Cold Hardiness Considerations for Restoration of Dutch Elm Disease-Tolerant American Elm

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INTRODUCTION

Tolerance of Dutch elm disease (DED) is the greatest challenge faced by American elm (*Ulmus americana* L.) populations in North America. However, adaptation to local environmental factors is also an important consideration for breeding efforts of DED-tolerant American elm because the species grows in wetlands and floodplains and was planted in urban settings across a very wide geographic range. For example, American elm grows from Florida to Canada, a territory that spans USDA Plant Hardiness Zones 9b through 2b, with 30-year average annual temperatures ranging from extreme −1 to −42.9 °C. In addition to DED tolerance, it seems likely that matching the cold tolerance of planting stock to the winter temperature extremes of a planting site may also be important for the success of restoration efforts. Questions exist for how genetic lines of DED-tolerant sources currently being tested for species restoration differ in cold hardiness and whether crossing these lines with American elm from colder plant hardiness zones can bolster the cold tolerance of resulting progeny. Here we describe the results of a preliminary test of possible differences in cold hardiness and field-winter injury of shoots of American elm from two maternal sources of DED tolerance crossed with paternal sources of large-residual American elm from three USDA Plant Hardiness Zones (USDA Agricultural Research Service 2018).

METHODS

An American elm restoration trial was established in a field located in the rich soils of the Connecticut River floodplain in Lemington, Vermont. Lemington is in Plant Hardiness Zone 3b, which had an average annual temperature ranging from extreme minimum −37.2 to −34.4 °C from 1976 to 2005. Current-year shoots were collected from two maternal sources of DED tolerance (i.e., Valley Forge and R18-2); four paternal sources from Plant Hardiness Zone 5a; three paternal sources from Zone 6b; and four sources from Zone 6a in December 2016, February 2017, and April 2017. Shoots were transported to our cold-tolerance laboratory where they were chopped into 5-mm internodal segments and subsamples exposed to gradually lower test temperatures ranging from +5 to −90 °C. After low temperature exposure, rehydrated shoot segments were tested for electrolyte loss following possible low temperature damage using a multielectro-conductivity bridge. Because cell membranes damaged by freezing injury leak electrolytes, we measured the relative electrolyte leakage (REL) from samples as an indicator of cell injury. The temperature (T_m) at the midpoint of progressive REL increases—that terminate with maximum-electrolyte loss with complete cell death—were used as an estimate of shoot-cold tolerance (Schaberg et al. 2000, 2005; Strimbeck et al. 1995). In addition to laboratory measurements, in July 2017 after leaf-out, winter shoot mortality was visually assessed as dark colored and sunken portions of stems on current-year shoots (Saielli et al. 2014). Deer browse

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Figure 1.—Differences in mean (± SE) shoot cold tolerance (T_m) between the three paternal source hardiness zones in midwinter–February 2017. Means with different letters are significantly different at $p \leq 0.05$, based on results from a Tukey HSD test.

was also quantified during July assessments because it was noted that browse pressure was high and could limit the complete accounting of the percentage of terminal shoots damaged by freezing injury.

RESULTS

Shoots were most cold tolerant in midwinter, followed by late fall, and then early spring. Regardless of date, there were no differences in shoot cold tolerance associated with maternal sources of DED tolerance. Indeed, cold tolerance means for Valley Forge and R18-2 sources were near identical on each sample date. In contrast, regardless of date, paternal sources from Zone 5a (i.e., the coldest zone tested) were significantly more cold tolerant than trees from Zone 6b (i.e., the warmest zone) with trees from Zone 6a being intermediate in cold tolerance. This pattern was most pronounced and significant in midwinter (Fig. 1) when ambient air temperatures in the field reached their lowest (i.e., −30.8 °C). July assessments of shoot winter injury in the field confirmed widespread (i.e., >83 percent) of sample trees exhibited freezing injury visible as dead shoot tips with dark sunken lesions on the bark. However, because deer browse damage was so high (with nearly 84 percent of trees in the planting overall showing browse damage), an accurate estimate of the percentage of winter-injured current-year shoots was impossible to assess.

DISCUSSION

Shoot cold tolerance was greatest in winter—a time when greater cold tolerance would be most protective. The lack of differences in maternal cold tolerance may be due to extensive selection for DED-tolerance and a lack of local adaptation to the cold. The overall pattern of cold hardiness among paternal sources was consistent with the origins of their plant-hardiness zones (e.g., trees from sources with parental heritage from the coldest hardiness zones were more cold tolerant than tree from sources from the warmest hardiness zone). Indeed, in winter the difference between cold tolerance means for sources with paternal heritage from the coldest versus the warmest hardiness zones was ~7.4 °C, which is within 1 °C of the 8.3 °C average divergence in mean minimum temperature experienced within these zones from 1976 to 2005.

CONCLUSIONS

American elm bred for DED-tolerance are vulnerable to freezing injury that can reduce crown fullness. However, the differences in cold tolerance consistent with the temperature zone of paternal sources that we detected suggest that improvements in local adaptation to the cold can be transferable via selective breeding.

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