http://www.nrs.fs.fed.us/disturbance/invasive_species/hwa/effects_impacts/hybrid_hemlocks/
Web site of U. S. Forest Service, Northern Research Station

Development of Resistant Hybrid Hemlocks

Research Issue

Both native populations and landscape plantings of hemlocks [*Tsuga canadensis* (L.) Carrière and *T. caroliniana* Engelm.] have been devastated by the introduced insect pest hemlock woolly adelgid (HWA) (*Adelges tsugae* Annand). In particular, *T. canadensis* is an important component of landscape plantings from the higher elevations of the Southeast, through the Mid-Atlantic and New England states and into the Midwest. Currently, there is no known host resistance in the eastern North American hemlocks (*T. canadensis* and *T. caroliniana*). Western North American hemlocks (*T. heterophylla* Sargent and *T. mertensiana* Carrière) exhibit host plant resistance that has kept HWA in check; in Japan and China HWA is a minor pest due to a combination of host plant resistance and natural enemies. Using effective biological control agents, in combination with the development of resistant hybrid hemlocks, offers the best opportunity for maintaining hemlocks in the landscape. With no known host plant resistance in the eastern North American species, hybridization with resistant Asian or western North American species is the most sustainable approach for preserving the species in planted landscapes.

Our Research

- Produce clonal hemlock propagules of previously generated interspecific *Tsuga* hybrids and of *T. chinensis* seedlings of documented wild-collected germplasm accessions for further evaluation of adelgid tolerance and growth characteristics in multiple environments
- Evaluate the growth and resistance to HWA of hybrid-crosses between *T. chinensis* and *T. caroliniana* established at the USDA ARS Beltsville Research Center and a replicated field trial of documented wild-collected *T. chinensis* germplasm
- Determine nature of incompatibility between *T. canadensis* and other *Tsuga* species
- Determine fertility of interspecific *Tsuga* hybrids for generation of F2 and backcross populations and potential for hybridization with natural populations of *T. caroliniana*
- Develop technique for inoculating and screening container-grown *Tsuga* for comparison with field inoculation studies

Expected Outcomes

Demonstration that interspecific hybridization of *T. chinensis* with the susceptible species *T. caroliniana* and *T. sieboldii* is a promising method of producing hemlocks that are resistant to *A. tsugae* and have good growth characteristics.

Knowledge of incompatibility reactions between *Tsuga canadensis* and other *Tsuga* spp., which can then serve as a starting point for developing methods to overcome breeding barriers (via embryo rescue or direct somatic embryogenesis from endosperm).

Research Results

The initial stage of the U.S. National Arboretum breeding program established the selfing ability, compatibilities, and incompatibilities of interspecific *Tsuga* crosses. Molecular studies verified hybrids between *T. caroliniana* and *T. chinensis* (Franch) E. Pritz and between the Asiatic species *T. chinensis, T. diversifolia* (Maxim.), and *T. sieboldii* (Carrière). No hybrids between *T. canadensis* and the Asian species were found. Preliminary data from our lab show successful pollen tube growth and penetration of ovules > 6 weeks post-pollination in viable and non-viable crosses. In viable crosses, the ovule continues growth and matures; however, in non-viable crosses, the ovule fails to develop. This can be caused by a lack of fertilization or zygotic failure. This cause for failure has implications for developing methods to overcome breeding barriers between *T. canadensis* and resistant Asian species.

The original hybrids are demonstrating intermediate field tolerances to HWA, but long-term success may require combining diverse sources of resistance and evaluating new parental combinations. Preliminary data suggest that the direction of the cross may influence resistance, perhaps a result of paternally inherited chloroplast and maternally inherited mitochondria on secondary metabolites. Production of large F2 and backcross populations are necessary to maximize HWA resistance in hybrids. Furthermore, the fertility of *T. caroliniana* x *T. chinensis* hybrids will have to be evaluated to determine the ability for introgression of *T. chinensis* genes into natural populations of *T. caroliniana*.

Tsuga canadensis and *T. caroliniana*, the two eastern U.S. native species plus the Asian species *T. chinensis* and *T. sieboldii*, and the hybrids *T. chinensis* × *T. caroliniana* and *T. chinensis* × *T. sieboldii*, were artificially infested with the crawler stage of *A. tsugae* in the early spring of 2006 and 2007. After 8 or 9 weeks—when the spring (progrediens) generation would be mature—counts were made of the adelgid. In both years, the density of *A. tsugae* was highest on *T. canadensis*, *T. caroliniana*, and *T. sieboldii*; lowest on *T. chinensis*; and intermediate on the hybrids. On *T. chinensis* and the *T. chinensis* hybrids, fewer adelgids settled, fewer of the settled adelgids survived, and the surviving adelgids grew more slowly. Thus, both non-preference (antixenosis) and adverse effects on biology (antibiosis) are mechanisms of the host resistance. Tree growth (height) was associated with resistance, but no association was found between time of budbreak and resistance that was independent of the taxa. Many of the hybrids grow well, have attractive form, and are promising as resistant landscape alternatives for the native hemlocks.

Bentz, S.E., Montgomery, M. E. and Olsen, R. 2008. Resistance of hemlock species and hybrids to hemlock woolly adelgid In: Onken, B.; Reardon, R., eds. Morgantown, WV: Fourth hemlock woolly adelgid symposium, Hartford, CT, U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team: 137-139.

Montgomery, M. E.; Bentz, S. E.; Olsen, R. T. 2009. Evaluation of hemlock (*Tsuga*) species and hybrids for resistance to *Adelges tsugae* (Hemiptera: Adelgidae) using artificial infestation. Journal of Economic Entomology. 102: 1247-1254.

Research Participants

Principal Investigators

- Michael Montgomery, Research Entomologist, U.S. Forest Service, Northern Research Station
- Susan Bentz, U.S. National Arboretum
- Richard Olsen, U.S. National Arboretum

Research Partners

- Kevin Conrad, Curator, Woody Landscape Plant Germplasm Repository, USDA-ARS, U.S. National Arboretum
- Margaret Pooler, Research Geneticist, USDA-ARS, U.S. National Arboretum

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