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Eradication of Plant Pathogens in Forest Nursery Irrigation Water

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Abstract

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Interest in rational use and reuse of water has increased in recent years, especially in forest nurseries. However, before water can be reused in nurseries, it must be properly treated to eradicate plant pathogens to reduce risks of pathogen dispersal and losses to disease. In the present study, the efficacy of irrigation water treatment by ultrafiltration and conventional physical-chemical treatment was studied to eliminate *Botrytis cinerea*, *Cylindrocladium candelabrum*, *Ralstonia solanacearum*, and *Xanthomonas axonopodis*, the pathogens most commonly found in Brazilian forest nurseries. Ultrafiltration eradicated over 99% of *R. solanacearum*, *X. axonopodis*, and *B. cinerea* and 100% of *C. candelabrum*. The few remaining cells or conidia of *R. solanacearum* and *B. cinerea* did not induce disease in irrigated rooted cuttings. Flocculation and fast sand filtration used in physical-chemical treatment completely eliminated *C. candelabrum* but the other pathogens were only removed after chlorination of the filtered water. Both forms of treatment are viable, practical, and safe methods for plant pathogen removal from irrigation water.

Water is an increasingly limited natural resource which is in high demand for agricultural production. Worldwide, 60 to 90% of available water is used for agricultural purposes (36). In Brazil, it is estimated that 70% of water is consumed in agriculturally related activities (29). One such economically important activity in Brazil is production of *Eucalyptus* spp. by rooted cuttings or seedlings in forest nurseries, which may utilize surface waters (rivers, streams, lakes, and reservoirs), well water, and precipitation to meet their demands. Water consumption in forest nurseries was reported to vary from 35 to 49 liters/day per thousand cuttings, with 70% of the total consumption destined for the growth and hardening phases of plant production (40). In a preliminary survey, water consumption in eight clonal eucalypt nurseries was found to vary from 9 to 38 liters/day per thousand cuttings (*unpublished data*). Only two of the nurseries relied solely upon well water, while the rest depended on two or more surface water sources. Furthermore, most nurseries had rainwater collection or drainage systems and discharged the rainwater along with nursery wastewater.

With the recent increases in nursery production and public pressure to preserve natural resources, coupled with the increasing scarcity of adequate water supplies, interest in rational use and reuse of nursery irrigation water is on the rise. The practice of recycling irrigation water increases the amounts of nutrients in the water (50) and can result in savings of 50% of fertilizer and 30% of fresh water consumed (52). However, recycled water may be contaminated with plant pathogens, such as propagules of fungi (44) and Oomycota (27,53), bacterial cells or spores (13,34), and nematodes (11). Therefore, recycled water may be an important source of pathogen dispersal leading to significant losses in nursery production (32,41). Analyses of untreated irrigation water from different phases of eucalypt clonal propagation showed that spores of *Botrytis cinerea* Pers. and *Cylindrocladium candelabrum* Viégas are often found (28). Other organisms commonly associated with eucalypt cutting infections and that are dispersed rapidly in nurseries in warm, nutrient-rich irrigation water include *Xanthomonas* spp. and *Ralstonia solanacearum* (Smith) Yabuuchi et al. (55).

Treatment of irrigation water before reuse is a viable alternative for reducing fresh water consumption and the risk of disease in plant nurseries. Various water treatment methods are available, including conventional physical-chemical treatment (coagulation, flocculation, sedimentation, filtration, and chlorination), membrane filtration, ozonation, pasteurization, slow sand filtration, and ultraviolet radiation. The treatment method chosen by end users depends on raw or recycled water quality, volume of water usage, and cost.

Conventional physical-chemical treatment is the most widely used process in public water treatment plants (PWTP) (26). The treatment process includes rapid mixing, flocculation, sedimentation, fast sand filtration, and disinfection. Aluminum or iron salts are typically used as coagulants in the rapid mixing step. These coagulants hydrolyze and form gelatinous precipitates that interact with suspended solids (e.g., fungal and bacterial propagules) to form flocs. During flocculation, the water is slowly agitated to increase the flocs to a size at which they decant during sedimentation (9). Clarified water from the sedimentation tank is then filtered in a sand bed to remove remaining flocs and, finally, chlorinated to eradicate pathogenic microorganisms (31). The most commonly used disinfectant (chlorine) can be added in the form of gas (Cl_2) or as sodium hypochlorite (NaOCl) or calcium hypochlorite ($Ca(OCl)_2$). Chlorine hydrolyzes in water to form hypochlorous acid + hypochlorite ion ($HOCl \rightarrow OCl^- + H^+$). The sum of hypochlorous acid and hypochlorite ion present is termed free residual chlorine. The proportion of the nonionized and ionized forms is pH dependent and, because the nonionized form is a more efficient oxidant, the chlorine contact time should be run at pH $\leq$ 8. Disinfection with chlorine is due to oxidative damage of the microbial cell wall and membrane, followed by chlorine diffusion into the cell and alteration of vital cell functions (26). High free residual chlorine concentrations in irrigation water may induce plant toxicity and reduce seedling growth and development.

Membrane filtration is classified according to membrane pore size: microfiltration (0.1 to 10 µm), ultrafiltration (0.02 to 0.1 µm), and nanofiltration (500 to 20,000 Da) (10). Membrane filtration has been successfully used to remove plant pathogens in irrigation water and hydroponic solutions (15,22,36,42,47). This treatment process is highly efficient and, because it does not require addition of any chemical products, membrane filtration does not chemically alter the nutrient content of the water supply (36,42).

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