Steaming is an Efficient Way to Treat Soil, Potting Mix, Pots, and Other Supplies Infested by Plant Pathogens

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Infected nursery plants play an important role for the spread of many plant pathogens, among them *Phytophthora ramorum*, the causal agent of Sudden Oak Death and Ramorum blight. In order to minimize the risk for disease transmission to new areas, nurseries are inspected regularly for *P. ramorum*, and federal regulations require the eradication of infested plants and disinfestations of nursery soil and equipment (USDA APHIS 2020). Heat treatment is a well-established method for the mitigation of plant pathogens. The National Ornamental Research Site at Dominican University of California (NORS-DUC) is a federally funded research nursery that develops and tests methods for managing federally regulated quarantine organisms, including *Phytophthora* species. At NORS-DUC, we use steaming to decontaminate research plots in which experiments with *Phytophthora ramorum* or other quarantine pathogens were conducted. Laboratory trials have shown that heat treatment at a temperature of 50°C for at least 30 minutes inactivates *P. ramorum* (Schweigkofler et al. 2014). Based on research done at NORS-DUC, USDA APHIS accepted steaming as an official treatment for nursery soil infested with *P. ramorum* (USDA APHIS 2020). Steaming is now an established part of the Best Management Practices (BMP) in several nurseries and botanical gardens in California and other states (Elliott et al. 2021). Steaming can be used to mitigate existing soil beds *in situ*, but also potting mixes, pots, and other nursery equipment, and will reduce the risk of establishment and transmission of plant diseases. However, it has to be considered that some plant pathogens, esp. endospore-producing bacteria, but also some fungi, can tolerate much higher temperatures than *P. ramorum* and will survive at 50°C.

Steaming can be achieved using different methods. For the traditional top-down approach, a steam sock made out of a permeable material is placed on top of the area to be steamed, and then the area is covered with a tarp to contain the heat. The time and energy needed to reach the target temperature depends on a number of parameters, among them steamer size, type of treated material, size of treated soil plot, soil moisture and structure (compactness), soil depth, and ambient temperatures. With our commercial steaming unit (SIOUX Steam-Flo SF-20), huge piles of pots can be steamed within two to three hours, but it can take up to 12 or more hours to steam a soil plot to a depth of 20 cm. Top-down steaming can be used successfully for treating potting mix up to 4 cubic yards. However, most native plant nurseries need to steam larger quantities of soil and potting mixes, upwards of 15 cubic yards at a time. Steaming such big quantities requires substantial longer time as well as more fuel to run the steamer, resulting in higher costs.

Figure 1. A manifold developed at NORS-DUC for steaming using 'bottom-up' heat transfer.

NORS-DUC developed a manifold heating system to deliver heat more effectively using a bottom-up approach. Our manifold consists of five cross pipes 10′ across connected at a 90° angle to a central pipe of 12′. All pipes are stainless steel and have a diameter of 1.5″ (Figure 1). Every 18″, a 1/8″ hole was drilled into the bottom side of the cross pipes to limit the chances of clogging the holes with soil. The size specifications of the manifold will vary depending on the specific nurseries soil holding area. The use of stainless steel increases the longevity of the manifold, however cheaper versions using black steel pipe were developed by several nurseries and used successfully. The

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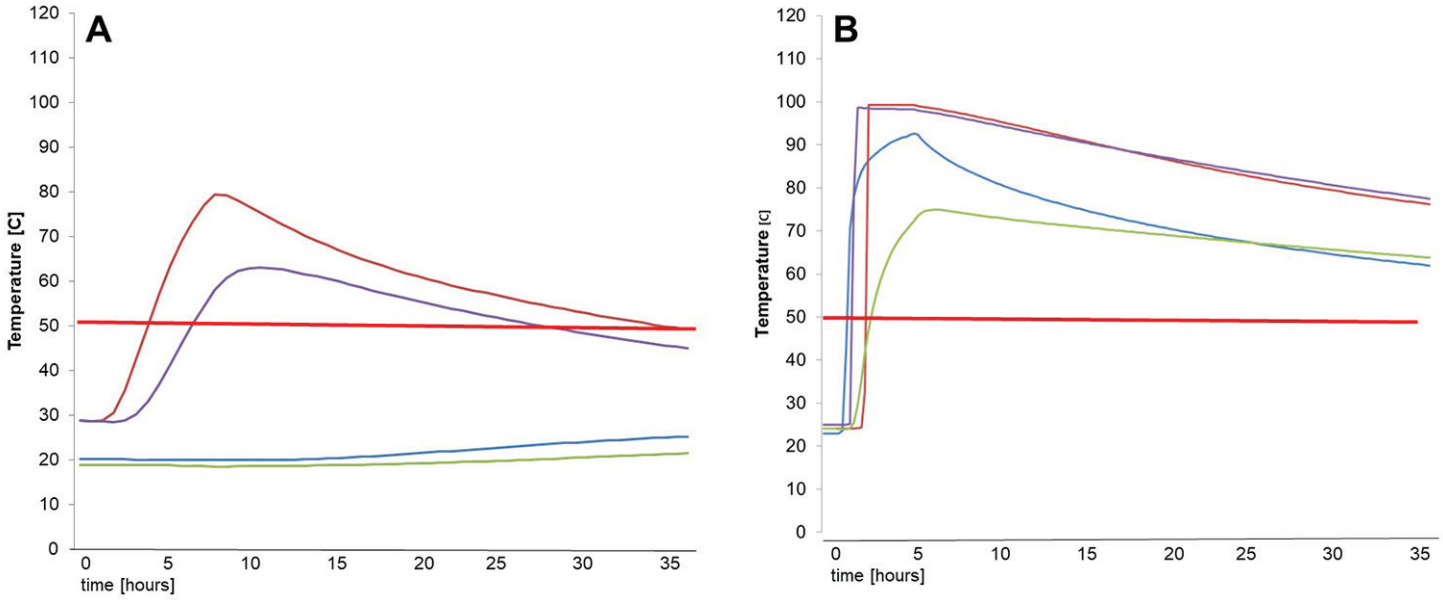

Figure 2. Temperature profile for steaming 7.5 cubic yard pile of potting mix using A) a 'top-down' (without manifold) and B) a 'bottom-up' (with manifold) approach. The target temperature of 50°C is shown as a straight red line. The steamer was switched off after 7 hours (A), and 1.5 hours (B), respectively. Temperatures were measured at the top area of the pile (red and purple lines), and the bottom of the pile (green and blue lines), respectively.

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size of the manifold can be adapted according to the needs of the nursery, however it is important to have the correct number of orifices drilled in the pipes to achieve the needed steam output. The company producing the steamer provides a table for calculating the right number of orifices based on steamer type, steam pressure, length of pipe used, and pipe diameter. Using a manifold changes the direction of the heat transfer and significantly decreases the time needed to reach our target temperature of 50°C.

We compared the time needed to steam 7.5 cubic yards of soil mix, a pile which was 24 inches high, using the traditional top-down method and the bottom-up manifold method. Using the traditional top-down method, the target temperature was reached within the upper 6 inches of soil mix after seven hours, however the target temperature had not been reached at the bottom of the pile. Using the bottom-up manifold method, all areas reached the target temperature within 1.5 hours (Figure 2).

NORS-DUC offers a 'Steaming-on-the-Go' service for nurseries, and other stakeholders in Northern California, who need to disinfect supplies, potting mixes, or soil plots *in situ*, but lack the needed equipment. We bring our steam unit to the site for a controlled heat treatment, using temperature sensors to ensure the target temperature is reached. The service not only serves to fulfill BMPs and USDA APHIS regulations, but can also help to cut costs and time for the nurseries, who otherwise would need to buy new supplies or use other, more time-consuming cleaning methods. For

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Figure 3. 'Steaming-on-the-Go' of huge numbers of pots can be achieved in a relatively short time at low costs.

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example, used pots — often still containing plant debris or soil which might be contaminated by plant pathogens — have to be disinfested before they can be reused or replaced with new ones. Recently we steamed 175,000 used pots for a grower which only took three days (Figure 3). At an average price of 50 to 75 cents per pot, the costs for replacing the pots would be approximately $100,000, which is many times higher than the cost for steam cleaning. Steaming is also a relatively ecologically friendly method which can reduce the use of toxic chemicals and plastic waste.

Still, questions remain on the effect of steaming on the microbial biodiversity, such as survival of different microbial groups and re-colonization pattern of the treated potting mix, as well as possible effects on the chemical soil properties. Research at NORS-DUC was initiated in collaboration with Pennsylvania State University to study these changes in soil properties and possible effects on plant growth.

Further information on the 'Steaming-on-the-Go' program can be found on the NORS-DUC website: **https://www.dominican.edu/directory/national-ornamentals-research-site-nors-duc/publications-and-information-nurseries**. For help with designing a manifold please contact Vernon Huffman at **vernon.huffman@dominican.edu**.

References

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