SILVICULTURAL TREATMENTS TO IMPROVE PONDBERRY STEM LENGTH GROWTH

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Abstract—Pondberry (*Lindera melissifolia* (Walter) Blume) is a deciduous woody shrub in the Lauraceae that is endemic to low-lying forests in seven southeastern states. In the Mississippi Alluvial Valley, pondberry occurs in the understory of bottomland hardwood forests. This rare shrub was listed as an endangered species in 1986. The U.S. Fish and Wildlife Service published a pondberry recovery plan in 1993, establishing objectives for recovery and delisting the species. One action step to delisting pondberry is the development of management practices to recover and conserve the species. The Center for Bottomland Hardwoods Research, Forest Service, U.S. Department of Agriculture (Southern Research Station) initiated a comprehensive research program to study pondberry in 2002. Findings from much of this research, particularly research on pondberry ecophysiology, provide implications for active management of this species. This manuscript draws upon research findings to propose silvicultural treatments for improving stem length growth of existing pondberry plants. I also describe field experiments that are needed to confirm that proposed silvicultural treatments will sustain existing pondberry colonies.

INTRODUCTION

Pondberry (*Lindera melissifolia* (Walter) Blume) is a woody shrub in the Lauraceae. It is extant in seven states across the southeastern United States including Alabama, Arkansas, Georgia, Mississippi, Missouri, North Carolina and South Carolina, and presumed extirpated from Louisiana and Florida. The species was listed in 1986 as endangered under the federal Endangered Species Act of 1973 (Currie 1986). A subsequent recovery plan was completed in 1993 with the objective to delist the species (DeLay and others 1993). Based on this recovery plan, pondberry would be down-listed from endangered to threatened when there are 15 protected, self-sustaining populations distributed throughout the species' historic range, and would be considered for delisting when there are 25 such populations (DeLay and others 1993). A recent 5-year review by the U.S. Fish and Wildlife Service indicated no change in the endangered status of pondberry as populations were considered stable or declining depending on location (Wiggers 2014).

Little knowledge of pondberry biology was available when the initial recovery plan was written (Klomps 1980, Priest and Wright 1991, Richardson and others 1990, Tucker 1974, Wright 1989, 1990a, 1990b, 1994). In the past 20 years, information on pondberry biology has greatly increased (Aleric and Kirkman 2005a, 2005b, Beckley and Gramling 2013, Connor and others 2007, 2012, Devall and others 2001, Echt and others 2006, 2011, Fraedrich and others 2011, Godt and Hamrick 1996, Gustafson and others 2013, Hawkins and others 2007, 2009a, 2009b, 2010, 2011, Lockhart and others 2012, 2013, Smith and others 2004, Taylor 2008, Unks 2011, Unks and others 2014). A formal program of pondberry research in the Mississippi Alluvial Valley (MAV) was initiated in 2002 by the Forest Service, U.S. Department of Agriculture, in cooperation with the U.S. Army Corp of Engineers and the U.S. Fish and Wildlife Service. This research was prompted by the need for more biological information on pondberry in the MAV that would better inform the question as to whether construction of the Yazoo Backwater Pump Project proposed by the U.S. Army Corp of Engineers would affect pondberry populations in the Delta National Forest, Sharkey County, MS. After 12 years of research on the ecology and ecophysiology of pondberry in the MAV, information has been developed to consider silvicultural treatments designed to increase pondberry stem length growth. My objectives in this paper are to 1) review the life history characteristics of pondberry, including recent research findings, 2) use this information from pondberry life-history characteristics to propose silvicultural treatments to increase pondberry stem length growth, and 3) discuss potential silviculture research that could increase pondberry stem length growth in the MAV. The focus of this paper is pondberry found in the MAV unless otherwise explicitly noted.

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LIFE-HISTORY CHARACTERISTICS

Pondberry is a deciduous, aromatic shrub that grows 30 cm to 2 m in height. Disjunct populations grow in seasonally flooded bottomland hardwood forests in the MAV (Hawkins and others 2009b) and along the edges of isolated Carolina bays, limestone sink ponds, sand ponds and lowland sand prairie depressions in the southern Atlantic Coastal Plain and eastern Gulf Coastal Plain (Wiggers 2014). Hydroperiod at these latter sites is typically maintained by precipitation, although some sites may be supplemented with groundwater. In contrast, hydroperiod in bottomland hardwood forests is thought to be maintained by overbank flooding, local precipitation or storage in depressions (Wiggers 2014). Habitat destruction, fragmentation, altered hydroperiods, and competing vegetation are potential threats to pondberry populations. Further, pondberry is susceptible to the lethal laurel wilt, a vascular disease caused by the fungus *Raffaelea lauricola*, which is transmitted by the invasive redbay ambrosia beetle (*Xyleborus glabratus)* (Fraedrich and others 2011). Therefore, pondberry populations are particularly vulnerable to local extirpation (Beckley 2012).

Pondberry is considered flood tolerant. However, recent research indicates that soil flooding is not required for the development of vigorous pondberry plants. For example, Lockhart and others (2013) showed 2-year-old pondberry plants were minimally affected by 45 or 90 consecutive days of soil flooding over two growing seasons in an outdoor flooding impoundment facility. Survival, stem length and stem diameter were similar between non-flooded and flooded plants. However, Hawkins and others (2009a) reported less biomass for juvenile pondberry receiving 30 days or 60 days of soil flooding than for plants receiving no soil flooding. Hawkins and others (2009a) indicated that actively-growing first-year plants are not adapted to tolerate extended flooding conditions.

Wright (1990b) hypothesized that soil flooding serves to minimize interspecific competition in pondberry populations. Wright (1989) found competing species had twice the stem length as pondberry when grown at the higher end of a pond bank, suggesting that soil flooding at the lower end of the bank was helpful in reducing interspecific competition. Pondberry populations are found in areas where they are most competitive but not necessarily in areas where they grow optimally in the absence of competition. Possible competing species, such as American buckwheat vine (*Brunnichia ovata* (Walters) Shinners) (Wright 1990b), *Smilax* spp. and *Vitis* spp. (Hawkins and others 2010), are less flood tolerant than pondberry and therefore may be at a competitive disadvantage when found in areas with longer hydroperiods.

Pondberry in the MAV is observed in the understory of mature bottomland hardwood forests (Klomps 1980, Priest and Wright 1991, Smith 2003, Wright 1989). Therefore, it has been classified as shade tolerant (Devall and others 2001). Wright (1990a) showed that pondberry could generate positive net photosynthesis at light levels as low as 5 percent of full sunlight, and increased photosynthetic rate as light increased to about 50 percent of full sunlight. Aleric and Kirkman (2005a) showed that best Atlantic Coastal Plain (ACP) pondberry growth occurred at light levels near 40 percent of full sunlight. Lockhart and others (2013) showed that pondberry plants raised under 37 percent light had greater stem length growth than plants raised beneath 70 percent or 5 percent light. Unks and others (2014), using ACP pondberry plants, confirmed the findings of Lockhart and others (2013) that low light levels (< 5 percent light) resulted in decreased growth. These studies show that pondberry can acclimate to a wide range of light availability, but best stem growth occurred at around 40 percent of full sunlight. This conclusion is further substantiated by Lockhart and others (2015). Pondberry raised for four growing seasons in 5 percent light were released to either 70 percent or 37 percent light. After three growing seasons with increased light availability, plants raised in 37 percent light had 23 percent greater stem length than plants raised in either 70 percent or 5 percent light.

Observations of extant pondberry populations found in the shaded understory of mature bottomland hardwood forests do not take into account past disturbance. Current pondberry populations may be legacies from past forest disturbance that provided conditions for establishment and development of vigorous pondberry populations. When the forest canopy closed during normal stand development processes, the amount of available light decreased, leading to decreased pondberry growth. Beckley (2012) indicated that many pondberry populations in the ACP have been exposed to anthropogenic or natural disturbances through time. Therefore, Lockhart and others (2012) also consider pondberry in the MAV a disturbance-dependent species. Field observations and results from research cited above indicate that silvicultural treatments designed to (1) increase light levels reaching the forest understory, and (2) control vegetation competing with pondberry, could be used to increase pondberry stem length growth.

SILVICULTURE TREATMENTS

Mature bottomland hardwood forests in the MAV typically have a closed or partially closed overstory canopy due to minor natural disturbances or past harvesting practices. Sunlight that filters through these canopies has led to the development of a dense midstory canopy composed of shade-tolerant species. Available light in the understory of these forests is oftentimes less than 5 percent of full sunlight (Cunningham and others 2011, Jenkins and Chambers 1989, Lockhart and others 2000, Lhotka and Loewenstein 2006). Therefore, silvicultural treatments are needed to increase the amount of available light reaching the understory to increase pondberry stem length growth.

Research indicates that silvicultural treatments, such as midstory canopy removal, designed to increase the vigor and growth of advance bottomland red oak (*Quercus* spp.) reproduction may also be applicable to increase the stem length growth of pondberry. For example, Lockhart and others (2000) found that removal of the midstory canopy by chainsaw felling and treatment of stumps to prevent sprouting increased understory light availability to 40 percent of full sunlight. Lhotka and Loewenstein (2006) found that chainsaw felling of the midstory canopy (defined as trees not in the dominant or codominant crown class) increased understory light availability to 21 percent of full sunlight. Guttery and others (2011) found that chemical treatment of the midstory increased light availability reaching the understory by 56 percent, from 14 percent of full sunlight in untreated plots to 32 percent of full sunlight in treated plots. The high variability among these studies of understory light levels following stand treatment is due to differences in initial stand structure, species composition and level of treatment. Further, additional midstory canopy treatments may be necessary to control future competing vegetation, especially if shade-tolerant stems that were considered too small to treat in the initial treatment respond to increased light availability (Lockhart and others 2010). However, these results indicate that treatment of the midstory canopy will significantly increase light availability to understory plants such as pondberry.

While these treatments have been successful in increasing advance oak reproduction vigor and growth, they have not been scientifically tested for pondberry. Glitzenstein (2007) reported on the creation of forest canopy gaps over pondberry colonies in the Francis Marion National Forest in South Carolina. Sub-canopy trees were also felled and pondberry shrubs were clipped to induce sprouting. Pondberry can produce numerous sprouts and ramets when the shoot is clipped (personal observation). Three years following initial treatment, pondberry stem numbers increased 9 percent and total stem length (sum of the lengths of all stems in the colony) increased 119 percent (Glitzenstein 2007). Glitzenstein (2007) indicated that vegetation competing with pondberry was reduced or eliminated during the 3-year period following gap creation and initial competition control.

Glitzenstein (2007) and Lockhart and others (2015) show that pondberry will increase stem length growth with increases in light availability. Other plant species will also increase stem length with increases in light availability, including herbaceous plants and vines than can compete vigorously with pondberry. In the MAV, flood water may reduce this competing vegetation. If flood water does not reduce competing vegetation, then mechanical or chemical treatment will be needed to reduce vegetation that threatens to overtop pondberry.

In addition to variations in hydroperiod, pondberry populations in the ACP experience periodic fire disturbance. Infrequent, low-intensity fire is hypothesized to reduce competition from other plant species (Unks and others 2014). Concurrently, pondberry is able to survive such fires by regenerating from rhizomes. However, Unks (2011) cautioned that high-intensity fires may kill pondberry. Wiggers (2014) stated that the relationships between pondberry and fire is complex and requires further study. It is unknown if prescribed fire can be a silvicultural treatment in managing competing vegetation in pondberry populations in the MAV. Fire is poorly understood in MAV natural disturbance regimes and requires further study.

FUTURE RESEARCH

Priorities for research to determine silvicultural treatments that increase pondberry stem length growth would logically include long-term applied field studies with existing pondberry populations. Many pondberry colonies in the MAV are declining due to a lack of canopy disturbance, which results in low light availability. For example, a 30-m buffer is established around extant pondberry colonies on the Delta National Forest prior to tree harvesting operations (Banker and Goetz 1989). No silvicultural treatments are allowed near pondberry populations; therefore, low understory light levels remain despite forest canopy disturbance that increase light levels reaching the understory in the remainder of the stand

Overstory canopy and midstory canopy manipulation with mechanical and chemical treatments should be tested to determine specific protocols that increase light reaching pondberry plants. Further, individual stems can be severed at the ground line to induce sprouting. Stem clipping, in concert with increased light availability, has shown promise as a way to reinvigorate individual pondberry plants (Unks and others 2014). Additional research should include silvicultural treatments to control expected increases in competition from vines and other plants that will also respond to increased light availability. Ideally, study sites should be located along an elevational gradient. Low-elevation sites will flood more frequently than relatively higher elevation sites; therefore, natural hydroperiod effects on pondberry and potentially competing plants can be observed. Field experiments should be located on public lands to reduce the risk of changes in land ownership or landowner management objectives during ongoing long-term field experiments.

Pondberry field research will be difficult. First, colonies are scattered and small in area. This will largely negate the use of standard experimental research designs with proper replication on individual populations, such as split-plot designs to test various midstory competition control treatments. The risk of treatment effects from one plot affecting adjacent plots will be high, as little space will be available for effective buffers between treatments. A completely randomized design or a paired-plot design may be necessary, with individual pondberry colonies within populations used as experimental units, but this will require a large number of colonies to reduce the variability within colonies. Second, individual pondberry colonies will have high variability, as individual stems may be male or female, of different ages, and of seedling or ramet origin. High individual stem variability will require a large number of stems in each experimental unit. Planted pondberry seedlings or stecklings can be used in concert with research on extant plants to reduce variability in addition to testing artificial regeneration techniques (see Devall and others (2004) and Smith (2003) for examples of planting pondberry). Third, pondberry is an endangered species. Field experiments will require special use permits from the U.S. Fish and Wildlife Service. Further, experiments on public land, such as on the Delta National Forest, may require additional documentation, including possible National Environmental Policy Act (NEPA) approval. A considerable amount of time and planning will be necessary to obtain all approvals before field research can begin.

CONCLUSIONS

Pondberry is a disturbance-dependent species that requires somewhere between 40 percent and 70 percent of full sunlight for best stem length growth. In the MAV, pondberry populations are often found in the understory of bottomland hardwood forests–presumably relic populations reflecting past disturbance. Light levels in these populations can be as low as 5 percent of full sunlight, resulting in poorly-formed plants.

Research has shown that pondberry can respond to increases in light availability through greater stem length growth. Silvicultural treatments, such as mechanical or chemical control of midstory forest canopies, may be an effective tool to increase light available to extant pondberry populations. Further treatments will likely be necessary to control vegetation that will also respond to increased light availability and compete with pondberry, especially if flood waters are ineffective at reducing this competition.

Field research is needed to confirm that application of treatments suggested in this paper can be effective silvicultural tools to increase pondberry stem length growth. Results from this research could be used to develop a pondberry population maintenance program that will require initial treatments to release extant pondberry with periodic treatments to control new competing understory vegetation. This program will require monitoring of extant pondberry populations and discovery of new pondberry populations to coordinate timely application of competition control treatments and ensure long-term population viability.

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