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SEED GERMINATION OBSERVATIONS OF THE FEDERALLY LISTED *Lindera melissifolia*—*Lindera melissifolia* (Walt.) Blume, pondberry, is a federally endangered (United States Fish and Wildlife Service [USFWS] 1986) deciduous, aromatic shrub in the Lauraceae. It occurs in seasonally flooded wetlands and is extant in only six states (AR, GA, MO, MS, NC, SC). The major threats to this species include the loss or alteration of appropriate habitat through drainage modification, timber cutting, or the conversion of land for pine plantations, agriculture and urban development (USFWS 1993). This species is a rhizomatous, clonal shrub, predominately reproducing asexually. Plants are dioecious (separate female and male plants) and most populations are dominated by male plants (Wright 1990, USFWS 1993, Wright 1994, Godt and Hamrick 1996). Many populations consist of one or two clones of a single sex, suggesting little potential for successful sexual reproduction or adaptation to environmental change. Furthermore, infrequent sexual reproduction and seedling recruitment suggest that reintroduction of new populations will be necessary for species recovery (Godt and Hamrick 1996, Devall et al. 2001).

Lindera is described as either dioecious or polygamodioecious (Radford et al. 1968). Plants that are polygamodioecious can have a few perfect flowers or a few flowers of the opposite sex on the same plant. This may explain why a few fruits are occasionally produced in populations that appear to be all female (pers. obs.). Pale yellow flower clusters appear in late February to mid-March before leaf-break, and bright red drupes develop from August to early October (Patrick et al. 1995, pers. obs.). Flowers are believed to be insect pollinated, but there is little opportunity for pollen transfer among isolated populations.

Flower and fruit production is sporadic and can vary greatly from year to year (Morgan 1983, Wright 1990). Limited information is available on seed dispersers of *L. melissifolia*, but the bright red drupes suggest that they are dispersed by birds or mammals (USFWS 1993). Germination of *Lindera benzoin* (L.) Blume (spicebush; a widespread congener) seed was greatly reduced when fruit pulp was intact compared to seed with fruit pulp removed (Meyer and Witmer 1998). This suggests that frugivores may play a critical role by removing fruit pulp, aiding in germination as well as dispersal. Some *L. melissifolia* populations have produced numerous viable seeds, but seedlings are rarely observed in the wild (Wright 1989, USFWS

Table 1. **Number of seeds that germinated in each treatment for the pond that was not inundated. A total of 5 seeds per replicate were sown in each treatment combination**

Treatment	Germination
surface + litter + pulp + cage	2
surface + litter + pulp + no cage	0
surface + litter + no pulp + cage	5
surface + litter + no pulp + no cage	2
surface + no litter + pulp + cage	0
surface + no litter + pulp + no cage	0
surface + no litter + no pulp + cage	4
surface + no litter + no pulp + no cage	1
2.5 cm deep + litter + no pulp + no cage	4
5.0 cm deep + litter + no pulp + no cage	4

1993, Devall et al. 2001, Smith 2003). Even though viable seeds are produced, it is unclear why germination is extremely limited in natural populations (USFWS 1993).

The absence of seedling establishment, and thus the limited ability to establish new colonies may be another factor contributing to the decline of this species (Morgan 1983, USFWS 1993). It is possible that lack of seedling establishment is due to the loss of suitable habitat required for seed germination. Pondberry often occurs along margins of seasonally flooded wetlands, and it is unclear how the hydrologic cycle influences seed germination and seedling establishment. Little information is available on the germination requirements for this species (Wright 1990, USFWS 1993, Smith 2003). It is possible that leaf litter inhibits seedling emergence (Werner 1975, Carson and Peterson 1990, Peterson and Facelli 1992), because a dense canopy and litter accumulation may prevent seeds from receiving light needed for germination. In the southeastern Coastal Plain, fire may have played a role in the past, providing suitable microsites for germination by removing leaf litter and decreasing the abundance of competing hardwoods.

The purpose of this study was to determine the effects of leaf litter, planting depth, pulp removal, and flooding on seed germination using a combination of field and shade-house germination studies. The objectives were to gain insight into the germination requirements of this species to assist in developing management strategies to promote sexual reproduction in natural populations and for future reintroduction efforts.

Pondberry fruits (201 drupes) used in all germination studies were collected in the Delta National Forest, Sharkey Co., Mississippi on November 4, 2002. Seeds were sown and treatments were applied 9 days following collection as recommended by Baskin and Baskin (1998) (i.e., within 7–10 days of collection). Three forested depressional wetlands located in Baker County, Georgia at Ichauway, a reserve of the Joseph W. Jones Ecological Research Center, were selected as study sites for field experiments. These wetlands are dominated by swamp blackgum (*Nyssa sylvatica* var. *biflora*) and pond-cypress (*Taxodium ascendens*). Germination was examined for seeds placed on the soil surface with litter and no litter, pulp and no pulp, and cage and no cage using a three-factor design, including two additional treatments (with litter, no pulp, and no cage) of different planting depths (2.5 and 5.0 cm).

A 10 m^2 plot was established along the margins of each wetland. Each treatment was randomly assigned to a 1m^2 subplot with five seeds per treatment. A total of 150 seeds was either lightly pressed in the surface or buried at 2.5 or 5.0 cm below the soil surface. Litter was removed by raking or was left intact on the mineral soil surface. Additional accumulations of leaf litter were removed biweekly. The fruit pulp was either removed and the seed was then rinsed with water, or the drupe was left intact. For the bird and mammal exclusion treatment, a cage (0.5 m^2) of fine metal mesh attached to a wooden frame was placed on top of the plot. All seeds were watered at the time of treatment application. Seeds were monitored biweekly for presence or absence of surface sown seeds and germination.

Table 2. Seeds that germinated in each treatment combination for the shade-house study (mean ± SE, N = 3). A total of 5 seeds per replicate were sown in each treatment combination

Depth (cm)	Flooded	Germination
2.5	Yes	4.33 ± 0.33
2.5	No	4.67 ± 0.33
5.0	No	4.67 ± 0.33

An additional 45 seeds were used in a more controlled germination trial to examine the influence of soil depth and flood regime on germination. The seeds were sown on November 10, 2002 outside the Jones Center greenhouse under an open shade-house. Fruit pulp was removed from each seed, and five seeds were sown in plastic containers and randomly assigned to one of the following treatments: (1) flooded for three months and then drained, planted at a depth of 2.5 cm; (2) kept moist, planted at a depth of 2.5 cm; and (3) kept moist, planted at a depth of 5.0 cm. Each treatment was replicated three times (total of 45 seeds).

Of the three wetland study sites, two were flooded during the winter due to exceptionally high precipitation levels (National Climate Data Center, Asheville, North Carolina). Therefore, statistical analysis of the data was not possible due to lack of treatment replication. Prior to inundation, most of the seeds missing from the surface were those with fruit pulp and exposed (i.e., no cage and no litter). In the wetland where treatments were not flooded, germination began mid-April and no new seedlings were observed after the first week of May. Neither litter presence nor sowing depth influenced seed germination, but of the caged seeds, more seeds germinated when pulp was removed than with intact pulp (Table 1).

Germination of seeds in the shade-house began at the end of March and continued until mid-May (4–5 months after treatments were applied). There was no difference among the three treatment combinations. The flooded treatment at 2.5 cm had a total of 87% germination and the non-flooded treatments at 2.5 cm and 5.0 cm both had 93% germination. Of the 45 seeds sown, a total of 41 germinated (Table 2).

Despite the limited replication and number of seeds available for experimental purposes in this study, our observations about the germination requirements of this species may be useful in seedling establishment efforts and assessment of natural populations. Our study confirms that a high percentage of germination can be achieved in containers. We also observed that seedlings do not have distinct above ground cotyledons and may be easily mistaken for new stems. Thus, the previous observation that seedlings are rarely observed in the wild (Wright 1989, USFWS 1993, Devall et al. 2001, Smith 2003) may be due partly to the difficulty in distinguishing new stems from seedlings.

Even though field data were inconclusive due to the flooded site conditions, litter and planting depth did not seem to influence seed germination in the site that was not inundated. The absence of the unprotected seeds with pulp suggests that fruits were removed by birds or small mammals. Removal of pulp prior to planting in the field appears to enhance germination.

This study did not specifically address cold stratification, but all seeds were sown outdoors soon after collection and experienced seasonal fluctuations in temperature. It is unknown if cold stratification is a requirement for germination. Therefore, more controlled experiments are needed to determine the role of stratification on seed germination for *L. melissifolia*.

Because flooding and planting depth made no difference in seed germination in the shade-house study, we presume that seed germination in the field may still occur once flood waters recede, although seed viability under extended periods of inundation is unknown. Based on studies by Smith (2003), seed viability appears to be at least up to 7 years following planting in the field.

Even though seeds in field and shade-house studies germinated readily, identification of factors constraining or enhancing seedling establishment in natural habitats remain speculative. Previous investigations have had little success with direct seeding or transplanting seedlings for new population establishment (Wright 1994, Smith 2003). To effectively manage

and conserve populations of *L. melissifolia*, more information is needed to understand how flooding and fire influence seedling establishment and how management activities could enhance this process.—KATHERINE M. ALERIC and L. KATHERINE KIRKMAN, JOSEPH W. JONES ECOLOGICAL RESEARCH CENTER, ICHAUWAY, ROUTE 2, BOX 2324, NEWTON, GEORGIA 39870.
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