RESEARCH PAPER 47
MARCH 1962

ERADICATING EUROPEAN PINE SHOOT MOTH ON ORNAMENTAL PINES WITH METHYL BROMIDE

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The junior author, R. M. Thompson, is an entomologist in the Plant Pest Control Division, Agricultural Research Service, Sacramento, Calif., and a specialist in large-scale fumigation. His knowledge of fumigation apparatus and techniques was indispensable to the proper planning and conduct of these studies under the time limitations imposed by the nature of the problem.

SUMMARY

The recent introduction of the European pine shoot moth into this region poses a serious threat to natural pine stands. To combat this threat, quarantines were invoked and eradication programs undertaken. Destruction of infested trees has been used tentatively as an eradication technique. In the meantime, fumigation with methyl bromide was tested over the period of a year to ascertain its usefulness in eradication.

Results of this study show that 100-percent control of the shoot moth can be obtained over a wide range of seasonal conditions. Over most of the year, the margin between complete control with minor tree damage and intolerable damage is quite narrow. Lodgepole and Japanese black pines cannot be fumigated without intolerable damage at the higher temperatures prevalent in spring and early fall. In winter, however, with lower temperatures and longer treatment periods, tree damage for all species tested can be kept at a minimum while achieving complete shoot moth control.

For treatment of nursery trees moved to permanent control chambers, it is recommended that fumigation be carried on during the winter months, using a gas concentration of 4 pounds per 1,000 cubic feet for 2-1/2 hours at 62° F., or 4 to 5 pounds for 3 hours at 52°. For treatment of trees in place, a method has been devised which adjusts treatment time according to fluctuations in chamber temperatures. The vapor pressure of the gas is used as an index to the effect of an average chamber temperature obtained for a 30-minute period. Treatment is continued until the sum of these index numbers reaches the desired total effect of time and temperature.

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INTRODUCTION

With discovery of the European pine shoot moth in 1959 on ornamental pines in Seattle, Wash., and elsewhere in Washington and Oregon, a need arose for a method of treatment that would insure complete kill of the shoot moth without serious damage to the infested pine. Emergency measures, adopted at the request of the Northwest Forest Pest Action Council, were taken to prevent spread of the moth to natural stands of pine, especially ponderosa pine. Quarantines were invoked, and eradication was undertaken at Spokane, Wash., and Portland, Salem, and Eugene in Oregon.

Destruction of infested pines was adopted as the only known method of completely destroying known infestations and thereby preventing further spread. While destruction was a desperation measure, it was recognized that some other form of 100-percent effective control would soon be essential. Thus, a crash program of research was undertaken and, fortunately, a suitable method developed, as presented in this report.

This is the first in a series of reports on experimental fumigation with methyl bromide to develop a method for eradication of European pine shoot moth on ornamental pines. This report is based on a series of tests in Seattle, Wash., and vicinity from December 1960 to November 1961, using individual pines in ornamental plantings. Other reports in the series will cover equipment and methods, fumigation of ornamental nurseries, and fumigation of forest-tree planting stock.

These reports are being issued now so that the essential data will be available immediately for quarantine purposes. Later the experimental work and the findings will be reported more fully for research workers and others interested in the details.

From a thorough review of the extensive literature on attempted control of the shoot moth, it was evident that fumigation with methyl bromide offered the best chance of early success. Tests in the Lake States and in Canada have shown this method to give a very high degree of control, but did not conclusively demonstrate that it could be used as an eradication measure. Methods for field use had to be devised.

The testing program required a great deal of cooperation. Many public-spirited home owners made their ornamental pines available for the tests despite the knowledge that some of the trees would be killed. Employees of the Washington State Department of Natural Resources located test trees and carried the brunt

of the public relations program. National Forest Resource Management provided funds and manpower for the fumigation and administering of the project. The Pacific Northwest Forest and Range Experiment Station, with the assistance of the Agricultural Research Service, planned, directed, and analyzed the technical phases of the project.

OBJECTIVES

The first aim of the study, basic to the conduct of subsequent tests, was to develop a standardized method of applying methyl bromide to outdoor-growing trees, utilizing or modifying existing equipment as needed. The achievement of this aim is described under "Preliminary Studies."

Subsequent objectives were to define for the most common tree hosts and for specific times of the year:

(a) the relative importance of treatment factors (moisture, gas concentration, temperature, time period, and tree species) in causing shoot moth mortality and damage;

(b) combinations of treatment factors at which 100-percent shoot moth mortality is obtained; and

(c) combinations of treatment factors at which phytotoxicity becomes intolerable.

PRELIMINARY STUDIES

In December 1960, various factors affecting the mechanical application of the gas were tested. These included: (1) need for forced circulation (fans), (2) size of chambers, (3) time gas was held in chambers, (4) temperature during treatment period, and (5) density of tree canopy. In all tests the gas was heated as it was introduced into the fumigation chambers. The findings were to be utilized in prescribing a standard method of application used in subsequent tests.

Results of these tests will be reported separately. As background for this report, however, it can be stated that satisfactory gas circulation and gas retention were obtained for 3 hours or more, without forced circulation, using three of four chamber sizes tested. Neither temperature nor canopy density had significant effects on gas circulation. However, it was found with mugho pine that failure to leave space between the top of the tree crown and top of the chamber resulted in abnormally low insect mortality.

Two chamber sizes found satisfactory--5'x5'x5' and 10'x10'x10'--were used to enclose trees of appropriate size in ensuing tests. Gas was consistently introduced in heated form. With mugho pine, it was prescribed that "head space" be at least 1-1/2 to 2 feet.

METHODS AND PROCEDURES

Four test periods were chosen to encompass the range of tree host and insect development considered likely to affect the results of fumigation as follows:

Test period	Tree condition	Insect condition
Winter (December)	Dormant	Third instar larvae, inactive
Early spring (March-April)	Buds dormant or commencing to swell	Third and fourth instar larvae, starting to feed
Late spring (May)	Shoots half grown	Larvae full grown, pupation commencing
Fall (September-November)	Entering dormancy	Third instar larvae, active

In December alone, the effect of a film of moisture over the tree parts was studied in relation to effectiveness of fumigation, as measured by shoot moth mortality. In all test periods, the effects of gas concentration, time, temperature, and tree species were studied in relation to shoot moth mortality and tree damage. Gas concentration was expressed in pounds per cubic foot for planning purposes, but check measurements in ounces per cubic foot were obtained with a thermal-conductivity gas analyzer during the treatment of each tree. Time was expressed in hours and half hours. Temperature ranges were employed to gear treatments to existing weather; temperature was measured every 30 minutes at midchamber height by means of an 8-inch photographic solution thermometer inserted into the chamber. The differential between outside and chamber air temperatures was measured to estimate the effects of solar radiation and was used as a guide in designing tests. Five species of pines were used: winter--mugho (*Pinus mugo* Turra), Scotch (*P. sylvestris* L.), lodgepole (*P. contorta* Dougl.), and Japanese black pine (*P. thunbergii* Parl.); early and late spring--mugho and Scotch; fall--Scotch, lodgepole, Austrian (*P. nigra* Arnold), and Japanese black pine.

Shoot moth mortality was determined for each tree by clipping up to a maximum of 100 infested bud clusters and opening the buds under a microscope. If a larva showed movement in any of its body parts, it was considered a survivor. An attempt was made to separate natural mortality from that caused by the gas.

Tree damage caused by methyl bromide was expressed in arbitrary damage classes, with records being obtained at regular intervals over a period of 6 months. Early symptoms of damage, particularly in terms of resinosis--

droplets of resin on needles--were determined by close examination within the first 2 weeks after treatment. Damage classes are given below:

Class	Damage intensity	Symptoms of damage
A	No damage	No discoloration of foliage, although occasional resinosis may occur at extreme needle tips
B	Light	Apical 1/16 to 1/2 inch of needles turning brown
C	Moderate	Some foliage with entire needles turning brown
D	Heavy	Complete foliage loss, although new shoots or adventitious buds may subsequently form
E	Severe	Tree dead or dying, as shown by discoloration in cambial region of branches

Relative Importance of Treatment Factors

Basic to the whole analysis was a means for expressing the combined effects of time and temperature in one unit. This expression was needed to interpret the effects of all other factors, as well as the individual effects of time and temperature.

The combined effects were approximated by using as an index number the vapor pressure of the gas equivalent to the average chamber temperature obtained for a 30-minute period and accumulating these index numbers according to the number of 30-minute periods constituting the treatment. Vapor pressure values were obtained by interpolation of tabulated values for 20-degree intervals in Dow's specifications on methyl bromide. Henceforth in this report the sums of these units of vapor pressure x time will be called vp. t sums.

Effect of a uniformly moist tree condition on shoot moth mortality was determined by comparison of treatments on five pairs of mugho pines. One tree in each pair was given an atomized water spray until a fine film of moisture remained on the tree. The other was thoroughly dried by use of a squirrel-cage blower. Inside and outside temperatures were recorded and gas concentration measured every 30 minutes during a 2-hour treatment. Shoot moth mortality was determined by removing and examining every infested bud cluster on each tree.

Statistical analysis was used to determine whether significant differences in percent mortality occurred between trees in treated pairs, and correlation was attempted between vp.t sums and mortality.

The significance of time and temperature on shoot moth mortality was determined by methods described under "Treatment Factors Causing Complete Shoot Moth Mortality" (below).

The relationship of time and temperature to tree damage was determined for each test period. Damage class of each tree was plotted over vp.t sums for each tree species.

The relationship of temperature alone to shoot moth mortality could not be determined from these data.

The relationship between temperature and tree damage was determined by comparing damage class for each tree with average chamber temperature, for each tree species, treatment period, and time of year. The lowest temperatures associated with the start of damage in each damage class were tabulated for each set of conditions. Since small differences in temperature may have a significant effect over a period of time, comparison of total treatments in terms of vp.t sums was also made. The latter shows how much treatment is tolerated at a given temperature before a specific degree of damage occurs (table 1).

The importance of gas concentration on shoot moth mortality was determined by (a) inspection of data for the early and late spring tests, since shoot moth kill was nearly complete, and (b) graphing percent mortality over vp.t sums for the fall tests to show separate trend lines for 3 and 4 pounds by tree species.

The relation of gas concentration to tree damage was determined for each test period except winter by plotting damage class for each tree by species and gas concentration over corresponding vp.t sums.

The relationship of tree species to shoot moth mortality and tree damage was determined by methods used in the preceding sections.

Treatment Factors Causing Complete Shoot Moth Mortality

The study approach was to follow a split-plot statistical design replicating time, temperature, gas concentration, tree species, and locality. Following the rather restricted winter tests, the plan was to use broad ranges in treatment factors and to narrow these ranges in subsequent testing periods. As a result, the relationship between combinations of treatment factors and complete shoot moth mortality could be determined with precision only in the fall tests. However, in the winter tests the arbitrarily chosen range in treatment factors also produced very useful data. A summary of treatments over the year is shown in table 2. Progress by test periods is summarized below.

Table 1.--Comparison of lowest average chamber temperatures at which different degrees of damage occurred on different pine species with different treatment periods at three times of the year

Time of year (months)	Pine species	Treatment period	Lowest chamber temperature at which different degrees of damage occurred				Total treatment tolerated by trees			
			Class B	Class C	Class D	Class E	Class B	Class C	Class D	Class E
		Hours	-------- Degrees F. ---------				------- Vp.t sums ---------			
March-April	Mugho, Scotch	2	55	62	79	66	80	92	126	100
	do.	2½	53	60	66	1/80	97	110	125	160
	do.	3	54	59	62	62	120	132	138	138
May	Mugho, Scotch	1½	88	88	86	93	111	111	108	120
	do.	2½	--	1/78	1/74	84	--	155	145	175
September-October	Austrian, Scotch	1½	78	1/87	--	--	93	111	--	--
	do.	2	69	1/79	--	--	106	126	--	--
	Japanese black, lodgepole	1½	--	74	83	81	--	87	102	99
	do.	2	62	66	69	--	92	101	106	--

1/ Single tree represented.

Table 2.--Summary of fumigation treatments on ornamental pines in and near Seattle, Wash., December 1960 to November 1961

Test period (month and year)	Species of pine	Trees[1/]	Gas concentrations	Temperature ranges	Treatment time
		Number	Pounds per 1,000 cubic feet	Degrees F.	Hours
December 1960	Mugho	10	5	32-72	2
	Scotch	6	5	32-72	3
	Mugho	4	5	32-72	3
	Japanese black	2	5	32-72	3
	Lodgepole	8	5	32-72	5
March-April 1961	Scotch	2	4	45-65	2
		2	4	45-65	2½
		2	4	45-65	3
		2	5	45-65	2
		2	5	45-65	2½
		2	5	45-65	3
		2	6	45-65	2
		2	6	45-65	2½
		2	6	45-65	3
	Scotch	2	4	66-85	2
		2	4	66-85	2½
		2	4	66-85	3
		2	5	66-85	2
		2	5	66-85	2½
		2	5	66-85	3
		2	6	66-85	2
		2	6	66-85	2½
		2	6	66-85	3
	Mugho	2	4	45-65	2
		2	4	45-65	2½
		3	4	45-65	3
		2	5	45-65	2
		2	5	45-65	2½
		3	5	45-65	3
		2	6	45-65	2
		3	6	45-65	2½
		2	6	45-65	3

See footnote at end of table.

Table 2.--Summary of fumigation treatments...(Continued)

Test period (month and year)	Species of pine	Trees[1/]	Gas concentrations	Temperature ranges	Treatment time
		Number	Pounds per 1,000 cubic feet	Degrees F.	Hours
March-April 1961	Mugho	4	4	66-85	2
		2	4	66-85	2½
		2	4	66-85	3
		2	5	66-85	2
		2	5	66-85	2½
		2	5	66-85	3
		2	6	66-85	2
		2	6	66-85	2½
		2	6	66-85	3
May 1961	Scotch	4	3	65-105	1½
		4	3	65-105	2½
		4	4	65-105	1½
		4	4	65-105	2½
	Mugho	4	3	65-105	1½
		4	3	65-105	2½
		4	4	65-105	1½
		4	4	65-105	2½
September-November 1961	Scotch	4	3	60-75	2
		4	4	60-75	2
		2	3	76-85	1½
		2	4	76-85	1½
	Austrian	5	3	60-75	2
		5	4	60-75	2
		2	3	76-85	1½
		2	4	76-85	1½
	Lodgepole	4	3	60-75	2
		4	4	60-75	2
		2	3	76-85	1½
		3	4	76-85	1½
		3	4	40-49	3¼-3½

See footnote at end of table.

Table 2.--Summary of fumigation treatments...(Continued)

Test period (month and year)	Species of pine	Trees[1/]	Gas concentrations	Temperature ranges	Treatment time
		Number	Pounds per 1,000 cubic feet	Degrees F.	Hours
September-November 1961	Japanese black	4	3	60-75	2
		4	4	60-75	2
		2	3	76-85	1½
		3	4	76-85	1½
	Total	194	--	--	--

1/ Duplicate treatments included.

December.--A total of 22 trees had sufficient shoot moth populations to be useful for analysis. Complete kill of shoot moth larvae was obtained on 13 trees; survivors were found on 9 other trees. Data from eight additional trees were not usable, chiefly because of insufficient shoot moth populations. However, two of these were characterized as abnormal since the trees (mugho pine) completely filled the chambers, and one lodgepole pine, treated for 5 hours, died. Number of larvae per tree averaged 34, ranging from 11 to 90.

March.--A total of 77 trees, including 6 duplicate treatments, was fumigated. Only two trees showed survivors; each had one larva. Proving realistic were two temperature ranges, planned to coincide with overcast and clear weather respectively. Check examinations for molting and migration of larvae were made to detect differences in larval exposure to the fumigant, as compared with the winter period. As a result of too broad a span in the higher temperature range, 10 trees died following treatment. Number of larvae per tree averaged 41 and ranged from 2 to 130.

May.--A total of 32 trees was treated. Because rainy weather delayed the start of the tests until pupation was imminent, trees were treated at random temperatures. During the first 5 days of testing, a sudden change to warm weather caused higher chamber temperatures than desired. As a result, 12 trees died following fumigation. On two undamaged trees, single specimens of living pupae were found. Number of larvae and pupae per tree averaged about 50 and ranged from 12 to 150.

September-November.--A total of 55 trees, including duplicate and special treatments, was fumigated. Complete kill of larvae was obtained on 22; survivors were found on 33 trees. This was the most sensitive test of the year, because of the large numbers of larvae on test trees. Of 2 blocks of 32 trees each, 1 was completed early in October as scheduled. Cold and rainy weather delayed progress on the second block until it was necessary to eliminate the higher temperature range from the test. Eventually strip heaters were used to fumigate the last five trees at the desired temperature. Use of narrow temperature ranges and only one time period per temperature range resulted in close control of the experiment. Number of larvae per tree averaged 84 and ranged from 2 to 398. The tree having 398 larvae showed 1 survivor.

Interpretation.--Data on the incidence of complete shoot moth mortality from different test periods varied in their usefulness for analysis. For the winter and fall tests, percent shoot moth mortality was plotted by tree species over vp.t sums. For the early and late spring tests, in each of which only two trees showed survivors, inspection of data was sufficient. Summary of survival and mortality of the shoot moth at different sums of vp.t units for all tests is presented in table 3.

Variation in insect mortality with time of year could only be deduced. Such deductions have a relatively sound basis only for the winter and fall tests.

Treatment Factors Causing Intolerable Tree Damage

Intolerable damage is defined in this report as damage which may lead to the death of the tree. Damage in class C, involving partial foliage loss, is considered as tolerable. Damage in classes D and E is regarded as intolerable.

An explanation for variation in damage between tree species given the same or similar treatment, in terms of vp.t sums, was sought. This variation was noticeable with Scotch, mugho, and Austrian pines, and striking with lodgepole and Japanese black pines. A previously mentioned method was used. Damage class for each tree by species was plotted over average chamber temperature for each treatment period.

The key analysis regarding intolerable damage was concerned with the amount of damage occurring at the point where the vp.t sums insure 100-percent control of the shoot moth. Graphs of damage class over vp.t sums were taken and a vertical line drawn through the "critical point." The number of trees in each damage class to the left of the line (below the critical point) was counted and expressed as a percent of the total. The percentage of trees falling into classes D and E represent the amount of intolerable damage to be accepted at the optimum treatment. A table was prepared to show the average incidence of damage to be expected at all times of the year, with the exception of the late fall block on which records are not complete. Figure 1 illustrates the analytical procedure for the March tests.

Table 3.--Results of fumigation treatments on European pine shoot moth in relation to sums of vapor pressure x time units, at four times of the year, for trees surviving fumigation

Test period (month and year)	Total trees	Trees with shoot moth surviving at vp.t sums of--						Trees with shoot moth eradicated at vp.t sums of--					
		Below 96	96-100	101-105	106-110	111-115	Over 115	Below 96	96-100	101-105	106-110	111-115	Over 115
	Number	Number						Number					
December 1960	22	8	1	0	0	0	0	1	1	1	1	3	6
March-April 1961	67	1	0	0	0	0	1/ 1	11	5	4	5	2	38
May 1961	20	1	0	1	0	0	0	2	0	1	2	3	10
September-November 1961	55	12	6	5	5	2/ 5	0	2	2	6	4	6	2
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
December 1960	--	89	50	0	0	0	0	11	50	100	100	100	100
March-April 1961	--	8	0	0	0	0	1/ 3	92	100	100	100	100	97
May 1961	--	33	0	50	0	0	0	67	0	50	100	100	100
September-November 1961	--	86	75	45	55	45	0	14	25	55	45	55	100

1/ Single larva on tree seriously damaged by fumigation apparently migrated from nearby untreated pine.
2/ Two Japanese black and three lodgepole pines.

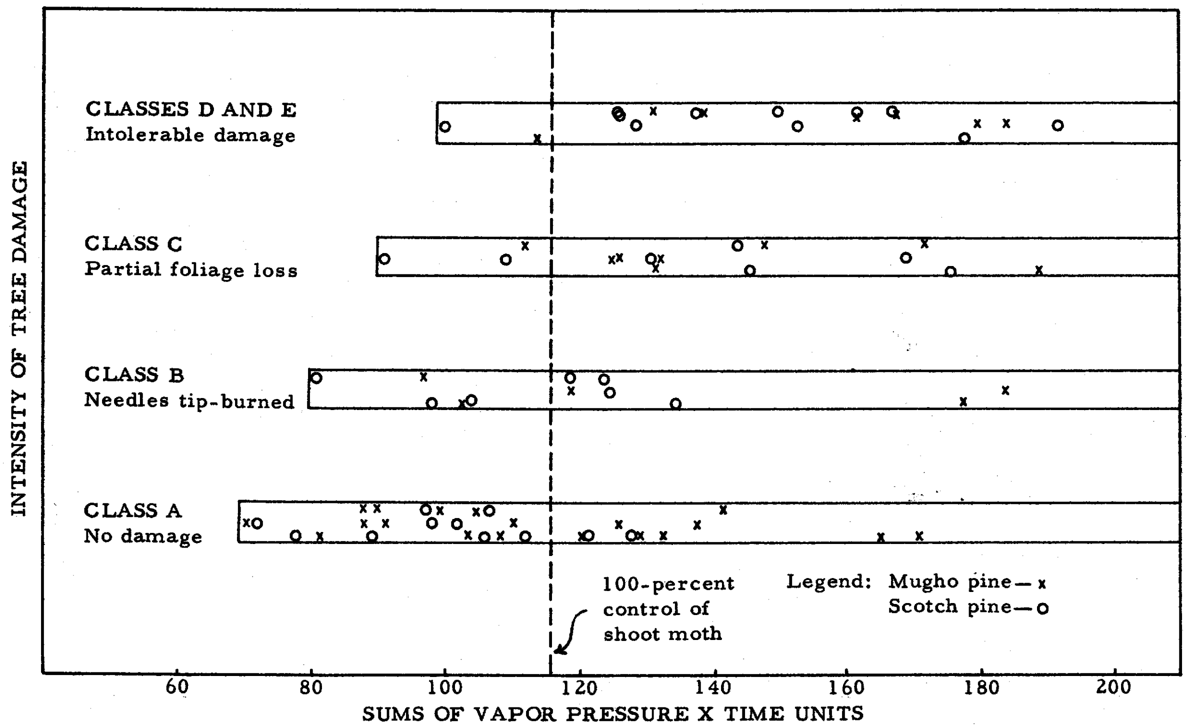

Figure 1.--Relationship of degree of damage resulting from fumigation to sum effect of time and temperature, and dividing line at which 100-percent control is consistently obtained, March 1961.

RESULTS

Relative Importance of Treatment Factors

1. A uniformly moist tree condition was found to have no significant relationship to shoot moth mortality. On the other hand, the mortality on individual trees was correlated with vp.t sums. Because of the wide range of temperature in the test, it is still possible that at temperatures around 40° F. moisture may reduce kill of shoot moth.

2. Time and temperature were the major factors affecting shoot moth mortality and tree damage.

3. Temperature had an independent effect on tree damage, aside from its combination effect with time. Incidence of damage in each tree class was greater as the average chamber temperature increased, even with the same sum of vp.t units.

4. Gas concentration, within the range tested, had no visible effect on shoot moth mortality and tree damage. No differences could be found between 4,

5, and 6 pounds per 1,000 cubic feet during early spring and 3 and 4 pounds during late spring and fall.

5. Tree species was a factor in damage. The species most resistant to damage at all temperatures were Scotch, mugho, and Austrian pines. In the fall tests both Japanese black and lodgepole pines were susceptible to damage when average chamber temperatures exceeded 60°. At higher temperatures, damage to Japanese black pine was generally tolerable, while that on lodgepole was mainly intolerable.

Treatment Factors Causing Complete Shoot Moth Mortality

1. Complete shoot moth mortality in the fall tests was obtained with combinations of time and temperature resulting in a sum of 116 vp.t units. Transposed, the following are convenient treatments:

1-1/2 hours	90° chamber temperature
2 "	74° " "
2-1/2 "	62° " "
3 "	52° " "
3-1/2 "	40° " "

The basis for selecting 116 vapor pressure x time units as the standard for obtaining complete shoot moth mortality is shown in table 3.

2. The extent of variation in shoot moth mortality with time of year could not be clearly defined. However, the point at which complete mortality occurred during December, March, and May was apparently below that established in the fall tests. In March, most of the larvae migrated to new buds following a molt, and some killed larvae were found outside the buds. One exceptional recovery occurred in the March tests--a fresh attack by an active larva was found on a seriously damaged tree. It is believed that the larva migrated from nearby unfumigated trees.

3. Variation in shoot moth mortality with tree species was not clearly evident. However, all four trees having a surviving shoot moth (one survivor on each tree) in the March and May tests were Scotch pine. Mugho pine was the other tree species equally represented in these tests. In the fall test, percent survival at any given sum of vp.t units was higher on lodgepole and Japanese black pines than on Scotch and Austrian pines. In this test all survivors at 111-115 vp.t units were on lodgepole and Japanese black pines.

Treatment Factors Causing Intolerable Tree Damage

1. Time, temperature, and tree species were the major factors related to damage. Gas concentration within the range tested appeared to have no significant effect.

2. Except in the winter tests, the margin between obtaining 100-percent control with tolerable damage and intolerable damage was very narrow, even for mugho, Scotch, and Austrian pines. It was determined that two sensitive species--lodgepole pine and Japanese black pine--cannot be fumigated without serious damage, except in late fall and winter.

3. In the winter tests the margin between 100-percent control and serious damage was relatively broad. No damage occurred up to a sum of 116 vp.t units. Insufficient data were obtained to pinpoint the start of serious damage.

4. In early spring, late spring, and early fall fumigation at prescribed time and temperature, a small proportion of the resistant species suffered intolerable damage. No significant difference in the incidence of damage was found between these three times of year. The distribution of damage at 116 vp.t units for Scotch and mugho pines for the three periods, is shown below:

Damage class	Trees (number)	Trees (percent)
A	38	65
B	11	19
C	5	9
D + E	4	7
Total	58	100

The reason for pooling classes D and E is that both show complete loss or death of foliage, which is classed as intolerable damage. Periodic records on phytotoxicity show that 50 percent of the trees losing all their foliage eventually die.

5. In late fall and winter fumigation at average chamber temperatures below 60°, the incidence of damage is somewhat reduced, even though a longer treatment period is required.

CONCLUSIONS

1. Because of the narrow margin between complete shoot moth kill and the incidence of serious damage, recommended procedures must be followed closely to obtain the desired eradication results.

2. In eradication programs in which time is at a premium, ornamental pines can be fumigated at any chamber temperature between 45° and 100° F. Duration of treatment must be adjusted according to the vp.t sums as treatments proceed.

3. Outdoor treatments of nursery stock rooted in the ground should be made during winter so that all pine species can be treated with a minimum of damage resulting. Time of treatment must be adjusted according to chamber temperatures, using vp.t sums as in item 2.

4. For treatments of lifted or potted nursery stock to be made in a permanent chamber under controlled conditions, the best combinations of treatment factors, as determined from a vp.t sum of 116, are as follows:

Gas concentration (pounds per 1,000 cubic feet)	Chamber temperature (degrees F.)	Treatment period (hours)
4	62	2-1/2
4 or 5	52	3

These recommendations will produce minimum damage to foliage. Roots must be protected by soaking soil around potted trees and enclosing root balls of lifted stock with polyethylene. A complete list of all time and temperature combinations satisfactory for use is given in table 4.

Table 4.--Combinations of treatment factors which will produce 100-percent control of European pine shoot moth with minimum tree damage (gas concentration--4 pounds per 1,000 cubic feet)

Chamber temperature (degrees F.)	Treatment period		Chamber temperature (degrees F.)	Treatment period	
	Hours	Minutes		Hours	Minutes
45	3	28	68	2	14
46	3	24	69	2	11
47	3	19	70	2	9
48	3	15	71	2	7
49	3	12	72	2	4
50	3	8	73	2	2
51	3	5	74	2	0
52	3	1			
			75	1	58
53	2	58	76	1	56
54	2	55	77	1	54
55	2	52	78	1	52
56	2	49	79	1	50
57	2	46	80	1	49
58	2	43	81	1	47
59	2	41	82	1	44
60	2	38	83	1	42
61	2	35	84	1	41
62	2	31	85	1	39
63	2	28	86	1	37
64	2	25	87	1	35
65	2	22	88	1	33
66	2	19	89	1	32
67	2	16	90	1	30