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# Susceptibility of Fraser, Canaan, and Nordmann Fir to Root Rot Incited by *Phytophthora cactorum* and *Phytophthora drechsleri*

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Summary. **The susceptibility of fraser fir (*Abies fraseri*), canaan fir (*A. balsamea* var. *phanerolepis*), and nordmann fir (*A. nordmanniana*) to phytophthora root rot (PRR) incited by *Phytophthora cactorum* or *P. drechsleri* was assessed in two experiments in central Pennsylvania. In an 8-week greenhouse study, seedlings and transplants growing in soilless substrate were inoculated with *Phytophthora* in flooded and non-flooded settings. In an 8-week outdoor study conducted in raised planting boxes filled with soil, transplants were inoculated with *Phytophthora* species in well-drained and poorly drained soil. Based on foliar disease ratings, mortality rates, and dry shoot and root weights, differences in susceptibility to *P. cactorum* and *P. drechsleri* existed between these true fir (*Abies*) species. Fraser fir was very susceptible to *P. cactorum* and *P. drechsleri*. Canaan fir had strong resistance to *P. cactorum* and *P. drechsleri* in well-drained settings but was susceptible in poorly drained settings. Nordmann fir had very strong resistance to *P. cactorum* and *P. drechsleri* in both well-drained and poorly drained settings.**

Fraser fir was the most valuable cut Christmas tree species in the United States in 2009, accounting for $89.1 million in sales for producers (U.S. Department of Agriculture, 2009). In the past two decades, demand for fraser fir has increased and consumers now consider it a premium product (Chastagner and Benson, 2000; Tompkins, 2000; Williams, 2002). This demand has resulted in production of fraser fir in sites ill-suited to the species, including poorly drained soils (Johnson, 2009; Owen, 2005). The limiting factor in fraser fir Christmas tree production on poorly drained sites is PRR, which may be incited by several *Phytophthora* species (Benson et al., 1976; Kuhlman and Hendrix, 1963; Quesada-Ocampo et al., 2009; Shew and Benson, 1981). Fraser fir specimens with PRR symptoms sent to the Pennsylvania Department of Agriculture Plant Diagnostic Laboratory between 1986 and 2011 most frequently contained *P. cactorum*, *P. cryptogea*, or *P. drechsleri* (T. Olson, personal communication).

Fraser fir is considered very susceptible to PRR, with minor differences in susceptibility occurring between seed sources (Frampton and Benson, 2004). Canaan fir is closely related to fraser fir and has been reported to survive in soils conducive to PRR (Brown, 2000; Potter et al., 2010). Greenhouse and shadehouse testing of multiple seed sources of canaan fir two-year-old and three-year-old seedlings growing in soilless substrate in North Carolina found susceptibility to *P. cinnamomi* in all seed sources, although some variation in degree of susceptibility occurred (Benson et al., 1998b).

Studies conducted in North Carolina indicate variation in resistance to *P. cinnamomi* exists between true fir species as containerized seedlings in soilless substrate, with the greatest tolerance or resistance to *P. cinnamomi* being observed in momi fir (*A. firma*) and turkish fir [*A. nordmanniana* ssp. *equi-trojani* (syn. *A. bornmuelleriana*)] (Benson et al.,1998a; Hinesley et al., 2000). In the Benson et al. (1998a) study, nordmann fir had less severe foliar symptoms than fraser fir but was still determined to be very susceptible to *P. cinnamomi*.

Despite having considerable resistance to *P. cinnamomi*, momi fir has little potential as a cut Christmas tree crop because of its morphological features and susceptibility to spring frost damage (Hibbert-Frey et al., 2010; Hinesley and Frampton, 2002). Turkish fir is a better candidate as a cut Christmas tree crop and is considered either a natural hybrid between greek fir (*A. cephalonica*) and nordmann fir or a subspecies of nordmann fir (Farjon, 2010; Liu, 1971). The close relationship between turkish fir and nordmann fir suggests that nordmann fir might possess *Phytophthora* resistance genes. Nordmann fir is more readily available in the U.S. conifer industry than turkish fir and additional testing on its resistance to PRR-inciting *Phytophthora* is warranted.

This study involved testing fraser fir, canaan fir, and nordmann fir for resistance to PRR incited by *P. cactorum* or *P. drechsleri*. Inoculation tests were done in a 2009 greenhouse experiment with seedlings and transplants growing in soilless substrate and in a 2010 outdoor experiment in planting boxes containing transplants growing in soil, with a flooding treatment included to create conditions favorable for PRR.

## Materials and methods

In Summer 2009, a greenhouse experiment was conducted in University

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**Units**

| To convert U.S. to SI, multiply by | U.S. unit | SI unit | To convert SI to U.S., multiply by |
|---|---|---|---|
| 0.3048 | ft | m | 3.2808 |
| 2.54 | inch(es) | cm | 0.3937 |
| 16.3871 | $inch^3$ | $cm^3$ | 0.0610 |
| 0.0254 | mil | mm | 39.3701 |
| 28.3495 | oz | g | 0.0353 |
| 1 | ppm | $mg \cdot L^{-1}$ | 1 |
| (°F – 32) ÷ 1.8 | °F | °C | (°C × 1.8) + 32 |