SHELTERS AFFECT TREE SEEDLING ESTABLISHMENT UNDER GRASS COMPETITION

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Abstract. We investigated growth and water relations of tree seedlings grown in treeshelters surrounded by competing grass. Treeshelters were placed over one-year-old gambel oak (*Quercus gambellii*) and bigtooth maple (*Acer grandidentatum*) planted in field soil, and crested wheatgrass (*Agrypyron cristatum* x *A. repens*) was planted around half of the trees. Trees were irrigated only the first year. Surviving plants were counted over two years, and above-ground growth, root growth, and leaf water potential were measured the second year. Without shelters, all maples and most oaks under grass competition died within two years, while about half or more of those in shelters survived. Sheltered trees with competition had more height growth, and thus were able to extend foliage above the competing grass, and were under less water stress. Without competition, maple outgrew oak both above and below ground, but sheltered maple grew less than unsheltered maple, while the reverse was true for oak. Shelters reduced water stress in both species across all treatments. Shelters have the potential to increase seedling survival and growth when herbaceous competition is present, and increase drought tolerance, but the response will depend on the species.

Roads cut through mountainous or hilly terrain are common in the Intermountain region of the US. The sideslope landscapes resulting from these road cuts are often unconsolidated soil that can easily erode and slump. Successful vegetation establishment and root growth on these sideslope landscapes is important for stabilizing soil. Successful plant establishment can also achieve an aesthetically pleasing roadside appearance, but these landscapes generally need to have low maintenance and minimal irrigation requirements.

Drought-tolerant grasses can establish rapidly in these environments, but their root systems do not provide as much shear strength as woody plants (10) nor do their roots penetrate the soil as deeply (2). A number of woody species native to the Intermountain region are found on arid sites (3) and are more likely to have deep rooting (2) that could anchor soil on sideslopes along roadways. Woody plants, however, take longer to provide anchoring benefits from root penetration than grasses because of slower growth (9). If woody plants are planted concurrently with grasses, benefits from deep rooting may be delayed or lost due to competition (8) and animal depredation.

Transluscent plastic shelters placed over seedling trees have been shown to reduce animal depredation (7), increase stem elongation (5), reduce water stress and increase survival (6). When growing in competition with other plants, shelters could provide trees with growth space and reduce competition for light. Shelters themselves, however, reduce light and trees in shelters can exhibit leaf morphology characteristic of shade acclimation (5). Reduced light penetration to the foliage would suggest reduced photosynthesis and less root growth (1), possibly negating some advantages of shelters. The objective of this study was to determine if tree shelters can improve establishment of two native woody species under herbaceous competition.

Methods

This experiment was conducted at the Utah State University research farm in Logan, Utah (USDA hardiness zone 5a) with bigtooth maple (*Acer grandidentatum*) and gambel oak (*Quercus gambellii*), native to the Intermountain region. In early April, 1993, we planted one-year old, 0.1 m (4 in) high, seedling plants, nursery grown in 160 ml tubes, in a well-drained Millville silt loam (coarse-silty, carbonatic, mesic, Typic Haploxeroll) that had 0.17 m/m (2 inches/foot) available water content to a depth of 2 m (6.5 ft). Treatments included species, +/- grass competition and +/- shelters. The experimental design was a three-way randomized complete-block, with each species x competition x shelter block replicated seven times, and individual trees were randomly assigned to treatments. Immediately after planting 1.25 (4.1 ft) high brown-transluscent plastic shelters (TreeEssentials, Inc, St. Paul, MN) were placed over treatment trees, and 'Newhy'

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Table 1. Percent survival during two growing seasons for bigtooth maple and gambel oak grown with (+) and without (-) treeshelters and grass competition.

		Percent Survival					
		Fall 1993		Spring 1994		Fall 1994	
Competition	Shelter	Maple	Oak	Maple	Oak	Maple	Oak
+	-	100	86	71	43	0	29
+	+	100	100	86	86	86	43
-	-	100	86	100	86	100	86
-	+	100	100	100	100	100	100
		Main Effects[z, y]					
Competition		ns		*		**	
Shelter		ns		ns		ns	
Species		ns		ns		ns	

[z]Treatments significant at 1% (***), 5% (**), 10% (*), level of probability or nonsignificant (ns)

[y]Analysis of variance on main treatment effects only because survival was not replicated at the level of treatment interactions. Values were the average of the species x competition x shelter replications.

wheatgrass (*Agropyron cristatum* x *A. repens*) was seeded in a 0.5 m (1.6 ft) radius around the trees with competition. Trees were watered the first growing season with one drip emitter applying 2 liters of water per tree once a week. The experiment was not irrigated the second year. Weeds were removed by cultivation or tilling from the entire plot as they appeared.

Surviving trees were counted at the end of the first season, at the start the second season prior to budbreak, and finally at the end of the second season prior to leaf fall. We measured total tree height in fall 1994 on the single leader for trees in shelters, and for non-sheltered trees under competition. Because non-competition trees not in shelters were multi-stemmed, all dominant shoots originating from the root crown were measured, and the average height calculated. All leaves for each tree were collected in September, 1994, with the exception of non-sheltered maples under competition because all trees had died and leaves had senesced and fallen off, and measured for total leaf area with a leaf area meter (Model CI-203, CID Inc., Vancouver WA).

Eight trees without grass competition, four oak and maple replicates +/- shelters, were randomly selected for root studies. Roots of trees under competition were not investigated since few plants survived and fine roots of the trees could not be distinguished from the grass. In September 1994 a pit was excavated immediately to the south and under each of the selected trees to a depth and width of 1 m (3.2 ft). A 1-m^2 (11 ft^2) grid divided into 100 cm^2 (16 in^2) cells was placed over the soil profile face nearest the tree, and the number of fine (non-woody, < 1mm [0.04 in]) and woody roots (non-flexible > 1mm diameter) observable in each cell was counted.

On July 7 and August 25, 1994, midday (between 12 noon and 2 PM) leaf water potential (Ψ) was measured with a pressure chamber (series 3000, Soil Moisture Inc., Santa Barbara, CA) to assess plant water status. Predawn Ψ was not measured because prior work had shown that Ψ at predawn was higher than those not in shelters even when well watered (5). A single leaf was excised from each tree before dawn, immediately sealed in an aluminum bag (4), and returned to the laboratory for measurement with a pressure chamber, usually within an hour.

Water potential, leaf area, and shoot elongation data were subjected to analysis of variance appropriate for a three-way complete block design. Survival was calculated as the mean of the replicates for each competition x species x shelter treatment combination. Consequently, statistical comparison with analysis of variance could only be performed on the main treatment effects. The effect of treatment interactions could only be compared observationally. Differences in fine and coarse root number were first analyzed by comparing number of woody and fine roots among competition and species combined for the whole profile. Change in average root number for the same treatments by depth was then compared with woody and fine roots combined, and the change in total root number was plotted against depth for species x shelter treatments.

Results and Discussion

Shelters generally improved tree survival and growth under competition, but the species responded differently (Table 1). After the first growing season with irrigation, only two oaks overall had died. Competition evidently reduced winter hardiness, as a number of trees of both species had died between the fall and spring counts. Survival, then, of trees with competition was significantly lower than for the trees without competition. Observationally, three oak and two maple without shelters under competition died, however, while in shelters, only one tree of each species under competition died. The summer of 1994 was exceptionally hot and dry, as average high temperature was 2 C above normal for June, July, and August; and rainfall was only 29 mm (1.13 in or 40% of normal) for this period. At the end of the second season, overall survival of trees under competition was significantly lower than those without grass competition, while no maple or oaks without competition had died after the first season. While the interactive effect of shelters and competition on survival could not be statistically tested, observation showed that shelters clearly benefited maple survival under competition. By fall of the second year, all maples without shelters were dead while only one in shelters had died. Shelters did not appear to benefit oak under competition, however, two survived without shelters but only three with shelters.

Table 2 Midday water potential on two dates in 1994, and leaf area and shoot elongation for bigtooth maple and gambel oak grown with (+) and without (-) treeshelters and grass competition.

		Water Potential, MPa				Growth			
		July 7		August 25		Leaf Area, cm²		Height, cm	
Competition	Shelter	Maple	Oak	Maple	Oak	Maple	Oak	Maple	Oak
+	-	-3.01	-3.2	----	-4.00	--	21	17.6	15.3
+	+	-2.11	-2.16	-3.08	-3.03	323	54	50.4	13.2
-	-	-2.47	-2.28	-2.86	-3.40	2147	324	50.3	15.0
-	+	-2.31	-2.02	-2.26	-2.71	1305	720	84.4	29.4
Competition[z]		ns		**		ns		***	
Shelter		**		***		ns		***	
Species		ns		**		***		***	
C*Sp		ns		ns		ns		***	
C*Sh		*		ns		ns		ns	
Sp*Sh		ns		ns		*		***	
C*Sp*Sh		ns		--		--		ns	

[z]Treatments significant at 1% (***), 5% (**), 10% (*), level of probability or nonsignificant (ns)

Shelters reduced water stress through the second season, particularly during early summer for trees under competition (Table 2). On July 7 leaf water potential (Ψ) was significantly less negative for all trees in shelters, and under competition sheltered trees of both species were less water stressed than those without shelters. By late summer, most non-sheltered trees under competition had died, making water stress comparisons impossible. Again, however, shelters reduced overall water stress, as trees in shelters had less negative Ψ than those without, consistent with prior reports (6). Less water stress in shelters was likely due to reduced transpiration (5) that reduced depletion of soil moisture.

Competing vegetation suppressed stem elongation and total leaf area, most likely due to competition for light (Table 2). Non-sheltered oak and maple under competition were unable to elongate above the competing grass stems and thus received little light. If leaves cannot absorb enough sunlight for photosynthesis, there is no carbon for elongation and additional leaves are not produced (1), and in the case of maples, all non-sheltered trees in grass died. In contrast, sheltered maples under competition utilized the additional space provided by the shelters to elongate and develop new leaves beyond competing grass foliage.

Maple and oak above-ground growth responded very differently to shelters (Table 2).

Table 3. Total number of roots observed in a m² soil profile for bigtooth maple and gambel oak grown with and without treeshelters.

	FINE ROOTS		WOODY ROOTS	
	Maple	Oak	Maple	Oak
No Shelter	203	81	41.0	5.8
Shelter	234	174	5.8	14.0
Species[z]		*		**
Shelter		ns		**
Sp* Sh		ns		***

[z]Treatments significant at 1% ***, 5% **, 10% *, level of probability or nonsignificant (ns)

Oaks were much slower growing than maple, as they had much less leaf area and elongation across all treatments, which could explain why fewer sheltered oak than maple survived competition. For maple without competition, shel-tered trees elongated more than non-sheltered, but non-sheltered trees had nearly twice the total leaf area. A trade-off between enhanced elongation and leaf area in shelters was consistent with reports elsewhere (5). This trade-off benefited trees under competition, but means less productive leaf area for those trees without competition. However, oak apparently was unable to utilize conditions in shelters as much as maple. Both leaf area and elongation of oaks with no competition was greater with shelters than without.

Differences in top growth were reflected in root growth (Figure 1, Table 3). Consistent with more leaf area and shoot elongation, maple had more fine and woody roots than the oaks (Table 3). Shelters had no effect on fine root growth, but the number of woody maple roots compared to non-sheltered was reduced, suggesting that less total leaf area reduced transport of carbon to structural roots. Shelters had no significant effect on either woody or fine root number in oak. We saw no treatment differences in root numbers down to 0.5 m (1.6 ft) depth (Figure 1). Below 0.5 m (1.6 ft) depth, species differences in above-ground growth were reflected in root growth, as maple had significantly more roots than oaks. Non-competition maples had significantly more total roots than non-competition oaks by 0.8 (2.6 ft) m depth, and significantly more than all other treatments by 0.9 m (3 ft) depth. These results would suggest that maple without shelters, at least initially, would provide more resistance to soil shear given its greater number of woody roots (9, 10).

Conclusions

Shelters have some promise in establishing seedling trees in arid environments with competing herbaceous vegetation, depending on the species. When a species can utilize the space and light provided by shelters to increase stem elongation, the increased leaf area and reduction in transpiration rate (5) afforded by shelters can allow a tree more access to soil water and sunlight, and it will be better able to compete with surrounding vegetation. A slow-growing species like gambel oak that was unable to elongate enough to utilize shelters would not benefit as much as a faster-growing species such as bigtooth maple. Indeed, oaks without competition did not grow as much as bigtooth maple. Even if shelters do not enhance growth for all species, the protection from external damage, such as animal browse, can enhance establishment (7). The presence of shelters could also facilitate weed control by eliminating potential damage from drift of herbicides.

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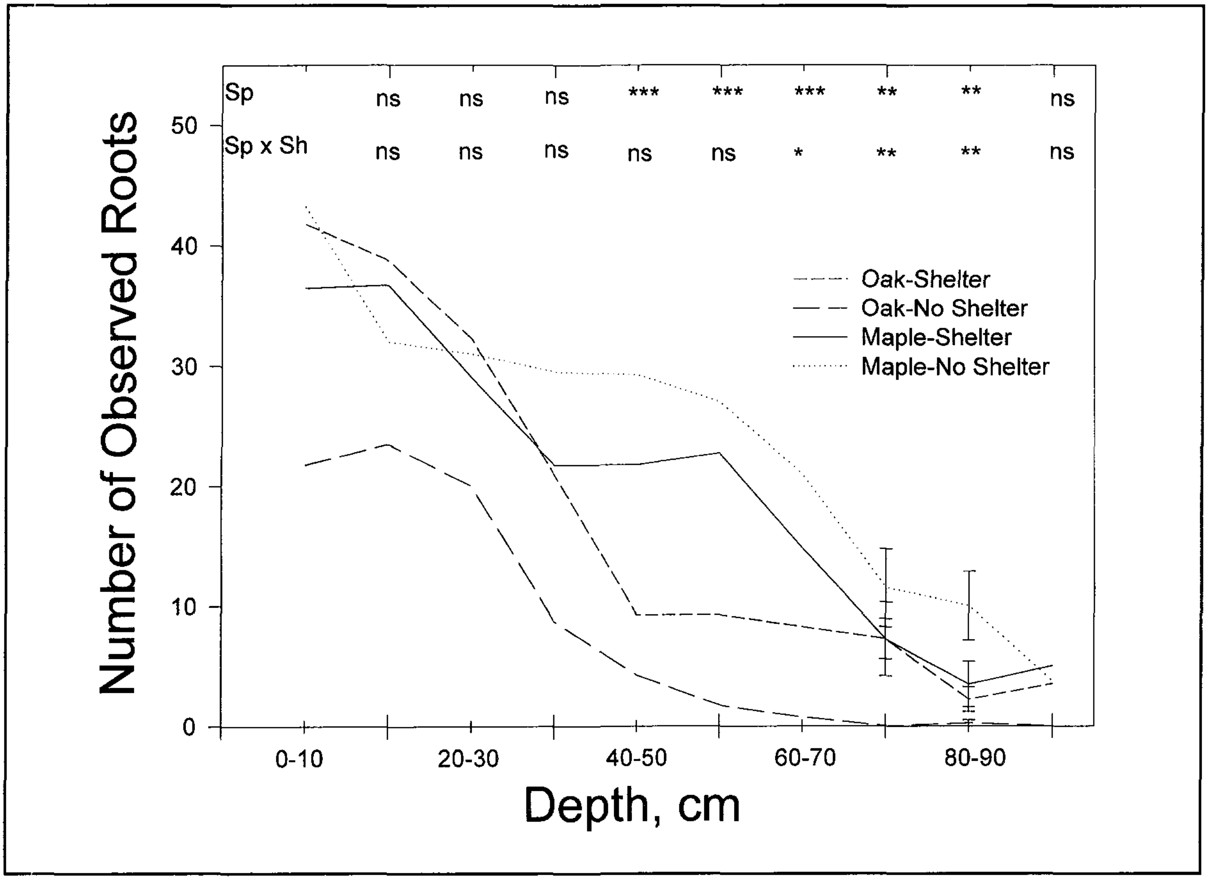

Figure 1. Total root number by depth observable in a 1 m wide soil profile immediately under bigtooth maple and gambel oak with and without treeshelters grown without competition. Error bars are included only for those depths where the species x shelter interaction term was significant.