Methyl Bromide Fumigation of Containers Filled with Growing Media[1]

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Abstract.--Containers filled with peat-vermiculite growing media were fumigated with methyl bromide/chloropicrin (98%;2%), which was more effective than heat sterilization in controlling a soilborne disease. Because small volumes of growing media are isolated in spacially separate containers, considerably lower fumigant application rates were effective. Economic analysis proved methyl bromide fumigation to be cost effective because seedlings grown in treated containers were consistently larger.

INTRODUCTION

The greenhouse complex at the W.H. Horning Tree Seed Orchard was built in 1976 and is operated by the USDI-Bureau of Land Management to produce seedlings for tree improvement activities in northwestern Oregon. Annual production in the two shelterhouse-style greenhouses averages around 650M seedlings, depending on which container size is used. Reforeatation seedlings are grown in Ray Leach pine cells R [4 in^3 (65 cm^3)], whereas grafting root stock and seedlings for progeny tests are produced in Ray Leach super cells R [10 in^3 (164 cm^3)].

During the 1982 growing season, several Northwest container nurseries began noticing a needle tip twisting and necrosis of Douglas-fir [Pseudotsuga menziesii (Mirb.)Franco] and other conifer seedlings. These initial symptoms were followed by stunting, chlorosis, and sometimes death of the affected seedlings. Because this species was most commonly affected, this disorder became known as Douglas-fir dieback (Rusted 1988). Dieback symptoms are characteristic of many different types of root injury, including damage from fungal pathogens which could be transmitted in certain batches of growing media.

Container nursery managers observed that the symptomatic seedlings were often restricted to individual containers or blocks of containers (fig. 1). This "block effect" could be caused by a problem with reusable containers, or contaminated batches of growing media. Because the disease was more prevalent in previously-used containers, one hypothesis was that some sort of biological pathogen was being carried over between crops in the growing media that remained in the used containers. Another possibility was that batches of the peat-vermiculite growing medium could have become contaminated with a soilborne pathogen, and then distributed to specific groups of containers.

CONTAINER/GROWING MEDIA STERILIZATION TREATMENTS

Beginning in 1984, a series of operational experiments were conducted at the Horning greenhouse to see if the dieback problem could be cured with sterilization treatments of the containers or growing media. A battery of 21 different treatments was tried on a small scale during the 1984 growing season (fig. 2), but the only promising one involved heat sterilization of the growing medium in an autoclave. The soilborne pathogen hypothesis was further strengthened by the fact that healthy seedlings could be grown in batches of "bad soil" (media collected from containers with symptomatic seedlings) after it was autoclaved. Contaminated containers were also a possibility because a test between new and re-used containers revealed that 94% of the seedlings in the used containers exhibited dieback symptoms, compared to only 6% in the new containers.

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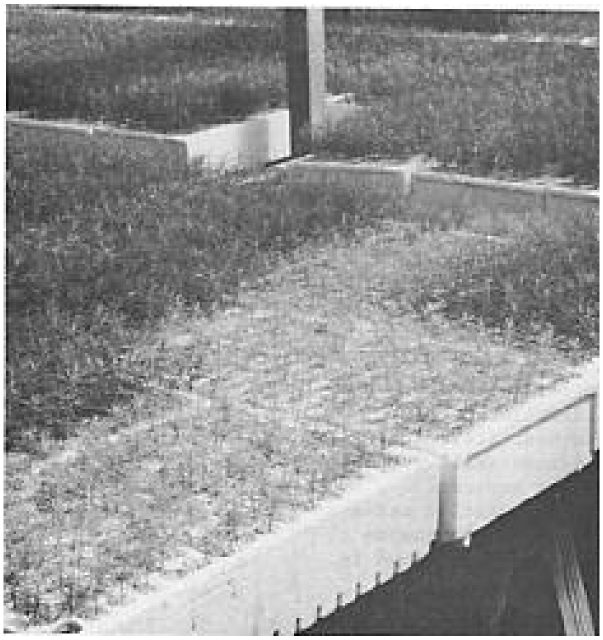

Figure 1 - The "block effect", in which disease symptoms are restricted to seedlings in certain used containers, is thought to be related to soilborne pathogens which are transmitted on particles of growing media or root pieces that remain in the container between crops.

Based on these promising initial trials, two different methods of heat sterilization of the growing media were tested during the 1985 growing season. One batch of growing media was again autoclaved, and another treatment consisted the standard horticultural practice of steam sterilizing growing media, which was contracted to a local ornamental nursery. The steam sterilization contract specified that the growing media bheld at a temperature of 200 °F (94 °C) for 30 minutes, instead of the normal heat pasteurization treatment which consists of temperatures of only 140 to 177 °F (60 to 82 °C) for the same time period. Following these heat treatments, the growing media was loaded into containers, and sown in the normal manner. A third growing media sterilization treatment with methyl bromide fumigation was added to further test the soilborne pathogen hypothesis. In this treatment, containers were filled with peat-vermiculite growing media and then fumigated with 98% methyl bromide/2% chloropicrin (MBC-2). At the end of the specified aeration period these filled containers were sown and placed in the greenhouse, and the seedlings were grown under normal nursery culture.

The 1985 sterilization trials revealed that, although the steam sterilization treatment gave poor results, both the autoclaved growing media and the MBC-2 fumigation greatly reduced or even

Figure 2 - Early operational trials with a variety of different container and growing media treatments showed that heat sterilization greatly reduced the number of symptomatic seedlings.

Table 1 - Container and growing media sterilization trials at the W.H. Horning greenhouse in 1985

TREATMENTS	NUMBER OF SEEDLINGS TOTAL	NUMBER OF SEEDLINGS SYMPTOMATIC	PER CENT OF TOTAL
STEAM STERILIZED GROWING MEDIA	154	49	31.8 %
AUTOCLAVED GROWING MEDIA	180	8	4.4 %
MBC-2 FUMIGATED GROWING MEDIA IN CONTAINERS[1]	194	0	0.0 %

[1] - Containers filled with growing media were fumigated with methyl bromide/ chloropicrin (98%:2%)

eliminated the number of symptomatic seedlings (table 1). Note that the steam sterilization and autoclave treatments involved only the growing media whereas the methyl bromide fumigation treated both the growing media and the containers. Although the Horning nursery personnel did not routinely sterilize their containers between crops, they did clean and sterilize small test groups of containers with Physan 20^R or a 10% chlorox solution. These surface sterilants have not proven to be effective in killing fungal pathogens on containers, however, so infected growing media could still be transmitted on the containers to reinfect the new growing media (James and others 1988). This could possibly explain why the heat treatments were less effective than the chemical fumigation. The high amount of disease in the steam sterilization treatment could be attributed to difficulties in achieving uniform heat penetration of large volumes of growing media, whereas the autoclaved growing media was more effective because it was treated in smaller batches. Although differences in sample sizes and cultural treatments made statistical analysis difficult, it was concluded that the MBC-2 fumigation showed promise as an operational way to treat large numbers of filled containers. Even though the autoclave treatment was more effective than steam sterilization, it was considered to be impractical for large-scale nursery operations and was therefore eliminated from subsequent tests.

Building on the successes of the previous season, it was decided to implement the growing media and container sterilization treatments on an operational scale during the 1986 season, using thousands of filled containers instead of only a few hundred. The steam sterilization treatment was attempted again because it was felt that heat penetration problem could be corrected. A large batch of growing media was again steam sterilized before the containers were filled, and another group of filled containers was fumigated with MBC-2. A 50 lb (22.7 kg) tank of MBC-2 as used to treat a space of approximately 300 yd^3 (230 m^3), which converts to an application rate of 0.17 lb/yd^3 (0.10 kg/m^3). The fumigant was applied under a polyethylene tarp, and the pressurized liquid was introduced into an evaporation barrel to promote complete vaporization. After a standard aeration period, the containers were then seeded and grown under the normal cultural regime in the greenhouse.

Table 2 - Operational scale container and growing media sterilization treatments at the Horning greenhouse in 1986

TYPE OF TREATMENT	TOTAL SEEDLINGS	SYMPTOMATIC SEEDLINGS NUMBER	SYMPTOMATIC SEEDLINGS PERCENT
STEAM STERILIZED GROWING MEDIA	58,016	3,091	5.3 %
MBC-2 FUMIGATED GROWING MEDIA IN CONTAINERS[1]	12,544	2	0.0 %

[1] - Containers filled with growing media were fumigated with methyl bromide/ chloropicrin (98%:2%)

The results of the 1986 trials showed that chemical fumigation was again effective in treating the Douglas-fir dieback disease (table 2). The steam sterilization treatments were more effective than the previous year but still did not completely eliminate the disease symptoms. It is interesting to note that the MBC-2 fumigation treatment was again effective, even though the 0.17 lb/yd^3 (0.10 kg/m^3) rate was considerably lower than the 0.50 to 1.00 lb/yd^3 (0.30 to 0.60 kg/m^3) rate that is listed on the fumigant label for potting soil. Other sources also recommend higher application rates: Handreck and Black (1984) recommend a rate of 0.83 lb yd^3 (0.50 kg/m^3) for treating growing media, compared to Bunt (1988) who recommends 1.17 lb yd^3 (0.70 kg/m^3). This effectiveness at lower application rates may reflect the way that the MBC-2 is applied - the fumigant is able to penetrate the small volume of growing media in the individual containers much easier than a large pile of growing media.

Each year since 1986, the Horning greenhouse has used methyl bromide fumigation to sterilize their containers after they were filled with growing media, resulting in the elimination of Douglas-fir dieback. Although the actual cause of the Douglas-fir dieback syndrome was never identified at the Horning container nursery, the success of the methyl bromide fumigation suggests that it was caused by a biological pathogen, probably a root fungus. Research in British Columbia has shown that Pythium ultimum, a minor root pathogen, was associated with this disorder in Canadian container nurseries (Husted 1988).

CURRENT FUMIGATION PROCEDURES AND RESULTS

The following paragraphs describe the fumigation procedures currently in use at the W.H. Horning greenhouse.

The containers are filled with peat-vermiculite growing media in the normal manner, transported to the empty greenhouse, moistened to normal germination water content, and placed on the raised benches. Another layer of empty container racks is placed on top of the filled containers to provide an air space (fig. 3). The drain hole in the concrete floor is sealed to avoid leakage before the entire group of benches is covered with a 6-mil plastic tarp; this operation requires four people to make sure that the tarp does not hang up or tear on the corners. The tarp is then sealed around the bottom by wetting the concrete floor and placing bags of growing media around the edges. The temperature of the growing media is allowed to warm to around 60 °F (16 °C) through solarization, or the greenhouse is heated if the weather is cool and cloudy. It is important to moisten and warm the growing media in the containers to stimulate disease organisms, and make them more susceptible to the fumigant. Other container nursery managers have reported poor results when the containers were fumigated under dry, cool conditions (Jopson 1989; Schaefer 1989).

Figure 3 - Containers filled with moist growing media are fumigated with methyl bromide/chloropicrin (98%:2%) in a warm greenhouse by injecting the fumigant under a sealed polyethylene tarp.

The Horning greenhouse currently contracts with a private pesticide applicator to apply the methyl bromide after the filled containers are situated under the fumigation tarp. The contract applicator uses a "hot shot" application technique where the methyl bromide is injected over heated coils to produce more efficient vaporization; this technique allows them to use a vSry low MBC-2 application rate of 0.0035 lb/ft (0.056 kg/m). Fumigation is normally done on a Friday to allow an exposure period of at least 3 days over the weekend; Handreck and Black (1984) recommend an fumigant exposure period of 2 to 4 days whereas Bunt (1988) specifies 4 to 5 days.

On the following Tuesday, the greenhouse cooling fans are used to exhaust any fumigant that may have escaped through the tarp. Next, the greenhouse is checked with a Draeger methyl bromide detector to make sure that it is safe to enter, because the concentration of methyl bromide in a work area should not to exceed 5 ppm. If it is safe to proceed, the fumigation tarp is removed from the benches, starting at the end near the exhaust fans. It is important to allow an adequate aeration period because some ornamental plants are sensitive to even small amounts of bromide. Methyl bromide can be difficult to remove from organic material, and so a 4 to 10 day period is usually recommended (Bunt 1988; Handreck and Black 1984). To make certain that it is safe to sow the seedling crop, lettuce seeds are sown in a couple of containers and the germinants are observed for a few days. If there are no problems, the filled containers are sown and placed in the greenhouse to begin the germination period.

Table 3 - Chemical fumigation produced larger Douglas-fir container seedlings for 2 consecutive growing seasons at the W.H. Horning greenhouse

GROWING SEASON	FUMIGATION[1] TREATMENT	FINAL SEEDLING SIZE HEIGHT (cm)	CALIPER (mm)
1988	UNFUMIGATED	25.4	2.88
	FUMIGATED WITH MBC-2	29.7	3.32
1989	UNFUMIGATED	17.4	2.33
	FUMIGATED WITH MBC-2	24.9	3.04

[1] = Containers filled with growing media were fumigated with methyl bromide/ chloropicrin (98%:2%)

Increased seedling growth due to fumigation

Even though Douglas-fir dieback has not been a problem in recent years, the Horning greehouse still realizes a benefit of methyl bromide fumigation of the containers and growing media. In fact, all the different conifer species produced at the nursery have been grown in fumigated growing media with good results. A control treatment of unfumigated containers is left each year to check on fumigation effectiveness, and the growth of these seedlings is monitored during the growing season. In each of the last 2 years, the seedlings in the non-fumigated containers were initially chlorotic and stunted compared to the treated population. Although the seedlings eventually attained normal color and appearance, they remained measurably smaller throughout the growing season. When seedling height and caliper measurements between the two groups was compared, the seedlings in the non-fumigated containers were consistently smaller than the seedlings in the fumigated containers (table 3). Although the difference in seedling height may not be great enough to affect production, the smaller calipers could produce serious economic consequences. Many of the unfumigated seedlings would have to be culled using a 0.12 in. (3 mm) minimum caliper, which is common for coastal Douglas-fir seedlings in this size of container.

The economics of fumigation

Under the current system using a professional applicator, fumigation cost for a crop of 430,000 seedlings in 10 in^3 (164 cm^3) containers was:

Labor	
Nursery set-up labor	$ 700
Contract fumigation	1,700
Materials	
Fumigant	$ 400
Tarp	200
Total Cost	$3,000

Cost of fumigation per thousand (M) seedlings =

$3,000/430M - $6.98/M

A benefit:cost (B:C) ratio can be computed by comparing the $3,000 fumigation cost to the estimated increase in seedling yield. Average seedling losses to Douglas-fir dieback were estimated to be 118, or 47.3 M of a 430 M crop. Using an average value for reforestation seedlings, the benefit of fumigation can be calculated:

47.3 M seedlings X $150/M seedlings = $7,095

For the more valuable tree improvement seedlings, the economic benefit is even greater:

47.3 M seedlings X $500/M seedlings = $23,650

A comparison of these benefits to the above costs produced favorable B:C ratios:

for reforestation seedlings

$7,095:$3,000 = 2.4:1

for tree improvement stock

$23,650:$3,000 = 7.9:1

CONCLUSIONS AND RECOMMENDATIONS

The W.H. Horning tree improvement greenhouse plans on continuing to fumigate their containers and growing media with methyl bromide as long as an economic benefit can be realized. The fumigation procedure outlined in this paper has proven to be safe and easy to monitor, and is not considered to be hazardous to nursery workers or the environment.

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