fusarium root rot of ponderosa and other species of pine has been a serious problem in at least two forest nurseries in the interior of Oregon and California. Most recent losses have occurred in the Forest Service Nursery near Bend, Oreg., which produces ponderosa pine. Typically, the disease kills 1- to 3-month-old seedlings by girdling the taproot at the ground line or just below the root crown. The diseased seedlings eventually turn brown and wither, as though killed by drought.

The nursery at Bend is in a basin of lava rock and has a fine sandy loam soil 12 to 18 inches deep with pH from 6.7 to 7.2. Soil temperatures at 2 inches frequently reached 100^0 F. in July and August. The first sowings in 1948 showed losses from root rot by mid-July. Isolations made at that time from diseased 1-0 stock yielded primarily a species of Fusarium. This report covers many series of tests in seedbed and greenhouse made in ensuing years to determine the best method of control.

Parallel tests in greenhouse were run to determine the pathogenicity of the Fusarium and the effect of soil temperatures on virulence of the parasite.

Identify of Isolated Organisms

Fungi associated with root rot were isolated from surface-sterilized sections of diseased roots or stems of seedlings placed in malt agar in vitro. Of several hundred 'isolations attempted, 60 percent yielded a Fusarium. Snyder [2] identified the fungus as Fusarium oxysporum f. p . Occasionally Ramularia spp., Pythium ultimum, and Rhizoctonia solani also were isolated in pure culture. Common contaminates were Penicillium spp., Mucor, and Trichoderma lignorum.

Description of Tests

From 1950 to 1955, a series of seedbed treatments was made in plots 4 feet wide by 4 and 10 feet long. These plots were arranged in Latin squares, five seedbeds wide, with five replications for each randomized treatment. As elsewhere in the nursery, watering was by overhead sprinklers.

Numerous control treatments were tried; these included soil fumigation, soil acidification, and application of fertilizers and various organic matter including forest duff and pine sawdust. The effects of various rotation crops were tested. Soil antibiotics also were tried.

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[2] Identification by courtesy of Dr. William C. Snyder. Vice Chairman, Department of Plant Pathology, University of California, Berkeley, Calif.

Laboratory Tests

Fusarium oxysporum f. pini was grown in liquid buffer media at 22° C. to test the effect of pH on growth. Two isolates were used in this test. At the end of 1 month, growth was determined on a dry weight basis.

In these tests Fusarium oxysporum f. pini made best growth by weight at pH 6.0 to 6.4. Whether optimum pH corresponds to virulence was not determined.

On malt agar, adjusted to the optimum pH, Fusarium oxysporum f. ini grew best at 22° C. (71° F.), but grew almost as well at 30° C. (86° F.). The relationship of soil temperature to virulence was later tested in the greenhouse.

In laboratory tests in vitro, Trichoderma lignorum (Tode) Harz. did not noticeably restrict the growth of Fusarium oxysporum f. pini.

Greenhouse Tests

Wisconsin-type tanks were used for soil-temperature tests. Seedlings grown in three replicated containers indicated that Fusarium oxysporum f. pini was most virulent when soil temperatures were about 80° F. and higher.

Temperature (°F.)	Seedlings examined	Seedlings infected
	number	*percent*[1]
62	55	9
78	47	28
92	46	33

[1] Based on number of seedlings examined.

Additional tests of nursery soil were made after 100, 200, and 400 cubic yards to an acre of fresh pine sawdust had been disked in. Soil with 100 cubic yards of pumice and peat to an acre was tested concurrently. Analysis of variance of the results of these tests showed that for total germination, mortality, and final stands, the application of 100 cubic yards of sawdust to an acre gave significantly superior results at the 5 percent level (table 1). Higher applications of sawdust stunted the seedlings.

TABLE 1.--Emergence, mortality, and final stand of ponderosa pine after 10 weeks in a greenhouse test

Special treatment		Average results		
Additive	Rate[1]	Emergence	Dead	Final stand
		Number[2]	*Percent*[3]	*Percent*[3]
None.............	--	13.2	7	93
Peat moss........	100	23.9	9	91
Pumice...........	100	26.1	28	72
Sawdust..........	100	30.2	6	94
Do...........	200	32.0	9	91
Do...........	400	31.3	6	94
Water............	Doubled	22.6	[4] 14	86

[1] Rate for organic materials and pumice was in cubic yards to an acre.
[2] Average for a pot.
[3] Based on number of emerged seedlings.
[4] Mostly damping-off.

Another series of greenhouse tests was made to determine the potential for infection of treated and untreated soil. Soils taken from three locations were tested in a series of three pot replications. Identification of the isolates from diseased seedlings by percentages showed, that Fusarium oxysporum f. pini predominated throughout (table 2).

The percentage of Fusarium isolated from infected seedlings decreased with soil cultivation and especially in soil with pine sawdust. Rhizoctonia and Pythium, however, showed some increase in cultivated and sawdust-amended soil. There was also a noticeable increase in the percentage of Trichoderma and Penicillium in cultivated and sawdustamended soil. Increase of the latter two molds may contribute to the decline in virulence of Fusarium (1).

Greenhouse tests indicated that Captan 75 percent applied as a seed coating may be an effective fungicide for reducing early damping-off of ponderosa pine. This was later confirmed in nursery applications.

TABLE 2.--Percentage of isolations by soil treatment in greenhouse tests

Isolates[1]	Wild land (pH 6.3)	Cultivated (pH 6.5)	Sawdust[2] added (pH 5.8)
	Percent	*Percent*	*Percent*
Alternaria	6.3	7.1	2.2
Fusarium	62.2	54.8	41.4
Mucor	7.9	6.9	4.8
Penicillium	8.6	8.2	10.9
Pythium	1.5	7.6	13.9
Rizoctonia	7.8	3.8	10.2
Trichoderma	5.6	3.6	14.1
Others	.1	8.0	2.6

[1] Isolations numbered 74 from sagebrush wild land, 222 from cultivated soil, and 97 from sawdusted soil.
[2] Sawdust at 100 cubic yards per acre, plus ammonium phosphate and aluminum sulfate.

Nursery Tests

Among the soil fumigants tried, chloropicrin gave best control of the Fusarium root rot in 1-0 seedbeds; it also increased the density of the stand and the size of seedlings. At the end of the second season, however, the 2-0 stock in the fumigated beds was stunted and chlorotic. Stunting appeared to be related to reduction in mycorrhizal development (3). Fumigation, therefore, was judged undesirable for control of Fusarium root rot at this nursery.

Acidifying the soil gave some control of root rot, but also reduced density of the stand and caused chemical injury.

Addition of various chemical fertilizers gave no significant control of root rot. Applications of high amounts of nitrogen frequently increased losses from root rot.

Numerous other chemical treatments to the soil gave varying results; a few were partially effective, but generally they did not provide significant control of Fusarium root rot.

Antibiotic organisms isolated from the nursery soil were grown on barley and inoculated into freshly sown seedbeds. Such organisms as a Streptomyces sp., Penicillium spp., and Trichoderma lignorum were used in the antibiotic tests and gave negative results. The Streptomycete had shown positive antagonism to the Fusarium in vitro.

Of the various crops rotated in the control program, cereals reduced root rot most and seemed to promote the best growth of ponderosa pine seedlings.

Several seasons of testing by means of small randomized plots and greenhouse tests demonstrated that some important factor was not receiving adequate consideration.

During the 5-year period (1950-55) when these tests were made, losses from root rot were recorded for the entire nursery. Comparison of losses from root rot with local weather records showed that the greatest losses occurred during years with the hottest summers (fig. 1). Furthermore, counts of root rot usually showed the heaviest losses on the south half of east-to-west seedbeds.

Of organic substances disked into the soil, pine sawdust gave the best control of root rot in nursery test plots. However, when similar treatments with sawdust were applied to several entire seedbeds, the results obtained were somewhat erratic (table 3).

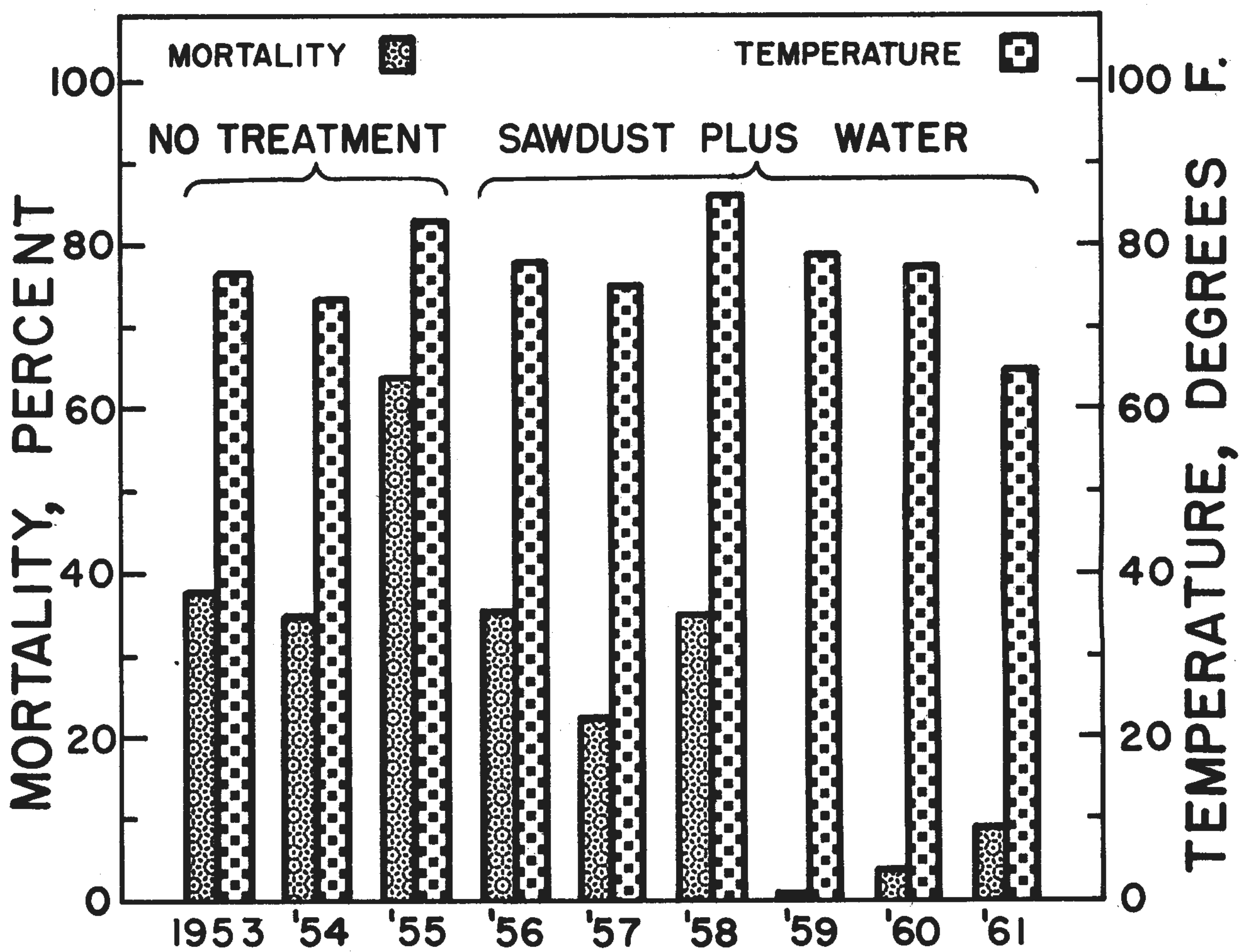

Figure 1.--Relationship of mean maximum temperature of air in August to mortality from root rot in 1-0 ponderosa pine.

TABLE 3.--Effect of sawdust treatment on final average counts of ponderosa pine

Fall application		Spring application	
Treatment	Seedlings	Treatment	Seedlings
Cu. yd./acre	*Av. No./plot*[1]	*Cu. yd./acre*	*Av. No./plot*[1]
None	121	None	97
100	120	100	113
200	119	200	132
400	155	400	137

[1] Plots 4 feet square.

The difference between the effects of applying sawdust in fall and spring did not appear significant. In the fall application, however, the sawdust was more decomposed by sowing time than in spring applications. This was probably an advantage because soil moisture could be kept more uniform. Also, better adjustment of the soil microflora probably resulted from applying sawdust in fall.

During the worst year for epidemic root rot, 1955, the progress of the disease was mapped bed by bed and section by section for the entire nursery. The heaviest losses occurred in areas of deficient watering. Such areas resulted mainly from wind action, and the soil usually was driest at ends of the beds, or next to the pipelines.

In 1956, a small series of watering tests was tried. Water was applied in light-to heavy amounts in an attempt to limit soil temperatures to 75°, 90°, and 105° F. Results were inconsistent, probably because the watering schedule was inadequate.

On the basis of greenhouse and large-scale analyses, a nursery wide program of disking in 100-150 cubic yards of pine sawdust per acre was begun in 1957. Disking was done late in the fall, with addition of 1,000 pounds of aluminum sulfate and 200 pounds of 16-20-0 chemical fertilizer to an acre. Beginning about July 1, seedbeds were heavily watered when soil temperatures approached 90° F. Heavy watering was continued until September, when summer heat and high soil temperatures generally end. Heavy watering not only cools the soil but reduces soil aeration, which has been detrimental to Fusarium spp. (2).

Losses from root rot were not reduced immediately after initiating heavy watering with addition of pine sawdust in the fall. However, rigorous adherence to heavy watering reduced 1959 losses from root rot to less than 5 percent, compared to a high of 65 percent in 1955 (fig. 1).

Heavy watering in summer and addition of sawdust and mineral fertilizer in fall following rye as a rotational crop are now followed for control of Fusarium root rot at the Bend nursery.

Heavy watering as done at the Bend nursery may be undesirable elsewhere. The Bend nursery soil has exceptionally good drainage through cracks in underlying lava rock; therefore, waterlogging is not a problem, although leaching may necessitate adding more fertilizer. With poorer drainage, excessive watering might prove detrimental.

Results of large-scale tests showed the Latin-square design to have been inappropriate for testing for disease control at Bend primarily because the plots were too small to show the influence of watering. However, when entire seedbeds were used as test plots the effect of watering became evident. Persistent virulence of Fusarium root rot may account for the erratic results. Tests obviously should continue for more than one season before their efficacy can be determined.

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