BOXELDER (*ACER NEGUNDO* L.) STAND DEVELOPMENT—CAN IT SERVE AS A TRAINER SPECIES?

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Abstract—Boxelder (*Acer negundo* L.) is a shade-tolerant species commonly found in west Gulf Coastal Plain floodplains. It is a desirable species for wildlife habitat, but has long been considered a "weed" for timber management, especially when regenerating forests to more desirable species. Results from an archived dataset of stem analysis from a variety of bottomland hardwood species showed the successional pathway of boxelder following the pioneer species eastern cottonwood [*Populus deltoides* (Bartr.) ex Marsh.] on point bars along former Mississippi River channels. We were not able to show trainer effects of boxelder from these two-aged stands. A conceptual model of tree species to plant with red oaks (*Quercus* spp.) in bottomland hardwood afforestation, along with personal observations of boxelder, were used to develop hypotheses for future boxelder stand development research to determine if boxelder could serve as a trainer species. These hypotheses are based on development in even-aged stands.

INTRODUCTION

Boxelder (*Acer negundo* L.) is one of the most widespread of the maples, occurring throughout the Eastern and Central United States and Central Canada (Overton 1990). It is a dioecious, shade-tolerant tree usually found on alluvial soils associated with fronts near rivers (Putnam and others 1960). Further, it is a short-lived (about 60 years) (Green 1934), medium-sized tree reaching 24 to 48 inches d.b.h. and 50 to 75 feet tall (Overton 1990). In the Lower Mississippi Alluvial Valley (LMAV), boxelder usually follows pioneer tree species colonizing new land (point bars) in floodplains (Putnam and others 1960), though it can function as a pioneer tree species in the invasion of old fields (Hosner and Minckler 1960). Boxelder has limited timber value, having been described as a "weed tree" (Putnam and others 1960) and "a worthless and undesirable competitor of good species in forests" (Maeglin and Ohmann 1973). It is, however, a favorable species for wildlife habitat (Overton 1990).

Trainer trees, sometimes called "nurse trees," "fillers," or "companion species," are trees that aid in the development of desired crop trees, but do not have the potential to outgrow crop trees in the rotation (Maine Forest Service 2006). Trainer trees are essentially trees competing with desired trees early in stand development. Trainer trees may be taller during the early stages of stem exclusion, but eventually crop trees stratify above trainer trees to form a majority of the overstory canopy as the stand matures. McKinnon and others (1935) indicate that trainer trees play an important role in improving the quality of crop tree boles by restricting growth of lower branches and hastening pruning. These stem development effects also increase merchantable heights of crop trees. Trainer trees, once relegated to lower canopy positions, increase vertical and horizontal stand structure, and provide additional niches for wildlife. Nicholas and Brown (2002) provide specific steps in the use of trainer species such as radiata pine (*Pinus radiata* D. Don), eucalypts (*Eucalyptus* spp.), poplar (*Populus* spp.), and willow (*Salix* spp.) in growing blackwood (*Acacia melanoxylon* R. Br.) for quality tree boles in New Zealand.

While an old concept (McKinnon and others 1935), the idea of using trainer trees is slowly gaining acceptance in southern bottomland hardwood management (Oliver and others 1990). For example, research has shown that sweetgum (*Liquidambar styraciflua* L.) can provide training effects to develop quality boles in red oaks (*Quercus* spp.) (Clatterbuck and Hodges 1988, Oswalt 2008). This knowledge has been applied to mixed-species plantings of sweetgum and cherrybark oak (*Q. pagoda* Raf.) with similar results (Lockhart and others 2006). Unfortunately, we have little knowledge of other bottomland hardwood species as potential trainers. Lockhart and others (2008) developed a conceptual model of potential tree species that could serve as trainer trees in mixed-species plantings with bottomland red oak species. This model was based on silvical characteristics of the tree species and personal observations, but little direct evidence of mixed-species stand development patterns. Therefore, the objective of this study is to determine boxelder stand development patterns using an archived dataset that includes stem analysis data from a variety of bottomland hardwood species. Our hypothesis is that boxelder, in even-aged stands, will exhibit rapid early height growth compared to neighboring tree species, but will eventually be overtopped, thereby providing trainer tree effects for other species.

METHODS

A hardwood growth and yield dataset developed between 1975 and 1977 is archived at the Southern Hardwoods Laboratory in Stoneville, MS. Dr. Bryce Schlaegel published a series of individual tree species volume and weight tables from this data (Schlaegel 1981, 1984a, 1984b, 1984c, 1984d; Schlaegel and Wilson 1983). Twenty-five stands were located in the LMAV and the adjacent Brown Loam Bluffs in westcentral Mississippi. A circular 0.2-acre plot was located in each stand. Four additional 0.2-acre plots were randomly located within a 5-acre circular area of the center of the first plot such that each plot fell within one of four quadrants of the first plot without overlapping any of the other plots. All trees >4.5 inches d.b.h. were tallied for species; d.b.h. (inches);

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crown class (dominant, codominant, intermediate, and suppressed); and distance and azimuth from plot center.

Trees for destructive sampling were selected after trees on all five plots in a given stand were measured. About 15 trees per stand were selected for destructive sampling with no fewer than 13 trees per stand. Tables of limiting distances by tree diameters for different basal area factors (BAF) were used to select sample trees. An initial BAF 35 was used to determine the number of trees to be sampled from the five plots. If fewer than 13 trees were selected, then a BAF 30 was used and tree selection redone. A BAF 25 was used to gather the minimum number of trees if efforts with the BAF 30 were unsuccessful. Trees were selected as part of a bottomland hardwood growth and yield study, and not for stand development research objectives.

Each selected tree was mechanically felled and marked at 5-foot intervals to the top of the tree. Discs, 1- to 1.5-inch thick, were cut at each mark beginning at the base of the tree. Discs were labeled as to tree number and disc number and sealed in polyethylene bags. Discs for each tree were then placed in a burlap bag and labeled as to location and tree number, then taken to the laboratory for further analysis. Stem analysis followed standard techniques (Oliver 1978, 1982). Age was determined for each disc, then subtracted from the stump disc age to determine tree age at each 5-foot length interval. This data was plotted to determine individual tree length development and compared with the development of other trees sampled from the plot. With stem analysis data, tree length is used instead of tree height to account for differences in actual tree height measurements using stand equipment, such as a clinometer, and the summation of 5-foot intervals from stem analysis. Tree length above the last harvested disc, but <5 feet, is not used in stem analysis. Further, differences >5 feet between tree height and length are probably the result of a crooked main stem near the top of the tree or measurement error.

Distances between boxelders and the other selected trees were calculated using the law of cosines (Selby 1969):

$$a^2 = b^2 + c^2 - 2bc(\text{cosine } A) \qquad (1)$$

where
- a = distance between two trees
- b = distance from plot center to boxelder
- c = distance from plot center to other selected trees
- A = angle between the two trees calculated as the difference between the two azimuths

Crown radii were calculated using d.b.h. and equations developed by Bechtold (2003) for eastern cottonwood (*P. deltoides* Bartr. ex. Marsh.) and Lockhart and others (2005) for boxelder.

In reviewing the dataset, four plots were found in two stands that contained a destructively sampled boxelder and a second tree species. In all cases, the second species was eastern cottonwood. Three plots were located on Indian Point near the Mississippi River in Desha County, AR (33°42' N, 91°7' W). Soil is the Sharkey-Commerce-Coushatta association, and is considered frequently flooded [Sharkey clay (very fine, smectitic, thermic Chromic Eqiapuerts), Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts), and Coushatta silt loam (fine-silty, mixed, superactive, thermic Fluventic Eutrudepts)]. The stand (stand 16) was dominated by eastern cottonwood that developed on a bar along a former channel of the Mississippi River. The stand initiated soon after a manmade channel diversion, called Caulk Cut-off, was completed in 1937. The stand contained 130 trees per acre (64 percent boxelder), 60 square feet of basal area per acre (67 percent eastern cottonwood), and an average stand diameter of 8.2 inches (14.2 inches for eastern cottonwood) (table 1). Trees destructively sampled for stem analysis were boxelder and eastern cottonwood.

The second stand (stand 19) was also located on Indian Point, but in Bolivar County, MS, about one-quarter mile north of the first stand. Soil is broadly mapped as alluvial soils with a loamy sand surface and sandy subsurface texture. The stand was a mixture of eastern cottonwood, black willow (*S. nigra* Marsh.), and riverfront hardwood species that also initiated soon after the Caulk Cut-off was completed. The stand contained 146 trees per acre [36 and 28 percent American sycamore (*Platanus occidentalis* L.) and eastern cottonwood, respectively]; 146 square feet of basal area per acre (74 percent eastern cottonwood); and an average stand diameter of 11.5 inches (21.5 and 18.5 inches for eastern cottonwood and black willow, respectively) (table 1). One boxelder and two eastern cottonwoods were sampled for stem analysis.

RESULTS

The plot age structure in both stands showed two distinctive age classes (figs. 1, 2, 3, and 4). Eastern cottonwood represented the older age class, while boxelder represented the younger age class.

Plot 16-2 contained three trees utilized for stem analysis: one boxelder and two eastern cottonwoods (table 2). The codominant eastern cottonwood was 14 years older than the boxelder. Further, it was 281 percent larger in d.b.h. and 127 percent taller in height than the boxelder. Average annual height growth was 3.4 and 3.3 feet for eastern cottonwood 1 and eastern cottonwood 2, respectively. Average annual height growth for the boxelder was 2.7 feet. The boxelder, which was underneath both eastern cottonwoods at the time of sampling (table 2), maintained a consistent increase in length, but not as rapid in length development as the eastern cottonwoods (fig. 1).

Plot 16-3 contained three boxelders and one eastern cottonwood from stem analysis (table 3). The eastern cottonwood was 31 years old, while the boxelders were 22 years old. Further, the eastern cottonwood was 214 percent larger in d.b.h. and 97 percent taller than the average of the

Table 1—Tree species composition, number per acre, basal area per acre, and average d.b.h. for stands containing boxelder used in stem analysis

Species	Stand 16			Stand 19		
	n	Basal area	Average d.b.h.	*n*	Basal area	Average d.b.h.
	trees per acre	*square feet per acre*	*inches*	*trees per acre*	*square feet per acre*	*inches*
American elm	—[a]	—	—	2.0 (<0.1)	0.4 (<0.1)	6.2 (0.6)
Black willow	1.0[b]	0.3	7.6	4.0 (1.4)	7.2 (1.9)	18.5 (2.4)
Boxelder	83.0 (4.8)	17.4 (1.0)	6.1 (0.4)	17.0 (5.0)	5.2 (2.1)	7.1 (1.0)
Cottonwood	36.0 (3.6)	40.2 (3.1)	14.2 (2.2)	41.0 (4.2)	107.1 (8.4)	21.5 (1.5)
Green ash	—	—	—	3.0 (0.7)	1.2 (0.3)	8.7 (0.3)
Sugarberry	6.0 (1.0)	1.4 (0.3)	6.0 (0.7)	27.0 (2.5)	7.9 (1.4)	6.7 (1.3)
Sycamore	4.0 (0.6)	0.7 (0.1)	5.6 (0.5)	52.0 (1.8)	16.4 (1.1)	7.4 (0.7)
Stand[c]	130 (18.4)	59.9 (12.3)	8.2 (0.5)	146.0 (19.5)	145.5 (30.5)	11.5 (0.9)

Numbers in parentheses represent one standard deviation.

[a] No trees for this species were present in the sampling for this stand.

[b] Only one tree was measured for this species resulting in no standard deviation calculation.

[c] Stand values are based on plot averages and not the addition of individual species trees per acre, basal area per acre, or average d.b.h.

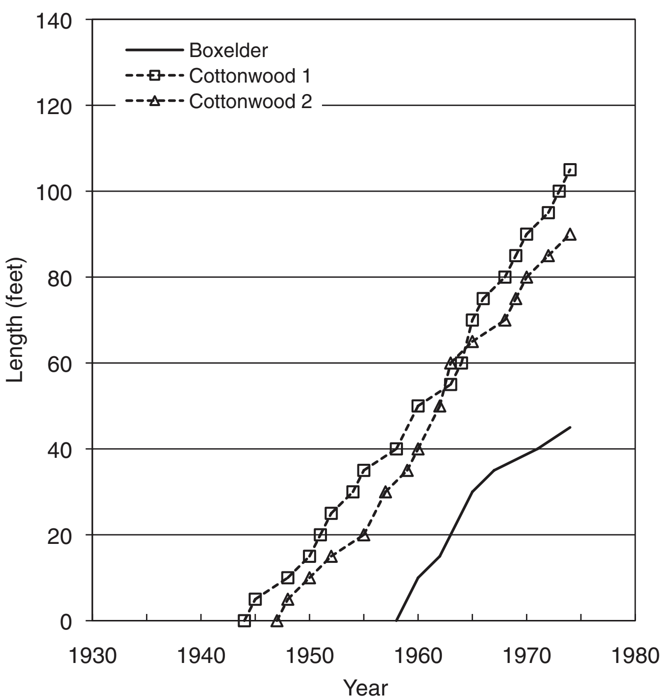

Figure 1—Boxelder and eastern cottonwood length development measured in a destructively sampled stem analysis plot (plot 16-2) on Indian Point, Desha County, AR, in 1977.

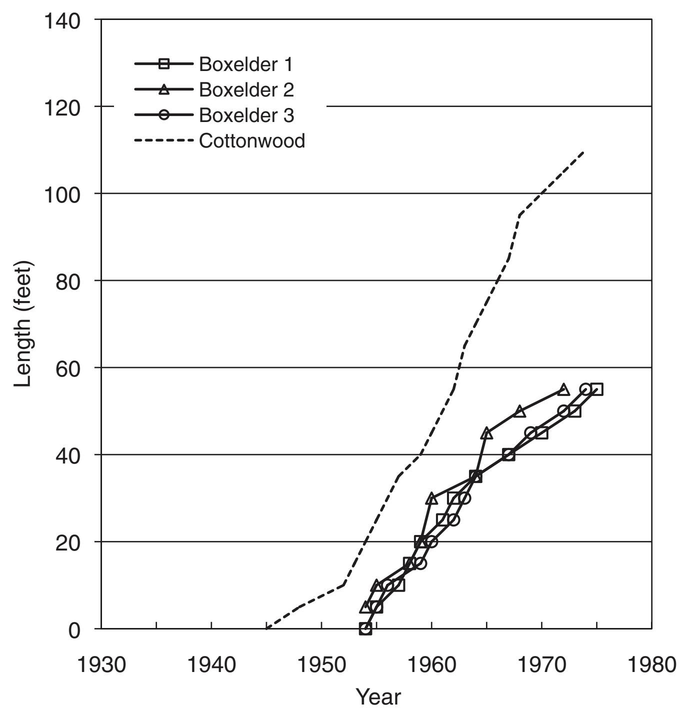

Figure 2—Boxelder and eastern cottonwood length development measured in a destructively sampled stem analysis plot (plot 16-3) on Indian Point, Desha County, AR, in 1977.

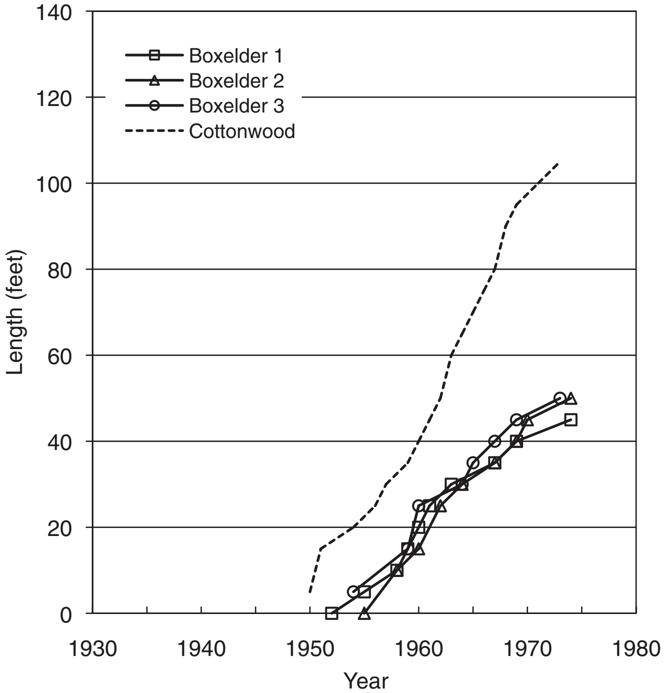

Figure 3—Boxelder and eastern cottonwood length development measured in a destructively sampled stem analysis plot (plot 16-4) on Indian Point, Desha County, AR, in 1977.

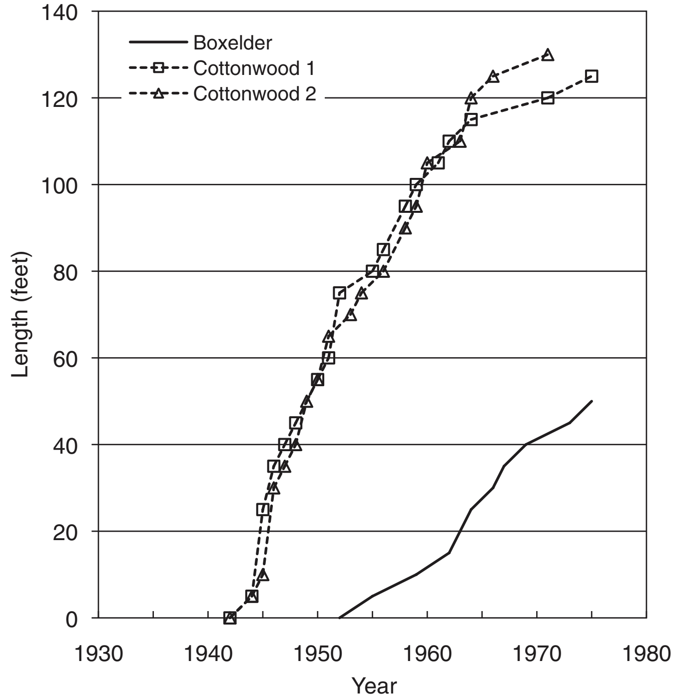

Figure 4—Boxelder and eastern cottonwood length development measured in a destructively sampled stem analysis plot (plot 19-5) on Indian Point, Bolivar County, MS, in 1977.

Table 2—Tree characteristics on a destructively sampled stem analysis plot (plot 16-2) on Indian Point, Desha County, AR, in 1977

Species	Age	D.b.h.	Height	Crown class	From plot center: Azimuth	From plot center: Distance	Distance from boxelder	Crown radius
	years	*inches*	*feet*		*degrees*	*feet*	-------------------- *feet*	--------------------
Boxelder	18	5.8	48	Suppressed	67	6.0		6.3
Cottonwood 1	32	22.1	109	Codominant	155	15.6	16.5	34.6
Cottonwood 2	29	10.0	96	Intermediate	285	8.8	12.7	17.5

Table 3—Tree characteristics on a destructively sampled stem analysis plot (plot 16-3) on Indian Point, Desha County, AR, in 1977

Species	Age	D.b.h.	Height	Crown class	From plot center: Azimuth	From plot center: Distance	Distance from cottonwood	Crown radius
	years	*inches*	*feet*		*degrees*	*feet*	-------------------- *feet*	--------------------
Boxelder 1	22	7.3	56	Intermediate	16	6.3	11.6	7.1
Boxelder 2	22	6.1	59	Intermediate	167	5.7	23.3	6.5
Boxelder 3	22	6.2	59	Intermediate	250	4.6	20.6	6.5
Cottonwood	31	20.4	114	Codominant	10	17.9		32.2

boxelders. As with the previous plot, the boxelders maintained a consistent increase in length, but not as rapid as the eastern cottonwood (fig. 2).

Plot 16-4 also contained three boxelders and one eastern cottonwood. The eastern cottonwood was only 2 to 5 years older than the boxelders, but was 174 to 302 percent larger in d.b.h. and 107 to 127 percent taller in height compared to the boxelders (table 4). Annual height growth was rapid for the eastern cottonwood (4.2 feet per year) compared to the boxelders (2.0 to 2.5 feet per year). As with the previous plots, the boxelders maintained a consistent increase in length, but not as rapid as the eastern cottonwood (fig. 3).

Plot 19.5 contained one boxelder and two codominant eastern cottonwoods. The eastern cottonwoods were the oldest and largest of the four plots at 34 years, 22.1 inches d.b.h, and 131 feet tall (table 5). They were slowing in length growth by the late 1960s, while the boxelder maintained slow, but consistent increases in length (fig. 4).

DISCUSSION

The dataset used in this paper was developed for a bottomland hardwood growth-and-yield study. Trees selected for destructive sampling were not selected to test hypotheses of bottomland hardwood stand development. The cottonwood trees may or may not have been in competition with the boxelder. Further, trees that appear to be competing with boxelder at the time of sampling may not have been competing with boxelder earlier in stand development. Regardless, this dataset, along with a conceptual model of tree species to plant with red oaks in bottomland hardwood afforestation and personal observations of boxelder, does present interesting questions for further study involving boxelder development and its potential role as a trainer species.

The finding of large, codominant eastern cottonwood in each of the stem analysis plots was not surprising since the plots were located along former channels of the Mississippi River in the batture lands—lands unprotected from river flooding. Soils were typical of new land formed along major river channels, where eastern cottonwood is considered a pioneer species (Greulich and others 2007). *Populus* species can tolerate sedimentation on these lands by developing new root primordia along the tree bole (Smith and Wareing 1972). As annual sedimentation decreases with increasing elevation from previous deposition, other tree species become established underneath the eastern cottonwood. This establishment pattern occurred in each plot with boxelder, although boxelder has also been observed to produce roots along its bole if covered by additional sedimentation (personal observation by the senior author). Our results, through stem age and length development analysis, confirm previous reports on the successional pathway of boxelder in riverfront

Table 4—Tree characteristics on a destructively sampled stem analysis plot (plot 16-4) on Indian Point, Desha County, AR, in 1977

					From plot center			
Species	Age	D.b.h.	Height	Crown class	Azimuth	Distance	Distance from cottonwood	Crown radius
	years	*inches*	*feet*		*degrees*	*feet*	---------- *feet* ----------	
Boxelder 1	24	4.9	48	Suppressed	39	5.6	23.5	5.9
Boxelder 2	21	7.2	53	Suppressed	164	7.9	28.0	7.0
Boxelder 3	22	6.4	53	Intermediate	224	5.8	21.2	6.6
Cottonwood	26	19.7	109	Codominant	299	21.9		31.2

Table 5—Tree characteristics on a destructively sampled stem analysis plot (plot 19-5) on Indian Point, Bolivar County, MS, in 1977

					From plot center			
Species	Age	D.b.h.	Height	Crown class	Azimuth	Distance	Distance from boxelder	Crown radius
	years	*inches*	*feet*		*degrees*	*feet*	---------- *feet* ----------	
Boxelder	24	6.6	52	Suppressed	359	7.1		6.7
Cottonwood 1	34	20.8	131	Codominant	140	24.2	30.1	32.7
Cottonwood 2	34	23.4	130	Codominant	191	18.4	25.4	36.4

hardwood stands (Maeglin and Ohmann 1973). Following eastern cottonwood establishment and development on newly formed land, species including boxelder, American sycamore, American elm (*Ulmus americana* L.), sugarberry (*Celtis laevigata* Willd.), and green ash (*Fraxinus pennsylvanica* Marsh.) become established (Hodges 1997).

We can neither prove or disprove our hypothesis that boxelder exhibited rapid early height growth compared to neighboring tree species in even-aged stands and was eventually overtopped, thereby providing training tree effects for these species. In each plot, eastern cottonwood became established before boxelder, resulting in two-aged stands. The rapid height growth of the older eastern cottonwood was too great for boxelder to ever become a member of the overstory canopy or to provide training effects on eastern cottonwood boles. We do present two hypotheses, based on the literature and personal observations, for future research consideration regarding boxelder stand development in mixed-species bottomland hardwood forests.

Hypothesis no. 1: Boxelder can serve as a trainer species for red oaks during development in even-aged stands.

A conceptual model of species to plant in intimate mixtures with red oaks in bottomland afforestation suggests that *Acer* species [boxelder, red maple (*A. rubrum* L.), and silver maple (*A. saccharinum* L.)] may be useful to "train" red oaks to develop better quality boles (Lockhart and others 2008). Tree characteristics that favor these species as trainers include fast (but not too rapid) early height growth, small relative twig diameter and durability, and an indeterminate shoot growth pattern. Following a period of slow early height growth, red oaks should be able to stratify above these species, primarily from crown abrasion following periodic, heavy wind events.

Boxelder's best growth occurs on sandy loam soils along river fronts. These sites, especially in the LMAV, are not commonly oak sites due to a basic or neutral soil pH. But, boxelder can grow on a variety of soils, ranging from heavy clays to pure sands, and is commonly associated with oaks such as Nuttall (*Q. nuttallii* Palmer), water (*Q. nigra* L.), willow, and overcup (*Q. lyrata* Walter) (Overton 1990). Therefore, natural mixtures of boxelder and bottomland oaks are not uncommon.

The senior author has observed annually for the past 9 years the development of an oak afforestation project on the Three Rivers Wildlife Management Area in Concordia Parish, LA. This site, adjacent to the Mississippi River mainline levee on the protected side of the levee, was a former agricultural field and then a pasture. It was planted in 1997 with Nuttall, water, swamp chestnut (*Q. michauxii* Nutt.), and white (*Q. alba* L.) oaks. The area was heavily invaded by other tree species early in stand development. A section of the stand was dominated early by boxelder and swamp dogwood (*Cornus drummondii* C.A. Mey.). The boxelder established from seed windblown from adjacent forests. The swamp dogwood reproduction was sprout origin resulting from periodic mowing of the site prior to planting trees. These species were 1.5 to 2 times the height of the red and white oaks during the early years of development. In the past 2 years, the planted oaks began emerging above these "competing" species and will soon become the primary overstory species. Boxelder and swamp dogwood will be relegated to lower canopy positions, but they are currently forcing the oaks to focus on height growth to overtop them instead of crown expansion. Oak crown expansion will occur after stratification above the boxelder and swamp, followed by increased diameter growth on a taller, cleaner bole.

Further circumstantial evidence that boxelder may serve as a potential trainer for *Quercus* spp. involves red maple in New England. Oliver (1978) showed a pattern of stand development in which black birch (*Betula lenta* L.) and red maple were initially taller than northern red oak. By age 40, the red oak stratified above the birch and maple, with the benefit of being trained by these species. As an *Acer* species, boxelder may provide a similar trainer role as red maple in the development of oaks on bottomland hardwood sites.

Hypothesis no. 2: Boxelder's time as a trainer species will be less than the time sweetgum serves as a trainer species for bottomland red oaks.

Clatterbuck and Hodges (1988) found that cherrybark oak would stratify above sweetgum in about 21 to 25 years in natural, old-field stands along minor stream floodplains in central Mississippi. A similar pattern of stand development occurred with sweetgum and bottomland red oaks (cherrybark, water, and willow) following clearcut harvesting, except it took the red oaks about 30 years to stratify above the sweetgum (Johnson and Krinard 1988). Further, Lockhart and others (2006) found cherrybark oak stratified above sweetgum between 17 and 21 years after planting in intimate mixtures. Interspecific competition between these species forced bottomland red oaks to grow in height to attain canopy position, resulting in high-quality boles. But our observations indicate potential shorter merchantable lengths on red oaks competing with boxelder because the oaks stratified above the boxelder earlier than the 21 to 30 years it takes red oaks to overtop sweetgum. Like sweetgum, boxelder can have rapid early height growth, but, unlike sweetgum, it apparently does not have the ability to sustain rapid early height growth for many years. Boxelder is a shade-tolerant, short-lived, small stature species while sweetgum is a shade-intolerant, long-lived, large species.

Research recommendations for boxelder involve the need for more knowledge about the interspecific interactions of boxelder and other bottomland hardwood species during early stand development. Can boxelder serve as a trainer species for oaks? Can boxelder serve as a trainer species for green ash? We believe it can, but further research is needed to confirm our observations. The use of trainer species to develop better quality boles and crowns of desired species is a simple, but often neglected, concept in mixed-species hardwood management. As we learn more about how bottomland hardwood stands develop, we can use this information to direct silviculture practices to better meet landowner objectives.

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