

Field susceptibility of Eurasian fir species to *Phytophthora* root rot – the Rice Paddy experiments

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Phytophthora root rot (PRR) often limits where noble fir (*Abies procera*) and Fraser fir (*A. fraseri*) Christmas trees can be grown. Overall, PRR is favored by saturated soil conditions resulting from poor drainage, over-irrigation, or excessive precipitation. Based on previous studies which have shown that Nordmann fir (*A. nordmanniana*) is much less susceptible to PRR under field conditions in the PNW, this Eurasian species is often planted in PRR conducive sites where highly susceptible species, such as Fraser and noble fir, can't be grown.

As a result of other trials which have shown that Turkish fir (*A. bornmuelleriana*) and Trojan fir (*A. equi-trojani*) Eurasian firs have the potential to make high-quality Christmas trees, there is increased interest in growing these species. If resistant to PRR, Turkish and Trojan firs would potentially provide growers with high-quality trees that could be planted in sites at high risk for PRR.

Greenhouse and field approaches are used to screen conifers for resistance to PRR at WSU Puyallup. Initial screening is often done by inoculation of container-grown seedlings under greenhouse conditions. Resistance screening under field conditions is then done using “rice paddy” field plots. The purpose of the following trials was to determine the susceptibility of Turkish and Trojan firs to species of *Phytophthora* that cause PRR in Christmas tree production regions throughout the United States under field conditions.

In a field trial done in 2013, 36 families of Turkish fir from three provenances (Bolu, Karabük, and Adapazarı) collections were evaluated for resistance to PRR. Noble, Fraser, and Nordmann firs were included in this trial for comparative purposes. Two large rice paddy plots were established containing 15 blocks of 40 trees (one tree per seed source) each, for a total of 30 trees from each family. The trial was repeated in 2014.



In March 2023, a series of 10 rice paddy plots were established to determine the susceptibility of 12 top performing families of Trojan fir from a recently completed CoFirGE-1 trial. All of these families are also included in the regional CoFirGE-2 plots which were established in throughout major Christmas tree production areas in the U.S. in 2023. The 2023 rice paddy trial includes families of Nordmann (11), Turkish (3), balsam (2), Canaan (2), Fraser (2), and noble (2) firs, which are also included in the CoFirGE-2 plots.



The soil in the WSU Puyallup rice paddy plots was infested with *Phytophthora* species. *Phytophthora* inoculum consisted of five species in the Turkish fir trial and four species in the Trojan fir trial. These species commonly cause PRR on Christmas trees: *P. pini* (Turkish fir trial only), *P. cactorum*, *P. cambivora*, *P. cryptogea*, and *P. cinnamomi*. The rice paddies were then flooded for 48-72 hrs after inoculation to create conditions that are favorable for infection, and seedlings were monitored for symptoms. The soil was infested and flooded a single time in the Turkish fir trial. In the Trojan fir trial, it was infested and flooded five times during 2023-2025. Disease development was then evaluated over a 14 week period in the Turkish fir trial and multiple times each year during the Trojan fir trial.



Turkish fir

The 2013-2014 Turkish fir trials demonstrated that Turkish fir families collected from different geographical regions were much less susceptible to PRR than noble and Fraser firs even when conditions are engineered to favor disease (Figure 1). Within-species variation among the Turkish fir families was observed and the level of disease on the low elevation Adapazari families was higher than the families from mother trees at higher elevations. Overall, the level of Turkish fir field resistance to PRR in these trials was similar to the two families of Nordmann fir that were included in the trials.

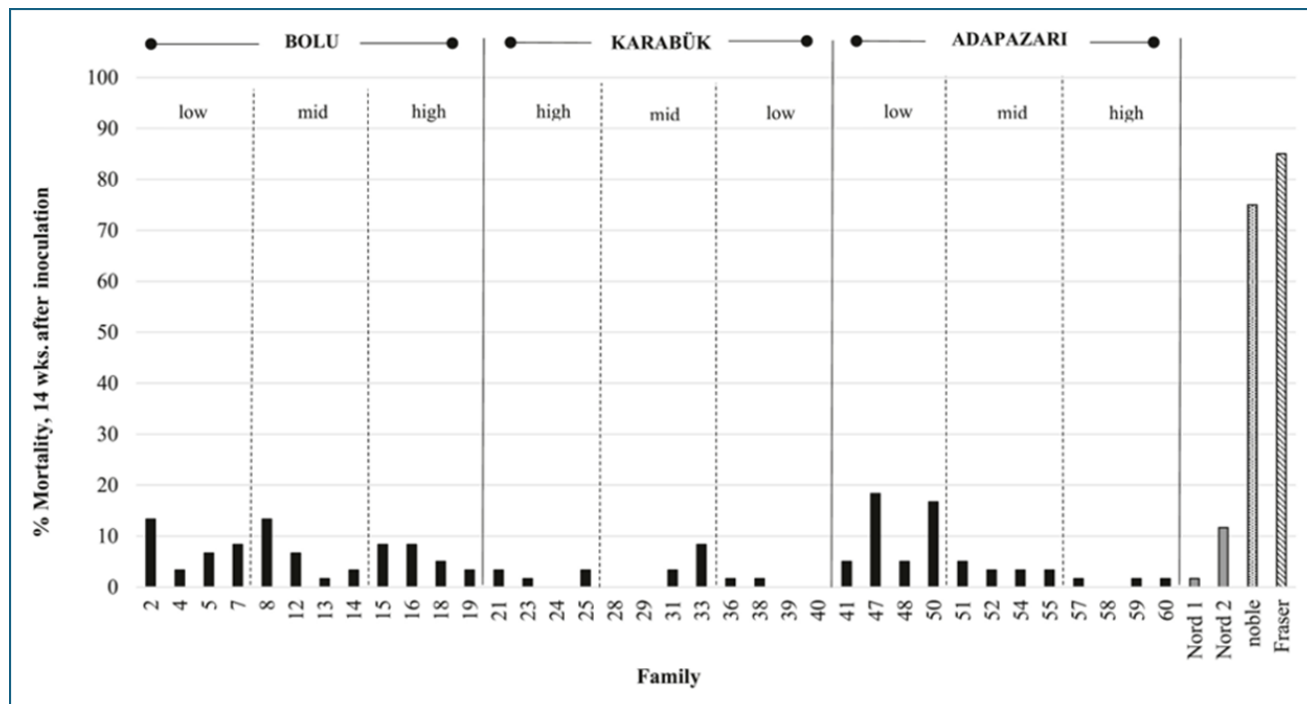


Figure 1. Mortality of *Abies* spp. in the 2013-2014 trials screening Turkish fir families for resistance to PRR. Percent mortality of 36 families of Turkish fir, two families of Nordmann fir, and one family each of noble and Fraser firs. Three provenances of Turkish fir (Bolu, Karabük, and Adapazarı) were represented by 12 families each, as indicated near the top of the graph. Within each provenance, four families represented mother trees growing at three elevation categories (low = 1,000-1,200 m; mid = 1,201-1,400 m; high = 1,401-1,700 m). Data from: McKeever, K.M., Johnson, J.S. and Chastagner, G.A., 2025. Field Assessment of Turkish Fir (*Abies bornmuelleriana*) Resistance to Five Root-Rotting *Phytophthora* Species. *Plant Disease*, 109(7), pp.1563-1571.

Trojan fir

Over the 3 year period since the start of this experiment, mortality increased at a high rate between May-September, corresponding to periods with higher temperatures. The Eurasian species (Nordmann, Turkish, and Trojan fir) have tended to have lower mortality than the North American species, with Fraser fir (*A. fraseri*) and noble fir (*A. procera*) having the highest mortality (39% and 79%, respectively) (Figure 2). While the highest levels of mortality that have developed on the Trojan and Nordmann fir families is less than 12%, some families have very low levels of mortality. No mortality has been observed to date on three families of Turkish fir and three of the 11 families of Nordmann fir (Figure 3).

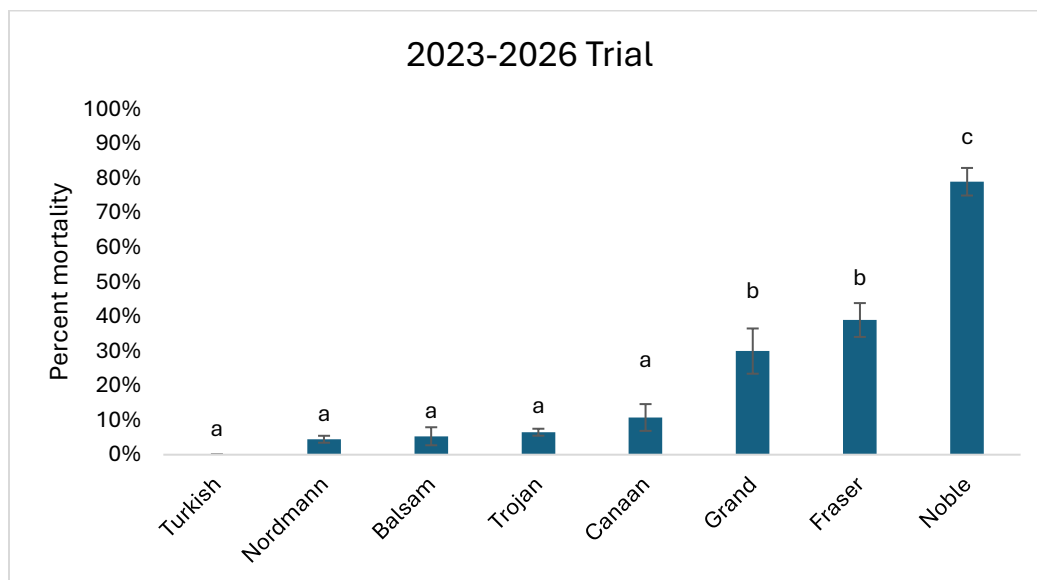


Figure 2. Percent mortality after 3 years of *Abies* spp. planted in 2023 and exposed to *Phytophthora* inoculum in 2023, 2024, and 2025.

Phytophthora species isolated from symptomatic plants included the four species in the mixed inoculum as well as some aquatic species in Clade 6 (*P. gonapodyides*, *P. chlamydospora*), *P. megasperma*, and *P. plurivora*. These additional *Phytophthoras* were also found in baits exposed to water in the rice paddies during flooding and in the creek where the irrigation water was obtained from. The detection of aquatic *Phytophthora* species from irrigation water infecting the host plants highlights the importance of managing water sources in nurseries and plantations to reduce potential pathogen spread.

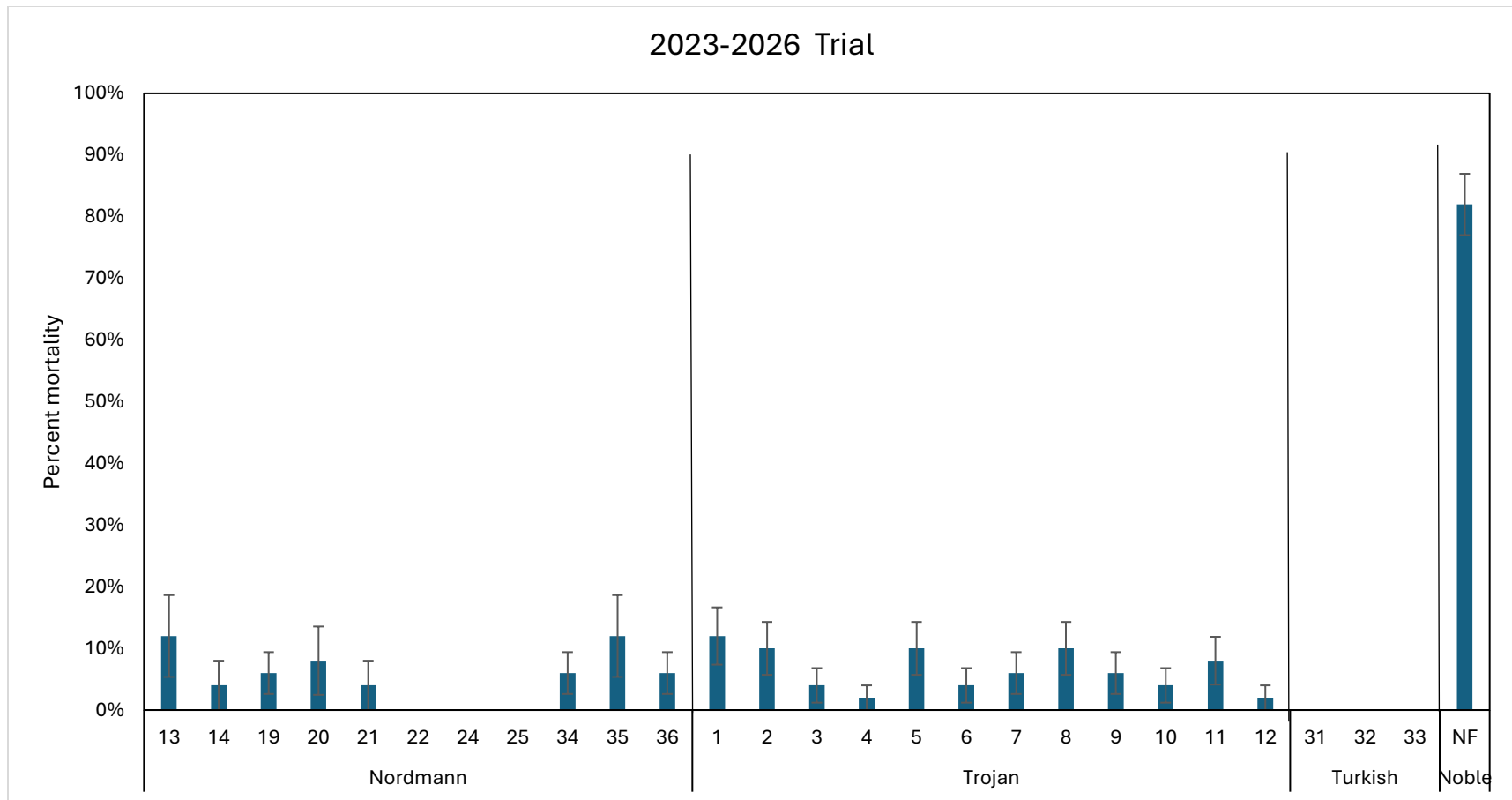


Figure 3. Mortality of individual *Abies* spp. families planted in the 2023 rice paddy trial after 3 years.