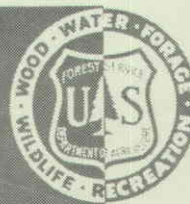


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**Eradicating
EUROPEAN PINE SHOOT MOTH
in Commercial Nurseries
with Methyl Bromide**

**by V. M. Carolin
and W. K. Coulter**

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE • FOREST SERVICE



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SUMMARY

This is the third in a series of reports on experimental fumigation of the European pine shoot moth in residential areas and nurseries. Methods and techniques derived in previous studies on single ornamentals were adapted to fumigation of a commercial nursery. An elongate cubical chamber was built for treatment of trees in rows.

Fumigation of an entire commercial nursery is feasible under conditions existing in the Puget Sound area of Washington during late fall and winter. All treatments in which ground tarps were used under chambers resulted in 100-percent shoot moth control. Two treatments in which wet soil was substituted for the ground tarp failed to give 100-percent control; one of these failures was due to too short an exposure period. Tree damage from fumigation was minor and most apparent on lodgepole pine and western white pine.

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ERADICATING EUROPEAN PINE SHOOT MOTH
IN COMMERCIAL NURSERIES WITH METHYL BROMIDE

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PACIFIC NORTHWEST
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INTRODUCTION

Infested nursery stock is the principal means by which the European pine shoot moth is spread from place to place. Because of the threat to native pine stands, several of the Western States have established quarantines to restrict entry of pines from infested States, and one has regulated intrastate shipments from areas harboring shoot moth infestations in commercial nurseries and ornamental plantings. Fumigation is the only known means of insuring that trees exposed to infestation are free of the shoot moth and safe to plant in uninfested pine-growing areas.

Methods for fumigating to eradicate the European pine shoot moth from single ornamental pines under outdoor conditions were described in two previous reports. The first^{1/} gave the results obtained from various combinations of time, temperature, and gas concentration at different seasons of the year. The second^{2/} described the equipment and procedures used and reported the tests on which the fumigation techniques were based. The principal accomplishments were:

1. Inexpensive portable chambers made of light frames and plasticized nylon covers, were developed; these showed only minor gas loss for periods up to 5 hours. Proving satisfactory and regarded as "standard" for outdoor fumigation were two cubical wooden-frame chambers, 5 x 5 x 5 feet and 10 x 10 x 10 feet, and two cylindrical chambers with a wire mesh frame, one 3 feet high (25 cubic feet) and the other 5 feet high (100 cubic feet).
2. A standard application technique was devised, in which gas was heated during introduction by routing it through coils in a bucket of hot water. The gas remained uniformly distributed so that circulating devices were unnecessary. However, in order to obtain precise measurement of the average chamber temperature, circulation of the gas-air mixture was desirable when heaters were used or when solar radiation was directed mainly on the top of the chamber.
3. A method was developed for adjusting treatment period according to chamber temperatures measured at 30-minute intervals, so as

^{1/} Carolin, V. M., Klein, W. H., and Thompson, R. M. Eradicating European pine shoot moth on ornamental pines with methyl bromide. Pac. NW. Forest & Range Expt. Sta. Res. Paper 47, 16 pp., illus. 1962.

^{2/} Klein, W. H., and Thompson, R. M. Procedures and equipment for fumigating European pine shoot moth on ornamental pines. Pac. NW. Forest & Range Expt. Sta. Res. Paper 50, 25 pp., illus. 1962.

to obtain 100-percent control with minimum tree damage. Time and temperature were the major factors in gaging the proper treatment. Gas concentration was a relatively minor factor in individual tree fumigation. Gas concentration of 4 or 5 pounds per 1,000 cubic feet was satisfactory.

4. Fumigation during winter resulted in the least tree damage to all pine species at the 100-percent control level. Fumigation at chamber temperatures of 45° to 65° F. during early spring (March) was likewise satisfactory.

These findings were applied and modified as needed in a test during a 2-week period in mid-November 1961 to determine the feasibility of treating all pines in a representative small commercial nursery. To complete the test as soon as possible, a six-man crew was used. The objective was to develop guidelines for use in fumigating pine nursery stock on the site in portable chambers. The primary value would be in application of findings to a coordinated eradication effort by nurserymen and interested agencies. However, the findings will be of use to individual nurserymen who want to fumigate small numbers of trees at the time of sale.

Three typical situations, requiring somewhat different procedures, were encountered:

1. Single trees and small groups of trees rooted in the ground were treated in standard chambers.
2. Trees in containers were grouped in standard chambers and various means used to protect the roots.
3. Trees in rows were treated in an elongate version of the 5- x 5- x 5-foot chamber with and without the conventional ground cloth.

THE TEST NURSERY

The nursery^{3/} covers about 5 acres, has 16 large planting beds, and contains a variety of trees, shrubs, and annuals. At the time of the tests, there were 302 pines ranging in size from 1-foot seedlings to 11-foot saplings. These trees were growing singly and in small groups, rows, and containers. For the most part the pines were intermixed with other coniferous and hard-wood trees and shrubs, although sections of individual rows were usually restricted to one species. To systematize group treatments, the location and sizes of the various species of pines were plotted on a sketch.

The shoot moth infestation in the pine was described as "moderate." Evidence of shoot moth damage could be found on all sizes, including 1-foot seedlings. Seven species were fumigated; the number of trees of each species, their size, and growing situation were as follows:

<u>Pine species</u>	<u>In ground</u>		<u>In containers</u>		<u>Total number</u>
	<u>Number</u>	<u>Height (Feet)</u>	<u>Number</u>	<u>Height (Feet)</u>	
Mugho	69	1-5	111	1-2	180
Western white	9	5	19	2-4	28
Austrian	5	3-7	13	4-8	18
Lodgepole	13	6-8	5	4-9	18
Japanese red	0	--	10	5-9	10
Scotch	1	11	0	--	1
Red (native)	1	3	1	7	2
	<u>98</u>		<u>159</u>		<u>257</u>

^{3/} Bonnybrook Nursery, 14319 100th Ave. N. E., Bothell, Wash.

METHODS

A gas concentration of 4 pounds per 1,000 cubic feet was used throughout the nursery fumigation. Adjustment of treatment period proceeded as follows:

1. The chamber temperature was measured at the time of gas introduction and every 30 minutes thereafter. Average temperatures were determined for each 30-minute period.
2. At the end of each 30-minute period, a table of absolute vapor pressure was consulted and the pounds-per-square-inch (p. s. i.) value recorded as an index number.
3. The values equivalent to chamber temperatures for 30-minute periods were added together as an index of treatment until the accumulated sum indicated that less than 30 minutes of further treatment was required.
4. The number of minutes in the final time period was determined by interpolation from a table of vapor pressure, using the ratio of additional vapor pressure needed over vapor pressure for the last temperature measured.

A table for conveniently locating the vapor pressure corresponding to a given chamber temperature is shown below:^{4/}

<u>Chamber temperature</u> (Degrees F.)	<u>Vapor pressure</u> (P. s. i.)	<u>Chamber temperature</u> (Degrees F.)	<u>Vapor pressure</u> (P. s. i.)
20-22	10	62-63	23
23-26	11	64-65	24
27-30	12	66-67	25
31-34	13	68-69	26
35-38	14	70-71	27
39-41	15	72-73	28
42-44	16	74-75	29
45-47	17	76-77	30
48-50	18	78-79	31
51-52	19	80	32
53-55	20	81-82	33
56-58	21	83	34
59-61	22	84-85	35

^{4/} Based on data from Chemical Safety Data Sheet SD-35, Methyl Bromide. Manufacturing Chemists' Association, Inc., 1625 Eye Street, N. W., Washington 6, D. C.

The sums of vapor pressure x time units designated for use in fumigating mugho, Scotch, Austrian, and native red pines ranged from 115 to 120. The number of units designated for lodgepole, Japanese red, and western white pines ranged from 110 to 114, because these species are quite susceptible to damage. Analysis of data from tests in residential areas, later, showed that there is no need to reduce the total treatment, when chamber temperatures are below 62° F.

The effect of fumigation on shoot moth larvae was determined by clipping all infested tips, opening the buds, and examining larvae under a binocular microscope. Phytotoxic effects of fumigation were determined by monthly examinations of all trees, starting in January and ending in June 1962.

Single Trees and Small Groups

Three kinds of standard chambers were used. The 5-foot cylindrical chamber was used six times for fumigating single, widely spaced mugho pines, 2 to 5 feet high, and once for a single western white pine with several smaller white pines in containers added to the treatment. The 5- x 5- x 5-foot cubical chamber was used three times for single mugho pines. The 10- x 10- x 10-foot cubical chamber was employed four times, for fumigating a single Scotch pine and groups of 5 lodgepole, 2 Austrian, and 20 trees of miscellaneous species.

Fumigation techniques were uniform except for two treatments of mugho pine. In these the ground tarp was omitted and the wet soil beneath the chamber was used as a gas seal.

Trees in Containers

Two kinds of chambers were used--the 5-foot cylindrical chamber for seedlings in small containers and the 10- x 10- x 10-foot cubical chamber for saplings in large containers. Seedlings in containers were stacked in rows with spaces between each container for gas circulation. Five lots were fumigated; three of these were mugho pines and two were western white pine. The number of trees in each lot ranged from 1 to 82. Saplings in containers were not stacked because of their weight and the relatively small numbers of trees involved. Three lots were fumigated, with one each of lodgepole, Austrian, and Japanese red pine. The number of trees in each lot ranged from five to eight.

Two methods were explored to prevent root damage by gas penetrating into containers. A water seal was used on some of the mugho pine seedlings in small containers; other mughos and all white pines in cans were wrapped in polyethylene bags up to the base of the tree stem. The water seal was obtained by dipping cans in a wheelbarrow of water and by hosing down somewhat larger clay pots and wooden containers. Large containers with saplings were saturated and then were wrapped with pieces of plasticized nylon identical with the material used for chamber jackets.

Trees in Rows

An elongate cubical chamber, adjustable in height and width from 4 to 6 feet and up to 25 feet in length, was built for these fumigations. In some cases, 5- x 5- x 5-foot cubical chambers lined up in a row would have served the same purpose. However, nearly twice as much wood surface would have been exposed, necessitating coating the boards with plastic paint to avoid sorption of gas.

Six 25-foot rows were treated; five of these were mugho pine and one was lodgepole pine. In four lots, the chamber was sealed at the ground line by digging a shallow trench and burying the bottom edge of the chamber jacket 8 inches in the moist soil; the water in the soil under the chamber served as the gas seal. In two lots, two strips of ground cloths were used. In one of these, the cloths were wrapped around the base of each tree. In the other, the two strips were run up to the tree bases, and the intervening spaces around the tree stems and between the strips were packed with wet soil.

Horizontal circulation of gas in these elongate chambers was compared by using two 8-inch household fans in three of the chambers and no circulating devices in the other three chambers. Variation in chamber temperature was checked with thermometers installed at the middle and both ends of each chamber.

DISCUSSION

The weather during the fumigation period caused some operational difficulties. Thawing after freezing temperatures on several nights turned the nursery beds into a sea of mud the next day. The foot traffic along one of the rows resulted in many of the small pines being splattered with mud, raising the possibility that mud encrusted on an infested shoot would prevent gas penetration. On other days, rain occurred and continued through the night. To insure that trees would be relatively dry the next day, at the end of the day's work chambers were placed over trees with the chamber jacket rolled up half-way.

Location of the nursery in a hollow, with a screen of tall trees on the south and west sides, restricted the amount of solar radiation available to heat the chambers. As a result, chamber temperatures for 30-minute periods ranged from 30° to 75° F. over the 2-week period. On several days the diurnal range was from 35° to 50°, resulting in lengthy treatment periods, many over 3 hours. However, temperatures were optimum for preventing damage to the trees by the fumigant.

Use of standard chambers was efficient, because of their simple design and the familiarity of the crew with the procedure. Setting up the elongate cubical chambers, however, was at first a slow process, because of limited space between the rows and some hindrance from overhanging hardwood foliage plus the need for the crew to get acquainted with the chambers.

The mechanics of determining the fumigation period by measuring chamber temperatures every 30 minutes and looking up the vapor pressure index in a table required constant checking. As a result, a simplified table, shown earlier in this report, was prepared. The lengthy fumigation periods increased the chances of arithmetic errors. In one of the 28 treatments, a computation error resulted in a treatment period too short to kill all the shoot moth larvae.

RESULTS

The fumigation test showed that fumigation of an entire commercial nursery is feasible under normal late-fall conditions in the Puget Sound area of Washington. Basic data are shown in tables 1 and 2. Specific findings were as follows:

1. All treatments using standard chambers with ground tarps resulted in 100-percent control. Results were similar both for trees in the ground and trees in containers.
2. Two treatments where wet soil was substituted for the ground tarp showed surviving shoot moth larvae. One used a standard 5- x 5- x 5-foot chamber and the other an elongate cubical chamber. In the former, one larva survived. In the latter, an arithmetic error resulted in a sublethal treatment (106 vp·t units) and seven surviving larvae were found.
3. Tree damage resulting from long treatment periods and relatively low temperatures was minor. Only lodgepole pine and western white pine showed appreciable damage. Some lodgepoles lost the 1960 foliage, with the current growth unharmed, and several western white pines turned red and lost all their foliage. All of these pines survived and produced new growth in spring.
4. Group fumigation of trees had no visible effect on gas concentration. Use of a 4-pound concentration at lower temperatures provides some leeway for increase in gas concentration by additional displacement of air volume by trees, since either 4 or 5 pounds is recommended in Research Paper 47 for temperatures of 52° or below.
5. The need for circulating devices in the elongate cubical chamber was neither proved nor disproved. Small differences in gas concentration occurred, but could have been due to chance.
6. Protection of roots of seedlings in containers was obtained for most species by soaking containers in water. The prompt appearance of damage symptoms on white pine in containers, however, suggested that some root damage had occurred.

RECOMMENDATIONS

1. The 5-foot cylindrical chamber, the 5- x 5- x 5-foot and 10- x 10- x 10-foot cubical chambers, and the recently devised elongate cubical chamber are adaptable to fumigation of commercial nurseries.
2. Standard procedures developed during fumigation of single trees in residential areas should be followed closely in nursery fumigation. Trees must be relatively dry at the time of fumigation, and foliage free of mud and other debris. Substitution of wet soil for the ground tarp as a gas seal is not recommended.
3. Gaging the treatment period by using vapor pressure values to reflect average chamber temperatures for 30-minute periods is an accurate and useful method. However, care must be taken to avoid arithmetic errors. Records should be kept independently by two observers and compared at intervals during fumigation.
4. To minimize tree damage, fumigation of commercial nurseries in western Washington and Oregon should be done at chamber temperatures between 40° and 65° F. If the local weather permits, late fall and winter are acceptable for fumigation operations.
5. Group fumigation of trees is an efficient and effective approach in nursery treatment. Group fumigation of seedlings in containers soaked in water is a useful and timesaving method. Some damage may occur to white pine, but recovery can be expected.
6. Grouping of trees for fumigation should be done according to resistance of different species to methyl bromide damage. Mugho, Scotch, Austrian, and native red pines can be fumigated over a wide range in chamber temperature. Lodgepole, Japanese red, and western white pines should be fumigated only at temperatures below 60° F.

Table 1.--Summary of fumigation treatments made at BonnybrookNursery near Bothell, Wash., in November 1961

STANDARD CHAMBERS--SINGLE TREES AND SMALL GROUPS IN GROUND

Pine species	Number of trees	Height of trees	Chamber size ^{1/}	Ground seal
		Feet	Cu. ft.	
Mugho	1	2	125	Nylon tarp
Mugho	1	4	100	" "
Mugho	1	2	100	Water
Mugho	1	4	100	Nylon tarp
Mugho ^{2/}	2	4	125	Water
Mugho	1	4	125	Nylon tarp
Mugho	1	2	100	" "
Mugho	1	3	100	" "
Mugho	1	3	100	" "
Lodgepole	5	6-8	1,000	" "
Austrian	2	7	1,000	" "
Scotch	1	11	1,000	" "
Miscellaneous	20	2-8	1,000	" "
Western white	9	5	100	" "

STANDARD CHAMBERS--TREES IN CONTAINERS

Western white	1 in can	4	100	Nylon tarp
Mugho	4 in cans	2	100	Water
	4 in cans	2		Plastic
	4 in pots	2		Water
	4 in tubs	2		"
	4 balled	2		Plastic
Mugho	82 in cans	2	100	Water
Mugho	4 in cans	2	100	Plastic
	5 in tubs	2		"
Lodgepole ^{3/}	2 in cans	4-7	1,000	"
	3 in tubs	4-7		"
	1 planted	9		Nylon tarp
Austrian ^{3/}	7 in cans	4-6	1,000	Plastic
	1 planted	8		Nylon tarp
Japanese red	5 in tubs	5-9	1,000	Plastic
Western white	18 in cans	2-4	100	"

See footnotes at end of table.

Table 1--Summary of fumigation treatments made at Bonnybrook

Nursery near Bothell, Wash.,...(continued)

MODIFIED CHAMBERS--ROWS OF TREES IN GROUND

Pine species	:	Number of trees	:	Height of trees	:	Chamber size ^{1/}	:	Ground seal
	:		:		:		:	
				<u>Feet</u>		<u>Cu. ft.</u>		
Mugho		13		1-2		500		Water
Mugho		13		1-2		500		"
Mugho		10		1-2		500		Nylon tarp
Mugho		12		1-2		500		" "
Lodgepole		7		6		600		Water
Mugho ^{2/}		6		5		500		"

^{1/} All 100-cubic-foot chambers were cylindrical with wire mesh frames. The 125- and 1,000-cubic-foot chambers were cubical with board frames. The 500- and 600-cubic-foot chambers were elongate cubical, 25 x 4 x 5 feet and 25 x 4 x 6 feet, respectively.

^{2/} Treatment unit in which surviving shoot moth larvae were found.

^{3/} For efficiency, trees in containers were placed in chamber set up for single large tree rooted in ground.

Table 2.--Results of fumigation treatments at Bonnybrook
Nursery near Bothell, Wash., in November 1961

Treatment number	Pine species	Number of trees	Methyl bromide treatment	Insects		Tree damage
				Total	Killed	
			Vp·t units	Number	Percent	
1	western white	1	110	0	--	A few needles burned
2	mugho	20	116	3	100	None
3	lodgepole	6	110	4	100	1960 foliage burned
4	Austrian	8	115	4	100	Some foliage lost on one tree
5	Japanese red	5	113	0	--	Slight discol- oration of foliage
6	mugho	1	116	6	100	None
7	mugho	1	115	3	100	None
8	mugho	1	116	2	100	None
9	mugho	1	115	0	--	None
10	mugho	2	116	7	86	None
11	mugho	1	101	2	100	None
12	mugho	1	120	1	100	None
13	mugho	1	116	3	100	None
14	mugho	1	117	3	100	None
15	lodgepole	5	110	11	100	1960 foliage burned
16	Austrian	2	116	6	100	A few needles burned
17	mugho	82	108	1	100	None
18	mugho	13	117	30	100	None
19	mugho	13	116	42	100	None
20	mugho	10	115	11	100	None
21	mugho	12	116	7	100	None
22	mugho	9	117	5	100	None
23	Scotch	1	115	0	--	None
24	lodgepole	7	104	84	100	None
25	mugho	6	106	36	81	None
26	western white	18	111	1	100	Several trees scorched
27	miscellaneous	20	116	5	100	Some foliage discolored on Japanese red
28	western white	9	110	0	--	Some burning of foliage