Yellow Birch: Guidance for Seed Transfer Within the Northeastern United States

Carolyn C. Pike and Christel C. Kern

Regeneration Specialist, U.S. Department of Agriculture (USDA), Forest Service, Eastern Region, State and Private Forestry, West Lafayette, IN; Research Forester, USDA Forest Service, Northern Research Station, Rhinelander, WI

Abstract

Yellow birch (*Betula alleghaniensis* Britton) is a small-seeded hardwood tree native to forests across northeastern North America. Genetic diversity of this species is high due to high levels of seed dispersal and pollen flow, though few parameters that describe gene flow have been reported. Yellow birch is capable of hybridizing with other *Betula* species. Common garden studies revealed relatively weak clines for growth traits but strong variation in phenological traits, indicating that seed transfer may be deleterious if seed is moved long distances. No empirical transfer distances have been suggested, but distances of 200 mi (322 km), or roughly 3 degrees latitude northward, is a safe recommend distance to avoid phenological mismatches. Widespread yellow birch decline has been described in Canada and attributed to climatic perturbations. Few major pests impact yellow birch except for decay fungi in decadent (overmature) stands. Yellow birch is likely to persist with climate change in its current range because of its high genetic diversity and gene flow.

Introduction

Yellow birch (*Betula alleghaniensis* Britton) is an opportunistic, relatively long-lived mesic hardwood that is readily found in hardwood forests of the Northeastern United States and Canada on a variety of soil types. The bark may be golden (figure 1) or brown in color (figure 2) and generally exhibits some peeling characteristics. Yellow birch has intermediate shade tolerance and is less shade-tolerant than its common associates, sugar maple (*Acer saccharum* Marshall) and American beech (*Fagus grandifolia* Ehrh.)(Beaudet and Messier 1998). Like other species in the *Betula* genus, yellow birch thrives on exposed or mixed

Figure 1. The shiny bark of this yellow birch is visibly distinguishable from other birch species in this forest. (Photo by Carolyn Pike, 2019)

Figure 2. The bark of this yellow birch tree is light brown in color and exhibits patterns of peeling similar to other trees in the genus. (Photo by Katie Frerker, USDA Forest Service, 2019)

mineral soil created by major disturbances (Caspersen and Saprunoff 2005, Kern et al. 2019) or on decayed wood debris (Marx and Walters 2008) (figure 3). Yellow birch populations are concentrated across northern portions of New York, New Hampshire, Vermont, and across Maine. The species also occurs in lower densities across the western Great Lakes region and at higher elevations along the southern Appalachians as far south as North Carolina. Three glacial lineages exist: a large eastern group (southern Appalachians to New England), a western group in the Great Lakes region, and a small group in Atlantic Canada (Thomson 2013, Thomson et al. 2015a). Introgression among *Betula* species (*B. papyrifera* Marshall, *B. lenta* L., and *B. alleghaniensis)* likely occurred during the last glacial maximum (Thomson et al. 2015a), but today the species are largely distinct (Thomson et al. 2015b). Yellow birch has experienced declines attributed to overmaturity (Woods 2000), lack of recruitment (Caspersen and Saprunoff 2005), and/or periodic freeze-thaw events (Bourque et al. 2005). Yellow birch seedlings are also prone to desiccation following lengthy periods of drought.

Yellow birch is not commonly planted because the species regenerates readily from seed. Excessive leaf litter and a lack of bare mineral soil can hamper regeneration success, especially on sites where light is limiting (Shields et al. 2007). In managed stands, natural regeneration is promoted with group or patch selection followed by scarification to expose mineral soil (Gauthier et al. 2016, Willis et al. 2015). In addition, one or more seed trees must be

Figure 3. Yellow birches grow best on bare mineral soil or any exposed surface such as the rock in this photo. (Photo by Matt Pickar, USDA Forest Service, 2021)

retained in, or near, harvest-created openings (stand basal area >1.3 m2/ha [5.7 ft2/ac]; <15 m [49 ft] away) (Caspersen and Saprunoff 2005, Willis et al. 2016). Release of advance regeneration through frequent selection cutting can also facilitate attainment of canopy positions for this species (Webster and Lorimer 2005). Seedling survival and growth are best on sites with medium to large light gaps (Kern et al. 2012, Gasser et al. 2010), although excessively large gaps can result in increased competition with shrubs or increased desiccation through temperature extremes (Hatcher 1966, Kern et al. 2013). The species' thin bark renders it highly sensitive to damage from sun scald and fires. Yellow birch root systems are generally shallow and thus sensitive to changes in soil temperature and moisture. White-tailed deer (*Odocoileus virginianus*) and snowshoe hare (*Lepus americanus*) commonly browse yellow birch seedlings. More information about the species' distribution, growth, and habitat can be found in Neesom and Moore (1998) and Erdmann (1990).

Genetics and Gene Flow

Yellow birch is monoecious and can produce male and female flowers on the same or different branches. Pollen is shed in the spring, and seeds are wind dispersed from August through September (Clausen 1973). The seeds are relatively small, with approximately 1,000 per gram (450,000 per pound) (Karrfalt and Olson 2008). The period of seed dispersal in yellow birch is more extended than other taxa with which it coexists (maple [Acer sp.] and beech [*Fagus* sp.]), resulting in a more persistent seed bank (Houle 1994) (figure 4). Production of male and female flowers may commence early in a tree's lifespan, sometimes before age 10 (Clausen 1980) but is generally much later (40 years and older) across most of its range (Erdmann 1990). Seed production increases with the age and abundance of yellow birch in the canopy (Drobyshev et al. 2014). Gene flow, measured with F_{ST} values (a ratio of genetic variation between sub-populations and the total population), has not been reported, but genetic and phenotypic variation is considered high due to effective dispersal of pollen and seed from both young and mature trees over their lifespan.

The *Betula* genus has a transcontinental range across the northern hemisphere and a complicated phylogeny (Wang et al. 2016). Yellow birch is hexaploid (Clausen 1973, Wang et al. 2016) and can hybridize with paper birch (*Betula papyrifera* Marshall, also a hexaploid), most commonly where the species ranges overlap (Barnes et al. 1974, Sharik and Barnes 1971, Thomson 2013, Thomson et al. 2015ab). Genetics studies of yellow birch have focused on the effects of introgression with other *Betula* spp., most commonly with *B. papyrifera* and less often with *B. lenta* (sweet, or black, birch). These natural hybridization events are most common in the lower Great Lake States where paper birch and yellow birch are sympatric, although the species are genetically distinct despite occurrence of hybridization events (Thomson 2013, Thomson et al. 2015b). Genetic

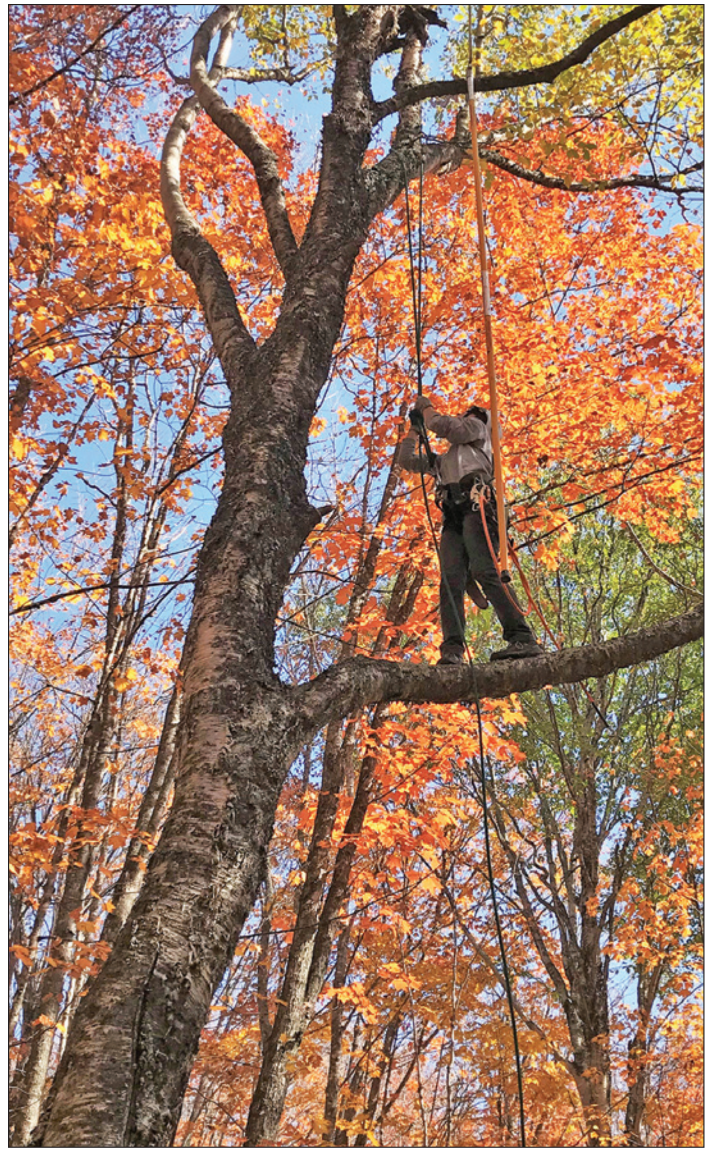

Figure 4. Yellow birch regenerates well on its own, but seeds are also collected and planted to supplement natural regeneration. (Photo by Richard Kujawa, USDA Forest Service, 2021)

diversity is highest for yellow birch in the central-western Great Lakes region where introgression with paper birch occurred historically (Thomson et al. 2015a, 2015b).

Seed-Transfer Considerations

Common-garden studies found weak clines (latitudinal or longitudinal) for growth traits in both seedlings and 5-year-old saplings (Clausen 1975, Leites et al. 2019). Growth rings, studied in stands of natural origin, were relatively insensitive to variations in climate as well (Drobyshev et al. 2014). Clinal variations along a latitudinal (north-south) gradient are more pronounced for phenological traits associated with cold tolerance than height growth, especially for young seedlings. For example, timing of growth initiation was consistently earlier for northern- than southern-origin sources while southern-origin sources extended growth longer into the late-summer months or early fall (Clausen 1968a, Clausen and Garrett 1969). This extension of the growing season into the fall may increase susceptibility to damage from fall frosts. Traits with uncertain adaptive value, such as catkin, bract, and fruit characteristics, do not follow clear geographic patterns (Clausen 1968b), implying that genetic variation is well-dispersed among stands (Clausen 1980).

A recent analysis derived critical (not to exceed) transfer distance for yellow birch and other taxa (Pedlar et al. 2021) from provenance trials by comparing mean annual temperature (MAT) of each seed source's origin to the MAT of each planting site. Tree height in yellow birch remained above the 10 percent threshold until transfer distances exceeded 7.8 °C (13 °F) to a cooler environment or 70-day shorter growing season (Pedlar et al. 2021). This critical transfer distance, based on tree height alone at a relatively small number of common gardens, may, however, overlook phenological differences that impact survival. Transfer distances of up to 200 mi (322 km) (approximately 3˚ latitude northward) is conservative but would likely avert phenological mismatches from excessively long-distance movement of seed. The 200-mi (322-km) distance is a general recommendation for white spruce (*Picea glauca* [Moench] Voss) (Thomson et al. 2010) which has undergone more extensive provenance testing and may be comparable to yellow birch because of its high genetic diversity and low clinal variation for growth traits. If yellow birch seed orchards are established, a variety of phenotypes from local areas and southerly sites should be incorporated to maximize genetic diversity. In the absence of artificial regeneration, silvicultural prescriptions that incorporate mature seed trees near exposed mineral substrates and canopy openings will improve natural regeneration of the species. As the climate changes, natural hybridization with paper birch may be exacerbated or deterred based on local weather cycles, but these events will likely be impossible to predict or avoid.

The geographic range that yellow birch occupies is not expected to change dramatically with climate change, but the quality and quantity of the habitats within its range may decline (Peters et al. 2020). Its high seed and pollen dispersal is favorable for the species to endure across a dynamic landscape in a changing climate, but fire and pests may negatively affect its habitat (Prasad et al. 2020). Yellow birch is also sensitive to summer droughts and freeze thaws in the spring and fall when trees are incompletely dormant (Cox and Zhu 2003), which may affect its survival if these conditions become more commonplace in the future. Yellow birch populations residing in its northern range edge were limited by substrate and seed availability but were otherwise relatively neutral to temperature extremes (Drobyshev et al. 2014), suggesting few barriers for its northward expansion. Genetics and seed-transfer considerations for yellow birch are summarized in table 1.

Insect and Diseases

Few major insects and diseases impact the growth and survival of yellow birch. Bronze birch borer (*Agrilus anxius* Gory) and birch skeletonizer (*Bucculatrix canadensisella* Chambers) can lead to mortality of mature trees. Birch leaves (figure 5) are also susceptible to feeding from the introduced gypsy moth (*Lymantria dispar dispar*) and the native forest tent caterpillar (*Malacosoma disstria* Hübner) which may contribute to yellow birch decline, especially in mature forests where trees experience other health issues.

Table 1. Summary of silvics, biology, and transfer considerations for yellow birch.

Yellow birch, *Betula alleghaniensis* Britton	
Genetics	• Hexaploid (6 sets of chromosomes) • Gene flow (pollen): high • Gene flow (seed): high
Cone and seed traits	• Small, winged seeds • 50,000 cleaned seeds per pound (992,250 seeds per kg) (Karrfalt and Olson 2012) • Seeds released in September
Insect and disease	• Bronze birchborer, nectria canker, cider conk, and skeletonizer • Decadent stands may exhibit crown dieback and decline
Palatability to browse	• High risk of herbivory from white-tailed deer and snowshoe hare
Maximum transfer distances	• No specific transfer distances have been calculated • Yellow birch should tolerate long distance transfers (200 mi [322 km], 3° latitude northward) • Potential to hybridize with paper birch or sweet birch where ranges overlap
Range-expansion potential	• Likely to expand range but requires suitable sub strate (e.g., exposed mineral soil) and sufficient light to survive (e.g., canopy gaps)

Figure 5. Yellow birch leaves are ovoid and serrated and sometimes difficult to distinguish from paper birch. (Photo by Jack Greenlee, USDA Forest Service, 2003)

No primary pathogens currently afflict yellow birch, but several decay fungi, such as cinder conk (*Inonotus obliquus* [Ach. ex Pers.]), are often found on mature or decadent trees (Brydon-Williams et al. 2021). Nectria canker (*Neonectria galligena* (Bres.) is damaging to yellow birch but is generally not destructive on a stand level (Ward et al. 2010); trees can live for many years with rather large cankers. Episodes of crown decline may occur with no clear cause, resulting in dead branches in the top of the tree and occasionally substantial crown dieback. Crown dieback may also be triggered by unusual weather events (Bourque et al. 2005) or site disturbance.

Address Correspondence to —

Carrie Pike, 715 W. State Street, Pfendler Hall, West Lafayette, IN 47907; email: carolyn.c.pike@usda.gov; phone: 765–490–0004.

Acknowledgments

The authors thank Steve Katovich and James Jacobs (USDA Forest Health Protection, St. Paul Field Office) for their assistance with insect and disease issues.

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