Minimum Temperature for Methyl Bromide Eradication of *Ceratocystis fagacearum* in Red Oak Log Pieces

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ABSTRACT

Schmidt, E. L. 1983. Minimum temperature for methyl bromide eradication of *Ceratocystis fagacearum* in red oak log pieces. Plant Disease 67:1338-1339.

Fumigation of naturally infected red oak log segments with methyl bromide eliminated the oak wilt fungus (*Ceratocystis fagacearum*) in sapwood at temperatures as low as 0 C. Fungus survival was sporadic in log sections fumigated at −5 C and subsequently aired for 4 days at 0 C. Fumigations at −10 C were not effective even when gas levels or exposure durations were increased by 50%.

Concern about accidental introduction of the oak wilt fungus (*Ceratocystis fagacearum* (Bretz) Hunt) into member nations of the European Economic Community has prompted rigid safeguards against importation of oak trees that might retain viable spores or mycelium. Importation of oak at high moisture content, ie, with some bark remaining, is considered undesirable. An effective methyl bromide (MB) treatment schedule that kills the oak wilt fungus in red (*Quercus rubra* L.) and white (*Q. alba* L.) oak logs and lumber has been developed from outdoor trials through the cooperative efforts of scientists in the United States and West Germany (3,5–8).

Treatment with pure MB at a rate of 240 g/m^3 of space beneath a polyethylene cover (with gas added after 24 hr to regain the original concentration) killed the fungus in oak sapwood when treatment duration was 3 days for logs and 2 days for lumber. No discoloration or degradation was noted in lumber or veneer cut from fumigated white oak logs. More than 20,000 isolation attempts from logs and more than 2,000 attempts from lumber confirmed that the fungus is eradicated at temperatures as low as 5 C (6).

The purpose of this investigation was to determine the minimum temperature at which *C. fagacearum* in infected oak log sections could be killed using the aforementioned fumigation schedule. Such data would be useful in formulating commercial treatment guides. Costs of supplemental heating of logs during winter fumigations could be reduced if the treatment killed the fungus at temperatures below 5 C. Pest control work with MB has shown that the successful treatment of a given commodity at various temperatures and gas concentrations cannot be accurately predicted from known laws and generalizations and that empirical data are a more reliable base for treatment recommendations (4).

Paper 13,394, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 55108.

Based on a presentation made at the 14th Annual Meeting of the International Research Group on Wood Preservation, Australia. IRG/WP/3243.

Accepted for publication 9 June 1983.

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MATERIALS AND METHODS

Naturally infected red oak boles (two trees cut in July 1982 and two cut in September, all with more than 75% of foliage wilted) were cut into 1-m segments and stored at 0 C to maintain viability of the oak wilt fungus until isolation and fumigation. For each fumigation trial, two log segments from different trees were sampled at each end (cross sections 5 cm thick, each sampled as described by Schmidt et al [8] at 50 sapwood locations around the circumference) for *C. fagacearum* using Barnett's oak wilt medium (1). Log sections were then end-coated with water-emulsified asphalt and aluminum foil to ensure gas penetration through the bark rather than through exposed ends. Thermometers were inserted in log segments to the sapwood-heartwood boundary and the segments were equilibrated in a controlled-temperature chamber (sealed for fumigation) until sapwood temperature reached air temperature (1–5 days). The chamber also contained a recording thermograph and small fan for gas dispersion. Pure MB was added through a volatilizer (copper coil in water at 50 C) at a rate of 240 g/m^3 of chamber space. Gas concentrations in the chamber were monitored periodically with a thermal conductivity gas analyzer to determine the CT (concentration × time) product, a value reflecting severity of treatment.

At the end of a fumigation trial, the chamber was vented for 15 min before the log sections were removed to a walk-in storage unit maintained at 0 C. After 4 days in the aerating unit, two cross sections were cut equidistant from the sealed ends of each log section and sampled as before for oak wilt fungus.

Fumigation trials began at 5 C (air and sapwood temperature) with subsequent attempts at 0, −5, and −10 C. Also, treatment severity was increased by 50% in gas loading or duration of fumigation at −10 C in attempts to lower the lethal threshold temperature.

RESULTS AND DISCUSSION

Fungus isolation results after fumi-

Table 1. Methyl bromide fumigation of log segments of *Quercus rubra* naturally infected with *Ceratocystis fagacearum* at various temperatures

Trial no.	Treatment severity (CT)[a]	Temperature of sapwood during treatment (C)	Temperature during incubation after venting (C)	Frequency of isolation of *C. fagacearum* (% positive from 200 attempts)[b]	
				Before gas	After gas
1	16,128	+5	0	33	0
2	15,504	0	0	37	0
3	14,976	0	0	30	0
4	14,592	−5	0	47	0
5	15,696	−5	0	16	0
6	15,648	−5	0	27	2
7	14,928	−5	−5	42	17
8	13,776	−10	0	16	16
9	15,168	−10	0	19	27
10	21,168[c]	−10	0	47	15
11	22,188[d]	−10	0	37	21

[a] CT = (average gas concentration in g/m^3) × time (hr).
[b] 100 samples from each of two replicate logs sampled before and after treatment.
[c] Gas dosage increased to 360 g/m^3 (50% higher than in all other trials) and boosted to this concentration after 24 hr.
[d] Exposure time increased to 108 hr (50% greater than standard duration).

gations are presented in Table 1. Treatments at −10 C (trials 8–11) were ineffective, even when treatment severity was increased by a 50% higher initial gas level (trial 10) or a 50% increase in duration of fumigation (trial 11). Log segments fumigated at −5 C and stored after venting at the same temperature also retained viable fungus (trial 7). The fungus was isolated from just one of six oak sections treated at −5 C and stored at 0 C (trials 4–6), whereas all fumigations at 0 C and higher completely eliminated *C. fagacearum*. Fungus isolation frequency averaged 33% (66/200) from log segments before effective treatments. The 4-day delay between removal of log segments from the gas and final isolation attempts permitted sorbed gas to complete its fungicidal action. Penetration studies have shown that gas concentrations deep in the sapwood increase for 3 days after ventilation of gas from the chamber (3). Chi-square analysis showed the effect of gas treatment on fungus recovery to be highly significant ($P < 0.001$).

Field tests with commercial-size logs have shown that the oak wilt fungus can be killed with MB during cool weather (as low as 5 C) in black (*Quercus velutina* Lam. [2]), red, and white oaks (6,8). Treatment severities (as reflected in the CT value) measured in this chamber study were only slightly (9% average) higher than those measured for log fumigations under tarp (6).

These data suggest that fumigation of oak logs using the successful field trial schedule of 240 g MB/m^3 (boosted after 24 hr) for 3 days will kill the oak wilt fungus if sapwood temperature remains at 0 C or higher. The low isolation rate of fungus after the trials at −5 C (four positive of 600 attempts) indicates that enough MB is sorbed or otherwise penetrates the logs at −5 C to be fungicidal if logs are subsequently stored at 0 C during degassing. This would allow some margin for error if sapwood temperatures were required to remain at 0 C or higher during fumigation. Thus, an unexpected or uncontrollable temperature decrease during the 3-day fumigation would have to lower sapwood temperature below −5 C to jeopardize the efficacy of the treatment.

ACKNOWLEDGMENTS

I wish to thank the National Lumber Exporters Association for support, M. Dietz and T. Hubbard for technical help, and the APHIS Methods Development Lab, Hoboken, NJ, for providing equipment.

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