PLANTED AND NATURAL TREE SEEDLING SURVIVAL AND DENSITY IN THREE FLOODPLAIN RESTORATIONS ON ABANDONED AGRICULTURAL FIELDS

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ABSTRACT.—In three floodplain forest restorations, established in abandoned agricultural fields in Illinois, permanent plots were sampled for 3 years to determine survivorship and density of planted tree seedlings, and species composition and density of natural regeneration. Planted tree survivorship decreased over time at all sites and after 3 years ranged from 32 to 61 percent. Planted density ranged from 780 to 1,330 individuals/ha and did not differ between species. Sapling/shrub stage natural regeneration ranged from 133 to 7,017 individuals/ha. Natural regeneration equaled or surpassed planted seedling density at two of the three sites. The site with greatest natural regeneration also had highest survival and density of planted trees.

Bottomland forests in the midwest have experienced extensive reduction and degradation since the 1930s. Large areas have been cleared for soybean production (Newling 1990). By the end of the 1980s, 81 percent of bottomland forest area had been lost (Allen and Kennedy 1989, Clewell and Lea 1990). Efforts to restore these systems only began in the 1980s and there is, so far, little published work on restoration of forested wetlands (Clewell and Lea 1990, Newling 1990).

Secondary succession in old fields in bottomlands proceeds at a rapid rate as long as propagules are reasonably nearby. Rapid site invasion is seen in tree species with wind dispersed seeds and in shrubs with seeds dispersed by water or animals. Heavy seeded species such as oaks, hickories, and pecans, invade much more slowly, making reintroduction of these species a major concern in restoration (Newling 1990).

A critical gap in research on bottomland hardwood forest regeneration is the identification of favorable conditions for natural regeneration and survival of planted wetland tree species. Studies show that with a seed source nearby natural regeneration density and survival may be equal to or greater than that of planted seedlings (Clewell and Lea 1990, Kolka and others 1998). In upland areas, hardwood plantations are usually unsuccessful without such weed control practices as herbiciding, mowing between rows, and installing tree cones (Allen and Kennedy 1989, Hansen and others 1993). In bottomlands, however, tall herbaceous weeds may be beneficial to planted seedlings by providing shelter from high light levels and temperatures, wind, and herbivores (Clewell and Lea 1990, McLeod and others 2000).

Woody cover may be beneficial by providing shade and producing humus (Clewell and Lea 1990). It is uncertain when a bottomland tree planting reaches the point where survival to maturity is likely. Natural tree regeneration experiences extremely heavy mortality for the first 5 years (Harper 1977). In these bottomland systems, chances for success have been found to be excellent with 35 percent survival or 1,161 stems/ha after 2 years (Newling 1990), or with at least 988 stems/ha when an average height of 2 m is attained (Clewell and Lea 1990).

The purpose of this study is to examine survival and density of planted bottomland tree species and density of natural shrub/sapling stage regeneration after 3 years at three sites in Illinois. We determine whether significant

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planted seedling mortality occurred between the second and third years and compare survival rates between four planted species. Planted tree density is compared with that of natural shrub/sapling stage regeneration.

STUDY AREA

The three study sites are in Illinois, along a north-south gradient of 443 km (fig. 1). The Rock River site is located adjacent to the Rock River in Henry County, IL (41° 33′ N, 90° 11′ W), near the town of Joslin. The Illinois River site is located 6.8 km from the Illinois River in Cass County, IL (40° 04′ N, 90° 18′ W) in the extensive lowlands surrounding the Sangamon River's confluence with the Illinois (the Sanga-nois). The nearest town is Beardstown. The Bankston Fork site is located 149 m from Bankston Fork in Saline County, IL (37° 44′ N, 88° 42′ W), near the town of Carrier Mills.

The Rock River and Illinois River sites occur on floodplains, while the Bankston Fork site occurs on glacial lake plain (Willman and Frey 1970). The Rock and Illinois are large streams, approximately 190 m in width at the study sites (Rock River 57 year mean discharge – 6,424 ft^3/sec, Illinois River 10 year mean discharge – 19,464 ft^3/sec) (Sullivan and others 1990, Wicker and others 1998). Bankston Fork is a small stream, less than 10 m wide.

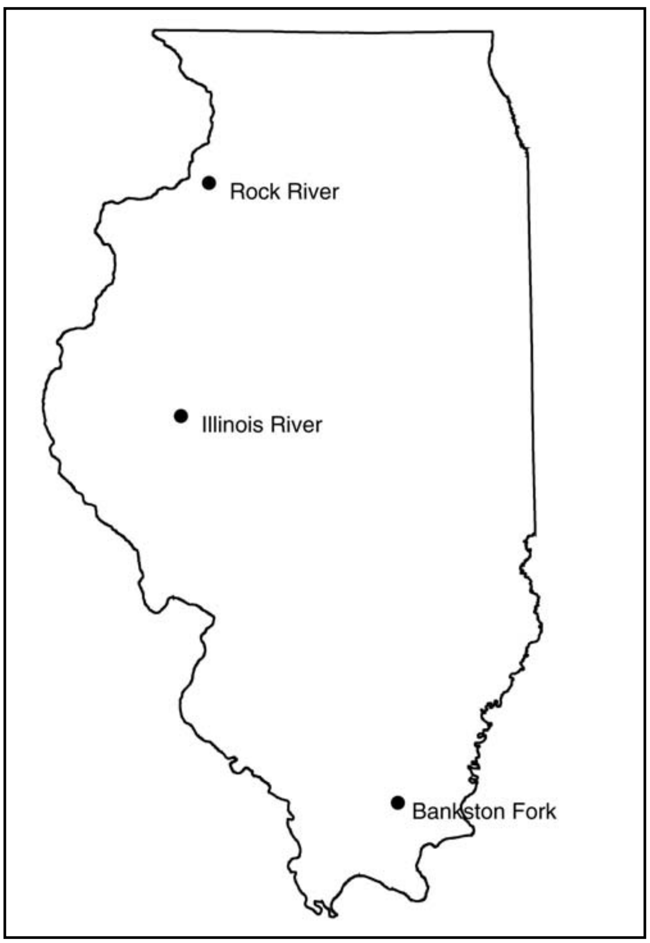

Figure 1.—*Study areas.*

Soils at the three sites are similar and range from silt loam to silty clay loam, and from Typic Fluvaquent to Cumulic Endoaquoll. The Rock and Illinois River sites generally flood during the winter and early spring, and again once or twice early in the growing season (Fucciolo and others 2000, Sanganois State Wildlife Management Area staff personal communication). The Bankston Fork site rarely, if ever, floods but experiences saturated soil conditions early in the growing season (Fucciolo and others 2000).

All three sites are abandoned cropland. The Rock and Illinois sites were in soybean 2 years prior to planting. The Bankston Fork site was cropped approximately 10 years before planting. All sites are adjacent to bottomland forest 50 to 60 years of age.

METHODS

Sites were cleared of vegetation and planted with 2-0 tree seedlings. Planting densities were similar: Rock River at 2,485 stems/ha, Illinois River at 2,149 stems/ha, and Bankston Fork at 2,470 stems/ha. Planting was carried out in the spring of 1998. At Illinois River and Bankston Fork, sites were simply left to revegetate naturally after planting. The Illinois River site is 1.7 ha in size and Bankston Fork is 0.8 ha.

At Rock River the site was more intensively managed. Planting cones were placed around seedlings, and the area between the rows was mowed and herbicided annually. Natural regeneration was allowed to proceed in an adjacent area. The planted area is 2.2 ha and natural regeneration occupies an adjacent 1.2 ha.

Seedlings planted were bottomland species native to the region at each site. Six species were planted at the Rock River site, four species at Illinois River and nine species at Bankston Fork (table 1). Green ash (*Fraxinus pennsylvanica* Marsh), pin oak (*Quercus palustris* Muenchh.), swamp white oak (*Q. bicolor* Willd.), and pecan (*Carya illinoensis* (Wang.) K. Koch) were planted at all sites. Other species planted at one or two sites include overcup oak (*Q. lyrata* Walt.), river birch (*Betula nigra* L.), red maple (*Acer rubrum* L.), silver maple (*A. saccharinum* L.), cottonwood (*Populus deltoides* Bartr. ex Marsh.), sweetgum (*Liquidambar styraciflua* L.), and black tupelo (*Nyssa sylvatica* Marsh.). At each site, all species were planted in equal numbers. Other tree species naturally occurring at one or more sites included American elm (*Ulmus americana* L.), sycamore (*Platanus occidentalis* L.), peachleaf willow (*Salix amygdaloides* Anderss.), black willow (*S. nigra* Marsh.), catalpa (*Catalpa speciosa* Warder), hackberry (*Celtis occidentalis* L.), white mulberry (*Morus alba* L.), and honeylocust (*Gleditsia triacanthos* L.).

At the Rock River and Bankston Fork sites, shallow hydrologic monitoring wells, stage gauges and water level and precipitation data loggers were installed and monitored monthly by Illinois State Geological Survey scientists (Fucciolo and others 2000). At all three sites, Illinois Natural History Survey soil scientists examined cores and mapped and described the soils.

Vegetation was quantified using stratified sampling. For the understory (tree seedlings < 1 m tall and herbaceous species), parallel transects were established perpendicular to the long axis of the sites at 15 m intervals at Bankston Fork and 20 m at Rock River. Understory vegetation was sampled as aerial cover (and number of stems for tree seedlings) by species in 1 m^2 quadrats at 15 m intervals along transects. At Rock River, 40 quadrats were sampled, and 10 quadrats at Bankston Fork. Understory vegetation was not sampled quantitatively at Illinois River; species dominance was determined by visual estimation.

Importance Values (IV's) were calculated as (relative frequency + relative cover)/2. Dominant species are considered to be those with IV's greater than 6 that are included when, starting with the most abundant, IV's are summed until a value of 50 is exceeded (modified from Federal Interagency Committee for Identifying and Delineating Jurisdictional Wetlands 1989).

For planted trees and sapling/shrub stage (≥ 1 m tall and < 10 cm DBH) natural regeneration at Illinois River, parallel transects were established at 50 m intervals with sample points every 15 m along transects. At Bankston Fork and for natural regeneration at Rock River, transects were established at 30 m intervals with sample points every 30 m. Sapling/shrub stage vegetation was tallied as number of individuals by species, planted or naturally occurring, in 100 m^2 plots. At Rock River, since planted trees occurred in well-defined and maintained rows, 30 m row sections were sampled at 300 m intervals.

Importance Values (IV's) were calculated as (relative frequency + relative density)/2. At Illinois River 14 plots were sampled and 6 plots at Bankston Fork. At Rock River, 14 planted tree plots and 15 natural regeneration plots were sampled. Plots were sampled annually at the end of the growing season. Nomenclature is according to Mohlenbrock (1986).

For statistical analyses, assumptions of normalcy were addressed using Kolmogorov-Smirnoff tests and normal probability plots. Independence of error was evaluated by examining plots of residual vs. predicted values. Data for the

Table 1.—*Planted and naturally occurring tree species (see methods for full scientific and common names)*

BANKSTON FORK	
Planted	**Natural**
Frax. pennsylvanica	*Frax. pennsylvanica*
Quer. palustris	*Quer. palustris*
Quer. bicolor	*Acer rubrum*
Carya illinoensis	*Ulmu. americana*
Quer. lyrata	*Plat. occidentalis*
Betu. nigra	*Popu. deltoides*
Acer rubrum	*Sali. amygdaloides*
Liqu. styraciflua	*Betu. nigra*
Nyssa sylvatica	*Cata. speciosa*
ILLINOIS RIVER	
Planted	**Natural**
Frax. pennsylvanica	*Frax. pennsylvanica*
Quer. palustris	*Acer saccharinum*
Quer. bicolor	*Acer negundo*
Carya illinoensis	*Ulmus americana*
	Plat. occidentalis
	Popu. deltoides
	Salix nigra
	Salix amygdaloides
	Celt. occidentalis
	Morus alba
	Gled. triacanthos
ROCK RIVER	
Planted	**Natural**
Frax. pennsylvanica	*Frax. pennsylvanica*
Quer. palustris	*Acer saccharinum*
Quer. bicolor	*Ulmus americana*
Carya illinoensis	*Popu. deltoides*
Acer saccharinum	*Salix nigra*
Popu. deltoides	*Salix amygdaloides*
	Morus alba

three sites were analyzed separately. At Illinois River, n=14. At Bankston Fork, n=6. For planted trees at Rock River, n=14 and for natural regeneration, n=15. Alpha levels of 0.05 were used to determine statistical significance.

In order to study change in planted tree survivorship (density) over time, one–tailed, unpaired T-tests were conducted to determine whether there were decreases between consecutive years (2000-2001). To determine whether there were differences between species in planted tree survivorship, one-way ANOVAs were conducted using species as treatments and densities (2001) as dependent variables. The analyses were limited to the four species present at all sites: green ash, pin oak, swamp white oak, and pecan.

Two-tailed T-tests were conducted to determine whether, after 3 years, there were differences between planted and natural tree densities. Because planted and natural stems occurred in the same plots at Illinois River and Bankston Fork, paired tests were conducted. An unpaired test was used at Rock River because planted and natural stems occurred in different areas. Because significant results for Kolmogorov-Smirnoff tests and presence of skewness in some data sets suggested problems with normalcy, and plots of residual vs. predicted values showed presence of outliers in some cases, a nonparametric Kruskal-Wallis test was conducted along with each parametric test. Test results were in agreement in every case (Systat, Inc., Evanston, IL).

RESULTS

Within the first year, all three sites supported dense herbaceous communities greater than 1 m in height (table 2). The Bankston Fork herb layer was dominated by inland rush (*Juncus interior* Wieg.), slender mountain mint (*Pycnanthemum tenuifolium* Schrad.), late flowering thoroughwort (*Eupatorium serotinum* Michx.), and Canada goldenrod (*Solidago canadensis* L.). Reed canary grass (*Phalaris arundinacea* L.), bur cucumber (*Sicyos angulatus* L.), giant smartweed (*Polygonum pensylvanicum* L.), and Ontario aster (*Aster ontarionis* Wieg.) were dominant at Rock River. Panicled aster (*Aster simplex* Willd.) and late flowering thoroughwort were the dominant herb layer species at Illinois River.

After 3 years, sapling/shrub stage natural regeneration ranged from 133 stems/ha at Rock River to 7,017 stems/ha at Illinois River (table 2). Seedling stage regeneration ranged from 5,750/ha at Rock River to 53,397/ha at Bankston Fork. Black willow and cottonwood dominated the sapling/shrub layer at Rock River while silver maple and cottonwood dominated at Illinois River. At Bankston Fork, green ash and red maple were dominant. Green ash was the most abundant tree seedling at Illinois River and Bankston Fork while silver maple was most numerous at Rock River.

In 2001, at the end of 3 years, planted tree density ranged from 780 stems/ha at Bankston Fork to 1,330/ha at Illinois River (fig. 2). Planted tree survivorship after 3 years was 61.9 percent at Illinois River, 43.5 at Rock River, and

Table 2.—*Dominant understory species, natural tree seedling density and shrub/sapling layer density as either importance value or number of individuals/ha*

BANKSTON FORK		ILLINOIS RIVER		ROCK RIVER	
Dominant Understory sp.	**IV**		**Estimate**		**IV**
Juncus interior	12.3	*Aster simplex*	dominant	*Phalaris arundinacea*	28.7
Pycnanthemum tenuifolium	10.0	*Eupatorium serotinum*	dominant	*Sicyos angulatus*	12.0
Eupatorium serotinum	7.7			*Popu. pensylvanicum*	9.3
Solidago canadensis	6.8			*Aster ontarionis*	9.1
Fraxinus pennsylvanica	6.5				
Dominant Tree Seedlings	**no./ha**		**Estimate**		**no./ha**
Fraxinus pennsylvanica	25,599	*Fraxinus pennsylvanica*		*Acer saccharinum*	3,750
Ulmus americana	19,997	*Acer saccharinum*		*Ulmus americana*	750
Acer rubrum	7,801	*Ulmus americana*		*Morus alba*	750
Total	53,397	Total		Total	5,750
Dominant Sapling/Shrubs	**no./ha**		**no./ha**		**no./ha**
Fraxinus pennsylvanica	300	*Acer saccharinum*	2,627	*Salix nigra*	60
Acer rubrum	240	*Populus deltoides*	1,977	*Populus deltoides*	60
Total	1,000	Total	7,017	Total	133

31.6 percent at Bankston Fork (fig. 3). Planted tree density was found to decrease between the second and third year (2000-2001) at the Rock River site (14.9 to 10.8 individuals/100 m^2), but did not change at Illinois River or Bankston Fork (fig. 2).

Although green ash had the greatest planted tree density after 3 years at Rock River and Bankston Fork, test results on planted tree density by species were not significant for any site (fig 4). After 3 years, natural sapling/shrub density was greater than planted tree density at Illinois River (70.2 vs. 13.1 individuals/100 m^2) and less than planted tree density at Rock River (1.3 vs 10.8 individuals/100 m^2). Natural sapling/shrub density and planted tree density did not differ at Bankston Fork. Illinois River, the site with the highest survival rate and density of planted trees, also had the greatest density of natural shrub/sapling stage regeneration (fig. 5).

DISCUSSION

Because 35 percent survival (Newling 1990) and 400 stems/acre (Clewell and Lea 1990) after 2 or 3 years have been reported as promising results, good to at least adequate planted tree survival and density was observed at all sites (32 to 61 percent, 316 to 538 stems/acre). In three other studies of bottomland tree restorations, third year survival ranged from 58 to 84 percent (Kolka and others 1998, Dulohery and others 2000, McLeod and others 2001), and a fourth study reported 10 percent survival after 5 years (Conner and others 2000).

Two of the three sites (Illinois River and Bankston Fork) in the present study exhibited no significant mortality between the second and third years. This may indicate that the high mortality phase associated with initial seedling establishment is coming to an end, and provides further evidence that 3 to 5 years after planting is a good time to judge chances for success.

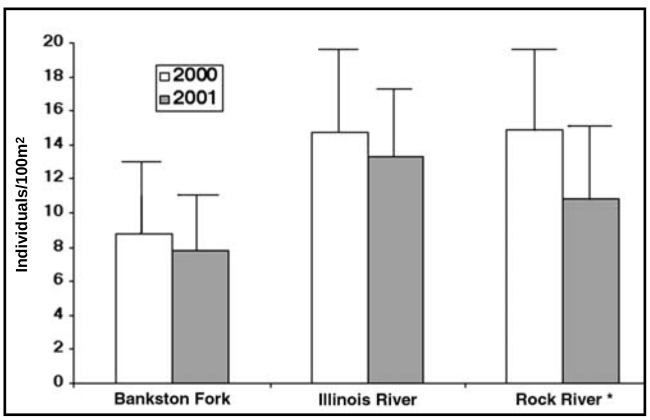

Figure 2.—*Planted tree mortality (mean, standard dev. of decrease in density), 2000-2001.*
** = significant decrease.*

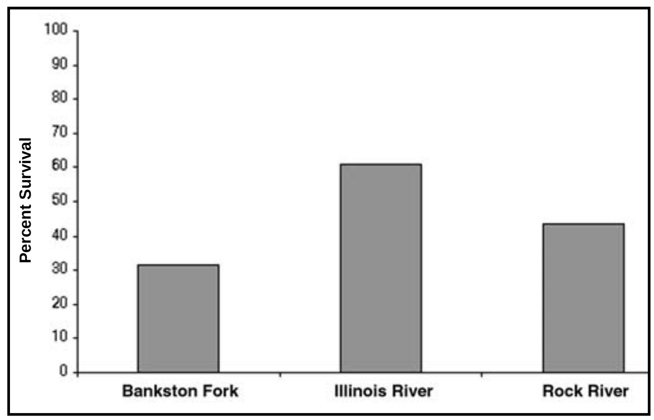

Figure 3.—*Planted tree survivorship (percent survival) after 3 years.*

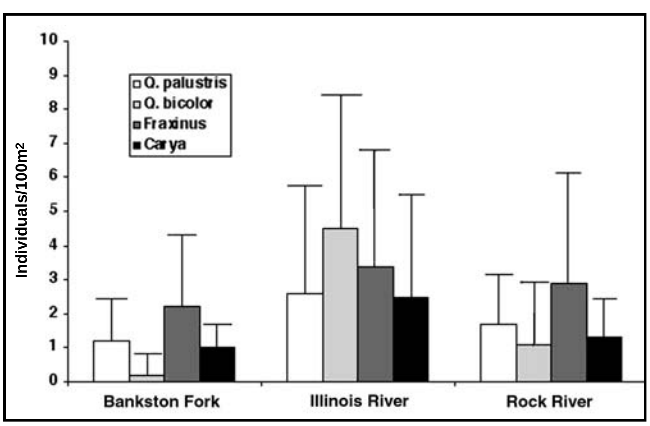

Figure 4.—*Planted tree survivorship (mean, standard dev. of density) by species after 3 years.*

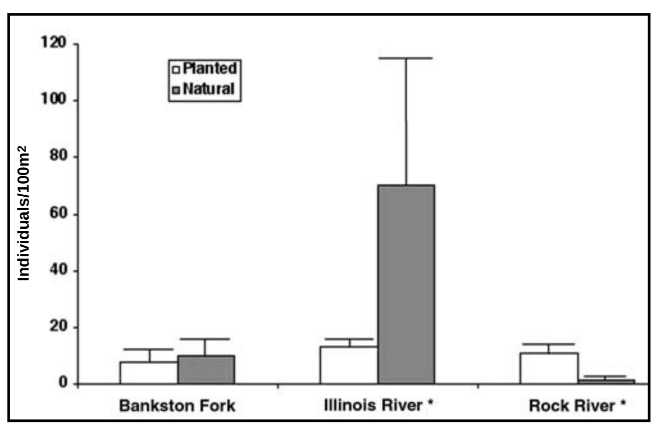

Figure 5.—*Planted tree density vs. natural sapling/shrub density (mean, standard dev.) after 3 years.*
** = significant difference.*

The lack of difference in survival between species at all sites was surprising. At Rock River and Bankston Fork, green ash density was almost twice the average planted tree density (1.7 and 1.9 times, respectively). It appears that the extremely high variation in density among plots masked any effect, and larger sample sizes may have been appropriate. Kolka and others (1998) and Dulohery and others (2000) found green ash survival to be among the highest in their studies and Dulohery and others (2000) found green ash height growth to be greatest.

Two of the three sites (Illinois River and Bankston Fork) had shrub/sapling stage natural regeneration that equaled or surpassed planted tree density. The site with the highest planted tree survival and density (Illinois River) had the greatest density of natural shrub/sapling regeneration as well – five times as great as planted tree density. Bankston Fork showed adequate planted tree survival (32 percent, 316/acre) in spite of dense herbaceous and shrub/sapling cover. Neither of these sites had weed control or release thinning. Dulohery and others (2000) and McLeod and others (2001) found that removing impenetrable (480 to 1,490 stems/acre) willow cover did not improve survival of planted seedlings. Conner and others (2000), however, found that green ash survival was lower in areas cleared of willow. McLeod and others (2000) demonstrated that annual clearing of dense herbaceous cover had no effect on planted bottomland tree survival.

At Rock River, where planted rows were mowed and treated with herbicides annually, trees exhibited an intermediate level of survival (43.5 percent). This could support the theory that removal of herbaceous and woody cover may not improve survival of planted stock. Rock River was the only site that showed a significant decrease in planted tree density between the second and third year. In addition, the adjacent natural regeneration area had a very low density of shrub/saplings and the lowest density of natural tree seedlings (133/ha, 5,750/ha).

The Rock River site experiences winter conditions quite different from the two more southerly sites. Here, mechanical ice breakup in periods of bank full discharge occurred in 2000 and 2001 and are not historically uncommon (Wicker and others 1998, personal observations). At Rock River, random occurrence of ice jams may outweigh other factors in determining survival of planted and natural seedlings alike. Mechanical ice breakup at bank full stage limits development of woodlands in low areas along streams. This phenomenon is capable of killing poles and saplings and is an important cause of mortality for seedlings in floodplains (Scott and others 1997, Smith and Pearce 2000).

SUMMARY

The results of this study indicate that on abandoned agricultural fields in bottomlands in Illinois, planted tree survival may begin to stabilize after 3 years. In this study, planted trees showed adequate to good survival and density (≥ 32 percent, 780 stems/ha) when native bottomland species were selected and planted at a level of 2,220 to 2,470/ha. Green ash appeared to perform best, but differences were not significant. Slower growing, heavy seeded species (pin oak, swamp white oak, and pecan) also performed adequately.

Natural regeneration generally equaled or exceeded density of planted stems, and dense shrub/sapling and herbaceous cover did not appear to detrimentally affect planted stock. Annual mowing and herbicide application did not seem to result in greater planted tree survival, but stochastic events (e.g., ice jam damage) may negate any positive effects.

The site with the most abundant natural regeneration also supported the greatest survival and density of planted trees. However, this may simply demonstrate that the best sites for natural regeneration are also the best sites for planted tree survival. Since dense cover has both positive and negative effects on tree seedlings, the overall effect of natural regeneration on planted stock may be neutral.

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