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Soil Treatments for the Potential Elimination of *Phytophthora ramorum* in Ornamental Nursery Beds

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ABSTRACT

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Ramorum leaf blight, caused by *Phytophthora ramorum*, has reemerged at several California nurseries after removal of infested material. In many cases, reemergence was not associated with reintroduction of the pathogen and may be attributed to inoculum surviving in soil beds because *P. ramorum* propagules can survive for over a year in soil. Using artificially infested soil in microcosms, fumigation and heat treatments were examined as potential eradicants of *P. ramorum* from soil. Treatments with chloropicrin, Vapam, and iodomethane were effective in reducing *P. ramorum* propagules below detection limits. Basamid was consistently effective only when fully incorporated into the soil. Application of Basamid (392 kg/ha) at infested ornamental nursery sites mirrored results from microcosm experiments, indicating that a tarp cover over treated soil is necessary for reliable efficacy. Dimethyldisulfide, 1,3-dichloropropene, and two formulations of hydrogen dioxide were less effective, resulting in only partial reduction of propagules. In heat treatments, *P. ramorum* in soil microcosms remained detectable 42 days after microcosms were incubated at 30 and 22°C but was not detectable in soil heated above 40°C for 3 days. Results from a solarized field plot indicate that prolonged sublethal temperatures, between 35 and 40°C for 42 days, can be effective in eliminating detectable propagules of *P. ramorum*.

Phytophthora ramorum is thought to be a pathogen introduced to the west coast of the United States and, prior to its discovery as the cause of tree mortality in coastal California woodlands, it had been reported as a foliar pathogen of ornamental *Rhododendron* and *Viburnum* spp. in Germany and the Netherlands (20,24). Awareness that these plants served as hosts in Europe led to examination of ornamental plants in areas of California infested with *P. ramorum*. It was determined that *Rhododendron* spp. and many other plants were serving as hosts to *P. ramorum* (2).

Growing awareness of the wide host range of *P. ramorum* and evidence of the pathogen in nurseries caused concerns about the possibility of spreading the pathogen with the movement of ornamentals. California is the leading producer of ornamental plants in the United States and ships plants throughout North America (4). In an attempt to limit the potential spread of *P. ramorum* to other regions, the United States Department of Food and Agriculture–Animal and Plant Health Inspection Service (APHIS) issued the "Order Restricting Movement of Nursery Stock from California Nurseries" in April 2004 (3).

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This was followed in October, 2004 by the APHIS "Official Regulatory Protocol for Nurseries Containing Plants Infected with *Phytophthora ramorum* (Sudden Oak Death)" (2). This "Confirmed Nursery Protocol" delineated monitoring and sanitation procedures for wholesale ornamental nurseries shipping plants outside of their county boundaries. The APHIS procedures call for inspections, *P. ramorum*-free certification, destruction of infested plants, and the elimination of *P. ramorum* from soil or gravel beds where container-grown plants might be placed.

P. ramorum has been shown to survive for extended periods in soil, indicating that effective remediation of nurseries harboring the pathogen will require thorough disinfestation of soil media and soil beds. In artificially infested potting media or sand, several studies indicate that propagules of *P. ramorum*, either fully exposed or imbedded in leaf tissue, can remain viable for a year or more (16,21,23). Baiting tests conducted in a California production nursery in 2005 following removal and destruction of an infected *Camellia* crop detected *P. ramorum* propagules in soil collected from the underlying nursery beds for more than 75 days after removal of plants and plant debris (26).

Agricultural systems have commonly used fumigation to manage soilborne pests (1,10,11,18,25). Hence, when the need arose to eliminate *P. ramorum* from infested nursery soils, APHIS specified several chemical treatment materials in the Confirmed Nursery Protocol. These included chloropicrin, dazomet, metam-sodium, and methyl bromide. Unfortunately, these treatments are problematic in many nursery production situations. Many nurseries are situated within urban centers and cannot accommodate the required buffer zones between fumigation sites and schools or homes, or they have small, inaccessible spaces which are not conducive to conventional soil fumigation equipment. Other problems involve township caps on fumigants that force nursery production to compete with other agricultural crops for use of the material, and the phase-out of methyl bromide. Additionally, container nurseries do not contain typical field soils that are compatible with conventional shank fumigation equipment. Nursery beds under potted plant stock commonly consist of packed gravel over soil, with gravel layers 15 cm or more in depth. Moreover, the efficacy of the APHIS-recommended soil treatments has not been determined for *P. ramorum* in the nursery environment. For example, monitoring a nursery treated with Basamid (392 kg/ha) and the label-recommended "water barrier" over the soil surface following application showed that the label treatment did not eradicate *P. ramorum* (26). Finally, there are additional fumigants available or under development such as dimethyldisulfide and iodomethane that might be suitable for nurseries but were not included as options in the APHIS listing of approved materials.

The Confirmed Nursery Protocol does indicate that heat can be used as an alternative to soil fumigation. Soil solarization and steam treatments have been successful in controlling other plant pests in other production systems but little information is available to guide the use of these technologies in container nursery beds (5–8,17,19). The main limiting factor in using heat for soil bed sanitation is the ability to deliver heat through the soil profile. Dart et al. (9) were able to isolate *P. ramorum* down to 10 cm in several commercial nurseries in Washington. In California, *P. ramorum* could be detected at depths down to the hard pan ranging from 15 to 45 cm (26). The temperatures attained at different soil depths via steam and solar treatments are highly influenced by solar radiation intensity, soil moisture, and soil texture and density (15).

This study was initiated to examine options for elimination of *P. ramorum* from nursery beds. Chemical and nonchemical