

DIRECT SEEDING OF FINE HARDWOOD TREE SPECIES

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Abstract.—Direct seeding of fine hardwood trees has been practiced in the Central Hardwoods Region for decades, but results have been inconsistent. Direct seeding has been used for reforestation and afforestation based on perceived advantages over seedling planting, including cost and operational efficiencies, opportunities for rapid seedling establishment and early domination of planting sites by desirable trees, improved tree form through increased competition, and ability to select the parentage of planting stock. Some barriers to successful direct seeding have included poor seed quality, improper handling or planting of seed, seed predation by rodents and other seed predators, and difficulty in establishing germinants due to competing vegetation. The literature and current field practice indicate direct seeding of black walnut, butternut, black cherry, American chestnut, and chestnut hybrids can be a viable regeneration technique, but success is dependent on proper seed collection, handling and sowing procedures, protection of seed from predation, and effective weed control maintained until seedlings are established.

Direct seeding of fine hardwood tree species has been used for afforestation and reforestation efforts for many years with mixed results. Direct seeding has several advantages over planted seedlings. For example, direct seeding has a lower initial cost than planting seedlings. Direct seeding results in undisturbed root system development, thus avoiding the root damage and transplanting shock associated with planting bare-root seedlings. Direct seeding may be more flexible in the timing of the planting, depending on the species being planted and seed treatments. Direct seeding may also correspond better with the equipment and labor available to private landowners. The desire to create high density tree plantations to quickly occupy the planting site and encourage development of straight boles and small side limbs, and subsequent natural pruning, has also created interest in using direct seeding. Seed for direct seeding can be collected from parent trees with

desirable characteristics such as disease resistance, rapid growth rate, superior wood quality, or selected provenance (Rasmussen et al. 2003, Van Sambeek 1988).

Practitioners using direct seeding can experience challenges in application, resulting in poorly stocked plantings or outright regeneration failures in several cases. The following sources of failure were reported: planting seed that is not viable, incorrectly handling and sowing seed resulting in reduced viability, seed predation (primarily by rodents), lack of site preparation or site preparation that does not adequately control competing vegetation, failure to maintain control of competing vegetation until germinants or seedlings are established, poor sowing technique or soil conditions resulting in failure of seed to germinate or mortality of new seedlings, and failure to match the tree species to appropriate growing sites.

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Several studies and reforestation projects have demonstrated that direct seeding of fine hardwood species such as black walnut (*Juglans nigra* L.), butternut (*Juglans cinerea* L.), northern red oak

(*Quercus rubra* L.) and white oak (*Quercus alba* L.), black cherry (*Prunus serotina* Ehrh.), American chestnut (*Castanea dentata* (Marshall) Borkh.), and chestnut hybrids can be successfully established. This paper examines the literature and field practices related to direct seeding of black walnut, butternut, black cherry, and chestnuts planted for reforestation and afforestation in eastern North America, with the objective of outlining recommended practices to increase success. Direct seeding of oak species was reviewed in detail by Dey et al. (2008).

SPECIES REVIEWS

Black Walnut

Black walnut is one of the most promising species to regenerate by direct seeding; however, results with direct seeding of black walnut have been inconsistent (Rasmussen et al. 2003).

Black walnut seed may be collected locally or purchased through commercial outlets. Some sources have recommended using local seed or seed collected from areas within 100 to 200 miles south of the planting location to take advantage of superior growth demonstrated by seed from areas south of the planting area. Deneke et al. (1981) and Bey (1980) noted that using seed from 100 to 200 miles south of the area to be planted resulted in better growth except in the far northern part of the black walnut range.

Seed can be sown cleaned or in the husk. Nielsen (1973) suggested that walnuts thoroughly cleaned of all husk material may not be pilfered by rodents to the extent that walnuts planted in the husk may be. There are several examples of heavy pilferage of husked walnut after planting, but these seeds may not have been cleaned to the degree in the previous instance (Phares et al. 1974). If collectors want to clean the seed, it should be done before the husk dries. Seeds still in the husk need to be stored carefully to avoid heating due to decay of the husk, resulting in possible death of the seed. Storage in cool conditions or in small lots allowing for good air circulation is recommended to keep from overheating the seed (Williams 1982). Immersing freshly husked

walnut seed in water and removing floating seed are recommended to increase the number of sound or viable nuts that may be planted. Seeds may be planted in the fall at or shortly after collection, or they may be stratified and planted the following spring. The stratification period for optimum seed germination is 90 to 120 days at 1 to 5 °C (Bonner and Karrfalt 2008), but some seed sources may yield varied results. Some seed may not germinate until the second season after planting (Van Sambeek et al. 1990).

Dierauf and Garner (1984) examined the influence of nut size and planting depth on seedling performance over 5 years. Nuts were sorted into three size classes: small (1 to 1.25 inches), medium (1.25 to 1.5 inches), and large (greater than 1.5 inches). Nuts smaller than 1 inch were discarded. Size-sorted, stratified nuts were sown in March at depths of 3, 5, and 7 inches. Nuts in the medium class produced the most seedlings after one growing season followed closely by the large class. Small walnuts lagged far behind. The 3-inch sowing depth resulted in the most seedlings after one growing season. At five growing seasons, there was no strong relationship between seedling height and nut size or depth of planting.

Studies evaluating season of planting have produced variable results, but the operational advantage seems to go to fall planting, which eliminates additional seed handling, results in natural stratification, and may provide for improved germination and earlier seed emergence in the spring (von Althen 1969). Some studies indicated that spring planting resulted in higher stocking, possibly due to decreased time of exposure to seed predators. In either case, the potential for seed predation should be carefully evaluated. Planting seed near woodlands or other habitat that harbors rodents can result in massive loss of seed to predation (Wendel 1979, Williams and Van Sambeek 1984). Direct seeding areas within 300 feet of woodlands or other favorable habitats for squirrels and other seed predators may result in heavy seed losses. Seed protection may provide improved germination and establishment when seed predation is likely.

In a study of several reproduction methods for black walnut in Ontario, Canada, the depth of planting was examined as a possible deterrent to seed predation (von Althen 1969). Black walnut seed was planted in open fields and small openings in hardwood woodlots at depths of 2, 6, and 10 inches. Deep seeding delayed germination and reduced total germination in the open field plantings with third year survival of 93, 85, and 72 percent for fall seeded black walnut planted at 2, 6, and 10 inches deep, respectively. Survival of spring seeded germinants was only slightly lower for each depth. Nuts planted in the woodland openings experienced heavy predation by squirrels with 78 to 86 percent of planted nuts eaten; 60 percent of planting spots were disturbed in the first 4 weeks. In another experiment, seeds planted in woodland openings yielded 80 percent of seed spots stocked for seed protected with 24-inch-tall and 30-inch-wide wire screens versus 16 percent stocked with no seed predator protection. Nursery seedlings (1-0) planted in the same experiment yielded 94 percent stocked after two growing seasons and were recommended as superior to direct seeding for reliability of regeneration and growth of black walnut.

Fall and spring direct seeded walnut and spring planted walnut seedlings were compared over a 7- year period on four nonforested sites in western Virginia (Dierauf and Garner 1984). Nine seeds were planted at spots on a 6.6-foot grid. Seedlings were planted on the same spacing. Simazine and paraquat dichloride was sprayed around but not over each seeding and planting spot at planting and for 3 years after planting. March seeding resulted in 90 percent of the seeded spots with at least one seedling compared to 76 percent for November seeding. Planted seedlings averaged 98 percent survival over the four tracts. By the end of the seventh year, approximately 14 percent of the seeded seedlings had died. The tallest seedlings in each direct seeded spot grew faster than the planted seedlings for the first 3 years and at about the same rate thereafter. Planted seedlings grew slowly in the first two seasons, but growth improved in the third and fourth seasons.

The average height of all trees 7 years after planting equaled: planted seedlings (10.0 feet), March sown seed (9.5 feet), November sown seed (9.4 feet).

Stratified and sprouted seed can be used to increase the potential for desirable stocking and better control tree spacing (Fig. 1). Black walnut progeny tests using sprouted seed have demonstrated high survival rates and height growth equivalent to seedling plantings of the same genetic families (data on file with the Hardwood Tree Improvement and Regeneration Center, West Lafayette, IN). Jacobs and Severeid (2004) reported black walnut survival over 95 percent 5 years after sowing sprouted seed in Wisconsin. Davis et al. (2004) recommend using pre-germinated seed in direct seeding operations to improve density control and to replace failed seedlings early in plantation establishment.



Figure 1.—Stratified black walnut seeds that are beginning to sprout. (Photo by James R. McKenna, U.S. Forest Service)

Careful site selection is as crucial to direct seeding of walnut as it is for planting walnut seedlings. Soil surveys should be consulted to assist in evaluating the site suitability for black walnut plantings along with the recently developed Black Walnut Suitability Index available in participating states on their USDA Natural Resources Conservation Service Web Soil Survey sites (Wallace and Young 2008). SoilWeb is a new tool available to smart phone users that provides on-site soil information based on GPS-determined location (Beaudette and O'Green 2009). Combining the real-time soils information from SoilWeb with the more detailed information in the Web Soil Survey, Black Walnut Suitability Index, and references such as Ponder (2004) provides convenient tools for resource professionals and landowners to evaluate sites for planting black walnut and other tree species. Soil testing for pH and nutrients can help determine appropriate sites and suggest soil amendments that may improve establishment and long-term performance.

Site preparation is a key practice for seedling survival and establishment. Black walnut is a species that can pioneer in established grass and weeds, but growth is often slow and survival reduced. Glyphosate is the most commonly listed herbicide for pre-planting control of perennial weeds and grasses and should be applied in the summer or fall before sowing. Some practitioners apply post-emergent herbicides over the planting area in the spring before seedling emergence, stating that the killed vegetation provides natural mulch for the emerging seedlings (Edge 2004). Some post-emergent herbicides used for direct seeding include glyphosate, clethodim, clopyralid, sulfometuron methyl, imazaquin, and fluzifop-p-butyl.

A study on graded surface-mine land demonstrated black walnut seeded into perennial grasses yielded 38 to 50 percent establishment and 42 to 48 cm average stem height after two seasons when glyphosate and simazine applications were used to control grass and forb growth (Philo et al. 1983). They found that

black walnut direct seeded in May of 1980 on soil banks of Illinois land surface mined in the 1960s benefited from 2 years of weed control. Seeds planted in established perennial grasses germinated and grew at a much lower rate than seeds provided with 2 years of weed control using glyphosate or glyphosate and simazine. Reduced germination in plots sprayed with simazine and glyphosate compared to glyphosate only indicated a possible negative effect on germination by simazine. The authors suggested that simazine might have less negative effects at a lower rate of application than was used in the experiment (5 lb/acre). Some sources recommend delaying pre-emergent herbicide application until after the first year of seeding to avoid possible damage to seed germination. Several successful plantings mentioned in research literature or extension publications indicated pre-emergent herbicides were successfully applied shortly after direct seeding. Some pre-emergent herbicides used for direct seeding include simazine, oryzalin, pendimethalin, oxyfluorfen, and metolachlor.

Van Sambeek (1988) listed some steps to follow to improve success when direct seeding black walnut. Prepare the site before planting by killing competing vegetation. Place collected seed in water and remove floaters. Break open a sample (10 to 20) of seed to determine the percentage of sound seed. Viable seed has white, firm kernels. Non-viable seed has shriveled, beige or brown kernels that are watery or give off a rancid odor. The percentage of sound seed should guide planting density. If seed is spot-planted, 80 to 100 percent sound seed should be planted at two seeds per spot, 60 to 80 percent sound at three seeds per spot, 40 to 60 percent sound at four seeds per spot, and less than 40 percent viable seeds at five or more seeds per planting spot. Seed should be planted 2 to 3 inches deep and can be oriented in strips, triangles, or squares, depending on whether rows or spots are to be sprayed for weed control. Seeds should be protected from squirrels and other seed predators with mechanical barriers or chemical repellents. An inexpensive repellent application entails placing a generous amount of fresh cow manure over each

planting spot (Williams and Funk 1979). Thin to the best seedling in each planting spot following the first or second growing season. Planting seed about 8 inches apart in each spot will make it easier to drive a spade through the top of the taproot to kill unwanted seedlings or to lift and transplant extra seedlings in the fall or the following spring.

Robison et al. (1997) make several recommendations based on experience with nursery seedling production and experimental and field experience with direct seeding. Intensive site preparation is required for successful seedling establishment, and weed control for at least three growing seasons can increase the ability of seedlings to occupy the site. Screening for suitable walnut sites, soil testing, and nutrient management in conjunction with effective weed control can also enhance seedling growth and establishment and provide a better opportunity for long-term productivity. Choose seed sources for best long-term results by using local or southern sources. Rodents pose a significant threat to direct seeding success rate. Late spring planting of stratified or pre-germinated seed may provide for quick emergence of seedlings in a season when other food sources are available for predators. Providing alternate food sources or cull seed between rodent habitat and direct seeded areas may help reduce predation, especially if lightly disked in so seed begins the stratification and germination process. Circumstantial evidence indicates that squirrels ignore sound air-dried seed with dead embryos or that squirrels detect volatiles produced during stratification, which can be masked by fermenting grain in fresh cow manure.

A long-term study applied to planted walnut seedlings, but with application for direct seeding as well, indicated that seedlings protected from wind for the first 4 years after planting developed and retained a large advantage in height and diameter growth compared to those without wind protection (Heiligmann et al. 2006). Black walnut seedlings grown in an open field location but protected from wind by a barrier made of lathe snow fence during

their first 4 years of growth demonstrated increased growth after the first growing season and maintained a significant growth advantage after 11 growing seasons compared to unprotected seedlings. After 11 years the protected seedlings showed 21 percent improved survival, 60 percent more diameter growth, and 70 percent more height growth versus unprotected seedlings. Unprotected seedlings showed discolored leaves in late August; protected seedlings did not display discolored leaflets until at least mid-September. This difference disappeared after the wind barriers were removed after the fourth year. Protected walnut also developed larger crowns and leaf areas. After 2 years the leaf area of protected seedlings was 1.75 times that of unprotected seedlings.

Butternut

Butternut has been the subject of much less experimentation in direct seeding than black walnut. Butternut has become rare in most of its former range due to disease, particularly butternut canker (*Ophiognomonia clavignenti-juglandacearum* ((Nair, Kostichka, & Kuntz) Broders & Boland), and land use patterns that may not favor regeneration of this relatively short-lived tree. Direct seeding butternut has many points in common with direct seeding black walnut. Butternut seed collection and handling procedures as well as planting procedures are similar to those of black walnut. Due to the rarity of butternut and the attractiveness of the seed to squirrels and other seed predators, seed should be protected from predation by barriers or other physical or cultural methods. Stratifying seed and planting sprouted seeds with protection from seed predators is an intensive direct seeding technique, but it also provides the best chances for establishing seedlings.

The butternut canker disease can be carried on the seed and infect newly sprouted seedlings (Andre et al. 2001), so collection of seeds from uninfected or apparently healthy and vigorous trees is preferred. Andre et al. tested several methods to decontaminate butternut seed before planting. They found that soaking the seed in boiling water for 1 minute was

effective in eliminating butternut canker infection and did not negatively impact seed germination. Seed collectors should be aware that butternut hybrids, generally with Japanese walnut (*Juglans ailanthifolia* Carr.), are commonly encountered and are often prolific nut producers (Woeste et al. 2009). The Identification of Butternuts and Butternut Hybrids guide can assist seed collectors in recognizing butternut hybrids from butternut for seed collection (Farlee et al. 2010a). Efforts are under way to identify disease resistant butternut. But until disease resistant seed sources are available, pure butternut plantings or plantings with a high proportion of butternut are not recommended, because of a high probability of early mortality. Scattering butternut through a planting has the advantages of maintaining some butternut in the area, limiting the amount of butternut canker inoculum and hosts, and providing adequate diversity of trees for a well-stocked planting (Farlee et al. 2010b).

Experiments with direct seeding butternut have shown that the seedlings require full sunlight and may have difficulty competing with associated fast growing shrub and tree sprouts, so weeding or crop tree release may be required to establish the butternut in a direct seeded planting (Ostry et al. 2003). Sprouted butternut seeds have been used for progeny tests by the Hardwood Tree Improvement and Regeneration Center and have performed similarly to seedling plantings; however, sprouted seedlings were reported to be more labor intensive to establish than dormant 1-0 seedlings due to cumbersome procedures to sprout, store, and transport the seed, and effort and supplies needed to protect the seed from predation (McKenna et al. 2011).

American Chestnut and Chestnut Hybrids

American chestnut and the back-crossed hybrid chestnuts being bred for resistance to chestnut blight are trees of great interest to landowners, agencies, and the surface mining industry in the eastern United States for reforestation and land reclamation. As disease resistant chestnuts are made available, the re-introduction efforts may include direct seeding. Sprouted American chestnut seed was spot planted

in mixed plantings with sprouted northern red oak and black walnut seed near Rockland, WI, in the spring of 1995 and 1996. Seed and resulting seedlings were protected with 24-inch-tall tree tubes through the following spring. By November 2002, American chestnut and black walnut survival was more than 95 percent, and red oak survival was about 85 percent. The reduced oak survival was primarily the result of seed predation. American chestnut was significantly larger in d.b.h. and height compared to both black walnut and northern red oak (Jacobs and Severeid 2004). Fields-Johnson et al. (2010) reported direct seeded American chestnut survival after one growing season was 76 percent compared to 83 percent for bare-root seedlings. French et al. (2008) reported American chestnut direct seeded on the Cumberland Plateau had greater first-year survival (61.8 percent) than containerized transplants (51.2 percent), but height and diameter growth were greater for the containerized transplants.

American chestnut, Chinese chestnut (*Castanea mollissima* Blume), and three back-crossed hybrids of these two species were direct seeded in May 2008 on loosely graded surface-mine soils in West Virginia. Some seeds were protected with 18-inch-tall tree shelters, while others were unsheltered. Combined survival for all seed types 4 months after planting was 72 percent. Seed protected with tree shelters had 81 percent survival, while unprotected seed had 63 percent survival (Skousen et al. 2009). Predation did not pose a problem at the study location. Chinese chestnut had the highest survival (82 percent) and American chestnut had the lowest survival (67 percent) of all seed types, while the hybrids were intermediate in survival. Direct seeding was found to be the most cost effective and efficient method for establishment; however, planting of seedlings was found to ensure greater survival, better control over tree spacing, and enhanced ability to compete with other vegetation. Direct seeded trees did not compete adequately with resprouting vegetation that had been cleared (Phelps et al. 2005).

Chestnuts may be planted in the fall shortly after collection or stored for spring planting. Seed should be floated in water, and unfilled or immature seed removed. Seed collected in extremely dry conditions should be left in water overnight to restore normal seed moisture. Fall planted seed should be protected from predators. Nuts to be stored for spring planting should be allowed to surface dry after floating and then be stored in unsealed bags at 1 to 3 °C for 1 to 3 months. Nuts should be sown 0.75 to 1.5 inches deep (Bonner and Karrfalt 2008). American chestnut can grow rapidly on ideal sites, so consideration should be given to interspecific competition when designing the planting. The sprouted seed planting of Larry Severeid in northwestern Wisconsin, composed of a mixture

of American chestnut, black walnut, and northern red oak (Fig. 2), is an example of a well-stocked direct seeded planting where American chestnut growth has outstripped neighboring oaks and black walnut (Jacobs and Severeid 2004).

The American Chestnut Foundation provides the following guidelines for planting American chestnut and chestnut hybrids. The ideal pH range is 4.5 to 6.5, and ideal planting sites should be well drained with sandy to loamy soils. Avoid sites with heavy clay soils or poor drainage. Early spring planting is recommended. Seed may be sprouted by this time, and if so, the seed should be planted with the radicle facing down and covered with 0.5 to 1 inch of soil. Long

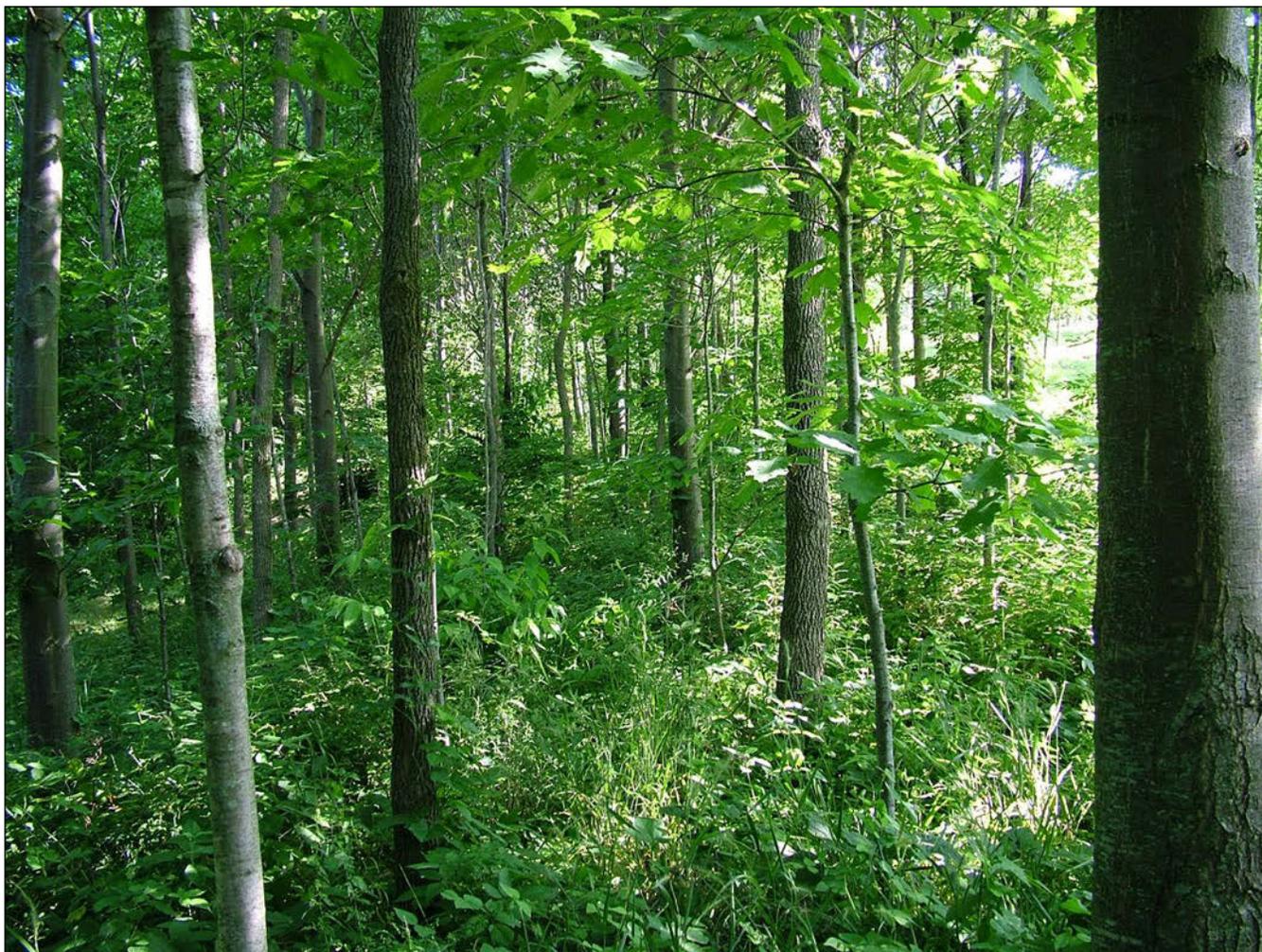


Figure 2.—Fifteen-year-old planting of American chestnut (right foreground), black walnut (middle), and red oak (left foreground) established by directing seeding using sprouted seed in 1995 and 1996. (Photo by Lenny D. Farlee, Purdue University)

radicles may be clipped before planting. Protection from seed predators is required even after seedling emergence, because squirrels will dig up the seedling to access the remainder of the nut. Protection can be provided by placing partially buried tree tubes, wire cones, or cages over planted nuts (Fitzsimmons 2006). Another economical technique to protect seed of chestnuts or other hardwoods from rodents uses a number 2 (20 oz) can. One end of the can is removed, and an X or cross pattern is cut in the center of the other end. Pliers or a similar tool are used to curl back the four corners of the cut to allow a space for the seedling to emerge (Fig. 3). The can is pushed into the soil over a planted seed until the cut end is flush with the surface. Non-aluminum cans generally rust away before they present a barrier to growth of the seedling. Burning the can before use will accelerate corrosion (Diller 1946).

Black Cherry

Black cherry use in direct seeding has been less successful compared to the other species covered in this paper. Huntzinger (1972) reported that seed treatment and storage, depth of seed sowing, and protection from deer browsing are important contributors to direct seeding success for black cherry in the Allegheny Plateau. Planting in areas with established grass or weeds may lead to long establishment periods or failure unless intensive



Figure 3.—A can prepared for placement over a planted seed. (Photo by Mel Baughman, University of Minnesota)

vegetation control measures are employed. Direct seeding black cherry was recommended for cutover mixed hardwood areas where advance regeneration is lacking.

Fresh seed collected in September should be cleaned of pulp, allowed to surface dry, and then sown immediately if fall sowing is desired. For spring sowing, the dried seed is stored in sealed polyethylene bags at room temperature for 2 to 4 weeks and then stratified for sowing in March or early April. The recommended stratification period is 120 days at 2.8 to 5 °C.

A sowing depth of 1.5 inches combined with early sowing, either fall or spring, gave the best results. This finding stands in contrast to the general recommendation of sowing seed at a depth of one to two times seed diameter. Two potential sowing patterns were recommended. Plant a minimum of four seeds per 1-foot-diameter spot, with spots spaced 4 by 4 feet apart. This spacing should result in closed canopy within about 4 years, and the dominant seedling at each spot could average more than 8 feet tall at 4 years. The other recommended method involves planting 9 to 12 seeds in a 2-foot-diameter spot and spacing spots at about 15 by 15 foot spacing.

Protection from deer browsing is required for establishment, with fencing as the recommended method. A study comparing the performance of 1-0 bare-root seedlings, direct seeding, and containerized seedlings of red oak, tuliptree (*Liriodendron tulipifera* L.), and black cherry planted on cutover forest land on the Fernow Experimental Forest in West Virginia reported that mice and chipmunks destroyed most of the direct seeded red oak and black cherry. As a result, few seedlings and few trees were in dominant or codominant positions after 7 years, compared to 1-0 seedlings (Wendel 1979).

In direct seeding in reclamation projects, Davidson (1980) noted that black cherry has performed poorly. For direct seeding for reclamation, he recommended early spring planting of stratified seed, but fall seeding

is acceptable as long as seed will not be washed away or covered too deeply by siltation. Broadcast seeding is easiest but requires large amounts of seed and may not perform well if seed is not incorporated in the soil. Spot seeding or drilling uses less seed and allows for control of spacing and soil coverage of seed.

Direct seeding of many hardwood species has been done successfully for years on the southeastern Iowa property of Larry Krotz (pers. commun. 2011). Black cherry does not have a good success rate with direct seeding. Krotz now leaves selected black cherry as seed trees or erects perches to encourage birds to plant cherry in regeneration areas. He prefers having the black cherry seeded in by birds several years after oaks and walnuts so it does not outcompete these species in the plantings. This approach may also lead to better stem form on the cherry due to increased competition for sunlight.

Mixed Species

Direct seeding is often applied with a mix of species to produce a diverse planting. Recommendations for successful direct seeding operations can apply to a broad range of hardwood species, as illustrated by the literature and experience recounted thus far. Several extension publications, based on both scientific research and repeated practical experiences, provide some general principles for improving the success of direct seeded plantings.

Rasmussen et al. (2003) consider direct seeding a proven, effective method of establishing conservation plantings in Nebraska. Several advantages of direct seeding include replication of natural forest establishment processes, potential for high density plantings, less critical moisture conditions for dormant seed than planted seedlings, and development of undisturbed root systems with no transplant shock. Establishment costs are typically cheaper than for seedling plantings. Potential disadvantages include difficulty in controlling competing vegetation, lack of familiarity with the direct seeding method, uncertainty about seed viability, and seed predation.

Recommendations include floating fresh seed for 1 hour and discarding floaters. To avoid heating, do not store large quantities of seed together. Plant seed within 1 month of collection or stratify seed for spring planting, according to species requirements.

Mixed species plantings are recommended. Planting can be done in rows or by broadcasting seed with seeding rates of 4,000 to 8,000 seeds per acre to achieve at least 400 living stems per acre in 5 years. Row planted seed is placed 6 to 12 inches apart with rows spaced no more than 16 feet apart, depending on the equipment to be used for maintenance. Black walnut is mentioned as a species that should be included in the seed mix due to high germination rate, early growth performance, and potential timber value. Site preparation is critical to successful planting. Perennial grass and weeds should be killed the fall before planting using post-emergent herbicide. The site should be disked as if to prepare for a corn or bean crop a few weeks before sowing to allow the soil to settle. Scatter seed with a fertilizer spreader, manure wagon, or by hand, and disk seed in to a depth of 2 to 4 inches. Disking in two directions yields the best results. After seeding, roll the site with a soil packer to get firm seed to soil contact. Row-seeding by machine (Fig. 4) involves calibrating the machine to the desired spacing and a sowing depth of 2 to 4 inches. Once seeds are planted, pack the row by running a tractor, truck, or ATV tire over the row to seal in the seed. Chemical or mechanical weed control will be needed for the next several years to control competing vegetation. If animal feeding pressure is anticipated, protect the 50 to 100 best seedlings per acre with animal control devices such as tree shelters.

Edge (2004) surveyed 31 direct seeded plantations in southwestern Wisconsin ranging from 1 to 7 acres and 1 to 6 years old using 0.01-acre plots for weed competition level, species composition, stand density, and seedling height. Tree species included black walnut, northern red oak, white oak, bur oak (*Quercus macrocarpa* Michx.), swamp white oak (*Quercus bicolor* Willd.), sugar maple (*Acer*



Figure 4.—Mechanical direct-seeder for row-sowing hardwood seed. (Photo by Lenny D. Farlee, Purdue University)

saccharum Marshall.), and shagbark hickory (*Carya ovata* (Miller.) K. Koch.). Plantings were all high density sowings on former agricultural fields with stand density goals between 3,000 and 8,000 stems per acre. One site was broadcast seeded by hand and the rest were planted with a seeder or drill, with some occasional hand planting of light seeded species such as sugar maple. Twenty-nine sites were fall planted and two were spring planted. The average stocking for the machine planted sites was 3,359 stems per acre, including an average of about 400 volunteer elm and box elder stems per acre. In general, black walnut had the most consistent stocking with most sites supporting more than 500 stems per acre or an assumed field germination rate of 60 to 70 percent. Red oak was more variable and had an assumed rate of 30 to 40 percent. White oaks were the most variable, with

two total germination failures. Black walnut also had the best annual height growth, averaging 14.8 inches per year, compared to 4.3 inches for red oak. In mixed plantings, this resulted in quick dominance by black walnut and suppression of the oak seedlings. In one 6-year-old plantation, the black walnut was 22 feet tall and formed a canopy, with red oak 5 feet tall in the understory. Mechanical or spot seeding is a more efficient use of seed than broadcasting, allowing better control over stand density and the convenience of rows for access.

Many foresters in this survey were drilling seed into untreated grass or other cover and then treating the vegetation with glyphosate before tree seed germination in the spring. Weeds were treated in subsequent years with pre-emergent herbicides

such as simazine or sulfometuron methyl. Be aware of differential growth rates when doing mixed species plantings. Exercise caution with pre-emergent herbicides during the first growing season. Pendimethalin has been commonly used over broadleaf seeds and simazine has been used over oak and walnut, but little research has been done to determine impact on germination and growth of the hardwood seedlings.

The Illinois Direct Seeding Handbook (Herman et al. 2001) listed recommendations and resources for improving direct seeded plantings. Important points to increase success include collection and proper handling of high quality seed, preparing the planting site, properly planting the seed, maintaining weed control until seedlings are established, and protecting planted seed from seed predators. Recommendations on seed collection and handling include testing seed lots by floating and cutting to be sure good seed is being collected. Handle seed so that excessive heating or drying does not occur before the seed is planted. Fall planting simplifies handling and reduces viability losses that can occur in storage or from improper stratification procedures. Eliminate competing vegetation before planting using herbicides, tillage, or both. If seed is to be spot or row planted, a cover crop may be left between planting spots or rows. Weed control begins with site preparation before planting and extends until the seedlings are established and competitive with other vegetation on the site. Higher seedling numbers per acre can speed the process of shading out the competing vegetation. Several herbicides, previously listed in the black walnut section, are available for site preparation before planting and weed control after seedling emergence.

Seed predation is listed as the most common cause of failure for direct seeded plantings in Illinois (Herman et al. 2001). Plantings planned for small forest openings, or within 100 yards of rodent habitat may best be accomplished by using seedlings. Sample trapping can be used to estimate the number of rodents in the planting area. Plowing, mowing, disking, and burning can be used to reduce or eliminate rodent

habitat. Creating raptor perches may help control small mammals through increased predation.

GENERAL RECOMMENDATIONS

Direct seeding is a viable option for regeneration of fine hardwood trees. As with seedling planting, a direct seeding operation must be properly planned and executed to have any chance of successful establishment. Planning begins well in advance of planting with an evaluation of the planting site for suitability to the species of interest, preparation of the site for the control of competing vegetation and seeding, and collection and storage of viable seed in adequate numbers to fully stock the planting area. The site potential for seed predation by rodents or other seed predators should also be evaluated. The site will require modification that includes protective measures for seed to prevent pilfering (Figs. 3 and 5), or consideration of switching to bare-root or other seedling stock for regeneration. Squirrels and other seed predators are able to rapidly depopulate a direct seeding in areas such as forest openings or fields within 300 feet of suitable habitat. Direct seeded plantings using hardware cloth sheets or cones, partially buried tree tubes, and the previously described cans for seed protection have resulted in well-stocked plantings. Placing fresh cow manure over the top of seed or providing sacrificial areas of planted seed between seed predator habitat and the planting site are additional options for reducing losses to seed predators.

To evaluate site suitability for the selected tree species, landowners should consult the appropriate soil surveys and soil tests, reference information such as the Black Walnut Suitability Index in the Web Soil Survey, and talk with local experts on soils and reforestation.

Site preparation begins the summer or fall before direct seeding in the case of cropland or pasture and grassland. Perennial grasses and weeds should be controlled with tillage or herbicides to provide a planting site free of established competitors. The method of planting will determine the soil preparation



Figure 5.—Use of tube and wire screen to protect sprouted seed from seed predators. (Photo by James R. McKenna, U.S. Forest Service)

required before planting. Broadcast seeding generally requires a site tilled similar to a field to be sown to grain crops. Strip or spot planting may be best accomplished on untilled ground depending on the equipment used.

Seed collection involves determining where suitable seed can be obtained, collecting, and testing the seed for viability through floating and cutting open a sample of seed from each lot to inspect the seed quality. Low quality will require sorting out bad seed if possible, and collecting enough viable seed. In the period between collection and planting, keep the seed cool and at acceptable moisture levels for the

species. The Woody Plant Seed Manual is an excellent information source for seed collection and handling (Bonner and Karrfalt 2008).

Fall planting of seed is the simplest approach to direct seeding, avoiding the need to store or otherwise treat the seed. Fall planting may result in higher germination rates and earlier seedling emergence than spring plantings. Fall planting may expose seed to a full fall and winter of seed predation pressure as well, so an evaluation of potential predation and protection measures may be needed to retain enough viable seed for a well-stocked planting.

Spring planting will require proper storage and, for most species, meeting the requirements for breaking seed dormancy. This usually involves stratification for 90 to 120 days. During storage and stratification, protect the seed from seed predators. Seed can be held until it sprouts to gauge the viability of the seed. Sprouted seed should be handled carefully to protect the base of the extending radicle and prevent excessive drying. Long radicles can be clipped back but should not be cut or broken at the juncture with the cotyledons. Sprouted seed may not be compatible with planting methods where the seed is churned or otherwise handled roughly. As a general rule, plant seed in the soil at a depth one or two times the seed diameter.

Ideal planting density is dependent on the planting method, seed quality, seed predator pressure, and seed treatment used. Sprouted seed can be treated like a seedling in terms of spacing, because the viability of the seed has been confirmed. Row or spot direct-seeded plantings can use several thousand seeds per acre and provide space for access to control weeds after planting. Broadcast sowing can use thousands to tens of thousands of seeds per acre and access after seedling emergence is limited. Sites expected to have seed predator pressure may be sown with high numbers of seed to overwhelm predators, provide protection to seed to prevent pilfering, or create conditions at the site that deter entry by seed predators.

Weed control treatments for the first 2 to 3 years will help seedlings retain a competitive advantage over other vegetation invading the site. Pre-emergent herbicides have been used successfully to control emerging weed competition. Rate of application is crucial to get good weed control but not harm emerging tree seeds. Consult the herbicide label and local experts for proper application rates. Some sources recommend delaying the application of pre-emergent herbicides until the second growing season, when the seedlings have emerged and established a root system. Some post-emergent herbicides, like clopyralid, may control weeds such as Canada thistle (*Cirsium arvense* (L.) Scop.) and ragweeds (*Ambrosia* sp.) in areas containing tree seedlings during the growing season. Follow label directions carefully to avoid damage to tree seedlings.

The literature and practical experience indicate the most common causes of direct seeding failure are ineffective weed control and seed predation, so careful attention to these management practices should help increase success rates. These sources also indicate there are several possible paths to success with direct seeding. Sprouted seed plantings managed like a bare-root seedling planting (Fig. 6), row or spot plantings (Fig. 7), and broadcast plantings have all produced successfully established tree plantings.

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Figure 6.—Fifteen-year-old black walnut planting established by direct seeding sprouted seed. (Photo by Lenny D. Farlee, Purdue University)



Figure 7.—Mixed oak and black walnut planting in Iowa established by direct seeding in the fall using a homemade row seeder. (Photo by Lenny D. Farlee, Purdue University)

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