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Variation in Resistance to Phytophthora Root Rot in Turkish and Trojan Fir

John Frampton
Christmas Tree Genetics Program
Department of Forestry & Environmental Resources
N.C. State University

Background

Past efforts to find useful levels of resistance to Phytophthora root rot in Fraser fir have been unsuccessful and led to the evaluation and use of other fir species to control this disease. Research has demonstrated that momi fir (*Abies firma*), also known as Dixie fir, and from Japan, is the most resistant fir. However, momi fir does not make a desirable Christmas tree due to its coarse branching habit, wide needles, and prickly foliage. Further, it breaks bud 3-4 weeks before Fraser fir making it extremely susceptible to spring frost damage. However, many growers have been purchasing greenhouse-produced momi fir to use as rootstock to graft Fraser fir onto and planting the grafts in known Phytophthora-infested areas.

While the use of Fraser fir grafted onto resistant rootstock is a sound strategy, development of fir that is both resistant and capable of producing a quality Christmas tree is needed in order to more cheaply reclaim areas lost to Fraser fir production because of Phytophthora. Turkish fir (*A. bornmuelleriana*) is a promising species for this role. All Turkish fir seedlings survived Phytopthora inoculations in early trials by Dr. Gary Chastagner (Washington State University) in 1989 and Dr. Mike Benson (N.C. State University) in 1997. In 2003, the NCSU Christmas Tree Genetics Program conducted a more comprehensive screening of 32 fir species from around the world. In that trial, Turkish and closely related Trojan fir (*A. equi-trojani*) ranked third and tenth for resistance to *Phytophthora cinnamomi* but mortality in these species was relatively high, 61.3% and 84.2%, respectively.

Variable results from greenhouse resistance screening trials as well as research field trial results and Christmas tree growers' experience all indicated that Turkish fir is not uniformly resistant to Phytophthora root rot. So, a systematic approach to understand and better use Phytophthora resistance within Turkish fir was undertaken.

In 2005, my colleague, Dr. Fikret Isik, and I embarked on a cone collection trip in northwestern Turkey (see *Limbs & Needles* 33(2):17-19 for details of that trip). We visited four provenances (geographic regions) of Turkish fir and two provenances of Trojan fir. At each provenance, we collected cones from about 20 trees starting from the lowest occurrence of the species up to the highest occurrence. As a result of this trip, we now have the most genetically diverse seed collection of Turkish and Trojan fir in the world.

Resistance Screening Trial

In March 2007, seeds from the 2005 cone collection were sown and cultured in the greenhouse. During summer of 2008, up to 80 seedlings from each of 105 families (almost 6,000 seedlings total) were inoculated with *P. cinnamomi* inoculum provided by Dr. Mike Benson. Subsequently, survival or mortality of each seedling was assessed biweekly.

Sixteen weeks after inoculation, overall seedling mortality was 56.5% for Trojan fir and 35.0% for Turkish fir. As a comparison, 97% of inoculated Fraser fir seedlings but only 3% of inoculated momi fir seedlings died. For Turkish and Trojan fir, there was a distinct relationship between mortality and geographic origin; mortality decreased from west to east (Figure 1). The western-most provenance of Kazdagi (Trojan fir) had the greatest mortality (58.2%) while the eastern-most provenance of Safranbolu (Turkish fir) had the least mortality (23.2%).

Within each provenance, open-pollinated families (i.e., seedlings from the same mother tree) varied considerably (Table 1). For example, seedling mortality for the Uludag provenance was 50.8% while its most resistant family had only 20.2% mortality and its most susceptible family had 82.8% mortality. Such variation allows us to select resistant material even from generally susceptible provenances. This is fortunate since Trojan fir is generally faster growing than Turkish fir and, based on my observations of young trees in natural stands, probably will produce better quality Christmas trees.

Mortality due to Phytophthora is under a large degree of genetic control. Estimates of family mean heritabilities were 0.88 for Turkish fir and 0.91 for Trojan fir. Thus, roughly 90% of the variation we observed among families for Phytopthora-induced mortality was controlled by genetics. So, resistant trees grafted into a seed orchard will pass this resistance on through their seeds.

Future Work

We will continue to culture the surviving seedlings from the Phytopthora inoculation trial. Fast-growing seedlings from the most resistant families will be used as stock plants and clonally multiplied as rooted cuttings for further study. The other surviving seedlings will eventually be planted in the mountains on at least one Phytophthora-infested site to evaluate how the resistance holds up under field conditions and against other genotypes for the pathogen.

An additional 12,000 Turkish and Trojan fir seedlings were sown in 2007 and are being grown for future field trials. Currently, these seedlings are overwintering in an open greenhouse in Avery County and will be moved into transplant beds during March 2009. We hope to establish four research field trials in 2011. These will be managed as Christmas trees for an entire production cycle. Growth, survival, Christmas tree quality, and needle retention will be assessed. Ultimately, selections will be made and grafted into a seed orchard. In the future, planting stock grown from the seed produced in this orchard will hopefully, greatly abate the adverse impact of Phytophthora root rot on North Carolina's Christmas tree industry. Since this planting stock will only be targeted for sites with Phytophthora problems, obviously, North Carolina Fraser fir, The Perfect Christmas Tree, will continue to be the state's premier species.

Practical Aspects

Developing resistant and improved Turkish and Trojan fir for North Carolina is a long-term effort. In the meantime, many North Carolina Christmas tree growers have been planting a modest amount of Turkish fir. Avery County IPM Technician, Doug Hundley, has been collectively ordering and distributing Turkish fir seedlings purchased from Brooks Tree Farm in Oregon for several years. The source is labeled "Bolu Kokez". Bolu refers to the provenance, i.e., the mountains north of the city of Bolu. Kokez is an area in these mountains designated for seed collection by the Turkish Ministry of Environment and Forestry. This material has proven to be more suitable than Turkish fir planted in North Carolina in the past; it has reduced bud abortion and faster early growth. Since the Bolu provenance also has a high frequency of resistance, continuing to cautiously use and appraise this source of Turkish fir seems prudent.

Although Turkish fir is occasionally used as a Christmas tree in other parts of the United States as well as in Europe, a better evaluation of its acceptability by U.S. Christmas tree consumers is needed. So, I dauntlessly initiated another research venture. In November, my wife and I received a beautiful Turkish fir Christmas tree from Louise and Rondal Farmer (Figure 2). It came from a research field trial in Alleghany County that the Farmers managed and that was visited during the farm tour of the NCCTA Summer meeting last September. The Farmers won first place in the "Other Species" category during the 2008 NCCTA tree contest with a Turkish fir from the same research trial. Jane and I set the tree up the weekend after Thanksgiving and took it down New Year's Day. We also decorated the mantle and an outdoor lamp post with some of the boughs cut from the bottom of the tree. It was a wonderful tree that we really enjoyed. However, it stopped taking up water after 2-3 days and lost more needles than a typical Fraser fir would have (although the outdoor boughs stayed fresh the entire time). Also, the tree did not emit a fragrance even though the needles released a nice citrusy aroma when crushed. (We did enjoy the aroma from a Fraser fir wreath in our sunroom.) Nevertheless, we were happy customers – thanks Louise and Ron.

While our research efforts have necessarily had to be focused, our species screening trial revealed that additional fir species have some Phytophthora resistance. With future research and/or grower experience, some of these may also prove useful for planting in Phytopthora-infested sites. In order of their relative resistance, these species include: pindrow (or Himalayan) fir, Toros (or cilician) fir, Siberian fir, King Boris fir, Nordmann fir, Greek fir, Chinese fir, and concolor fir. I am most interested in learning about your experiences with these or any other exotic fir species. Please feel free to contact me at 919-515-7580 or frampton@ncsu.edu.

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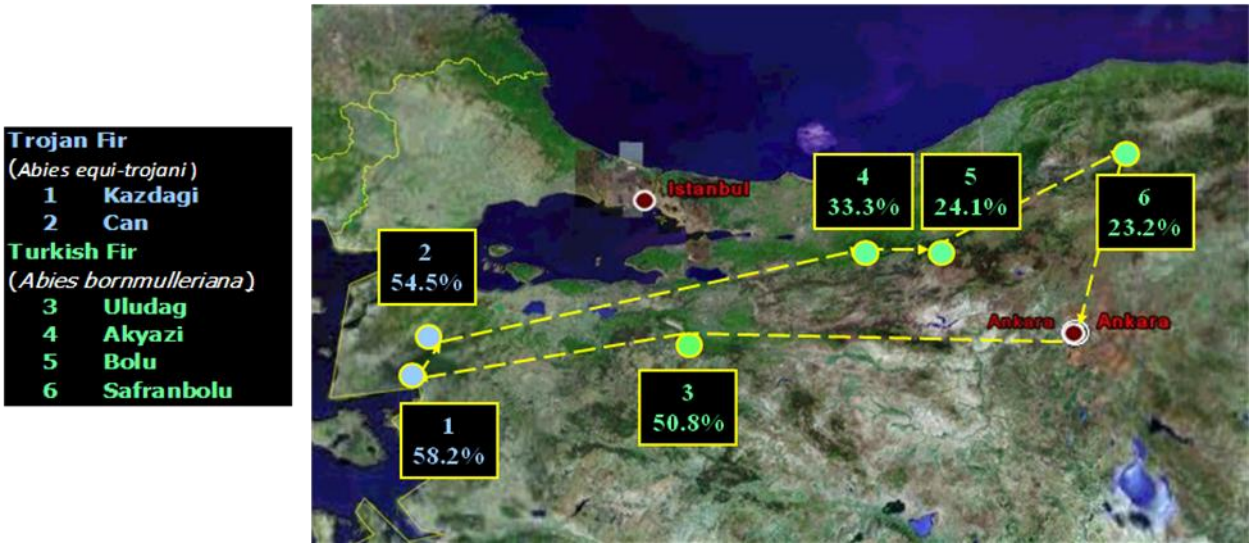

Figure 1. *Location in northwestern Turkey of the provenances of Trojan (n=2) and Turkish (n=4) fir sampled. In the Phytophthora inoculation trial, the mortality of seedlings (percentages indicated in boxes) varied by geographic origin; mortality decreased from west to east.*

Figure 2. *Decorated Turkish fir Christmas tree.*

Table 1. *Seedling mortality of Turkish and Trojan fir provenances and families 16 weeks after inoculation with* Phytophthora cinnamomi*.*

Provenance	# Families	--- Mortality (%) Week 16 --- Mean	Range of Family Means
		--- Trojan Fir (mean = 56.5%) ---	
Kazdagi	18	58.2	38.6-86.5
Can	16	54.5	19.7-78.6
		--- Turkish Fir (mean = 35.0%) ---	
Uludag	20	50.8	20.2-82.8
Akyazi	20	33.3	12.2-61.7
Bolu	12	24.1	10.9-39.9
Safranbolu	19	23.2	6.4-42.9