

## RESISTANCE OF HEMLOCK SPECIES AND HYBRIDS TO HEMLOCK WOOLLY ADELGID

S.E. Bentz<sup>1</sup>, Michael E. Montgomery<sup>2</sup>, and Richard T. Olsen<sup>1</sup>

<sup>1</sup>USDA-ARS, Floral and Nursery Plants Research Unit, U.S. National Arboretum  
3501 New York Ave., N.E., Washington, DC 20002

<sup>2</sup>USDA Forest Service, Northeastern Center for Forest Health Research  
51 Mill Pond Road, Hamden, CT 06514

### ABSTRACT

In this study, *T. canadensis*, *T. caroliniana*, and *T. sieboldii* showed high levels of susceptibility and *T. chinensis* exhibited high levels of resistance to hemlock woolly adelgid; the hybrids of the resistant *T. chinensis* and *T. caroliniana* or *T. chinensis* and *T. sieboldii* showed intermediate resistance to HWA. After six years in a field setting, many of the hybrid plants are attractive as replacement species and appear suitable for landscape use

### KEYWORDS

*Tsuga* interspecific hybrids, insect resistance

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### INTRODUCTION

The eastern North American native hemlock species, *T. canadensis* [L.] Carriere and *T. caroliniana* Engelm., are highly susceptible to injury from the hemlock woolly adelgid (HWA), *Adelges tsugae*, while the Asian species, *T. chinensis* (Franch.) E. Pritz, *T. diversifolia* (Maxim.) Mast., and *T. sieboldii* Carriere are reported to show more resistance (Del Tredici and Kitajima 2004, McClure 1992 and 1995, and Montgomery 1999). The U.S. National Arboretum initiated a hemlock breeding program in the 1990s to assess the potential for controlled hybridization among different hemlock species utilizing both the HWA-susceptible eastern species and the HWA-resistant Asian species. In 2002, we reported on the extent of self-compatibility and hybridization from controlled pollination of several hemlock species (Bentz et al. 2002, Pooler et al. 2002). Attempts to hybridize *T. canadensis* with three Asian species were unsuccessful. However, more than 50 authentic hybrids from crosses between *T. caroliniana* and *T. chinensis* were identified by DNA fingerprinting. Crosses between the Asiatic species also were also successful. The hybrids, seedlings of the parent species, and self-pollinated progeny were planted in a randomized block design at the USDA's South Farm, Beltsville, Maryland, in the fall of 2002. Hybrids between *T. chinensis* and *T. caroliniana* and between *T. chinensis* and *T. sieboldii* are showing good survival and vigorous growth at this site, while survival of *T. caroliniana* has been poor. In 2006, a study was begun to assess the resistance of these hemlock species and their hybrids to HWA and to evaluate their horticultural and landscape qualities.

In April of 2006 and 2007, trees of *T. canadensis*, *T. caroliniana*, *T. chinensis*, and *T. sieboldii* and interspecific hybrids between *T. caroliniana* and *T. chinensis* and between *T. chinensis* and *T. sieboldii* were inoculated with crawlers of the progrediens generation of the HWA. Due to variability in size and health of trees, unequal numbers of trees were used (Table 1). Small infested branches, collected from heavily infested trees located at the U.S. National Arboretum, were divided into bundles of two to four branches. The average number of egg masses per bundle, 554 and 626 in 2006 and 2007, respectively, was determined by counting all egg masses on 10 randomly selected bundles. These bundles were placed mid-branch on an interior branch of each tree and enclosed in mesh fabric bags in one to two days during the first week of April. In mid-June when approximately 50% of the progrediens were adults, establishment and development of HWA was monitored by randomly removing three twigs (2006) and five twigs (2007) from each bagged branch and taken to the laboratory for examination under the microscope. Bags remained on trees until July of each year to contain dispersal to adjacent branches or trees. The entire branch was removed from the test trees in November or December to sample HWA sistens populations on new growth, and HWA sistens on 10 twigs per tree were counted in the laboratory.

Table 1. 2007 census (number per centimeter) of progrediens generation 10-weeks after inoculation with HWA crawlers on plants from controlled pollinations of *Tsuga* species.

Hosts	N	TOTAL SETTLED	DEVELOPING	APTERA ADULTS
<i>Tsuga chinensis</i>	10	0.18±1.05	0.01±0.71	0.00±0.15
<i>T. chinensis</i> × <i>caroliniana</i>	14	1.96±0.89	0.52±0.60	0.02±0.13
<i>T. chinensis</i> × <i>sieboldii</i>	15	2.16±0.86	0.69±0.58	0.08±0.12
<i>T. sieboldii</i> × <i>chinensis</i>	12	2.91±0.96	1.06±0.65	0.09±0.14
<i>T. caroliniana</i> × <i>chinensis</i>	21	3.75±0.73	1.41±0.49	0.04±0.10
<i>T. sieboldii</i>	10	8.93±1.05	5.81±0.71	0.95±0.15
<i>T. caroliniana</i>	7	9.77±1.26	6.17±0.85	1.11±0.18
<i>T. canadensis</i>	11	9.96±1.00	6.99±0.68	1.83±0.14

Values are means ± SE per cm of previous year's twig growth.

The June 2006 and June 2007 data (Table 1) show high levels of infestation on *T. canadensis*, *T. sieboldii*, and *T. caroliniana*; intermediate infestation of the hybrids; and poor to no infestation of *T. chinensis* by the progrediens generation. Evaluation of the wintering, sistens generation on the new growth is shown in Table 2.

Table 2. Number sistens settled on new growth in December 2007 following inoculation the previous April.

Hosts	N	SETTLED/CM
<i>Tsuga chinensis</i>	10	0.03
<i>T. chinensis</i> × <i>caroliniana</i>	14	0.08
<i>T. chinensis</i> × <i>sieboldii</i>	15	0.44
<i>T. sieboldii</i> × <i>chinensis</i>	12	0.62
<i>T. caroliniana</i> × <i>chinensis</i>	21	0.30
<i>T. sieboldii</i>	10	3.87
<i>T. caroliniana</i>	7	2.97
<i>T. canadensis</i>	11	5.53

These results reflect the progrediens generation, except that the number on the hybrids is closer to the number on *T. chinensis*. The sistens were still in the first instar and appeared to be dead on all samples. We are not sure if this is an effect of leaving on the bags during the hot weather, summer drought, or the juvenile character of the trees.

In this study, *T. canadensis*, *T. caroliniana*, and *T. sieboldii* showed high levels of susceptibility and *T. chinensis* exhibited high levels of resistance; the hybrids between the resistant *T. chinensis* and *T. caroliniana* or *T. sieboldii* showed intermediate resistance to HWA. Further testing under natural infestation conditions is planned to evaluate whether the hybrids will demonstrate similar and/or adequate field resistance on a long-term basis. It will also provide opportunity to evaluate the flowering phenology of the hybrids to determine whether the potential for interbreeding with native populations exists. Lastly, after six years establishment in the field planting, it is apparent that many of the hybrid plants are attractive and suitable for horticultural and landscape use. Propagation for HWA testing and landscape evaluation is proceeding.

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