Influence of Initial Seedling Size and Browse Protection on Height Growth: 5-Year Results

Jeffrey S. Ward[1]

Ward, J. S. 1996. Influence of Initial Seedling Size and Browse Protection on Height Growth: 5- Year Results. In: Landis, T. D. South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 127-134. Available at: http://www.fcanet.org/proceedings/1996/ward.pdf

Abstract: Six plots were established in 1990 to examine the influence of initial seedling size and deer browsing protection on height growth for 5 tree species. Protective devices included plastic mesh and Reemay sleeves (60 cm), and Tubex and Corrulite tree shelters (120 and 180 cm). Species included northern red oak, black walnut, eastern white pine, Norway spruce, and eastern hemlock. Stem length, root length, root collar diameter, and number of twigs and first-order lateral roots were measured prior to planting. After 5 growing seasons, hardwood and white pine seedlings within tree shelters were significantly taller than seedlings protected by plastic mesh and spunbonded polypropylene sleeves. Mortality was lower for seedlings protected by tree shelters. Seedling height after 5 growing seasons was independent of initial seedling size for seedlings protected by tree shelters. Larger seedlings were taller after 5 growing seasons, and had lower mortality, than smaller seedlings. Severe grading may reduce gross nursery production, but would increase planting efficiency by increasing the proportion of seedlings that develop into large saplings.

INTRODUCTION

Ultimately, a nursery is as successful as the number of seedlings that survive and grow into mature trees. In forests with large deer herds, protection from browsing is essential for a successful planting program (Marquis 1977; George and others 1991). Protecting seedlings from browse damage is expensive, \$500/acre or more (Kays 1996). Planting inferior quality seedlings that have little chance of being successful (in dominant or codominant crown class at crown closure) further increases the effective cost (\$/successful seedling/acre). A better strategy may be to plant fewer, higher quality seedlings and invest in better browse and vegetation control (Zaczek and others 1995; Schuler and Miller 1996).

Recent studies have indicated the number of first-order lateral roots (FOLR) may be a superior criterion of seedling survival and growth (Kormanik 1986; Kormanik and others 1995; Schultz and Thompson 1990; 1996; but see Kaczmarek and Pope 1993). The objective of this study was to examine the interaction of browse protection and initial seedling characteristics on long-term seedling survival and growth. Both hardwoods and conifers were included because of local interest in increasing the conifer component in the forest. Planting areas were specifically located in areas with large deer herds.

METHODS

Seedlings were planted in 1990 at 6 study sites evenly split between Mohawk State Forest and Lake Gaillard in northern and southern Connecticut, respectively. Because hunting is prohibited on both forests, large deer herds impeded natural regeneration and destroyed artificial forest plantations. Deer densities averaged 21 /km^2 at Lake Gaillard and 18/ km^2 at Mohawk State Forest (Ward and Stephens 1995). Study sites on Mohawk State Forest were recent red pine clearcuts. Lake Gaillard study sites were abandoned agricultural fields. All plots were cleaned with chainsaw and machete prior to planting and 2 years after planting. Northern red oak (*Quercus rubra*), eastern white pine (*Pinus strobus*), and Norway spruce (*Picea abies*) were planted at both forests. Additionally, eastern hemlock (*Tsuga canadensis*) was planted at Mohawk State Forest and black walnut (*Juglans nigra*) was planted at Lake Gaillard. Seedling height (cm), root length (cm), and root collar diameter (mm) were measured prior to planting (Table 1). Numbers of first order twigs and first order lateral roots were counted.

Table 1. Initial seedling characteristics prior to planting: mean (standard error).

Species	Stem	Twig	RCD	FOLR	Root	N
Northern red oak	30.8 (0.5)	1.2 (0.07)	5.8 (0.1)	4.1 (0.2)	n/a	288
Black walnut	35.1 (0.7)	0.2 (0.01)	7.1 (0.1)	3.9 (0.2)	52.9 (0.7)	192
Eastern white pine	21.7 (0.5)	3.0 (0.15)	5.7 (0.1)	6.3 (0.1)	55.4 (0.7)	480
Norway spruce	22.3 (0.3)	9.8 (0.23)	3.6 (0.1)	4.8 (0.1)	42.8 (0.9)	400
Eastern hemlock	19.2 (0.3)	13.9 (0.26)	2.6 (0.1)	4.3 (0.2)	20.7 (0.4)	240

Stem - stem height (cm), Twig - number of primary twigs, RCD - root collar diameter (mm), FOLR - number of first-order lateral roots $\geq$ 1 mm diameter, Root - root length (cm)

Seedlings were stratified by root collar diameter before assignment to treatments. At each of the six sites 8-20 seedlings received each treatment. Tree heights (nearest cm), browse damage, and any distortions of the terminal leader were measured at the end of each growing season (~15 September). Browse damage was noted at the beginning (~1 December), middle (~15 February), and end of winter (~1 April). Damage to protective devices was noted during each field check.

The 6 treatments included: 60 cm high plastic mesh sleeve supported by a bamboo stake, 60 cm high spunbonded polypropylene (Reemay[3]) sleeve supported by a bamboo stake, 120 cm Tubex tree shelter, 180 cm Tubex tree shelter, 120 cm Corrulite tree shelter, and an unprotected control. Both bamboo and wood stakes were untreated. Mesh caps provided were placed over all tree shelters to prevent songbird entry into the tubes.

[3] *Use of trade name does not imply endorsement by the Connecticut Agricultural Experiment Station.*

Tukey's HSD test (SYSTAT 1992) was used to test differences in 5th year height among treatments and among initial seedling size classes. Pearson correlation coefficients were used to examine relationship between initial seedling characteristics and seedling height after 5 growing seasons. Five-year height was used rather than height growth because absolute height (and survival) is the ultimate criterion of success. Differences in seeding mortality rates among protection methods and initial seedling size classes were tested using procedures in Neter and others (1982). Preliminary analysis found little difference in height and mortality among tree shelter types and among sleeve types and unprotected controls. Therefore, data for the 3 tree shelter types were pooled. Data for the 2 sleeve types and unprotected controls were also pooled. Differences were considered significant at $p \leq 0.05$.

RESULTS

Heights of northern red oak, black walnut, and eastern white pine were significantly greater after 5 growing seasons when protected by tree shelters than when unprotected or protected by sleeves (Table 2). The increased height of seedlings protected by tree shelters was significant after I growing season for the hardwoods and 2 growing seasons for white pine (Ward and Stephens 1995). Unprotected black walnuts were actually shorter after 5 growing seasons than when planted. Seedlings protected by sleeves were not significantly taller than unprotected seedlings after 5 growing seasons, except for black walnut protected by mesh sleeves. Hardwoods clearly responded better to tree shelters than conifers.

Table 2. Seedling height (cm) at the end of five growing seasons by browsing protection method.

			Species		
Protection method	NRO[a]	WAL	WPI	NSP	HEM
Control	56.1 a[b]	32.3 a	105.4 a	80.3 ab	48.5 ab
Mesh sleeves	69.3 a	44.8 a	86.5 a	81.4 ab	63.2 b
Reemay sleeves	63.4 a	44.3 a	97.1 a	75.6 b	44.2 a
Tree shelters	132.5 b	103.3 b	134.9 b	89.4 a	63.2 b

a/NRO - northern red oak, WAL - black walnut, WPI - eastern white pine, NSP - Norway spruce, HEM - eastern hemlock.

b/ Column values for each species followed by the same letter do not differ significantly at $p \leq 0.05$.

Trees in tree shelters were taller relative to unprotected controls: black walnut 220% taller; northern red oak-136%; white pine, 28%; Norway spruce, 11%; and hemlock, 30%.

Initial size was important for growth and survival of seedlings not protected by a tree shelter, especially for conifers (Table 3).

Table 3. Seedling height (cm) at the end of five growing seasons by initial seedling characteristics for seedlings not protected by tree shelters.

	Species				
	NRO[a]	WAL	WPI	NSP	HEM
Stem height[c]					
Short	36.1 a[b]	39.2 a	68.0 a	65.1 a	41.3 a
Average	56.6 ab	41.4 a	78.3 a	80.6 a	41.1 a
Tall	66.7 ab	44.1 a	125.8 b	82.7 a	67.2 b
Very tall	81.6 b	43.6 a	142.3 b	82.8 a	64.8 ab
Root collar diameter[d]					
Small	46.3 a	41.5 a	72.9 a	65.5 a	57.7 ab
Medium	55.3 a	43.0 a	83.1 a	69.3 a	44.9 a
Large	64.5 ab	43.1 a	100.9 ab	82.4 a	52.0 ab
Very large	78.4 b	37.3 a	128.8 b	106.3 b	74.3 b
First order lateral roots					
0-2	48.6 a	45.3 a	135.0 a	66.6 a	40.2 a
3-4	71.4 ab	36.8 a	95.6 a	76.7 a	47.8 a
5-7	68.5 ab	41.1 a	87.2 a	71.8 a	60.4 ab
≥8	80.7 b	45.6a	96.7 a	103.4 b	79.0 b

a/ NRO - northern red oak, WAL - black walnut, WPI - eastern white pine, NSP - Norway spruce, HEM - eastern hemlock

b/ Column values for each species followed by the same letter do not differ significantly at $p \leq 0.05$.

c/ Stem height classes (short, average, tall, very tall) by species: NRO (0-19, 20-29, 30-39, and ≥40 cm), WAL (0-24, 25-34, 35-44, and ≥45 cm), WPI (0-14, 15-24, 25-34, ≥35), NSP (0-14, 15-24, 25-34, and ≥35 cm), HEM (0-14, 15-19, 20-24, and ≥25 cm).

d/ Root collar diameter classes (small, medium, large, very large) by species: NRO (0.4, 5, 6, ≥7), WAL (0-6, 7, 8, ≥9), WPI (0-4, 5, 6-7, ≥8), NSP (0-2, 3, 4, ≥5), HEM (0-1, 2, 3, ≥4).

Initial height had the highest correlation for eastern white pine and eastern hemlock, root collar diameter for Norway spruce, and first-order lateral roots for northern red oak (Table 4). Surprisingly, there was no significant correlation between seedling height after 5 growing seasons and initial seedling characteristics for northern red oak, black walnut, and eastern hemlock protected by a tree shelter (Table 4).

Table 4. Pearson correlation coefficients of initial seedling characteristics with stem height of survivors in 1994 (5-years post-planting). Stem - stem height (cm), Twig - number of primary twigs, RCD - root collar diameter (mm), FOLR - number of first order lateral roots (>1 mm diameter), Root - root length (cm), R/S - root to shoot ratio.

Species	Stem	Twig	RCD	FOLR	Root	R/S
			Protected by tree shelters			
Northern red oak	0.206	0.106	0.193	0.086	n/a	n/a
Black walnut	-0.110	0.052	0.009	0.194	-0.085	-0.064
Eastern white pine	0.267 *b	0.164	0.176	-0.020	-0.088	0.265 *
Norway spruce	0.488 **	0.329 **	0.317 **	0.215	0.133	0.228 o
Eastern hemlock	0.142	0.124	-0.090	0.041	0.216	-0.126
			Sleeves (mesh and Reemay) and unprotected			
Northern red oak	0.265 **	0.203 o	0.268 **	0.296 **	n/a	n/a
Black walnut	0.080	0.092	0.017	-0.024	0.071	0.032
Eastern white pine	0.543 **	0.389 **	0.351 **	-0.095	-0.127	0.455 **
Norway spruce	0.148	0.305 **	0.432 **	0.369 **	0.405 **	-0.260 **
Eastern hemlock	0.510 **	0.278 o	0.280 o	0.397 **	0.200	0.273

a/ Bonferroni adjusted probabilities: (**) $p< 0.01$, (*) $p < 0.05$, (o) $p< 0.10$

Initial stem height had the highest correlation with 5-yr height for eastern white pine and Norway spruce growing in tree shelters. Though not significant, larger seedlings protected by tree shelters were generally taller after 5 growing seasons than small seedlings (Table 5).

Table 5. Seedling height (cm) at the end of five growing seasons by initial seedling

characteristics for seedlings protected by tree shelters. (size classes and species abbreviation are as for Table 3).

	Species				
	NRO	WAL	WPI	NSP	HEM
Stem Height					
Short	111.7 a	123.0 a	123.0 a	72.0 a	52.9 a
Average	124.3 a	101.9 a	130.3 a	83.0 a	62.0 a
Tall	142.3 a	92.9 a	166.7 b	104.5 b	72.2 a
Very tall	146.0 a	103.8 a	130.3 ab	116.5 b	66.0 a
Root collar diameter					
Small	117.5 a	95.3 a	123.5 a	82.7 a	76.5 a
Medium	124.3 a	110.2 a	132.8 a	83.5 a	61.4 a
Large	131.9 a	107.1 a	145.6 a	90.8 a	63.4 a
Very large	148.8 a	93.4 a	148.5 a	104.4 a	61.9 a
First order lateral roots					
0-2	134.3 a	101.5 a	128.5 a	81.5 a	64.4 a
3-4	119.2 a	87.8 a	149.6 a	83.5 a	59.6 a
5-7	132.7 a	109.9 a	132.8 a	92.0 a	65.6 a
≥8	152.4 a	115.9 a	134.1 a	99.4 a	63.3 a

a/ Column values for each species followed by the same letter do not differ significantly at $p \leq 0.05$.

Mortality of all species was significantly lower when protected by tree shelters than when unprotected (Table 6). In general, mortality of seedlings in tree shelters was half that of unprotected seedlings. Neither mesh nor Reemay sleeves significantly decreased mortality rates relative to unprotected seedlings. Shorter northern red oaks had higher mortality than taller seedlings, but taller eastern white pine had higher mortality than shorter seedlings. Mortality generally decreased with increasing number of first-order lateral roots for all species except eastern hemlock.

Table 6. Seedling mortality (%) at the end of five growing seasons by browsing protection

	NRO	WAL	WPI	NSP	HEM
			Species		
Protection method					
Control	25.0 a[a]	25.0 a	50.0 a	44.0 a	63.3 a
Mesh sleeves	27.8 a	14.6 ab	48.3 a	31.0 ab	46.7 a
Reemay sleeves	22.2 a	20.8 a	50.0 a	38.0 a	48.3 a
Tree shelters	10.2 b	6.9 b	36.1 b	23.3 b	24.4 b
Stem height					
Short	29.2 a	12.9 a	37.1 b	19.2 b	29.0 a
Average	25.4 a	9.4 a	47.6 ab	32.7 ab	43.5 a
Tall	13.9 b	18.9 a	44.9 ab	36.9 a	43.3 a
Very tall	12.2 b	18.2 a	58.4 a	19.1 b	38.2 a
Root collar diameter					
Small	33.3 a	12.3 a	42.3 ab	25.5 a	65.0 a
Medium	25.9 a	17.7 a	36.3 b	37.2 a	41.4 ab
Large	13.3 b	15.4 a	49.5 a	28.1 a	37.0 b
Very large	12.4 b	6.7 a	51.2 a	28.1 a	34.5 b
First order lateral roots					
0-2	27.4 a	13.8 ab	51.2 ab	41.1 a	47.5 a
3-4	19.4 ab	15.6 ab	52.4 a	33.1 ab	37.9 a
5-7	9.0 b	22.0 a	44.9 ab	27.6 b	42.0 a
≥8	16.3 ab	3.4 b	38.0 b	23.1 b	30.4 a

DISCUSSION

Not unexpectedly, most species were significantly taller when protected by tree shelters than when protected by sleeves or unprotected (Table 2). This concurs with the earlier research which demonstrates the increased growth for hardwoods (Potter 1988; Lantagne and others 1990; Minter and others 1992; Kittredge and others 1992; Smith 1993; Lantagne 1996; Strobl and Wagner 1996; Schultz and Thompson 1996; Schuler and Miller 1996; Farley and others

1996; Clatterbuck 1996; but see Teclaw and Zasada 1996), and extends the increased height growth response to eastern white pine.

While conifers protected by tree shelters were significantly taller at the end of the 3rd growing season (Ward and Stephens 1995), the actual amount of height difference rarely exceeded one year's height growth. The increased height growth on Norway spruce and eastern hemlock protected by tree shelters was lost by the 5th growing season (Table 2). Browse damage through the 3rd year ranged from 65% for unprotected seedlings to 29% for seedlings protected by mesh sleeves (Ward and Stephens 1995). Even with the high levels of deer browse damage on these plots, tree shelters were a very expensive technique to marginally increase conifer height growth.

Earlier studies found that survival of northern red oak was increased (Smith 1993; Lantagne 1996; Farley and others 1996; Teclaw and Zasada 1996) or unchanged (Minter and others 1992; Smith 1993; Strobl and Wagner 1996; Schultz and Thompson 1996; Clatterbuck 1996) when protected by tree shelters. This study extends that observation to some conifers (Table 6). Relative to unprotected seedlings, 5 year mortality of seedlings protected by tree shelters was reduced by 28% (eastern white pine) to 72% (black walnut).

The absence of significant correlation between initial characteristics and 5th year height for hardwood seedlings protected by tree shelters was surprising (Table 4). Schultz and Thompson (1996) reported that among northern red oak and black walnut protected by tree shelters, seedlings with > 10 FOLR were slightly taller after 4 years than seedlings with < 6 FOLR, but no statistics were presented. I also found that among seedlings protected by tree shelters, large seedlings were slightly, but not significantly, taller than small seedlings after 5 years (Table 5). Some of the lack of difference among initial size characteristics may be attributable to grading at the nursery which discarded the lowest quality material.

Except for black walnut, initial size was more important for seedlings not protected by tree shelters and therefore subject to browse damage (Tables 3 and 4). Larger seedlings likely have more reserves than small seedlings and are better able to recover from browse damage. Absolute seedling size is probably not as important as relative size because growth conditions vary by year and bed. The largest size class for each of the initial seedling characteristics (initial height, root collar diameter, first-order lateral roots) accounted for approximately 20% of all seedlings. One-third of seedlings were in the largest size classes for at least one initial characteristic. Grading seedlings with the criteria that at least one initial characteristic be in the upper quintile size classes would result in high proportion of culls.

None of the initial seedling characteristics was consistently accurate for estimating mortality for all species (Table 6). Mortality decreased with stem height for northern red oak, but actually increased with stem height for eastern white pine. Similar to studies in the Midwest (Schultz and Thompson 1996), first order lateral roots had a significant, albeit small and inconsistent, effect on 5-year mortality for 4 of the 5 species studied (Table 4). The increased mortality of larger eastern white pine is puzzling. Pine that grow faster in the nursery may be more palatable than slower growing seedlings, and therefore are browsed more severely.

While FOLR was not as predictive of growth and mortality as found in other studies (Kormanik 1986; Thompson and Schultz 1993), this study does concur that larger seedlings have lower mortality rates and grow faster than smaller seedlings. Severe grading prior to planting, as suggested above, would decrease gross nursery production. Would a tougher grading standard be worthwhile? I split the northern red oak seedlings in this study not protected by tree shelters into two categories: large-those in the top 20% in at least size measure, and small-those not meeting the aforementioned criteria. If success is defined as a seedling 120 cm tall (4 ft) after five years, then 13% of large seedlings were successful compared with only 5% of small seedlings. This suggests a planter would need to plant nearly three times as small as large seedlings to reach the same stocking goals (Zaczek and others 1995).

ACKNOWLEDGMENTS
A special thanks to Division of Forestry, Connecticut Department of Environmental Protection, and the South Central Regional Water Authority who provided the land, materials, and personnel that made this research possible. This research was partly funded by McIntire- Stennis Project No. CONH-541.

---

[1]*Department of Forestry and Horticulture, The Connecticut Agricultural Experiment Station, 123 Huntington Street, PO Box 1106, New Haven, CT 06504; Telephone: 203/789-7238; Fax: 203/789-7232.*

LITERATURE CITED
Clatterbuck, W.K. 1996. Effects of tree shelters on initial growth of bottomland hardwood seedlings. pp. 72 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

Farley, M.E., P.S. Perry, and P.R. Woyar. 1996. Valley coal tree shelter field trial. pp. 60-63 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

George, D.W., T.W. Bowersox, and L.H. McCormick. 1991. Effectiveness of electric deer fences to protect planted seedlings in Pennsylvania. pp. 395-401 in 81 Central Hardwood Forest Conference. USDA For. Serv. Gen. Tech. Rep. NE- 148.

Kaczmarek, D.J., and P.E. Pope. 1993. Seedling morphology related to growth and survival of northern red oak. pp. 11 in 5th Workshop on seedling physiology and growth problems in oak plantations. USDA For. Serv. Gen. Tech. Rep. NC- 158.

Kays, J.S. 1996. Deer protection for small forest plantations: comparing costs of tree shelters, electric fencing and repellents. pp. 5-12 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

Kittredge, D.B., M.J. Kelty, and P.M.S. Ashton. 1992. The use of tree shelters with northern red oak natural regeneration in southern New England. North. J. Appl. For. 9: 141-145.

Kormanik, P.P. 1986. Lateral root morphology as an expression of sweetgum seedling quality. For. Sci. 32: 595-604.

Kormanik, P.P., S.S. Sung, T.L. Kormanik, and S.J. Zamock. 1995. Oak regeneration - why big is better. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-365.

Lantagne, D.O., C.W. Ramm, and D.I. Dickmann. 1990. Tree shelters increase heights of planted oak seedlings in a Michigan clearcut site. North. J. Appl. For. 7: 24-26.

Lantagne, D.O. 1996. Effects of tree shelters on planted red oaks in Michigan. pp. 24-28 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

Marquis, D.A. 1977. Devices to protect seedlings from deer browsing. USDA For. Serv. Res. Note NE-243.

Minter, W.F., R.K. Myers, and B.C. Fischer. 1992. Effects of tree shelters on northern red oak seedlings planted in harvested forest openings. North. J. Appl. For. 9: 58-63.

Neter, A., Wasserman, W., and Whitmore, G.A. 1982. Applied statistics. 2nd ed. Allyn and Bacon, Boston, Mass.

Potter, M.J. 1988. Treeshelters improve survival and increases early growth rates. J. For. 86: 39-41.

Schultz, R.C., and JR. Thompson. 1990. Nursery cultural practices that improve hardwood seedling root morphology. Tree Planters' Notes 41:21-32.

Schultz, R.C., and J.R. Thompson. 1996. Tree shelters for plantation establishment of bareroot red oak and black walnut in 5 Midwestern states. pp. 29-36 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

Smith, H.C. 1993. Development of red oak seedlings using plastic shelters on hardwood sites in West Virginia. USDA For. Serv. Res. Pap. NE-672.

Strobl, S., and R.G. Wagner. 1996. Early results with translucent tree shelters in southern Ontario. pp. 13-18 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

Schuler, T.M., and G.W. Miller. 1996. Guidelines for using tree shelters to regenerate northern red oak. pp. 37-45 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

SYSTAT, Inc. 1992. SYSTAT for Windows: Statistics, Version 5th ed. 750 p.

Teclaw, R., and J. Zasada. 1996. Effects of two types of tree shelters on artificial regeneration of northern red oak in northern Wisconsin. pp. 68 in Tree Shelter Conference. USDA For. Serv. Gen. Tech. Rep. NE-221.

Ward, J.S., and G.R. Stephens. 1995. Protection of tree seedlings from deer browsing. pp. 507-514 in 10' Central Hardwood Forest Conference. USDA For. Serv. Gen. Tech. Rep. NE-197.

Zaczek, J.J., K.C. Steiner, and T.W. Bowersox. 1995. Quality or quantity: stock choices for establishing planted northern red oak. p. 116. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-365.