protected from inoculum to serve as a control. After inoculation, the plants were placed in a moist chamber for 48 hours and then maintained on greenhouse benches.

RESULTS AND DISCUSSION

A. tenuis isolates from apple and pear produced chlorotic symptoms on inoculated leaves of both pear varieties similar to those observed under field conditions. Symptoms failed to develop on uninoculated leaves. The fungus was reisolated from inoculated leaves in every case. Various degrees of chlorosis developed on leaves that were immature at the time of inoculation, but failed to develop on mature ones. The youngest leaves at the time of inoculation showed the most pronounced chlorosis. Although leaves that were mature at inoculation failed to develop symptoms, the inocula were repeatedly reisolated from the symptomless leaves.

Chlorosis began to develop on upper surfaces of immature inoculated leaves in 3 to 4 days and symptoms became fully developed as the leaf matured (Fig. 1).

The apple and pear isolates were essentially identical and varied morphologically and culturally to resemble A. tenuis in the sense of Neergaard (2). The capacity of the fungus to inhibit chlorophyll development in immature leaves and become established and survive without symptoms in mature leaves agrees with its performance on other host plants (1, 3, 4). This explains its presence in lesions caused by other agents.

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BORAX TO CONTROL FOMES ANNOSUS INFECTION OF WHITE FIR STUMPS

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Abstract

Three methods of applying borax were tested for penetration into stump tissues and for effectiveness in controlling Fomes annosus infection of freshly cut white fir stumps. All borax treatments reduced infection significantly; dry powder was the most effective. The degree of penetration of xylem stump tissue and the effectiveness of control in the three methods tested were directly correlated.

Fomes annosus (Fr.) Cke. has been reported as the cause of a root and butt rot (2, 9) and a wound invader (11) of true firs in the Western United States. Because true firs were considered to be of little commercial importance, this pathogen was not considered an economically important pest of firs. But within the last few years, as the demand on forest resources

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in California has grown and the accessibility of higher altitude species has improved, true firs have been assuming greater importance in the nation's timber economy. Growing recreation pressures have also increased the value of true firs. These changes have resulted in an interest in intensifying the management of true firs.

Intensive management practices and harvesting will greatly increase the number of infection sites (cut stumps and wounds) which F. annosus may infect. With the increased value of the crop and the prospect of a greater F. annosus problem in the future, forest managers should be looking for some means of protecting true fir stands from infection. In particular, they need a way to protect freshly cut fir stumps with a chemical, such as the borax treatment recommended for the same disease in pines (1, 3, 5, 6).

Edmonds, Driver, and Russell (7) recently reported variable results in the control of F. annosus in western hemlock stumps with borax. They concluded that the effectiveness of control was closely correlated to the penetration of borax into the stump tissues and that variable penetration, among other factors, resulted from the nonresinous nature of the host and a rain washing of the borax-treated stumps. Because true firs are also nonresinous and grow at higher elevations where they are subjected to occasional summer rains, we concluded that testing of borax as a stump protectant of true firs was required before we could recommend control measures.

This paper reports a study of the effectiveness of borax in preventing stump infection in white fir, Abies concolor, by F. annosus.

MATERIALS AND METHODS

Two white fir pole stands, one in the central Sierra Nevada and one in the southern Cascade Mountains, were selected for the test because they fit these criteria: 1) They were essentially pure white fir pole-sized stands with sufficient trees of the required size within a small localized testing area; 2) they showed no signs of prior F. annosus activity; 3) there were no indications of previous cutting or logging; both stands appear to have grown up through an old brush field which most likely originated after a wildfire; 4) they were accessible early in the year when conditions for infection appear more favorable.

The Sierra Nevada study area was located on Robb's Peak (approximate elevation 6000 ft) on the Pacific District of the Eldorado National Forest west of Desolation Valley on an east-facing slope. The southern Cascade plots were located on Lost Creek (approximate elevation 6000 ft) in the Hat Creek District of the Lassen National Forest just north of Lassen National Park on a slight westerly slope.

In each plot, 200 live white firs between 3-7 inches in diameter (measured 12 inches above the ground level) were selected, numbered and cut at a height of 12 inches above the ground. The freshly cut stumps were treated with borax (technical grade sodium tetraborate decahydrate, 200 mesh) as follows:

1. Fifty stumps were dusted over the stump surface with dry powdered borax.
2. Fifty stumps were sprinkled over the stump surface with a 10% aqueous suspension of borax from a watering can.
3. Fifty stumps were sprinkled over the stump surface with a watering can containing a 10% aqueous suspension of borax and 2% Pinolene (Nu-Film 17)[2] as a sticker.
4. Fifty trees were sprayed with inoculum only.

In each area 200 stumps were cut, and all chemical treatments were made on the same day. The borax was applied within 30 minutes after the tree was cut. Each stump was inoculated twice with a freshly prepared aqueous suspension of F. annosus conidia obtained from malt agar cultures. The first inoculation was made the same evening the stumps were treated, and a second inoculation was made early the next morning. The temperature and moisture conditions from evening to noon were considered more favorable for the establishment of infection than any other period. At the time of inoculation the environmental conditions of Lost Creek were very favorable for infection. Three cool, light-rainy days followed.

Viability of the inoculum was tested by spraying it on 1-inch thick stem sections of 3-inch diameter white fir in Petri dishes at the time of inoculation. These discs were returned to the laboratory, incubated, and checked for the Oedocephalum stage of F. annosus. The results indicated that viable inoculum was used in all inoculations.

[2]A low molecular weight polymer of α-and β-pinene, manufactured by Miller Chemical and Fertilizer Corp.

The stumps were harvested 2 1/2 months after the plots were established. The top 8 inches of each stump was cut off and placed immediately in individual polyethylene bags, then taken to the laboratory, cut in half longitudinally, and rebagged.

Half of each stump was used in a F. annosus assay in which six wood chips were removed aseptically from the top 3 inches of the stump half. These chips were plated out on F. annosus selective agar (10) and examined periodically over a 3-week period for the asexual stage of F. annosus. The stump half from which the chips were removed was placed in a plastic bag and incubated at 15-20°C. These halves were examined for the presence of F. annosus twice over a 4-week period. The presence of the conidial stage on either the chips or the stump half was considered evidence of the successful invasion of the stump.

The second half of each stump was used to determine the degree of borax penetration. Using the tumeric method of Johnson and Cowling (8), I sprayed the radial face of each stump half with a saturated solution of tumeric in 95% ethanol. The stump was allowed to dry and then was sprayed with a 20% solution of HCl saturated with salicylic acid. A red color reaction or stain of the xylem indicated the presence of borax. The maximum depth of borax penetration of the sapwood and the heartwood was measured. Since there were stumps and areas in stumps in which no penetration occurred, the percentage of stump surface penetrated along the exposed face was estimated for both sapwood and heartwood.

RESULTS

All borax treatments reduced infection significantly, indicating that borax is an effective chemical protectant for preventing F. annosus infection of white fir stumps. Dry borax was the most effective and penetrated into the stump the deepest. The water-borax-sticker treatment was the least effective and the poorest in penetration.

In the Robbs Peak trials, 50% of the nontreated stumps and none of the borax treated stumps became infected (Table 1). In the Lost Creek trials, infection of nontreated stumps was higher, 70%, and the dry borax treatment was the only treatment in which no infection was found. In the laboratory examination of the infected stump samples, F. annosus conidiophores frequently were found developing on both the sapwood and heartwood -- a sign that both tissues had become infected in the field.

Table 1. Fomes annosus infection of borax-treated white fir, Abies concolor, stumps.

Treatment	No. stumps treated	No. stumps infected	% Infection
	Robbs Peak		
Dry borax	50	0	0
10% borax-water suspension	50	0	0
10% borax-water suspension w/2% pinolene	50	0	0
No treatment (inoculation check)	50	25	50
	Lost Creek		
Dry borax	50	0	0
10% borax-water suspension	50	2	4
10% borax-water w/2% pinolene	50	5	10
No treatment (inoculation check)	50	35	70

Table 2. Penetration of borax applied by three methods into the xylem of freshly cut white fir, Abies concolor, stumps.

Treatment	Sapwood penetration		Heartwood penetration	
	Avg. maximum depth (cm)	Avg. surface penetration (%)	Avg. maximum depth (cm)	Avg. surface penetration (%)
Dry borax	4.6	71	2.4	67
Borax-water suspension	2.6	63	0.8	38
Borax-pinolene-water suspension	2.4	49	0.5	25

Stumps varied widely in both depth of penetration and percentage of surface penetrated (Table 2). Furthermore, the heartwood and sapwood of the same stump differed significantly in these two factors. In extreme cases there was excellent penetration of the sapwood and no detectable penetration of the heartwood. On the average, borax penetration was greater in the sapwood than the heartwood. Among borax treatments, the dry borax treatment was superior to the others. It resulted in deeper penetration and in higher percentage of surface penetrated.

CONCLUSIONS

The inoculation method and conditions for infection were adequate for the test, as indicated by the amount of infection in the untreated checks. The differences in the amount of infection in the untreated checks were probably due to the more favorable environmental conditions which existed during the inoculations at the Lost Creek plot.

There was a direct correlation between penetration and control. A similar correlation was reported by Johnson and Cowling (8) in pine and Edmonds, et al. (7) in hemlock.

The differences in borax penetration of sapwood and heartwood in the same stump and variability between stumps are of concern. In fir, where significant infection occurs in both sapwood and heartwood, the penetration of borax into both these tissues becomes important.

The results of this study indicate that borax prevents infection of freshly cut white fir stumps by *F. annosus*. It would be desirable to have additional information on these points: 1) the effect of long-term weathering on borax retention and effectiveness in the nonresinous fir stumps, and 2) the length of time fir stumps remain susceptible to infection by *F. annosus*. Pine stumps are susceptible to infection for only a few weeks (4), and thus borax need remain effective for this short period. Edmonds, et al. (7) reported that long-term exposure to rain decreased the effectiveness of borax in nonresinous western hemlock. If fir remains susceptible to infection for long periods, the borax must retain its effectiveness for an equally long period if the stumps are to be completely protected from infection.

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