From Forest Nursery Notes, Winter 2008

© 122. Survival of Phytophthora ramorum in recirculating irrigation water and subsequent infection of Rhododendron and Viburnum. Werres, S., Wagner, S., Brand, T., and Kaminski, K. Plant Disease 91(8):1034-1044. 2007.

Survival of *Phytophthora ramorum* in Recirculating Irrigation Water and Subsequent Infection of *Rhododendron* and *Viburnum*

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ABSTRACT

Werres, S., Wagner, S., Brand, T., Kaminski, K., and Seipp, D. 2007. Survival of *Phytophthora ramorum* in recirculating irrigation water and subsequent infection of *Rhododendron* and *Viburnum*. Plant Dis. 91:1034-1044.

Phytophthora ramorum was studied in an open air simulation system with nine separate container stands each connected to its own water collection system. The water in these reservoirs was inoculated with *P. ramorum* and then used for overhead irrigation over the course of the season to study the spread of the pathogen and development of *P. ramorum* blight in *Rhododendron* and *Viburnum* spp. *P. ramorum* could infect plants through the use of contaminated irrigation water, with the maximum amount of infection of *Rhododendron* spp. less than 19%. In the 2 years of the study, symptom onset occurred 8 and 16 days, respectively, after water was first inoculated. The disease rate proportion of infected plants developing symptoms varied with year and season. In both years, the pathogen was detected in the water reservoirs over the course of the growing season.

Additional keywords: disease symptoms, latent infection, nursery

Since its original isolation in 1993, *Phytophthora ramorum* has become an important pathogen of quarantine significance. *P. ramorum* has been detected not only in diseased plants but also in soil and in water samples from rivers as well as from recirculation water in nurseries (15,16).

To economize water consumption in container nurseries, surplus water from irrigation and natural rain is collected from the container stands via drains and special drainage systems and stored in special reservoirs. From these reservoirs, the water is reused for irrigation. It is estimated that more than 90% of the surplus water can be recovered (10) and recirculated in commercial systems. This significantly reduces demand for fresh water, thus decreasing expenses, and prevents probably existing nutrients and pesticides from stands from entering the groundwater.

It is well known that contaminated recirculation water is a major means of dissemination of *Phytophthora* spp. However, there is little known about the survival of P. ramorum in water or whether plants can become infected when infested water is used to irrigate plants. In order to understand disease spread and develop control methods, it is of great importance to know whether irrigation with contaminated recirculation water can result in infection with *P. ramorum* and how long it takes until disease symptoms appear. The results should provide information for risk assessment of *P. ramorum*-contaminated water in practical uses in nurseries and for the development of control methods.

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Accepted for publication 27 March 2007.

doi:10.1094/PDIS-91-8-1034

MATERIALS AND METHODS

Simulation system. The simulation system was established outdoors in the research fields of the Bad Zwischenahn Research Institute, Germany. This system consisted of nine separate container areas (stands) of approximately 15 m^2 each with its own water recirculation system (Fig. 1). As is standard practice in commercial container nurseries, the potted plants were arranged on MyPex ground cover. From each stand, the surplus water from irrigation and natural rain was collected in a plastic water reservoir with a capacity of approximately 1,000 liters. The reservoirs were not covered. Each container stand had its own reservoir where the runoff water from the corresponding container stand was collected and from which the water was drawn for overhead irrigation with sprinkler heads. The reservoirs were filled with well water and pond water and replenished during the season when necessary. During the winter period of 2004–05, the water remained in the noncovered reservoirs according to commercial practice. Water quality was comparable with that used by growers in northern Germany. Chemical data of the water were analyzed by an official laboratory of the Chamber of Agriculture in Lower Saxony (LUFA Nord-West). The data (*not presented*) showed that the water was of the quality demanded for nurseries (1,7,20). Because it was an open-air simulation system, the recycled water mixed with natural rain water during the season.

The simulation system was first used for a pretest with *P. ramorum* in August 2003. The arrangement of treatments (Fig. 1) and the inoculum density was similar to 2004. During this pretest, the water reservoirs were inoculated but no plants were irrigated with the contaminated water. Water samples taken in December 2003 showed that *P. ramorum* was present not only in the infested but also in the noninfested water reservoirs. Four months later (28 April 2004), the pathogen could be trapped from the six infested reservoirs but no longer from the three control reservoirs (see below).

Plant material and cultivation. In 2004, rooted cuttings of *Rhododendron* cv. Cunningham's White were potted into 0.7-liter pots. The substrate used was peat with limestone (2.0 g $liter^{-1}$). The rooted cuttings were produced at the Bad Zwischenahn Research Centre and a local nursery. In all, 328 of these potted plants were placed in carrying trays in each container area at the beginning of May. For nutrition, the coated slow release fertilizer Osmocote Exact Standard 5-6M (3.0 or 4.0 g $liter^{-1}$) and the microelement fertilizer Radigen (100 mg $liter^{-1}$) were mixed into the substrate before planting. No additional fertilization was done. Osmocote Exact Standard 5-6M was used at the lower rate for the cuttings from the local nursery because their root systems were smaller than those from the Bad Zwischenahn Research Centre. The plants remained on the container stands until March 2005.

In 2005, 333 rooted cuttings of *Rhododendron* cv. Cunningham's White in 0.7-liter pots and 50 *Viburnum plicatum* cv. Mariesii in 2-liter pots were placed on