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Use of  
**SOIL FUMIGANTS**  
to Control Spread of  
**Fomes annosus**



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## **BACKGROUND**

**T**HE ROOT ROT caused by the fungus *Fomes annosus* is a serious threat to coniferous plantations throughout the North Temperate Zone. It is especially prevalent in plantations that have been thinned; and it commonly spreads through the roots from diseased trees to healthy trees.

In 1962-67 we conducted a series of experiments to provide preliminary information for testing the hypothesis: that a continuous band or zone of roots rendered unsuitable for invasion by *F. annosus* will prevent the underground spread of this fungus from diseased to healthy trees.

The initial introduction of *F. annosus* into a stand depends largely upon the occurrence of the first thinnings and consequently upon the age of the plantation. This is because fresh stump tissues offer especially suitable substrates for the germination of windborne basidiospores of *F. annosus*, and for the subsequent growth of the thallus (*Rishbeth 1950, 1951*).

Many studies have been made of this initial establishment; and several control measures, designed to prevent invasion by the fungus into previously unaffected stands, have been developed. Materials have been found that, when placed on the stump surface at the time of felling, act in various ways to hinder development of the fungus. The most successful of these materials are those that encourage rapid colonization of the

stump and roots by competing saprophytic fungi. Urea (Rishbeth 1959), borax (Driver 1963b), and sodium nitrite (Punter 1964) are among the most promising of these materials. Promising results, too, have followed the direct inoculation of freshly cut stump tops with *Peniophora gigantea*, an aggressive saprophytic fungal competitor of *F. annosus* (Garrett 1951 and Rishbeth 1961). Thus, in spite of the need for more research on this phase of control, much has been learned; and quite effective and practical measures are now in actual use (Driver 1963a).

Once the fungus is established in the stand, however, control becomes infinitely more difficult. Spread of the fungus from infected stumps to adjacent standing trees is by means of root contacts. It is highly probable that every tree in a 30-to-40-year-old pine plantation, planted originally at a 6-x-6-foot

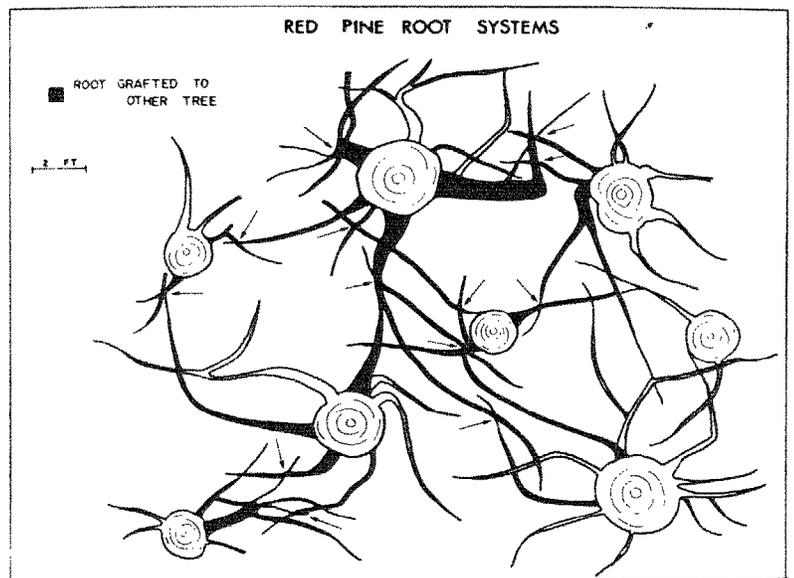


Figure 1. — The soil around the roots of these 30-year-old red pines was washed away with water to reveal the degree of root contact that occurred. Roots colored black are actually grafted to roots of other trees. *Fomes annosus* spreads from tree to tree underground by means of root contacts.

spacing and perhaps thinned once, is in root contact directly or indirectly with every other tree in the stand (fig. 1).

So potentially, once *F. annosus* has invaded the stand, all trees in the stand are subject to attack.

## **STUDY I**

### **ELIMINATION OR REDUCTION OF ROOT CONTACTS**

Root contacts could be reduced in one of two general ways. (1) They could be physically removed or severed by trenching, or interrupted by placing physical barriers below ground. Or (2) they could be treated in place by some means that would render them unsuitable for infection by *F. annosus*. *F. annosus* is not an aggressive saprophyte, and dead root tissues invaded first by other fungi are unlikely to be colonized subsequently by *F. annosus* (Rishbeth 1951).

At the outset it appeared that soil fumigants might be utilized to kill roots in place. These materials are toxic to many plant roots and soil microorganisms, and have been used with success to control the underground spread of oak wilt (Kuntz and Drake 1960) and Dutch elm disease (Himelick et al. 1963); and *F. annosus* was controlled temporarily in California by fumigating with carbon disulfide (Bega 1962). So experiment 1 was conducted to determine the effects of fumigation on the healthy roots of several coniferous hosts of *F. annosus*.

#### **Experiment 1**

##### **Effect of Soil Fumigants on Healthy Conifer Roots in Situ: Development of Techniques**

###### **Methods and Materials**

A 25-year-old mixed plantation of red, Scots, and pitch pines, growing on a deep, fine, sandy outwash soil was used in this experiment. The stand was planted originally at a 6-x-6-foot

spacing and had not been thinned. Eighteen 6-foot-long plots were established in September 1962. Each plot was placed halfway along and perpendicular to a line connecting two adjacent trees. Different concentrations of two fumigants – methyl bromide<sup>1</sup> and SMDC (Vapam)<sup>2</sup> – were introduced to different depths in holes prepunched with a crowbar at 1-foot intervals along this line. The general scheme was that used by Kuntz and Drake (1960). Methyl bromide at each of three concentrations (0.5, 1.0, and 2.0 pounds per 10 linear feet of plot) was introduced to each of nine plots (three plots at each concentration), by means of a MacLean rodent gun<sup>3</sup> to successive depths of 8, 16, 24, 24, 32, and 40 inches. A second hole at 24 inches was included to facilitate the timing of gas release from the 1-pound cans. The opening of each hole was closed with dirt after the fumigant was introduced. Dosages were regulated by timing the release of fumigant with a stopwatch.

Fifty, 100, or 200 ml./hole of SMDC stock solution diluted 1:10 were introduced to each of the other nine plots by a similar scheme except that only one 24-inch deep hole was used in each plot. After application, each hole opening was sealed with dirt.

The effect of fumigation on the soil microflora was studied. Four red pine plots (SMDC at concentrations of 50, 100, and 200 ml./hole; and methyl bromide at 2 pounds/10 linear feet) were sampled 2 weeks after fumigation. A soil auger was used to obtain samples from the 0-to-6-inch and 6-to-12-inch depths at distances of 6, 12, and 18 inches from the fumigation line opposite the 8-, 24-, and 40-inch-deep holes. Soil dilutions of 1:10,000, replicated three times, were plated into petri dishes containing peptone dextrose agar plus rose bengal and streptomycin (Martin 1950; Johnson 1957) in the manner described by Johnson et al. (1959).

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<sup>1</sup>Dow Chemical Co., Midland, Mich. Mention of a particular product should not be taken as an endorsement by the Forest Service or the U. S. Department of Agriculture.

<sup>2</sup>Sodium *N*-methyl dithiocarbamate: Stauffer Chemical Co., New York, N. Y.

<sup>3</sup>MacLean Equipment Co., Los Angeles, Calif.



Figure 2. — The pit was dug to permit measurement of the root injury produced by soil fumigant applied along the line between the two wooden stakes.

Approximately 1 month after fumigation the plots were excavated and the tree roots were examined for extent of injury (fig. 2).

#### **Results**

Figures 3 and 4 represent the general effects of methyl bromide on roots 1 month after fumigation and on the soil microflora 2 weeks after fumigation, respectively. Under the conditions of this test, the following general results and conclusions were obtained:

1. Red pine roots were killed readily by either SMDC or methyl bromide. Scots pine roots were slightly less affected and pitch pine roots were quite resistant.
2. Methyl bromide and SMDC at concentrations of 1 pound/10 linear feet and 200 ml./hole, respectively, applied to depths of 16 to 24 inches, killed the majority of red pine roots in a zone 2.5 to 3.5 feet wide on either side of the injection line.

Roots 3 to 6 inches in diameter were killed back to the root collar, but no injury occurred to the bole of the tree. Materials applied at the 8-inch depth were less effective than those applied at 16 or 24 inches both in the extent of horizontal root kill and in killing of surface roots. Fumigants applied at the 32-inch depth produced no added effect; and those applied 40 inches deep were not effective in killing roots near the surface.

3. The effects of fumigation upon the soil microflora at both the 0-to-6-inch and 6-to-12-inch levels were evident even 2 weeks after treatment. In general, the effects (decrease in colonies isolated) were greatest when the fumigants were applied to the 8-inch-deep holes and decreased as depth of application and horizontal distance from the line of injection increased, especially at the shallow depths. In the three SMDC plots examined, the effects increased with increasing concentrations of the fumigant.

Figure 3. — The condition of the roots in the upper 12 inches of soil 1 month after fumigation with methyl bromide at the rate of 1 pound per 10 linear feet of fumigation line.

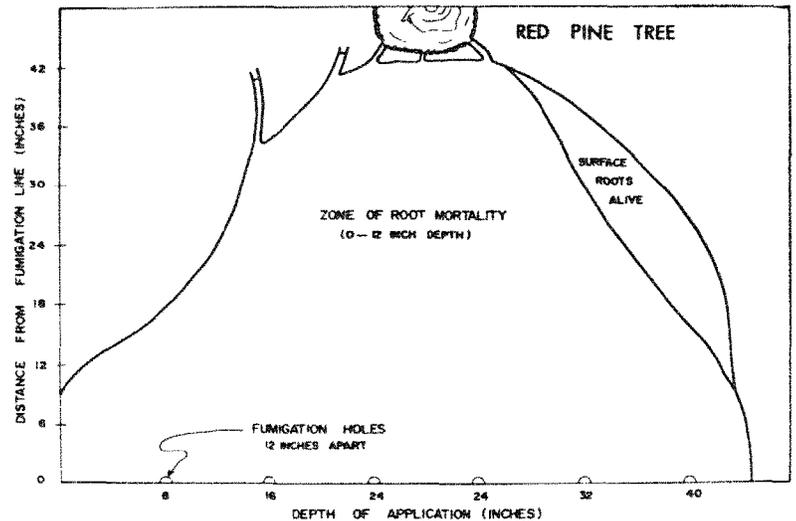
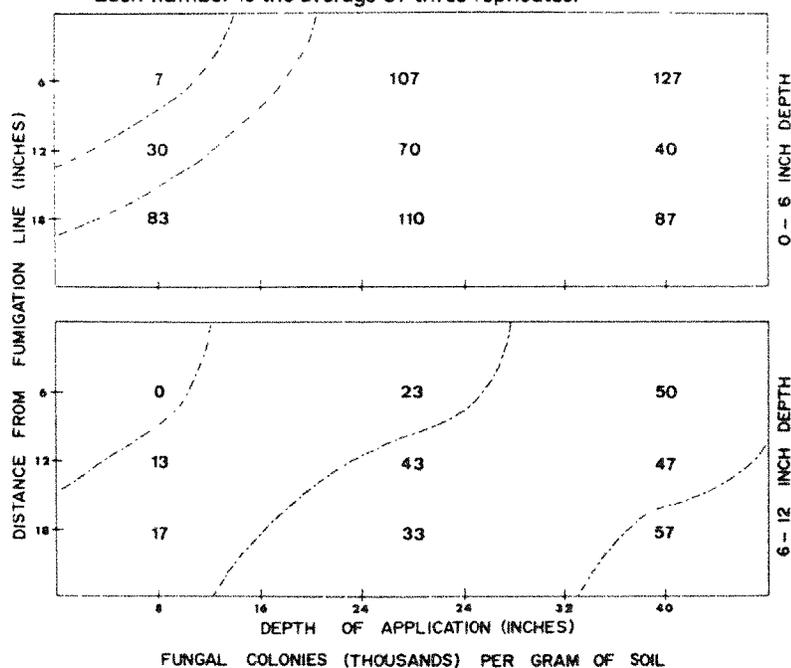


Figure 4. — Number (thousands) of fungal colonies per gram of soil isolated 2 weeks after fumigation with methyl bromide at 2 pounds per 10 linear feet of fumigation line. Each number is the average of three replicates.



## Experiment 2

### *Influence of Soil Type and Season on Fumigant Effectiveness*

#### Methods and Materials

Ten plots containing a total of 34 trees were established in June 1963 or in the spring and fall of 1964, using methyl bromide (1 pound/10, 8, or 7 linear feet of line) and SMDC (200 ml. of 1:10/hole) applied at 1-foot intervals along a line placed 4 feet from the trees, to a depth of 20 inches. Plots were located in a 35-year-old red pine plantation growing on a heavy sandy loam soil in northwestern Connecticut and in a 25-year-old stand growing on a light loamy sand in southeastern Connecticut. Both soils were heavier than that encountered in

experiment 1. Roots were excavated and examined for injury 3 to 12 months after treatment.

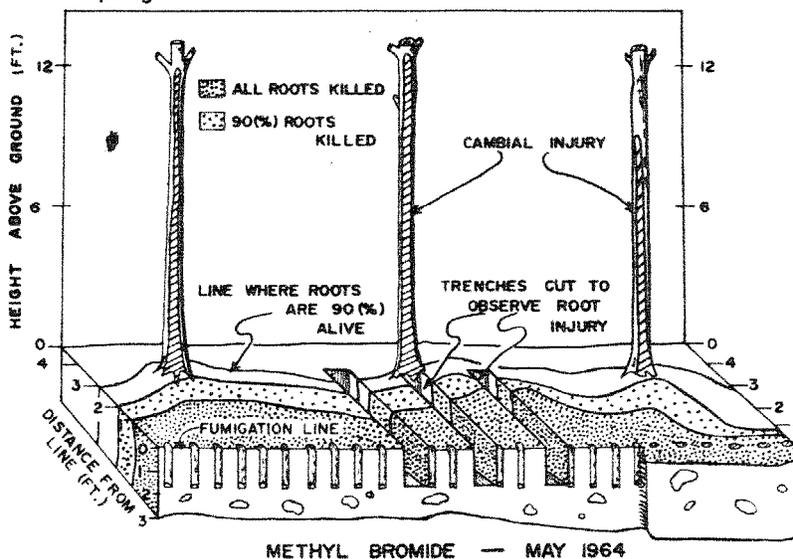
### Results

*Soil type.* – Very little difference in extent of injury occurred that was attributable to differences in soil type, either in incidence (distance from line) or in the severity (percent root kill) of injury.

*Season.* – Differences, primarily in the extent of above-ground injury to the stems of trees adjacent to the fumigation line, occurred in plots treated at different times of the year. The cambium of trees on plots treated early in the season was killed in wide streaks that extended as high as 15 feet above ground (fig. 5). No injury above ground occurred on the trees in plots treated late in the season.

*Methyl bromide versus SMDC.* – Under the conditions of the tests in 1963 and 1964, SMDC did not give as effective or consistent results as methyl bromide did. The pattern of root mortality was erratic: often roots close to the fumigant line

Figure 5. – A representative example of the effects of methyl bromide applied to a depth of 20 inches at 1-foot intervals along a line 4 feet from red pine trees in the spring.



itself were injured but not killed. This apparent contradiction to the results of the 1962 test (experiment 1) may be due to the heavier soils encountered in the 1963 and 1964 experiments or to the restriction of injection to a single depth in 1963 and 1964. And, as noted above, the concentration of methyl bromide was increased in several trials in experiment 2 while that of SMDC was not.

## **STUDY II**

### **EFFECT OF SOIL FUMIGANTS ON FOMES ANNOSUS IN INFECTED ROOTS OF RED PINE**

Once it was determined that roots of red pine could be killed readily by soil fumigation, several questions arose that made it necessary to determine the effects of the fumigants upon root systems already colonized by *Fomes annosus*: (1) would the temporary elimination of competitive or antagonistic fungi near infected roots provide a more suitable environment for *F. annosus*? or (2) would the treatment encourage saprophytic fungi to rapidly colonize the sterilized roots? And (3) would the state of root deterioration influence the effectiveness of the fumigants? These questions were explored in experiments 3 to 6 summarized below.

### **Experiment 3**

#### ***Effects of fumigants on F. annosus in variously-rotted root tissues***

#### **Methods and Materials**

In June and July 1963 tests were carried out in a 25-year-old red pine stand in north-central Connecticut. The stand, growing on a sandy outwash soil, had been thinned once in 1956. Treatments were applied to thirteen plots, each of which contained one of the following:

1. The infected stump and roots of a tree cut in 1956.
2. The infected stump and roots of a tree killed by *F. annosus* in 1962.
3. The stump and roots of a living tree infected with *F. annosus*.

In all cases, the presence of viable *F. annosus* fruiting bodies on the root collars was the criterion of infection. Trees killed in 1962 and the living infected trees were felled at the time of treatment and the resulting stumps were treated in the same manner as the stumps produced by the 1956 thinning. The following treatments were used:

1. Methyl bromide was applied to the plots (each plot consisted of a 10-x-10-foot square area with the stump at the center) in one of three ways:
  - A. One pound of methyl bromide was evenly dispensed among four crowbar holes. The holes, each 20 inches deep, were located halfway between the corners of the plot and the stump center.
  - B. One pound of methyl bromide was dispersed beneath a polyethylene tarp that covered the stump and the 10-x-10-foot square area. The tarp was trenched in along the four sides, but was elevated above the stumps and ground with branches to permit thorough dispersal of the gas (fig. 6).
  - C. A combination of (A) and (B).In treatments 1-B and 1-C the tarps were left in place for at least 24 hours.
2. SMDC was applied similarly, using a 1:10 aqueous dilution of the stock solution:
  - A. Two hundred ml. were applied to each of the four 20-inch deep holes.
  - B. One thousand ml. were sprinkled onto the stump top and duff, and the plot was covered with a polyethylene tarp.
  - C. A combination of (A) and (B).
3. Check plots were treated as in (1) and (2) except that no fumigants were applied.



Figure 6. — Methyl bromide is being introduced into the air space between the trenched-in polyethylene tarp and the infected stump. Branches placed over the ground elevate the tarp above the stump.

At intervals of about 1 week, 2 weeks, 1 month, and 2 months after treatment, a root was removed from each stump, washed under tap water and aseptically split longitudinally. Chips taken from decay columns were plated onto a selective medium (Kuhlman and Hendrix 1962). Plates were examined after 7 days for the presence of *F. annosus* and *Trichoderma viride*.

#### Results

The results of this experiment are given in table 1. No apparent control was effected by SMDC under the conditions of this test. This was supported also by the record that the roots of adjacent living trees were not severely injured even though they were within the treatment zone. The methyl bromide treatments were more effective. *Fomes annosus* was not isolated in repeated trials from the old infected stump roots that had received treatment 1-C, but it was isolated from similar roots that had received treatments 1-A or 1-B. Treatment 1-C also appeared fairly effective in killing the fungus in roots of living infected trees and of trees killed recently. Based on these results, a second experiment was performed, using treatment 1-C only.

Table 1. -- Effects of fumigation with methyl bromide or SMDC on *Fomes annosus* in roots of different stages of decay, July 1963  
(+ = *Fomes annosus* isolated)

Plot No.	Root condition	Treatment <sup>1</sup>	Date of treatment	Date of isolation				
				June 26	July 12	July 26	August 7	August 14
METHYL BROMIDE								
1	Well rotted	1-A	June 18	CON <sup>2</sup>	-	+	..	+
2	Well rotted	1-B	June 18	CON	+	..	..	..
3	Well rotted	1-C	June 18	CON	-	-	..	-
4	Dead (killed in 1962)	1-C	July 11	..	..	+	-	+
5	Live	1-C	July 17	..	..	..	+	..
SMDC								
6	Well rotted	2-A	June 18	+	+	..	..	..
7	Well rotted	2-B	June 18	CON	+	..	..	..
8	Well rotted	2-C	June 18	CON	+	..	..	..
9	Dead (killed in 1962)	2-C	July 11	..	..	+	+	..
10	Live	2-C	July 17	..	..	..	+	..
CHECK								
11	Well rotted	..	..	CON	+	..	..	..
12	Dead	..	..	..	..	+	+	..
13	Live	..	..	..	..	..	..	+

<sup>1</sup>Treatments refer to those described in text, Experiment 3.

<sup>2</sup>Contaminated.

## **Experiment 4**

### **Effect of Methyl Bromide on Survival of *F. annosus* in Roots**

#### **Methods and Materials**

Eighteen plots were established in a 30-year-old stand in south-central Connecticut in August 1963. The plantation, growing on a gravelly sandy-loam glacial till, had been thinned once in 1956.

The same three classes of root systems described in experiment 3 were treated. At intervals of 1 week, 2 weeks, 2 months, and 3 months after fumigation with treatment 1-C roots were excavated and isolations were made from selected portions. Check plots were tarped and trenched but not fumigated.

#### **Results**

After fumigation, *F. annosus* was not isolated from any of five well-rotted stumps and was recovered only once from the roots of a recently killed tree (table 2). Four of the five live trees yielded the fungus at some time during the study. Usually rot columns yielding *F. annosus* were surrounded by outer wood densely impregnated with pitch or resin. With few exceptions the aggressive saprophyte *Trichoderma viride* was isolated in pure culture when *F. annosus* was not.

The results of experiments 3 and 4 suggested that *F. annosus* could be eradicated more easily from some root tissues than from others, and that saprophytic fungi, notably *T. viride*, rapidly colonized fumigated roots previously inhabited by *F. annosus*. This was especially true for roots in an advanced stage of decay. These studies were expanded in 1964 to confirm the results of 1963 and to enable statistical analysis of the data.

Table 2. — Effects of fumigation with methyl bromide on survival of *Fomes annosus* in variously infected root tissues  
(+ = *Fomes annosus* isolated)

Plot No.	Root condition	Treatment	Date of treatment	Date of isolation — 1963			
				August 28	Sept. 3	Oct. 16	Nov. 20
1	Well rotted	1-C	08/19/63	-	..	-	-
2	Well rotted	1-C	08/19/63	-	..	-	-
3	Well rotted	1-C	08/19/63	-	..	-	-
4	Well rotted	1-C	08/19/63	-	..	-	-
5	Well rotted	1-C	08/19/63	-	..	-	-
6	Live	1-C	08/19/63	-	..	+	+
7	Live	1-C	08/19/63	+	..	-	+
8	Live	1-C	08/19/63	-	..	-	-
9	Live	1-C	08/19/63	..	+	-	+
10	Live	1-C	08/22/63	..	+	-	-
11	Trees dead	1-C	08/22/63	..	-	-	-
12	(killed by	1-C	08/22/63	..	-	-	-
13	<i>F. annosus</i>	1-C	08/22/63	..	-	-	-
14	in 1962	1-C	08/22/63	..	-	-	-
15		1-C	08/22/63	..	-	+	-
16	Old stump	Check	..	..	+	+	+
17	Living tree	Check	..	..	+	-	+
18	Dead tree	Check	..	..	+	+	+

## Experiment 5

### Effects of Methyl Bromide and SMDC on Survival of *Fomes annosus* in Variously Rotted Roots

#### Methods and Materials

Forty-five plots were installed in July 1964 in a 30-year-old stand that had been thinned in 1959. Fifteen plots (five for each of the three root conditions) were used for each of three treatments: namely, methyl bromide, 1 pound in the ground and 1 pound under the polyethylene tarp (1-C); SMDC, 800 ml. in the ground and 1,000 ml. on ground and stump under tarp (2-C); and the checks, tarped but not fumigated.

Three to 4 weeks after treatment, the root systems were

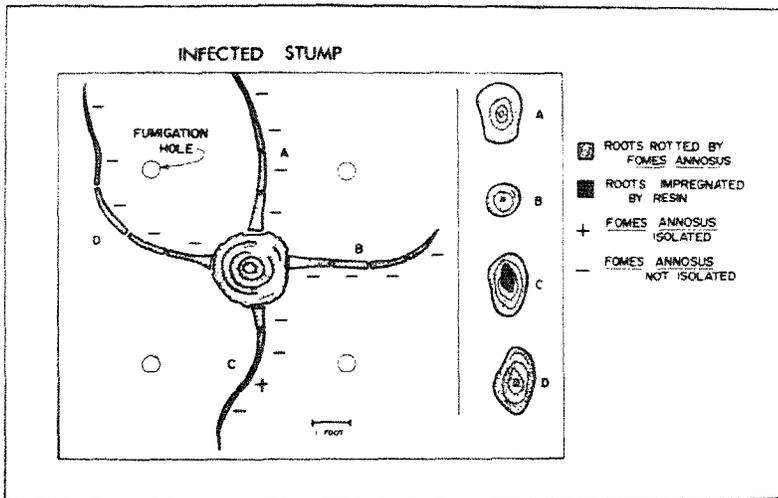


Figure 7. — Diagrammatic presentation of one of the well-rotted stumps treated with methyl bromide in experiment 5. The four major roots are shown with respect to the fumigation holes and to the points of isolation.

excavated, and the four major roots were measured, diagrammed with respect to the fumigation holes (fig. 7), and described as to their condition of decay. Over 2,700 isolations were made from these roots in the manner described in experiment 3.

### Results

The results are summarized in table 3. An analysis of variance indicated that differences in stump conditions and in treatments were highly significant, while the interaction between stump condition and treatment was not. Tukey's test was used to determine significant differences among means for treatment and stump condition.

At the 5-percent level, untreated, rotted, dead, and live root tissues yielded significantly different percentages of *F. annosus*. None of the treatments differed significantly from each other when applied to well-rotted stumps; methyl bromide significantly reduced *F. annosus* in live tree roots; and both methyl bromide and SMDC treatments significantly reduced *F. annosus* in dead tree roots.

Table 3. — The percentage of isolation chips that yielded *Fomes annosus*. Each figure represents the percentage of over 300 chips.

Treatment	Chips yielding <i>Fomes annosus</i> , by root condition		
	Well rotted	Live	Dead
	Percent	Percent	Percent
Checks	10.7*	41.7	76.2
SMDC (Vapam) (2-C)	10.7	22.0	29.7
Methyl bromide (1-C)	2.3	1.8	12.05

\*Lines connect values not significantly different from each other at the 5% level.

In all cases, the methyl bromide treatment was more effective than SMDC, and the SMDC treatment was somewhat more effective than no treatment.

In most cases where *F. annosus* was isolated from methyl-bromide-treated roots less than 4 inches in diameter, the rot columns were surrounded by outer wood densely impregnated with resin. Occasionally *F. annosus* was cultured from some of the roots over 6 inches in diameter. As in earlier experiments, *Trichoderma viride* was isolated frequently from fumigated roots, occasionally from the same chips that yielded *F. annosus*, but most consistently from well-rotted roots where *F. annosus* was killed by fumigation. *T. viride* also developed in abundance on the bark of treated roots — especially when the plots were covered with a polyethylene tarp for several days.

Experiments 3, 4, and 5 indicated that treatment of infected roots and stumps with fairly high concentrations of methyl bromide (2 pounds per plot and in most cases under a polyethylene tarp) markedly reduced *F. annosus* in these root systems and encouraged the rapid colonization of these tissues by other saprophytic fungi, especially *T. viride*. However, it remained to be seen whether the line-plot method of application and the dosages worked out under study I would be equally effective.

## Experiment 6

### Line Plot Fumigation Between Infected and Living Trees

#### Methods and Materials

In June 1963, two plots were established by injecting fumigant into 20-inch-deep holes at 1-foot intervals along a line separating, in each case, two apparently healthy 25-year-old red pines from adjacent stumps that bore viable sporophores. In one plot, 1 pound of methyl bromide was dispensed evenly among 9 holes; in the other SMDC was applied at the rate of 200 ml. of 1:10 dilution per hole. Four months later the root systems of trees and stumps were excavated and diagrammed and isolations for *F. annosus* were made.

#### Results

The results of isolation are indicated on figures 8 and 9 as positive (+) or negative (-). As before, methyl bromide (fig. 8), at the concentrations used, appeared more effective than SMDC (fig. 9) in killing the roots of the living trees and in reducing *F.*

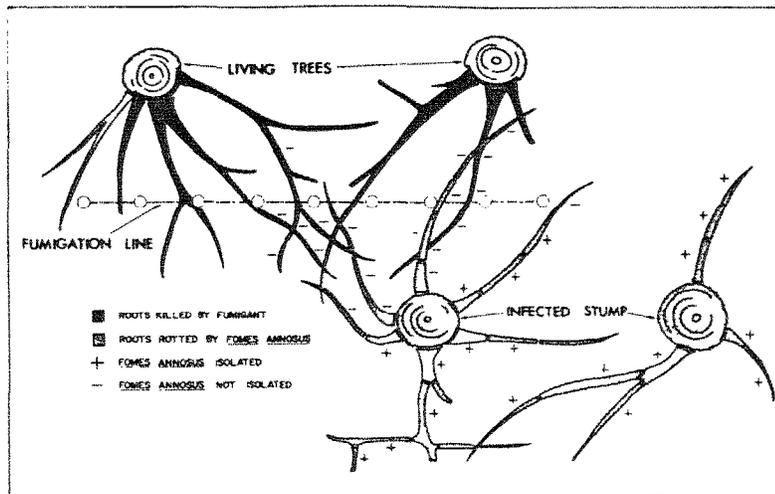


Figure 8. — The effects of methyl bromide on living roots and on *F. annosus* in roots of infected stumps.

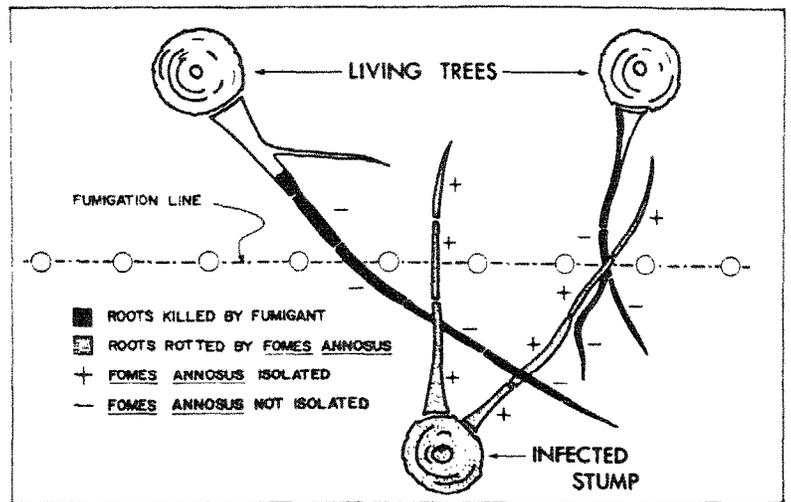


Figure 9. — The effects of SMDC on living roots and on *F. annosus* in roots of infected stumps. Roots killed by the fumigant are colored black, isolation results are shown as positive (+) or negative (-).

*annosus* in infected root systems. As noted in earlier trials conducted at this season of the year, injury to the boles above ground occurred in the methyl bromide plot.

### STUDY III

#### ESTABLISHMENT OF BARRIERS BY USING SOIL FUMIGATION

The experiments described in studies I and II provided the supporting information needed for a test of the original hypothesis that zones of roots killed by fumigation and then colonized by saprophytic fungi would prevent spread underground of *Fomes annosus*. Armed with this information, we began an experiment to test the efficacy of fumigation as a control of *F. annosus*.

## **Experiment 7**

### **Fumigation of Infection Centers**

#### **Methods and Materials**

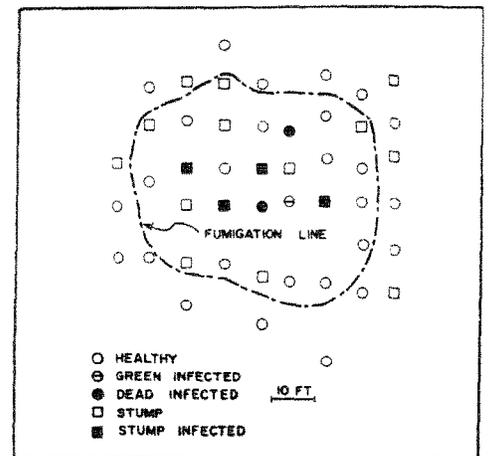
Twelve infection centers in red pine plantations located in New York, New Hampshire, Connecticut, and Rhode Island were selected for treatment in the fall of 1967 based on the following criteria:

1. Activity (trees currently dying from *F. annosus*).
2. Discreteness (centers separated from each other by at least 10 rows of healthy trees).
3. Size (perimeter of centers restricted to 4 chains or less).

All stumps and trees in and surrounding the infection centers were examined for fruiting bodies of *F. annosus*, and the centers were delineated on this basis. The fumigation line was established at least one healthy tree (without fruiting) outside of the outermost tree or stump bearing fruiting bodies. Methyl bromide, at the rate of 1 pound per every 8 linear feet, was dispensed into 20-inch-deep holes punched at 1-foot intervals along the fumigation line. The positions of the stump and trees in each plot were mapped and their disease conditions were noted (fig. 10).

Six months after treatment the effectiveness of the fumigant was assessed in several plots. All the roots in a zone 2.5 to 3.5 feet on either side of the fumigation line had been killed, and little injury was apparent above ground on stems 4 feet or more from the line. But the spacing of several plantations necessitated injecting the fumigant closer than 4 feet from some trees. And 9 months after treatment in such stands, injury to trees adjacent to the fumigant line were evident. Indeed several trees 2 to 3 feet from the line were damaged severely and probably will die. Underground, the bark had deteriorated on many roots, and many of them were colonized by stain fungi. Each of these plots, along with other plots yet to be established, will be examined annually to determine if breakover occurs and, if so, how or why.

Figure 10. — A map of one infection center showing the location of the fumigation line in relation to the infected trees and stumps. All infected trees and stumps bore fruit bodies of *F. annosus*.



## DISCUSSION

These studies demonstrated that soil fumigants can be used effectively to kill healthy roots of red pine in bands or zones of quite consistent widths. It was shown also that *Fomes annosus* was not selectively favored by the temporary reduction of normal saprophytic fungi in the soil but was itself markedly reduced in treated root systems previously infected. In addition, isolations from fumigated soil and roots revealed the rapid recolonization and buildup of saprophytes, especially *Trichoderma viride*. Studies elsewhere have shown that *T. viride* was highly resistant to fumigation with methyl bromide and rapidly repopulated fumigated soil (Wensley 1953).

These studies pointed out the difficulty of eliminating *F. annosus* from certain portions of infected root systems. This was probably attributable to poor penetration of fumigant through tissues impregnated with resin. Resinosis also has been reported to inhibit or restrict the movement of *F. annosus* in wounded roots (Wallis 1961). We observed repeatedly that a root was almost never uniformly resinous. Often a thoroughly impregnated section of a foot or so in length ended abruptly in either decayed or sound wood. Fumigation of such roots

resulted in eradication of *F. annosus* from the decayed portions, and rapid colonization of both the non-resinous decayed and sound portions by other fungi, particularly *Trichoderma*.

Large roots, primarily those greater than 6 inches in diameter, sometimes still harbored the fungus after fumigation. The only roots of this size encountered in these studies were restricted to within 2 feet of the stump.

Several factors are still unresolved. One of these concerns the time it will take for roots from adjacent trees to grow across the fumigated zone and re-establish contact with infected tissues. Another factor concerns the fate of the trees bordering the fumigation line, especially those trees within the 4-foot zone. A number of trees in this zone probably will die, and many more will be injured severely and become liable to bark beetle attack. Some stem injury and beetle attack occurred even on trees more than 4 feet distant. How trees with but half a root system alive will fare under drought conditions or even under normal stand competition remains to be seen.

Another point yet unresolved is the efficacy of delineating infection centers by the presence of sporophores rather than through actual isolation. This was done for several reasons. Our observations of a number of infection centers in the Northeast revealed that although a red pine may be infected and not bear fruit bodies, roots several feet from the tree on the side opposite the infection center usually are not colonized until after conks appear on the tree. Also, the technique must be one usable by foresters without benefit of isolation results. The readily recognized conks of *F. annosus*, their usually rapid development on infected trees – particularly in the fall – and the inclusion of a surrounding row of apparently healthy trees within the treated area ought to be an adequate method of delineating the infected area. The success or failure will be revealed with time.

The inconsistent results produced by SMDC (vapam) probably does not reflect the nature of the material but rather the concentration used. The amount employed was based upon early recommendations developed elsewhere for different purposes. More recent recommendations have called for applying

the material at greater concentrations (*Neely and Himelick 1965, 1966*). What should be borne in mind here is that these studies were not intended to compare materials, but to test the concept of a barrier zone composed of root tissue rendered unsuitable for colonization by *F. annosus*. If the concept proves sound, then further testing should be done with a variety of materials and concentrations.

We have not attempted to cost the materials or manpower required to locate, delineate, and treat infection centers. But it is probable that this technique, if successful, would be feasible only in stands where considerable values are at stake. Arboreta, seed orchards, recreational areas, and perhaps certain watersheds might warrant this treatment. Also, certain forest plantations in which preventive stump treatments have been made would be good prospects for fumigation treatment. In such stands infection centers would very likely arise through infection of overlooked stumps or of stumps whose treated surfaces had been scraped or damaged and consequently might be limited in number, small, and discrete and thus suitable for fumigation treatment.



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