DIRECT SEEDING WOODY SPECIES FOR RESTORATION OF BOTTOMLANDS

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Abstract—I direct seeded (broadcast) seeds of 39 species of trees and shrubs using an ATV-mounted rotary spreader to initiate restoration of bottomland forest on retired agricultural sites. Four sites were planted during February, 2000, and 13 additional sites were planted during April and May, 2001. After two growing seasons, stem density of direct-seeded species varied greatly among study plots (range = 0 to 888 stems/ha) but averaged only 110 stems/ha. I recommend that future efforts at direct seeding focus on seven shrub species (*Amorpha fruticosa* L., *Cephalanthus occidentalis* L., *Cornus* spp., *Crataegus* spp., *Ilex decidua* Walt., *Morus rubra* L., and *Prunus* spp.) and seven tree species (*Celtis laevigata* Willd., *Diospyros virginiana* L., *Fraxinus* spp., *Gleditsia triacanthos* L., *Robinia pseudoacacia* L., *Taxodium distichum* (L.) Rich, and *Ulmus* spp.] that successfully established in these trials.

INTRODUCTION

Forest restoration on bottomland sites is widespread and ongoing throughout the Mississippi Alluvial Valley. An estimated 200,000 ha are expected to be returned to bottomland hardwood forests by 2010 (Stanturf and others 2001). Restoration targets of >800,000 ha by 2020 have been suggested, with a hypothetical restoration potential of >3,000,000 ha (Haynes 2004). Historically, restoration of bottomland hardwood forests has focused on planting heavy-seeded tree species such as oaks (*Quercus* spp.) and pecan [*Carya illinoensis* (Wangenh.) K. Koch]. This focus was intended to ensure reestablishment of species that are relatively poor colonizers but are valuable for wildlife and timber production (Haynes and Moore 1988, King and Keeland 1999). Typically, plantings have been extensive (focused on maximizing area restored) rather than intensive (focused on success within a site; Haynes 2004). This approach usually entailed planting seedlings of 3 to 5 species on a 3.7-m (12-foot) grid (746 planted stems/ha) but with little site preparation or post-planting management. Although most restorations suffer from a lack of clearly-defined objectives, surviving stock of >309 stems/ha has been considered sufficient within some programs (e.g., Wetland Reserve Program; Stanturf and others 2000).

On many sites, natural invasion by colonizing woody species has been retarded by long distances to seed sources and on site allelopathic conditions. The combination of planting relatively few, slower-growing tree species and lack of natural recruitment has resulted in some sites being dominated by grasses and herbs, with a sparse stocking of relatively homogeneous saplings for 10 or more years after planting. The resultant slowly-maturing forests tend to have reduced species diversity with relatively homogeneous structure and uniform canopy. This structure promotes slow colonization by silvicolous wildlife, particularly birds, and inferior bole quality of potentially-merchantable trees.

These conditions are not optimal for management of either timber or wildlife. Indeed, I believe that when restoring bottomland sites, both timber and wildlife benefit from: (1) increased diversity of woody species and structural heterogeneity, (2) increased density of trees and shrubs, (3) restoration methods that are appropriate to site and landscape conditions, and (4) a reduced cost of restoration.

Increased diversity of woody species buffers restored forests from the ravages of insects and diseases. Indeed, combating pestilence in plantation monocultures can require considerable resources. In addition, increased species diversity enhances timber management options by buffering market fluctuations and providing increased flexibility of harvest. A diverse forest benefits wildlife by distributing food and shelter resources. In particular, the seasonality of species-specific fruit (mast) production and peaks in abundance of different insects provide complex and continuous food resources. Additionally, greater diversity in structural niches provides for use by an increased cadre of wildlife species.

On sites with abundant natural regeneration, either from an existing seedbank or colonization from external seed sources, higher densities of trees and shrubs provide benefits to both wildlife and timber production. Increased density of trees enhances timber management by promoting improved timber quality. Bole quality of high-value timber species (e.g., oaks) likely benefits from competition with trees of shorter-stature and shrubs [e.g., dogwood (*Cornus* spp.), hawthorn (*Crataegus* spp.), and plum (*Prunus* spp.)] as well as small-twigged canopy tree species [e.g., sweetgum (*Liquidambar styraciflua* L.)]. These competing species act as “training” or “nurse” trees that result in better bole quality of high-value timber species by encouraging vertical growth and discouraging lateral (epicormic) branches. Increased stature and limb-free boles result in improved timber quality and thereby increase management options. Additionally, increased tree densities provide for increased harvest options, wherein managers can choose among different strategies to achieve target results.

Increased stand densities benefit forest wildlife by more rapidly achieving ‘forest-like’ habitat conditions. Food and cover are provided quickly by shrub-scrub species with many suitable foraging sites for leaf-gleaning birds. Furthermore, shrubby habitats often provide an important food source, in the form of soft, fleshy fruits and small hard seeds, for migrating and wintering songbirds. Some birds of management concern [e.g., Bell’s Vireo (*Vireo bellii*), Orchard Oriole (*Icterus spurius*), and Painted Bunting (*Passerina ciris*)] breed in scrub-shrub habitats provided by “thickets” of invading trees. Many other species of forest-breeding birds use these shrubby areas post-breeding for cover and foraging (Kilgo and others

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1999). Indeed, for some species, these shrub-scrub habitats may be critical during the development of juvenile birds (Vega-Rivera and others 1999).

If an entire site is planted at high densities, however, the resultant dense canopy cover within the maturing forest will diminish its suitability for many wildlife species; densely-planted areas should be mixed with sparse or unplanted areas. Alternatively, management actions (e.g., patch cuts) should be undertaken to ensure sunlight penetration to the forest floor within parts of the stand. However, retention of some densely-stocked areas well beyond canopy closure (as opposed to thinning the entire stand) promotes dominant or emergent trees within the stand that benefit canopy-dwelling birds.

Historically, it was assumed that natural invasion of light-seeded species would result in restored forests that are diverse and densely stocked. Unfortunately, many reforested sites in the Mississippi Alluvial Valley are isolated within agricultural landscapes. Isolation limits natural invasion by woody species such that colonization cannot be relied upon to produce densely-stocked, mixed-species forests when sites are distant from existing forest edges (Allen 1990, Allen and others 1998, Twedt 2004, Twedt and Wilson 2002). Often lacking on these sites are species that produce soft, fleshy fruits or small seeds that are readily consumed by songbirds. To ensure species diversity on isolated sites, it is essential to plant several species.

Small, isolated forest patches attract few forest breeding birds (Mancke and Gavin 2000, Robbins and other 1989) and support a low reproductive rate for those present (Burke and Nol 2000, Nott 2000). Therefore, an alternative management strategy for these sites may be to plant and maintain these areas in shrubby, early successional habitat. Planting only a select subset of woody species could promote development of a shrubby 'disclimax' community. Long-term continuance of this shrubby habitat will likely require periodic perturbation of vegetation.

Impediments to increasing diversity and density of woody species on restored bottomland sites are primarily logistic and economic. Increasing densities of planted seedlings markedly increases cost of restoration. For example, moving from a 3.7-m (12-foot) spacing to 2.5-m (8-foot) spacing more than doubles the planting stock and labor required for restoration. The rapidly-escalating cost of planting trees at high densities is an impediment to increasing density of woody species using traditional restoration methods. Furthermore, because heavy-seeded oaks and pecans have historically constituted the bulk of planted seedlings, there has been little demand for seedlings of other species. Thus, even if the increased costs of achieving higher densities are accepted, there is a paucity of available seedlings for non-oak species with which to increase stand diversity.

Although relatively few non-oak species are readily available as seedlings, seeds of scores of shrubby and small-seeded tree species are available from commercial seed suppliers. Seeds of woody plants can be obtained at a fraction of the cost of seedlings and can be planted with comparatively little time and expense (Allen and others 2001). Furthermore, Twedt and Wilson (2002) suggested that wildlife (birds) benefit more from direct-seeding acorns than from restorations using planted oak seedlings.

Unfortunately, except for sowing acorns and pecans, little information is available on the methodology or success of directly-sown seeds on bottomland sites (Lof and others 2004). Allen and others (2001) state that direct-seeding of light-seeded species has been unsuccessful in the Mississippi Alluvial Valley, but no data or studies are cited to verify this claim. Twedt and Best (2004) found direct-seeded shrubby species were generally unable to compete with invasive exotic grasses within the Lower Rio Grande Valley. After evaluating 56 direct-seeded woody species in Maryland, Kimmons and others (1980) recommended *Amorpha fruticosa* L. and *Symphoricarpos orbiculatus* Moench. as producing consistently good results. Conversely, Holt (1998a, 1998b) found that directly sowing seeds of woody plants was successful at restoring shrubland in Australia.

I attempted to establish soft, fleshy-fruited, and small-seeded woody species on retired agricultural fields that were being reforested via direct seeding. This restoration study provides baseline empirical data on the rates of establishment and survival of shrub and small-seeded tree species when their seeds are broadcast on bottomland sites. However, because each species has unique environmental requirements for germination and subsequent survival, species-specific pre-planting seed preparation, optimizing season of planting, and matching of species to edaphic and hydrologic conditions will likely increase germination and survival. I chose a generic application method that was easily applied with a minimum of equipment and labor. Treatments were intended to increase the density and diversity of woody species, especially shrubby species, on restored sites to improve wildlife and timber value of restored bottomland hardwood forests.

SITES

Year 2000 Study Locations

The three study sites were agricultural fields that had been disked to reduce crop residue and were located at Bayou Cocodrie National Wildlife Refuge (NWR), Ferriday, LA, Mollicy Farms Management Area, Farmerville, LA, and Tallahatchie NWR, Grenada, MS. One additional study site was at Cache River NWR, Augusta, AR. This Arkansas site retained soybean stubble and had been planted with seedlings of 8 tree species (*Q. nuttallii* E.J. Palmer, *Q. nigra* L., *Q. phellos* L., *Q. pagoda* Raf., *Q. michauxii* Nutt., *Carya illinoensis*, *Fraxinus pennsylvanica* Marsh., and *L. styraciflua*) at a density of 750 seedlings/ha approximately 1 month prior to sowing of seeds in this study.

Year 2001 Study Locations

Thirteen, 0.8- to 1.2-ha sites were seeded during 2001. Most sites had been previously planted with seedlings, but survival was poor, and they were considered "failed plantings." These sites were disked to remove existing vegetation before seeding. I direct-seeded four sites on NWR property [Bayou Cocodrie NWR; Tensas River NWR, Tallulah, LA; and Yazoo NWR Complex (two sites), Hollandale, MS] and nine additional sites on private property within Mississippi that were enrolled in the USDA Wetland Reserve Program (WRP).

PROCEDURES

Between February 10 and 24, 2000, and April 20 and May 3, 2001, I direct-seeded woody plants using a rotary (cyclone) spreader mounted on the rear of an all-terrain vehicle (ATV). Seeds were mixed with pelletized limestone or gypsum as a physical carrier for the rotary spreader. Most seeds were obtained from the Louisiana Seed Company, Lecompte, LA, but a few species were obtained from Lovelace Seed Company, Elsberry, MO, or Sheffields Seed Co., Looke, NY. Seeds of four species were locally-collected.

Year 2000

Soil mycorrhiza (Endo Net Bulk Granular Mycorrhizal Inoculum, Reforestation Technologies International, Salinas, CA, www.reforest.com) were applied to parts of seeded fields, using the same rotary spreader. Seeds were cold stored prior to planting. On the 3 disked sites, seeds and mycorrhiza were incorporated into existing seedbeds using a wooden drag and/or a small disk pulled behind the ATV.

Using a split-plot experimental design, I applied seeds at 2 rates (whole-plot treatments) at each of the four study sites using four planting mixes (split plot treatments). Planting mixes were: (1) seeds of shrubby plants, (2) seeds of hard and soft mast-producing trees, (3) seeds of shrubby plants combined with seeds of hard and soft mast-producing trees (table 1), and (4) unplanted, non-seeded controls.

Table 1—Seeds of shrubs and trees direct broadcast at two application rates (high and low) using a cyclone seeder on four bottomland restoration sites during February, 2000

			Mean seeding rate			
			g/ha		Seeds/ha	
Species	Seeds/g	$/kg	High	Low	High	Low
Shrubs						
Amorpha fruticosa	9.0	41.80	49	14	441	128
Aralia spinosa	45.2	154.00	43	18	1,957	814
Asimina triloba	0.2	47.30	42	14	10	3
Callicarpa americana	14.1	213.40	13	6	186	78
Cephalanthus occidentalis	56.6	37.40	47	21	2,665	1,202
Cornus amomum	4.5	33.00	44	16	198	71
Cornus florida	2.3	33.00	18	3	41	6
Cornus stricta	5.4	66.00	42	18	228	95
Crataegus aestivalis	9.0	110.00	39	23	348	206
Crataegus marshallii	4.5	132.00	48	23	219	104
Halesia diptera	0.7	41.80	54	32	39	23
Ilex decidua	13.6	41.80	72	29	976	399
Malus angustifolia	2.8	165.00	15	1	42	3
Morus rubra	28.3	165.00	8	3	212	88
Prunus virginiana	3.6	17.60	40	21	146	76
Pyrus communis	2.3	88.00	9	2	21	5
Rhus copallina	24.9	22.00	45	16	1,126	389
Rhus glabra	22.6	33.00	43	17	962	382
Sabal minor	0.9	33.00	51	11	46	10
Sambucus nigra	79.2	37.40	40	21	3,148	1,683
Viburnum rufidulum	1.7	74.80	52	11	88	18
Trees						
Acer rubra	5.88	44.00	37	17	218	99
Albizia julibrissin	2.26	0.00	15	6	34	13
Celtis laevigata	3.85	55.00	54	27	207	105
Diospyros virginiana	0.81	17.60	123	30	100	24
Fraxinum pennsylvanica	11.31	33.00	71	10	799	115
Fraxinus profunda	5.43	41.80	22	14	119	78
Gleditsia triacanthos	1.27	27.50	207	54	262	69
Liquidambar styraciflua	9.05	92.40	66	11	597	102
Liriodendron tulipifera	3.62	22.00	96	13	346	45
Platanus occidentalis	63.35	0.00	355	95	22,489	6,018
Prunus serotina	2.26	26.40	58	31	132	70
Quercus michauxii	0.05	2.20	347	94	16	4
Quercus nigra	0.90	4.40	241	174	218	158
Quercus phellos	0.23	7.15	208	219	47	49
Quercus lyrata	0.06	2.20	325	84	21	5
Robinia pseudoacacia	10.86	66.00	57	25	622	269
Taxodium distichum	1.81	48.40	95	59	172	107
Ulmus crassifolia	29.41	105.60	16	8	478	228
Total			3,207	1,291	39,976	13,341

Within part of direct-seeded treatments (split-split plot), I planted seedlings of hard mast-producing trees (Nuttall oak, *Q. nuttalli*). Seedlings were 1-year-old (1-0) stock, planted at a high rate, 10- x 10-m spacing (100 seedlings/ha), or a low rate, 12- x 15-m spacing (56 seedling/ha). These planting densities were intended to provide ample inter-tree space for direct-seeded, as well as naturally-invading, woody trees and shrubs. Planted seedlings were not included in evaluation of direct seeding.

I applied treatments within 0.5- or 1.0-ha plots to attain desired densities of sown seeds at circa 400 g/ha (low seeding rate) and >1,000 g/ha (high seeding rate). Seeding rates were based on Holt's (1998b) recommendation of 400 to 1,000 g/ha of pure live seed (PLS) and Kimmons and others (1980) stated goal of circa 12,000 woody plants/ha.

Year 2001

All sites were disked by landowners to prepare seedbed for planting. Seeds were treated through cold stratification and/or acid scarification to promote germination in accordance with published recommendations (Schopmeyer 1974). Seeds were broadcast on entire study plots (i.e., there were no unplanted control plots). Eleven sites were planted with seeds of trees and shrubs (table 2), and 2 of the 13 sites were planted only with shrub seeds. After planting, sites were either disked, culti-packed, or rolled to incorporate seeds.

To assess seedling abundance, I used 2.52-m radius (20-m^2) circular plots located systematically along parallel transects that spanned study sites. I assessed seedling abundance on 2 sites planted in 2000 during fall of 2002; all other sites were evaluated during fall, 2003.

RESULTS

During 2000, seeds of 21 shrub species and 18 tree species were sown (table 1). Seeding rates varied slightly among study sites. High seeding rates were 870 to 1,250 g/ha for shrub seeds and 1,385 to 2,350 g/ha for tree seeds. Low seeding rates were 310 to 400 g/ha for shrub seeds and 418 to 890 g/ha for tree seeds. Cost of tree seed was $14/ha at low density and $65/ha at high density. Cost of shrub seed was $25/ha at low density and $43/ha at high density. During 2001, seeds of 25 shrub species and 14 tree species were sown (table 2). Seeding rates were 3,590 g/ha for shrub seeds and 3,120 g/ha for tree seeds.

On sites planted during 2000, I assessed seedling abundance on between 0.2 and 0.4 ha within sample plots. Mean stem density on direct seeded sites was 145.3 ± 47.1 stems/ha, but densities ranged from 45 to 258 stems/ha (fig. 1). However, seedling density on unplanted control areas ranged from 0 to 167 stems/ha. Thus, after adjusting for presumed natural invasion (i.e., density on control areas), net seedling densities ranged from 4 to 253 stems/ha (fig. 1). On sites planted during 2001, I assessed seedling abundance on between 0.1 and 0.2 ha within sample plots. Mean stem density on 2001 planted sites was 110.4 ± 66.3 stems/ha. Again, the range of observed densities was vast (0 to 888 stems/ha; fig. 2).

Only three direct-seeded species (*Cephalanthus occidentalis*, *Fraxinus spp.*, and *Prunus* spp.) were detected at densities >10 stems/ha (table 3). Other species detected at densities of >2 stems/ha were *Celtis laevigata*, *Crataegus* spp., *Gleditsia triacanthos* L., *Ilex decidua* Walt., *Morus rubra* L., *Robinia pseudoacacia* L., *Taxodium distichum* (L.) Rich, and *Ulmus* spp. (table 3). I detected seedlings of 8 additional species that had been directed seeded (table 3).

Table 2—Seeds of shrubs and trees direct seeded (broadcast) using a cyclone seeder on 13 bottomland restoration sites between 20 April and 3 May, 2001

	Seeding rate		
Species	Seeds/g	g/ha	Seeds/ha
Shrubs			
Callicarpa americana	613	49	30,037
Cercis canadensis	58	10	580
Cornus amomum	20	182	3,640
Cornus drummondii	36	91	3,276
Cornus florida	9	91	819
Crataegus crus-galli	14	361	5,054
Crataegus phaenopyrum	87	46	4,002
Crataegus viridis	48	91	4,368
Euonymus americanus	47	15	705
Ilex decidua	79	273	21,567
Ilex opaca	97	55	5,335
Morus rubra	580	88	51,040
Prunus americana	2	271	434
Prunus angustifolia	3	266	798
Prunus caroliniana	1	451	338
Prunus mexicana	2	91	182
Prunus serotina	13	269	3,497
Prunus virginiana	12	183	2,196
Rhus glabra	128	112	14,336
Rhus typhina	111	46	5,106
Sambucus canadensis	567	23	13,041
Sabal minor	5	63	315
Styrax americana	9	12	108
Vibunum dentatum	55	269	14,795
Viburnum prunifolium	15	182	2,730
Trees			
Acer negundo	55	59	3,245
Betula nigra	550	52	28,600
Catalpa bignonioides	56	209	11,704
Celtis laevigata	15	59	885
Diospyros virginiana	2	658	1,119
Fraxinus pennsylvanica	47	227	10,669
Gleditsia triacanthos	4	229	916
Nyssa biflora	7	114	798
Nyssa sylvatica	11	113	1,243
Platanus occidentalis	380	100	38,000
Quercus nigra	1	681	749
Quercus phellos	1	460	575
Robinia pseudoacacia	47	112	5,264
Sassafras albidum	11	47	517
Total		6,710	292,583

DISCUSSION

Study sites seeded during 2000 had been disked the previous fall. Some crop residue remained in clumps, and these seedbeds did not provide ideal conditions for incorporation of broadcast seeds. Thus, soil-seed contact was highly variable

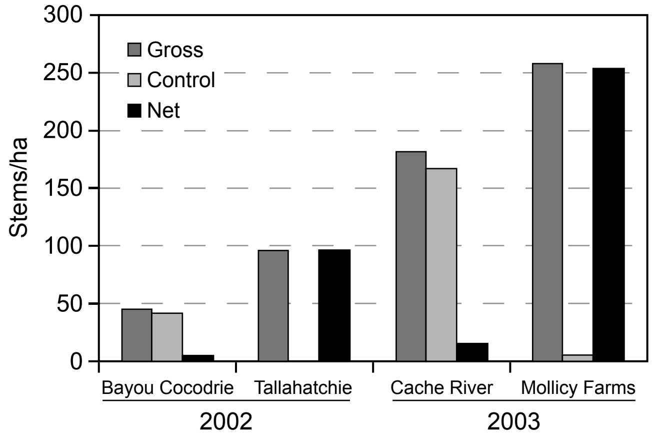

Figure 1—Stem density, during fall of 2002 or 2003, of shrubs and trees that were direct-seeded (broadcast) on four bottomland restoration sites during February, 2000, and their equivalent densities on unplanted control sites.

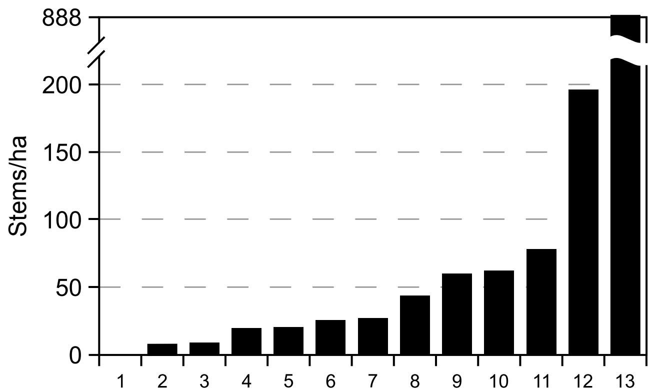

Figure 2—Stem density, during fall 2002, of shrubs and trees that were direct-seeded (broadcast) on 13 bottomland restoration sites during April or May, 2001.

within these sites and may have limited seed germination. Sparse establishment of seedlings contributed to my inability to determine any effect of mycorrhiza on seedling development.

Planting conditions at sites seeded during 2001 ranged from dry, sandy soils to wet, heavy-clay soils. Thus, not all species could be expected to perform similarly at all sites. Further, as no control sites were established during 2001 plantings, I could not account for confounding effects of natural invasion. Even so, most of these sites were >200 m from existing mature forest seed sources and likely had limited natural seeding. Notably, the site with highest stem density abutted mature forest.

Interestingly, of the sites planted in 2000, the two sites evaluated after three growing seasons had markedly higher stem densities than the two sites evaluated after two growing seasons (fig. 1). Lof and others (2004) found a similar increase in establishment percentages over a 4-year period for *Prunus avium* (L.) and *Crataegus monogyna* Jacq.

I recommend additional direct-seeding trials be undertaken using a limited number of species. Shrub species that appear to have promise for direct seeding on bottomland sites include:

Table 3—Establishment rate of shrubs and trees that were direct seeded using a cyclone seeder on 17 bottomland restoration sites during spring 2000 and 2001

Species	Stems/ha
Shrubs	
Acer rubra	0.3
Amorpha fruticosa	1.9
Celtis laevigata	7.6
Cephalanthus occidentalis	11.7
Cornus spp.	1.9
Crataegus spp.	3.2
Diospyros virginiana	1.6
Fraxinus spp.	47.6
Gleditsia triacanthos	4.1
Ilex decidua	5.4
Liquidambar styraciflua	0.9
Morus rubra	5.4
Platanus occidentalis	1.6
Prunus spp.	16.1
Quercus spp.	1.6
Robinia pseudoacacia	3.2
Sabal minor	0.3
Taxodium distichum	4.4
Ulmus spp.	3.5
Total	122.3

Amorpha fruticosa, Cephalanthus occidentalis, Cornus spp., *Crataegus* spp., *Ilex decidua, Morus rubra, and Prunus* spp. Tree species that should be further evaluated include: *Celtis laevigata, Diospyros virginiana, Fraxinus* spp., *Gleditsia triacanthos, Liquidambar styraciflua, Platanus occidentalis* L., *Robinia pseudoacacia, Taxodium distichum, and Ulmus* spp.

A few of these species (e.g., *Prunus* spp., *Diospyros* spp., *Gleditsia* spp., and *Robinia* spp.) have seeds that are large enough to be mixed with acorns when direct-seeding oaks using a modified soybean planter. I recommend a similar approach be undertaken with smaller-seeded species, wherein these seeds are planted using a modified “no-till” small grain seed drill.

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