Seedling Submergence Tolerance of Four Western Conifers

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Submergence tolerance of 2-year-old conifer seedlingsDouglas-fir (Pseudotsuga menziesii (Mirb.) Franco), lodgepole pine (Pinus contorta Dougl. ex Loud.), Engelmann spruce (Picea engelmannii Parry ex Engelm.), and blue spruce (P. pungens Engelm.)-was determined by submerging entire seedlings for 0, 3, 7, 10, 14, 21, and 28 days under non-aerated and aerated conditions. Less than a third of the seedlings of all species survived for 14 days, and all seedlings except some blue spruce died after 21 days of submergence. Forty percent of submerged blue spruce survived 21 days of submergence, No seedling of any species tolerated 28 days of submergence. Aeration did improve survival in some cases. Tree Planters' Notes 42(2):45-48; 1991.

Under natural conditions conifer seedlings can be completely submerged by melt or flood water in natural basins or near streams. For example, parts of Idaho's Targhee National Forest are occasionally flooded so that planted seedlings are entirely submerged for periods of up to 2 to 3 weeks (6). Because seedling mortality occurs in these areas, land managers need to know how long conifers can tolerate submergence, whether there are tolerance differences between species, and whether the aeration of moving water results in higher survival than in stagnant water.

We determined the tolerance of actively growing Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), and blue spruce (*Picea pungens* Engelm.) seedlings to total submergence in water for varying period under aerated and non-aerated conditions. The aeration treatments simulated flooded sites with fresh water flowing through them, while the non-aerated treatments mimicked flooded areas with stagnant water.

Methods

Three conifer species were tested for submergence tolerance under non-aerated conditions in 1986 and four species were tested under both non-aerated and aerated conditions in 1987. Douglas-fir, lodgepole pine, and Engelmann spruce seedlings came from seed sources in south-central Montana, whereas blue spruce seedlings were obtained from southeastern Idaho. All seedlings in the test were dormant 2-year-old bareroot stock and were planted singly in 2.5-cm-diameter by 25-cm-long containers in a sandy-loam medium. Trees were planted in a greenhouse until the initiation of vegetative growth, as determined by bud break.

In 1986, 24 seedlings each of Douglas-fir, lodgepole pine, and Engelmann spruce were used to determine submergence tolerance in non-aerated water. Four seedlings of each species were subjected to each of six treatments: controls (0 days), and 3, 7, 14, 21, and 28 days of submersion. The experiment was repeated in 1987 with an additional species (blue spruce), a seventh submergence treatment (10 days), and a parallel series of aeration treatments. Five seedlings of each species per treatment were used. Thus, we tested 72 seedlings (6 submergence treatments x 4 seedlings x 3 species) in 1986 and 280 (7 submergence treatments x 5 seedlings x 4 species x 2 aeration treatments) in 1987.

Seedlings were completely submerged in water-filled tanks that were 0.6 m wide by 1.2 m long by 0.9 m deep. Seedlings were aerated by bubbling ambient air through the water with a fish tank aeration unit. The tanks were kept in a greenhouse with day and night air temperatures of 24 and 13 °C, respectively.

We removed seedlings from the tanks after treatment, kept them under normal greenhouse conditions, and determined how many seedlings were dead or alive after 8 weeks. Dead seedlings were easily distinguished by dry brittle stems and needles. No statistical analysis was done and there was no within-year replication.

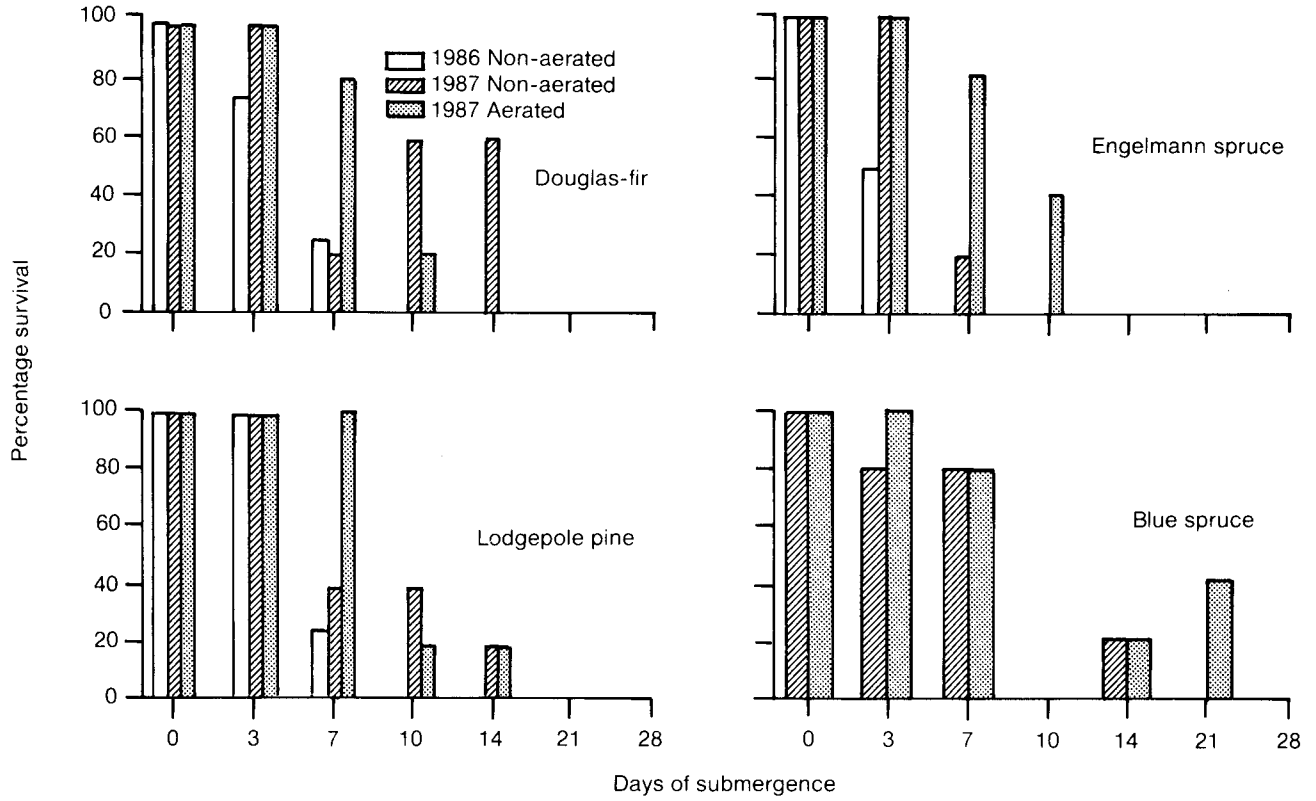

Figure 1—*Percentage survival of Douglas-fir, lodgepole pine, Engelmann spruce, and blue spruce seedlings under 1986 non-aerated, 1987 non-aerated, and aerated treatments under various periods of submergence.*

Results and Discussion

Effects of non-aeration. In non-aerated water, some seedlings of Douglas-fir, lodgepole pine, and blue spruce tolerated and survived complete submergence for at least 14 days while Engelmann spruce tolerated submergence for 10 days or less (fig. 1). Patterns of decreasing survival percentage with increasing length of submergence were consistent between species from year to year. Differences in the vigor of seedlings obtained from the nursery probably attributed to the inconsistences in submergence tolerance between years within species.

A search of the literature turned up no information on the effects of complete submergence on conifer seedlings but did produce findings on the impact of root flooding. Foliage and tree stems are not submerged during root flooding, and oxygen transport in the non-flooded portions of the tree is possible (2). Actively growing Sitka spruce *(Picea sitchensis* (Bong.) Carr.) seedlings were alive after 22 days

of root flooding (3). After 4 weeks of root flooding, Douglas-fir suffered high mortality, Sitka spruce, and western hemlock *(Tsuga heterophylla* (Raf.) Sarg.) showed intermediate mortality; and western redcedar *(Thuja plicata* Donn ex D. Don) and lodgepole pine showed high resistance to the effects of root flooding (7). Balsam fir *(Abies balsamea* (L.) Mill.), black spruce *(Picea mariana* (Mill.) B.S.P.), white spruce (*P. glauca* (Moench) Voss), eastern white pine *(Pinus strobus* L.), and red pine *(P. resinosa* Ait.) all tolerated root flooding for up to 48 days (1). Baldcypress *(Taxodium distichum* (L.) Rich) and redwood *(Sequoia sempervirens* (D. Don) Endl.) grow well even when their roots are flooded for long periods (5, 9). Although baldcypress and redwood can tolerate root flooding very well, most hardwoods are better able to tolerate flooding than conifers (4).

In our study, lodgepole pine and Douglas-fir tolerated submergence only slightly better than did Engelmann spruce (14 versus 10 days, respectively). Lodgepole pine tolerated root flooding much better than Sitka spruce in a study by Philipson and Coutts (8). The greater flood tolerance of lodgepole pine in Philipson and Coutts' study was attributed to its transport of oxygen in the xylem and bark while oxygen transport was confined to the bark for spruce and probably produced deficit O_2 levels. Our observations of lodgepole pine mortality after only 7 to 14 days of submergence are consistent with this hypothesis because pine seedlings that are submerged lose the ability to acquire oxygen for transport through the xylem tissues. Coutts (3) found that Sitka spruce survived longer periods of root flooding when dormant than when actively growing. We measured the tolerance of actively growing seedlings; it is possible that dormant plants would have shown greater tolerance to total submergence.

Effects of aeration. In 1987, seedlings of Engelmann (7 days' submergence), blue spruce (3 days' submergence), and Douglas-fir (7 days' submergence) survived longer periods of total submergence under aerated than non-aerated conditions whereas the opposite occurred for Douglas-fir (10 days' submergence) (fig. 1). Aeration increased short-term root flooding tolerance of Douglas-fir and Norway spruce *(Picea abies* (L.) Karst.) seedlings in experiments by Zaerr (10). However, Minore (7) reported that aeration of Douglasfir roots may reduce flood tolerance in some situations.

Except for 2 blue spruce seedlings that survived with aeration for 21 days, all other seedlings survived less than 21 days of total submergence. Engelmann spruce did not tolerate submergence for more than 10 days under aerated or non-aerated conditions. It was unknown why no blue spruce seedlings survived the 10-day submergence treatment while others survived the 14- and 21-day treatments.

Conclusion

Most actively growing seedlings of western conifers are killed after 10 to 14 days of submergence. Managers seeking to prevent mortality of conifer seedlings should therefore avoid planting in areas where flooding is expected and should attempt to drain flooded areas before 10 days. Engelmann spruce appears to tolerate total submergence less than Douglas-fir, lodgepole pine, and blue spruce. Aeration did in some cases improve survival.

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