Infected nursery plants play an important role in the spread of *P. 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 the disinfection of nursery soil and equipment.

The National Ornamental Research Site at Dominican University of California (NORS-DUC) is a federally funded research nursery devoted to test and develop environmentally friendly management options for quarantine pathogens of ornamental plants. In the laboratory we tested the effect of wet and dry heat on the survival rate of *P. ramorum* growing on Rhododendron leaf disks. Incubation at 30 °C showed little effect on the survival rate. At 40 °C, growth rates started to decrease. Incubation at 50 °C for 30 minutes (wet heat) inactivated *P. ramorum* entirely, whereas dry heat was slightly less effective. At the research nursery, thermal inactivation of plant debris, soil and nursery equipment infested by *P. ramorum* was achieved by steaming using a commercial steaming unit (SIoux Steam-Flo SF-1) at a minimum temperature of 50 °C for 30 minutes. Temperature increase was influenced by ambient temperature, soil depth and moisture content. Steaming was also used to decontaminate soils in two commercial nurseries in the Central Valley of California that were found positive for *P. ramorum* previously. No Phytophthora was detected in official samples post-treatment and consequently, the commercial nursery was released from federal quarantine.

Further studies on heat treatment and steaming in the laboratory and the research nursery on other Phytophthora species, such as *P. tentaculata*, indicate that the method might be suited to control a wide range of plant pathogenic oomycetes in nursery soils.

Material and Methods:

**Thermal experiments in the lab.** In order to simulate the effect of soil heating, we tested the impact of high temperatures on the growth of two *P. ramorum* isolates (Pr-1418886 and Pr-1418932), both NA1 in the laboratory. Two heat sources were used: wet heating, which resembles the conditions in steamed soil, and dry heating. Leaf disks of Rhododendron *catawbiense* ex English Rosarium were incubated with *P. ramorum*. Incubated for three weeks at 20 °C and leaf disks (diameter 5 mm) overgrown with mycelium and chlamydospores were used for the thermal experiment. In order to test the effects of dry heating against wet heating, leaf disks were incubated at 30 °C, 40 °C, 50 °C or 60 °C, respectively, for 30, 60 and 120 minutes in a dry incubator or a water bath.

After treatment, leaf disks were plated on PARPH-VII medium, incubated at 20 °C for a week and the percentage of disks that yielded a colony of *P. ramorum* recorded. Experiments were done in triplicate; each replicate contained ten leaf disks.

**Steam experiments at a research nursery at NORS-DUC**

The steaming experiments were carried out in research beds with a surface area of 3.7 m x 4.6 m (17 m²) which were lined with water-proof liners. The beds were filled with a 30 cm deep layer of gravelly loam soil with a pH of 5.8. The organic matter soil composition was 5.9 % of the soil, which was originally excavated from the Dominican campus. A steamer unit SIoux Steam-Flo SF-11 (Sioux Corp., Beresford, SD, USA) with a boiler horsepower of 10.67 and a steaming output of 168 hour was used with an attached soaker hose (length: 31 m) laid out on the soil surface, which was then covered with a waterproof pond liner-type tarp. In addition, several steaming events were carried out on research beds filled with potted plants (Rhododendron sp. and *Viburnum* sp.), which were used previously for *P. ramorum* infection studies, and also with pots alone. For all steaming experiments, the minimum soil temperature of 50 °C was kept for 120 minutes (‘inactivation period’) before turning off the steamer.

Effect of thermal treatment on the growth rate of *P. ramorum* isolates Pr-1418886 and Pr-1418932. Infected Rhododendron leaf disks were incubated at 30, 40, 50 and 60 °C for 30, 60 and 120 minutes, respectively, in a water bath (wet heat) and/or an dry incubator (dry heat). Error bars indicate 95 % confidence intervals.

**Conclusion:**

Experiments on the inactivation of *P. ramorum* from nursery soils using steam sterilization and solarization were effective. Heating the top soil layer (0-30 cm) to 50 °C for 120 minutes resulted in complete thermal inactivation of *P. ramorum*. Steaming was also used to treat soil at a commercial nursery found positive for *P. ramorum*, and consequently the nursery was released from federal quarantine.

**Temperature profiles of three steaming events at different soil depths.** A: research nursery at NORS-DUC, July 2012; B: research nursery at NORS-DUC, February 2013; C: commercial nursery in the Central Valley, CA, August 2012. Temperatures were measured at depths of 5 cm (red line), 15 cm (black line), and 30 cm (blue line). The horizontal line shows the target temperature of 50 °C. The ‘inactivation period’ (defined as the time between reaching the target temperature and turning off the steamer) is shown in red.

Steam treatment of pots and potted plants resulted in fast and efficient inactivation of *P. ramorum* from one-gallon pots and potted infected Rhododendron plants. Temperatures were measured at surface of pots (green line) and close to the root balls of potted plants (blue line). Steamed pots are reusable (below).

For steaming experiments with *P. tentaculata*, the pathogen was grown on filter paper.