Using a Steamroom to Sterilize Pallets of Styroblock™ Seedling Containers

Andy Trent
Robert L. James
Clarke Fleege
Gary Hileman

Andy Trent is Project Leader, USDA Forest Service at the Missoula Technology and Development Center (MTDC), 5785 Highway 10 West, Missoula, MT 59808; Tel: 406.329.3912; E-mail: atrent@fs.fed.us. **Robert L. James** is Plant Pathologist, USDA Forest Service, Forest Health Protection, 3815 Schreiber Way, Coeur d'Alene, ID 83815; Tel: 208.765.7421; E-mail: rjames@fs.fed.us. **Clarke Fleege** is Nursery Manager and **Gary Hileman** is gardener/foreman at USDA Forest Service Lucky Peak Nursery, 15169 E Highway 21, Boise, ID 83709; E-mail: cfleege@fs.fed.us.

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Introduction

Styrofoam™ container blocks (for example, Styroblock™, fig. 1), hereafter "blocks," are a popular system for growing seedlings in greenhouse nurseries. They come in a variety of sizes and can be reused several times. They must be sterilized before reuse because they may harbor pathogens that can cause diseases to seedlings. Potential pathogens, such as *Fusarium* spp., live on residual organic matter and within the inner cavity walls of blocks. They also may colonize fragments of roots left on containers after the seedlings have been removed.

Several approaches to sterilizing blocks have been investigated. Chemicals such as sodium hypochlorite (bleach) and sodium metabisulfite have been used. But these chemicals present problems with workers' exposure to toxic chemicals and disposal of the chemicals. Many nurseries use hot-water dipping (fig. 2), immersing blocks in hot water (from 140 to 160 °F [60 to 71 °C]) for about 2 minutes. This method kills most pathogens.

Hot-water dipping can be time-consuming and labor intensive. Blocks must be loaded individually into a cage or basket that holds 20 to 50 blocks. The cage is submerged in the hot water for 2 minutes. The blocks are removed and the process is repeated. At larger nurseries, where thousands of blocks need to be sterilized, this process can take many days. Additionally, the energy required to keep the water hot can be expensive.

The Missoula Technology and Development Center (MTDC) was asked to look at alternatives to hot-water dipping that would reduce the cost and labor required to sterilize blocks.

Testing Different Methods of Sterilization

MTCD conducted several evaluations to determine the effectiveness of different treatments for reducing fungal contamination on blocks. Blocks that were tested had been used to grow several seedling crops at a large forest seedling nursery. The goal was to determine whether such treatments could kill fungi that were potential pathogens, leaving the blocks relatively safe to reuse.

MTDC tested several different ways of sterilizing blocks. One method used radiofrequency (RF) waves to treat the blocks. Other methods used dry heat (low humidity) and wet heat (with high humidity).

Before treatment, each block was sampled for fungal colonization near the bottom of the cavities at the drainage hole, where the highest populations of contaminating fungi, including potential pathogens, tend to congregate. Two pieces of Styrofoam™ (about 2 by 5 mm) were cut from each sampled cavity using sterile procedures and placed on an agar medium selective for *Fusarium* spp. and closely related fungi. Plates were incubated for 7 to 10 days at about 24 °C (75 °F) under diurnal (day

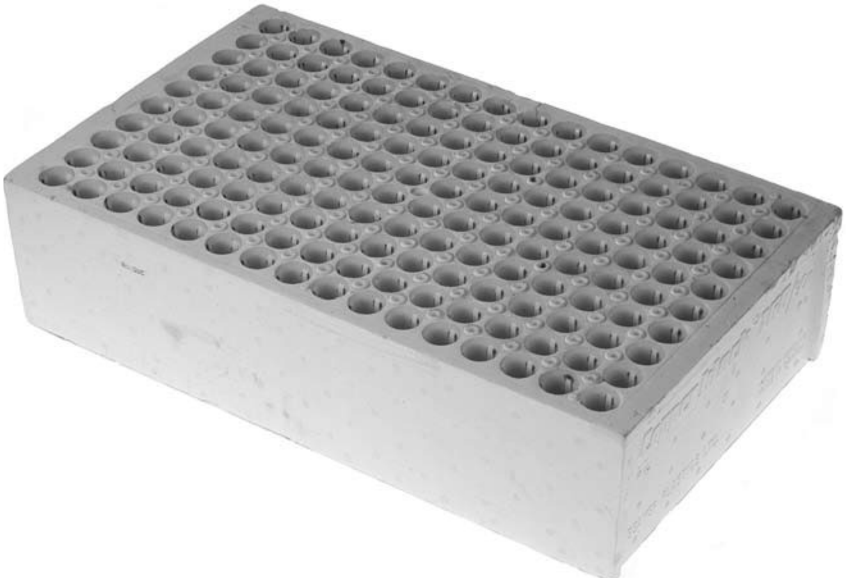

Figure 1—Stryrofoam™ container blocks (for example, the Styroblock™ manufactured by Beaver Plastics, Edmonton, AB) are used to grow seedlings in greenhouse nurseries. Styrofoam™ containers must be sterilized after each use to kill pathogens that damage future seedlings.

Figure 2—Blocks are loaded in a cage and submerged in hot water for 2 minutes during the conventional methods of sterilization. A forklift forces the blocks down into the water.

and night) cycles of cool, fluorescent light. Emerging fungi were identified by genus. Selected isolates were transferred to potato dextrose agar (growth medium) and carnation leaf agar for identification of the species of *Fusarium* and *Cylindrocarpon*. Block colonization was calculated as the percentage of sampled Styrofoam™ pieces that were colonized by a particular fungus. Specific cells were sampled in each block. Two small pieces of foam were taken from each sampled cavity.

After treatment, another two pieces of foam were taken from each sampled cavity. The fungal colonization (the number of sampled foam pieces colonized by particular fungi) before and after treatment were analyzed statistically.

Sterilization Using Radiofrequency Ovens

Radiofrequency (RF) wave ovens can raise the temperature of blocks to levels that will kill pathogens. Industrial RF ovens are used for baking, curing, and drying many types of foods and materials. These ovens operate at an electrical frequency of 10 to 100 MHz.

The material being heated is subjected to an alternating electrical field that makes the molecules inside the material rotate and move from side to side millions of times per second as they try to align themselves with the changing electrical field. This movement generates heat within the material similar to heat generated by friction. The ovens can be incorporated in a conveyor system to mechanize operations. Common microwave ovens operate on the same principle, but use radio waves of about 2,450 MHz to heat food and beverages.

PCS Inc. (Cleveland, OH) treated blocks with RF heating in a laboratory test oven. The oven operated at 40 kW at a frequency of 18 MHz using a parallel plate electrode system with variable electrode heights. The plate voltage was 12 kV. Ten blocks were divided into two groups of five containers each. One group of blocks was soaked in water before treatment; the dry group was not. The blocks in the wet group were immersed in water for a short period, shaken to remove excess water, and placed in the RF oven. The RF field was on for 2 minutes. Blocks were removed from the oven and the surface temperatures of cavities were measured with an infrared (IR) sensor. Temperatures varied somewhat, ranging from 80 to 120 °F (27 to 49 °C) and averaging 92 °F (33 °C).

The RF treatment (table 1) reduced pathogens when the blocks were wet. It was ineffective when the blocks were dry. Apparently, the thin film of water on the surface of the blocks is heated by the RF waves, killing fungal pathogens. The RF waves themselves are not toxic to pathogens because dry treatments are ineffective.

While the results indicated that RF treatment is effective when blocks are wet, the high cost of the RF oven and conveyor system (more than U.S. $65,000) probably would allow only the largest nurseries to use this method.

Low-Humidity Heat Treatment

Another method subjected the blocks to hot, low-humidity (dry) air in an oven. If the oven was actually a large room, pallet loads of blocks could be left in the room long enough to sterilize them. The blocks would not need to be handled individually or loaded as they are with hot-water dipping, freeing workers for other tasks while the blocks were being treated.

Individual dry blocks were treated in an industrial oven (fig. 3) for 10, 20, or 60 minutes at 170 °F (77 °C). Additionally, one set of blocks was wetted before the same treatments.

Subjecting the blocks to hot, low-humidity air for up to 60 minutes was ineffective (tables 2 and 3). Wetting the blocks improved the effectiveness, even when the blocks were heated for just 10 minutes.

Figure 3—Blocks were baked in an industrial oven set to 170 °F (77 °C) to determine whether dry heat would sterilize them.

Table 1—Test results for the radiofrequency wave oven. Styroblock™ containers were treated either dry or wet.

	Percentage colonization			
	Wet containers		Dry containers	
Fungus	Before	After	Before	After
Fusarium	54	3	73	71
Cylindrocarpon	2	0	1	1
Trichoderma	35	5	34	30
Penicillium	4	3	15	13
Other fungi	37	29	14	39
No fungi	0	60	0	0

Table 2—Test results for the industrial oven. Dry Styroblock™ containers were heated for 10, 20, and 60 minutes at 170 °F (77 °C).

	Percentage colonization					
	10 min dry		20 min dry		60 min dry	
Fungus	Before	After	Before	After	Before	After
Fusarium	11	19	7	8	7	7
Cylindrocarpon	2	0	0	0	0	0
Trichoderma	28	36	42	46	37	33
Penicillium	23	19	28	13	27	18
Other fungi	66	65	55	53	63	51
No fungi	0	0	0	0	0	13

Table 3—Test results for the industrial oven. Wetted Styroblock™ containers were heated for 10, 20, and 60 minutes at 170 °F (77 °C).

	Percentage colonization					
	10 min wet		20 min wet		60 min wet	
Fungus	**Before**	**After**	**Before**	**After**	**Before**	**After**
Fusarium	17	0	4	4	13	7
Cylindrocarpon	0	0	0	0	0	0
Trichoderma	8	4	4	0	4	33
Penicillium	33	4	38	0	29	18
Other fungi	75	0	83	13	79	8
No fungi	0	88	0	88	0	92

Bulk Testing Using Low- and High-Humidity Heat

Initial tests did not show whether the heat would penetrate to the innermost blocks (fig. 4). MTDC designed a test box (fig. 5) for a pallet load of about 50 blocks. A metal storage container (7 ft wide by 13 ft long by 7 ft high [2 m wide by 4 m long by 2 m high]) was insulated with rigid Styrofoam™ insulation. A residential sauna heater was mounted inside the box to heat it to 160 to 170 °F (71 to 77 °C). Designers fabricated a device to spill water on the sauna rocks to generate steam and raise humidity.

A series of tests were conducted using different exposure times with low and high relative humidities. During three tests conducted at low relative humidities (<30%), the blocks were wetted before they were heated for 15, 30, and 60 minutes. During three additional tests at high relative humidities (>75%), the blocks were not wetted before being heated for 15, 30, or 60 minutes.

These tests monitored blocks in the center of a pallet load. The blocks were thoroughly soaked with water for the tests that required wetting. Blocks were exposed to 160 to 170 °F (71 to 77 °C) for the appropriate time periods.

Blocks tested were from the USDA Forest Service Coeur d'Alene Nursery in Coeur d'Alene, ID. Samples were taken from the blocks before and after testing. High-humidity heat was more effective than low-humidity heat (tables 4 and 5). *Fusarium* and *Cylindrocarpon* colonization was eliminated even when the blocks were heated for just 15 minutes at high humidity.

Figure 4—Blocks loaded on a pallet were heated to 170 °F (77 °C). Tests were conducted at low and high (higher than 75%) humidities.

Figure 5—A storage container outfitted with a commercial sauna heater was used to sterilize blocks during testing.

Table 4—Results for bulk testing Styroblock™ containers in the MTDC sterilization container. Wetted blocks were treated for 15, 30, and 60 minutes with low relative humidities (<30%) at 170 °F (77 °C).

	Percentage colonization					
	15 min Low humidity		30 min Low humidity		60 min Low humidity	
Fungus	**Before**	**After**	**Before**	**After**	**Before**	**After**
Fusarium	0	0	79	88	46	13
Cylindrocarpon	0	0	42	0	0	0
Trichoderma	0	0	42	42	8	17
Penicillium	8	83	67	96	21	17
Other fungi	42	8	13	0	92	42
No fungi	0	0	0	0	0	17

Table 5—Results for bulk testing Styroblock™ containers in the MTDC sterilization container. Blocks were treated for 15, 30, and 60 minutes with high relative humidities (>75%) at 170 °F (77 °C).

	Percentage colonization					
	15 min High humidity		30 min High humidity		60 min High humidity	
Fungus	**Before**	**After**	**Before**	**After**	**Before**	**After**
Fusarium	58	0	50	0	25	0
Cylindrocarpon	0	0	0	0	0	0
Trichoderma	8	0	8	0	21	0
Penicillium	75	13	25	0	33	29
Other fungi	96	17	88	0	88	17
No fungi	0	71	0	100	0	54

Lucky Peak Nursery Steamroom

USDA Forest Service Lucky Peak Nursery, near Boise, ID, constructed a new greenhouse facility to grow container seedlings (figs. 6 and 7). The nursery needed an inexpensive way to sterilize large numbers of blocks. The nursery converted a cold storage room into a block sterilization room by piping in low-pressure steam to supply high-humidity heat. A propane boiler supplies steam to heat the room to a constant temperature of 160 °F (71 °C). Operators loaded blocks into the room, using a forklift and storage racks (fig. 8), treating the blocks for several hours to ensure that they were sterilized completely.

Sterilization Room

The sterilization room (fig. 9) measures more than 11,000 ft^3 (24 ft wide by 47 ft long by 10 ft high) (311 m^3 [7 m wide by 14 m long by 3 m high]), lined with 2-in (5-cm) thick rigid foam insulation. The rigid foam not only insulates the steam room to reduce energy costs, but protects the existing plywood from the high-temperature and high-humidity environment, which would cause the plywood to delaminate. Workers painted the foam with a special latex paint designed for the high-humidity and high-temperature conditions. The paint helps to seal the foam and prevents mold from growing.

The room is large enough for a forklift to load and unload the blocks easily. A drain in the middle of the room allows water that condenses from steam to drain.

Figure 6—The new greenhouse facility at the USDA Forest Service Lucky Peak Nursery near Boise, ID.

Figure 7—Seedlings growing in Styroblock™ containers in the new greenhouse facility at the USDA Forest Service Lucy Peak Nursery.

Figure 8—Blocks are loaded on storage racks inside the sterilization room.

Figure 9—A storage cooler was converted into a sterilization room. Steam pumped into the room provides high-humidity heat.

Boiler and Equipment

Steam generated by a 9.5-hp (approximately 400,000 BTU/hr) propane boiler (fig. 10) flows through a 1-in (2.6-cm) black pipe installed along the bottom of two sides of the room (fig. 11). The steam pressure was reduced from the standard 40 lb/in^2 (2.8 kg/cm^2) at the boiler to 10 lb/in^2 (0.7 kg/cm^2) before the steam entered the room. Holes 0.06 in (0.15 cm) in diamater were drilled in the pipe every 6 in (15 cm) to release the steam. Galvanized steel sheets installed behind the pipes protected the foam insulation from the steam.

Remote electronic controls set the temperature inside the room. Although the temperature probe to the electronic controller could be placed anywhere in the room, we put it in the middle block of a group of blocks on a pallet to ensure that the interior blocks were heated thoroughly. An electric water feed valve, chemical feeder, blowdown tank, and a water softener were added, as were relief valves and miscellaneous plumbing, including plumbing for the propane supply. Converting the room from cold storage to a block sterilization room cost about U.S. $24,000.

The time required to heat the room to sterilization temperature (160 °F [71 °C]) depends on the boiler size, room volume, and starting temperature. With an initial temperature of about 40 °F (4 °C), it takes about 15 hours to bring the sterilization room at Lucky Peak Nursery up to 160 °F (71 °C). Reheating the room for additional loads will not take as long. The walls, ceiling, and concrete floor will retain heat, which should reduce reheating time considerably. It is advantageous to fill the room with as many blocks as possible per load. The room holds about 4,000 blocks. The blocks should remain in the room for several hours at 160 °F (71 °C) to ensure sterilization.

Tests at Lucky Peak Nursery

Filling the room to capacity and heating it to 160 °F (71 °C) for 6 hours tested the sterilization room's ability to kill harmful fungi on reused blocks. Ten test blocks were placed randomly throughout the room in the center of blocks stacked on pallets. Results (table 6) indicate that the treatment is very effective. *Fusarium* levels were reduced from almost 90% to 5%. After treatment, 80% of the blocks had no fungal growth.

Further work could determine the minimum amount of exposure time required for sufficient sterilization. The less time required, the lower the energy costs of heating the room. However, it costs just U.S. $3 per hour to heat the room, so it's best to make sure that the blocks are heated long enough to sterilize them.

Figure 10—A 9.5 hp steam boiler was used to heat the sterilization room.

Figure 11—Black pipe distributes steam in the sterilization room. The pipe runs along the bottom of the side walls. Steam leaves the pipe through holes (0.06 in [0.15 cm] in diameter) drilled into the pipe.

Table 6—Test results for treating Styroblock™ containers at the Lucky Peak Nursery sterilization room. Blocks were treated at 160 °F (71 °C) for several hours.

	Percentage colonization	
Fungus	**Before**	**After**
Fusarium	90	5
Trichoderma	15	2
Penicillium	42	3
Other fungi	0	10
No fungi	0	80

Standard Operating Procedures

Lucky Peak Nursery plans to use the following procedure to sterilize blocks in the steamroom.

Day 1

0800 to 1200—One person using a forklift will fill the sterilization room with pallets loaded with blocks. This will take about 4 hours.

1200—The boiler is turned on and set to 160 °F (71 °C).

1700—The steamroom has reached 130 °F (54 °C).

Day 2

0700—The steamroom has reached 160 °F (71 °C). Blocks have been sterilized for several hours. The boiler is turned off. One person with a forklift removes blocks when they are needed for sowing. (About 4,000 blocks can be sterilized in one operation.)

Lucky Peak Nursery plans to use the steamroom for other tasks, such as heating lodgepole pine cones so the seeds can be extracted. The cones of lodgpole pine and some other conifers open only after they have been heated. The nursery also intends to use the steamroom to sterilize items used in bareroot and container seedling propagation (seed trays, mulch fabric, and so forth).

Conclusions

High-humidity heat is an effective alternative to hot-water dipping for sterilizing blocks. When the blocks and their environment were dry, heat treatments were less effective.

A steamroom developed at Lucky Peak Nursery effectively sterilized blocks. This room was large enough to handle blocks loaded on pallets, minimizing handling and reducing labor costs. The steamroom had to be insulated and equipped with a boiler that had enough capacity to provide steam for several hours. Inside temperatures had to be maintained above 160 °F (71 °C) with the humidity above 75%. The size of the sterilization room required for a nursery will depend on the number of blocks the nursery needs to sterilize, as well as the cost of boilers and other equipment needed for rooms of different sizes.

For smaller nurseries, a small shed may be used to sterilize 1 or 2 pallet loads of blocks at a time. If a boiler is too expensive, a commercial sauna heater can be used. A device could be fabricated that would periodically spray water on the sauna blocks, creating steam. This approach worked well during high-humidity tests at MTDC.