THE RESPONSE OF WILLOW OAK (*QUERCUS PHELLOS*) SEEDLING ROOTS TO FALL ENVIRONMENTAL CUES AND WINTER FLOODING

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EXTENDED ABSTRACT

The timing of seasonal flooding in bottomlands relative to seedling dormancy is a crucial determinant of how flooding affects seedlings (Sample and Babst 2020, Sample and others 2023). Alterations to seasonal flood regimes likely plays a role in poor regeneration of bottomland red oak species such as willow oak (*Quercus phellos*) in the Lower Mississippi Alluvial Valley, especially in greentree reservoirs (GTRs). For example, natural waterlogging tends to occur, as well as sporadic flooding, from mid-December through May, and it is assumed that dormancy confers greater resistance to flooding (Broadfoot and Williston 1973, Guttery and Ezell 2006, Therrell and Bialecki 2015). However, artificial flooding is typically initiated earlier in GTRs, often in November, but in some cases as early as October (Guttery and Ezell 2006, Wigley and Filer 1989).

This study investigated 1) whether roots of willow oak seedlings enter dormancy during winter, 2) if cold soil temperatures and other environmental cues reduce root activity in willow oak during winter, and 3) if reduced root activity increased root tolerance to winter soil flooding. We employed an experimental approach to study first-year willow oak seedlings in a greenhouse and a correlative approach to sample first-year, naturally seeded willow oak seedlings in the field. In the greenhouse experiment, soil temperature of potted seedlings was manipulated using large water baths that maintained temperatures within ±0.5 °C of set points (fig. 1).

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Figure 1—Willow oak seedlings in soil temperature control tanks. Pots in leak-proof plastic bags were placed in tanks to maintain soil temperature within ±0.5 °C. (Photo courtesy of Benjamin A. Babst)

In the greenhouse and field, willow oak leaves were semipersistent during winter. Retention of green leaves through the winter implies that carbon fixation and carbohydrate supply to the roots continued through both studies. In the greenhouse, root growth and respiration decreased when soil temperature was lowered. However, at 10 °C, which is close to the average soil temperature in the Lower Mississippi Alluvial Valley, root growth continued at a moderate rate. This suggests that willow oak seedling roots may not enter dormancy during winter. Temperature effects on root respiration were direct and immediately reversible, i.e., the effects of temperature were not due to acclimation by the roots. Though soil temperature clearly had a strong influence on root respiration, respiration also decreased over the winter months if soil temperature was held constant at 15 °C. Hence, something other than soil temperature caused reduced root activity in the winter but not to the same extent as low soil temperatures.

In the field, willow oak seedlings exhibited decreased root respiration immediately following frost events, but respiration rebounded as air temperatures increased. Root respiration was much more variable in the field than in the greenhouse and was positively correlated to average soil temperature and maximum daily air temperature. Root respiration also had weaker inverse correlations with photosynthetically active radiation and quantum yield of photosystem II.

Soil flooding initiated in December immediately halted root growth but did not reduce root respiration. Survival and spring growth were high for seedlings in all treatments. Seedlings that experienced warmer winter soil temperatures showed greater morphological indication of flooding stress, which included presence of hypertrophied lenticels and adventitious root growth to the surface of floodwater.

Our results indicate that soil temperature has a major influence on root growth and respiration, but daytime high air temperatures may also be important for root respiration. Root growth could continue during typical winter soil temperatures in the Lower Mississippi Alluvial Valley. This active tissue growth could be more vulnerable to hypoxia, but flooding stress on willow oak seedlings appears relatively low during the winter even when soil temperature is not low enough to stop root growth. It is not clear whether willow oak seedlings that retain leaves will be at a greater risk of damage or mortality due to overtopping by flood waters, which is common in bottomland forests and GTRs.

Because fall and spring flooding have negative impacts on willow oak seedlings (Sample and Babst 2020, Sample and others 2023), waiting to flood GTRs until root activity declines in early to mid-winter, and draining flood waters in early spring may decrease the stress experienced by willow oaks in these forests.

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LITERATURE CITED

Broadfoot, W.M.; Williston, H.L. 1973. Flooding effects on southern forests. Journal of Forestry. 71: 584–587.

Guttery, M.R.; Ezell, A.W. 2006. Characteristics of a bottomland hardwood forest under greentree reservoir management in east central Arkansas. In: Connor, KF., ed. Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-92. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 409–411.

Sample, R.; Babst, B.A. 2020. Autumn flooding disrupts seasonal nitrogen storage and impacts spring growth in *Quercus texana* seedlings. Trees. 34: 813–823. https://doi.org/10.1007/s00468-020-01960-5.

Sample, R.D.; Cook, J.; Babst, B.A. 2023. Resiliency of Nuttall oak but not Shumard oak to winter and spring flood: dormancy alone does not confer flood tolerance. Trees. 37: 1121–1136. https://doi.org/10.1007/s00468-023-02411-7.

Therrell, M.D.; Bialecki, M.B. 2015. A multi-century tree-ring record of spring flooding on the Mississippi River. Journal of Hydrology. 529: 490–498. https://doi.org/10.1016/j.jhydrol.2014.11.005.

Wigley, T.B., Jr.; Filer, T.H., Jr. 1989. Characteristics of greentree reservoirs: a survey of managers. Wildlife Society Bulletin. 17: 136–142.