TREE SHELTER AND INTERPLANTED N-FIXING SHRUB EFFECTS ON CROP TREE GROWTH ON A CALCAREOUS MINESOIL[1]

by

David A. Kost, Merlyn M. Larson, and John P. Vimmerstedt[2]

Abstract. In southeastern Ohio, we installed three studies to test the effects of plastic tube tree shelters and interplanted N-fixing shrubs on crop tree survival and growth. Study 1 on graded gray cast overburden used white ash (Fraxinus americana L.) and a hybrid willow (Salix matsudana x alba, or Austree) as crop trees. These were tested in factorial combination with 1.2 m tall tree shelters (present or absent) and N-fixing shrubs [none, bristly locust (Robinia fertilis Ashe), or Siberian peashrub (Caragana arborescens Lam.)]. Study 2 evaluated growth of bur oak (Quercus macrocarpa Michx.) as affected by soil surface (graded cast overburden or ripped topsoil), presence of tree shelters, and presence of interplanted Siberian peashrub. Study 3 tested Austree growth as affected by soil surface and presence of tree shelters. After four or five growing seasons, overall crop tree survivals were white ash (80%), bur oak (52%), and Austree (10% in study 1 and 25% in study 3). All crop tree species tended to survive better with tree shelters but only Austree in study 3 (36% with shelter vs. 14% without shelter) showed a significant difference. Tree shelters increased heights of white ash (102 cm with shelter vs. 21 cm without shelter) and bur oak (84 cm vs. 27 cm). Crop tree survival and growth were not affected significantly by interplanted N-fixing shrubs or by soil surface. In study 1 (cast overburden only), peashrub (64%) survived better than bristly locust (31%) but locust was taller (74 cm vs. 45 cm). In study 2, peashrub survived better on ripped topsoil (53%) than cast overburden (17%), but height was not impressive on either soil (41 ± 11 cm).

Additional Key Words: Fraxinus americana L., Quercus macrocarpa Michx., Salix matsudana x alba, Robinia fertilis Ashe, Caragana arborescens Lam.

Introduction

A variety of cultural techniques, such as fertilizing, herbiciding, soil ripping, spraying animal repellents, or planting containerized stock, can be used to improve tree survival and growth on surface mines. One of the newer practices is the use of tree shelters. Tree shelters are translucent plastic tubes available in various lengths up to 1.8 m that are installed over individual trees and supported by a stake. The shelter modifies the microenvironment around the tree seedling (increases humidity, decreases wind and light intensity) and promotes rapid height growth. The shelter also protects the seedling from vertebrate animal damage until it emerges from the tube. After the terminal bud emerges from the tube, additional growth may carry it beyond the reach of deer, although Ward and Stephens (1995) reported browse damage on trees that had emerged from 1.2 m tubes. Tree shelters show great promise for improving tree establishment but are expensive in terms of initial cost ($3.75 per 1.2 m tall shelter) and labor for installation and maintenance.

Tree growth on new minesoils, which are almost always deficient in nitrogen, may be improved by interplanting nitrogen-fixing shrubs. Although the primary expected benefit from the shrubs is an increase in available soil nitrogen, other possible benefits are the increased accumulation of organic matter and the reduction of wind.

There are a variety of N-fixing shrub species that can be interplanted with trees (Vogel,1981). Bristly locust is a native species that is well adapted to acid minesoils but also grows well on calcareous soils. It spreads by root suckers to form dense stands but is not considered a potential "pest" species

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[2]David A. Kost, Senior Research Associate, Merlyn M. Larson, Professor Emeritus, and John P. Vimmerstedt, Associate Professor Emeritus, School of Natural Resources, The Ohio State University and Ohio Agricultural Research and Development Center, Wooster, OH 44691.

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(Vogel,1981). Root suckering is reduced where ground cover is dense. Siberian peashrub is native to Siberia and Manchuria but has been planted widely for windbreaks on farms and for hedges and outdoor screening in towns of the upper midwest United States (Dietz and Slabaugh,1974). It is adapted to sandy, alkaline soil and open, unshaded sites. Carpenter and Hensley (1979) evaluated seven species of N-fixing shrubs, including bristly locust and Siberian peashrub, for adaptation to an extremely acid minesoil amended with lime. These two species have also been planted on alkaline iron and copper tailings in Michigan (Shetron and Carroll, 1977).

These studies used bur oak, white ash, and Austree as crop tree species. Bur oak and both white and green ash have shown good to excellent survival in other studies on the Muskingum Mine. White ash has a high N requirement for best growth (Mitchell and Chandler, 1939) and so may show a strong response to the interplanted N-fixing shrubs. Austree is a hybrid between Salix matsudana Koidz (native to Korea) and Salix alba L. (white willow; native to Europe and north Africa). It has potential for rapid growth and use in windbreaks and its leaves are an excellent source of animal fodder.

These studies evaluated effects of tree shelters and interplanted N-fixing shrubs on survival and growth of white ash, bur oak, and Austree. Two of the studies also compared tree and shrub growth on ripped topsoil versus graded cast overburden.

Methods

The studies are on Central Ohio Coal Company's Muskingum Mine, 5 km south of Cumberland, Ohio. Study 1 is west of State Route 83 in Muskingum County, and studies 2 and 3 are east of State Route 83 in Noble County. The area was mined using pan scrapers to remove and stockpile the topsoil, followed by draglines to uncover the Meigs Creek No. 9 coal seam. The overburden is predominately gray shale and limestone, with lesser amounts of sandstone and claystone.

Reconstructed soil surfaces consisted of graded gray cast overburden without topsoil, and graded cast overburden with 30 cm of replaced topsoil. The topsoil was ripped to 30-cm depth at 30-cm spacing after grading and then disked (ripped topsoil). Ripped topsoil is classified as Morristown silty clay loam, a loamy-skeletal, mixed (calcareous), mesic Typic Udorthent (Waters and Roth,1990). Soil physical and chemical characteristics are listed in Table 1. Cast overburden has greater sand content but lower levels of extractable nutrients in study 1 relative to studies 2 and 3.

All study areas received 448 kg/ha of 8-32-16 (N-P-K) fertilizer, plus ammonium nitrate at 224 kg/ha for study 1 and at 112 kg/ha for studies 2 and 3. The areas were seeded with an herbaceous mix containing the following species and seeding rates (kg/ha): orchardgrass-Dactylis glomerata L. (6.7), timothy-Phleum pratense L. (11.2), perennial ryegrass-Lolium perenne L. (9.0), Kentucky bluegrass-Poa pratensis L. (5.6), Mammoth red clover-Trifolium pratense L. (5.6), and Empire birdsfoot trefoil-Lotus corniculatus L. (5.6). Wheat (Triticum aestivum L.) at 1.3 hL/ha was included as a cover crop for studies 2 and 3. Plots were mulched with hay after seeding. Fertilizing, seeding, and mulching were done in spring 1988 for study 1 and in late summer 1987 for studies 2 and 3.

Tree rows were sprayed with glyphosate herbicide (2.24 kg active ingredient/ha) in 0.8 m-wide strips in April 1991, and trees and shrubs (except Austree) were planted within two weeks. Austree planting was delayed until 1992. All tree rows were sprayed with oryzalin herbicide (4.48 kg active ingredient/ha) in 0.8 m-wide strips in May 1991.

All studies used the same subplot design. Each subplot (5.5 m by 7.3 m) was planted with six crop trees (either white ash, Austree, or bur oak) arranged in two rows at 1.8 m by 1.8 m spacing. Crop trees were also planted on the borders at the ends of all plots. Plots interplanted with bristly locust contained eight locust, so that each crop tree was flanked by two locust planted in the tree row. Plots interplanted with Siberian peashrub contained 24 peashrubs, with each crop tree flanked by two groups of peashrubs planted in the tree row. Each peashrub group contained three plants spaced about 0.3 m apart. Brown plastic tube tree shelters were installed on all six crop trees in those plots that received shelters.

All studies had three

Table 1. Soil physical and chemical characteristics for study areas on the Muskingum Mine.

	Cast Overburden		Ripped Topsoil
	Study 1	Studies 2 and 3	Studies 2 and 3
Sieve Analysis	---------------- % by weight	--------------	
> 4 mm	41	30	18
2 - 4 mm	7	14	7
< 2 mm	52	56	75
Texture Analysis[1]	-------------------- %	--------------------	
Sand	66	36	28
Silt	23	41	40
Clay	11	23	32
pH	7.7	7.0	7.0
Extractable Nutrients[2]	------------------ kg/ha	------------------	
P	4	13	16
K	211	377	285
Ca	9442	14381	5824
Mg	606	1157	877
	---------------- meq/100g	----------------	
Cation Exchange Capacity	24	37	17

[1] < 2 mm fraction
[2] P by Bray-1 extraction. K, Ca, and Mg by ammonium acetate (1 mole/L) extraction.

replications. Study 1 used a randomized complete block design to test three interplanted N-fixing shrub treatments (no shrub, bristly locust, or Siberian peashrub), two tree shelter treatments (no shelter or 1.2 m tube shelter), and two crop tree species (white ash or Austree) in a 3 x 2 x 2 factorial experiment. The soil surface is graded cast overburden. Each replication measured 21.9 m by 21.9 m.

Studies 2 and 3 were separate but contiguous experiments using split-plot designs with soil surface (graded cast overburden or ripped topsoil) as main plots. Main plots measured 11.0 m by 14.6 m in Study 2 and 5.5 m by 14.6 m in Study 3. Study 2 (bur oak crop tree) had factorial combinations of two tree shelter treatments (no shelter or 1.2 m tube shelter) with two interplanted shrub treatments (no shrub, or Siberian peashrub) as subplots. Study 3 (Austree crop tree) had two tree shelter treatments (no shelter or 1.2 m tube shelter) as subplots. European alder [Alnus glutinosa (L.) Gaertn.] was planted in all subplots of the Austree study so presence of alder was not an experimental factor in the study. Each subplot contained eight alder, with each Austree flanked by two alder in the tree row.

In 1991, white ash was a mixture of seedlings from three half-sib sources grown at the Marietta, OH state nursery and was relatively small one-year-old stock. Bristly locust and European alder (Vallonia, IN state nursery), Siberian peashrub (Lincoln-Oakes, Bismarck, ND nursery) and bur oak (General Andrews Nursery, Willow River, MN) were purchased in 1990 and held as transplants in the OARDC nursery until 1991.

Because of considerable mortality due to a drought in 1991, all trees and shrubs that died, except European alder, were replanted in April 1992. Austree was also planted then. White ash and bur oak (Zanesville, OH state nursery), peashrub (Lincoln-Oakes nursery), and bristly locust (Augusta Forestry Center, Crimora, VA) were purchased new in 1992. Austree obtained from Austree, Inc. (Pescadero, CA) was received too late for outplanting in 1991 and so was held in the OARDC nursery until planting in 1992. Thus, Austree stock was stout, rooted cuttings about 30 cm long and 2-3 cm in diameter.

Tree shelters were installed on appropriate crop trees on April 27 and May 1, 1992.

We measured tree and shrub survival in May 1991, June 1992, and in September or October from 1991 through 1995. Crop tree heights (nearest cm) were measured in September 1992. Heights of all tree and shrub species were measured in September or October from 1993 through 1995. Survival and height of bristly locust were based upon the eight planted seedlings per subplot (sprouts not counted).

Data analysis used the ANOVA or GLM procedures of Statistical Analysis System (SAS) software (SAS Institute Inc.,1987). Survival percentages were transformed with the arcsine-square root function before analysis. If analysis of variance indicated significant (p=0.05) effects, we tested differences among means at p=0.05 using the LSD test.

Results

Crop Tree Survival and Growth

Study 1. Overall white ash survival was 57% the first year, increased to 86% after replanting the second year, and stabilized at 80% after five years. Tree shelters did not significantly affect ash survival but did produce a fivefold increase in height (Table 2). Height of ash without shelters showed little increase compared to the initial planting height of 15 to 20 cm.

Overall Austree survival was 55% the first year but decreased to 10% the second year (1993) presumably because of low rainfall (1.2 cm) from July 22 to September 1. Survival remained stable through the fourth growing season, but only 6 of 18 Austree plots had surviving Austree. First-year heights were significantly greater with shelters (95 cm) versus without shelters (35 cm). After four years, tree shelter effects on Austree survival and height were not statistically significant (Table 2).

Survival and height of ash or Austree were not affected by presence of interplanted shrubs (Table 2), or by significant interaction of shelter treatments with interplanted shrub treatments.

Study 2. Overall bur oak survival was 52% the first year (67% on ripped topsoil, 38% on cast overburden), increased to 75% after replanting the second year, and appeared to stabilize at 52% after five years. Bur oak tended to survive better on ripped topsoil and with tree shelters but the differences were not significant (Table 3). Tree shelters produced a threefold increase in height (Table 3). Heights of oak without shelters showed little increase compared to the initial planting height of 20 to 25 cm. Oak survival and height were not affected by interplanted Siberian peashrub (Table 3), or by significant interactions of the soil surface, shelter, and interplanted peashrub treatments.

Study 3. Overall Austree survival was 72% the first year (86% on ripped topsoil, 58% on cast overburden), decreased to 22% the second year (1993) because of low rainfall in August, and appeared to stabilize at 25% after four years. First-year heights were significantly greater with shelters (107 cm) versus without shelters (31 cm). After four years, Austree survived better with tree shelters and tended to survive better on ripped topsoil than on cast overburden (Table 3). Survival on cast overburden was similar in Study 3 (11%) and Study 1 (10%). Austree tended to be taller with tree shelters (Table 3).

Survival and Height of Interplanted N-fixing Shrubs and Trees - All Studies

In study 1 (graded cast overburden only) Siberian peashrub survived better than bristly locust but locust was taller (Table 4). Peashrub survival in individual plots ranged from 46% to 79%.

Table 2. Tree survival and height on graded cast overburden (Study 1) after four or five growing seasons as affected by tree shelters and interplanted N-fixing shrubs.

	Survival		Total Height	
	White Ash (yr 5)	Austree (yr 4)	White Ash (yr 5)	Austree (yr 4)
	--------- % --------		--------- cm --------	
Tree Shelter[1]				
Yes	87.0[2]	16.7	102 a	275
No	72.2	3.7	21 b	128
Interplanted Shrub				
None	77.8	5.6	65	250
Bristly locust	80.6	19.4	59	227
Siberian peashrub	80.6	5.6	62	212

[1]Tree shelters were installed on white ash at beginning of second growing season.
[2]Within a column and factor, means followed by different letters are significantly different at p = 0.05 using the LSD test.

Bristly locust survival in individual plots varied from 0% to 75%. Locust survival is based on the planted locust only (8 per plot). Several plots had volunteer locust from root sprouts, including one plot and adjoining area with 65 stems.

In study 2, peashrub survived better on ripped topsoil than on cast overburden (Table 4). Peashrub survival appeared lower in study 2 than study 1 (Table 4), with survival on cast overburden in study 2 being less than one-third that in study 1.

European alder in study 3 had excellent initial survival (97%) in June 1991. Survival decreased to 9% in September 1991 following the drought and stabilized at 7% after five growing seasons. The few surviving alder were on ripped topsoil (Table 4). European alder also showed a sharp decrease in survival (from 87% to 14%) during the 1991 drought in a herbicide study that benefited from two years of above average rainfall before the drought (Kost et al,1992).

Discussion

Tree shelters had a greater effect on tree survival and growth than interplanted N-fixing shrubs. Heights of white ash and bur oak and survival of Austree were increased by tree shelters. White ash and bur oak without tree shelters showed little height increase after five years, due in part to damage by rabbits and deer. These studies used relatively small plots (6 crop trees per plot) and tree shelters may have concentrated the animal damage on the unprotected trees.

Lack of height growth on unprotected trees in these studies does not agree with results from all other ongoing studies on the Muskingum mine. In a nitrogen fertilization study (Kost and Vimmerstedt,1994), white ash without shelters had similar survival (97%) and height (94 cm) after five years as trees with shelters in study 1 (Table 2). Thus, fertilized trees without shelters may grow as well as trees with shelters. In a species trial (unpublished data), white ash without shelters had similar survival (79%) but lesser height (34 cm) after four years compared to trees with shelters (74 cm) in study 1. In another study (unpublished data), bur oak without shelters had similar survival (56%) but lesser height (25 cm) after five years as trees with shelters in

Table 3. Tree survival and height after four or five growing seasons as affected by soil surface, tree shelters, and interplanted Siberian peashrub.[1]

	Bur oak (Study 2, yr 5)		Austree (Study 3, yr 4)	
	Survival	Total Height	Survival	Total Height
	---%---	------cm------	---%---	-----cm-----
Soil Surface				
Ripped topsoil	63.9[2]	72	38.9	219
Graded cast overburden	40.3	40	11.1	163
Tree Shelter[3]				
Yes	59.7	84 a	36.1 a	214
No	44.4	27 b	13.9 b	74
Interplanted peashrub				
Yes	52.8	53	---	---
No	51.4	60	---	---

[1]Interplanted peashrub was not a factor in Study 3 with Austree.
[2]Within a column and factor, means followed by different letters are significantly different at p = 0.05 using the LSD test.
[3]Tree shelters were installed on bur oak at beginning of second growing season.

Table 4. Survival and height of N-fixing woody plants after five growing seasons.

	Survival	Total Height
	------%------	-----cm----
Study 1- Graded cast overburden		
Bristly locust	30.8 b[1]	74 a
Siberian peashrub	64.2 a	45 b
Study 2- Siberian Peashrub		
Ripped topsoil	53.4 a	47
Graded cast overburden	17.2 b	34
Study 3- European alder		
Ripped topsoil	14.6	184
Graded cast overburden	0.0	--

[1]Within a study and column, means followed by different letters are significantly different at p = 0.05 using the LSD test.

study 2 (Table 3). In contrast to the tree shelter experiments, other ongoing studies were planted in 1989 or 1990 and had one or two years of above average rainfall before the drought in 1991. Thus, for species such as white ash and bur oak that survive well without shelters, the main benefit of shelters is increased height growth. Height growth may slow after seedlings emerge from the shelters (Lantagne,1995). By 1995, 33% of bur oak and 36% of white ash had emerged from shelters.

Austree survival was good on ripped topsoil but mediocre on cast overburden during the first growing season with adequate rainfall. The sharp decline in survival that probably resulted from the dry period in the second growing season suggests Austree, like other willows, requires abundant soil moisture. It will not be possible to monitor the long-term effects of the interplanted shrubs on Austree in study 1 because most plots do not have surviving Austree.

There are probably several reasons why the interplanted N-fixing shrubs have not affected crop tree growth. Nitrogen fixation by herbaceous legumes, which were present in all studies, may have nullified the effects of nitrogen fixation by the N-fixing shrubs. Although we did not measure the abundance of herbaceous legumes, we noticed that volunteer sweetclover (Melilotus officinalis Lam.) was prominent in the herbicide-treated tree rows in study 1 during the second season. The seeded birdsfoot trefoil was abundant in studies 1 and 2 in 1995. It is possible that the interplanted shrubs will contribute available N after herbaceous legumes are shaded out by crop trees. Long term studies would be required to test this.

Poor survival of bristly locust in some plots and overall poor growth of peashrub have reduced nitrogen fixation by these shrubs. We do not think that the nitrogen applied during ground cover establishment has prevented a crop tree response to nitrogen fixation by the shrubs. For example, in a study on the same site as study 1 (unpublished data), green ash grew taller with 168 or 336 kg N/ha in addition to N applied when ground cover was seeded.

Survival of bristly locust was variable in study 1 and in an adjacent study (unpublished data) on the same site. In the adjacent study, locust survived best in plots with the least ground cover when locust was planted. There were no obvious differences in ground cover in study 1 that would have contributed to the variation in locust survival. Although sprouting may allow one surviving locust to spread over a large area (Davidson,1979), several plots in study 1 had no surviving locust and thus no possibility of spreading by sprouting. Low initial survival for locust may not be a problem in routine reclamation plantings where locust is planted uniformly over a large area instead of being separated in research plots. To insure locust establishment it may be necessary for plantings to be spaced closer than the 1.8 m by 1.8 m used in study 1. Locust grew vigorously in several plots with abundant sprouts.

Siberian peashrub survived better than bristly locust, but peashrub growth was unimpressive due in part to animal damage. In northern Michigan peashrub survived better than bristly locust on alkaline iron tailings but neither species survived on alkaline copper tailings after five years (Shetron and Carroll,1977). On an acid minesoil in Kentucky, peashrub had 44% survival after four years but did not persist after 18 years (Wade et al,1985).

Conclusions

Tree heights were increased dramatically by tree shelters but it is too early to speculate if the increased growth would offset the costs of installing shelters. Bristly locust does not survive as well as Siberian peashrub but shows more potential for vigorous growth with concomitant nitrogen fixation.

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Literature Cited

Carpenter, P.L., and D.L. Hensley. 1979. Utilizing N_2-fixing woody plant species for distressed soils and the effect of lime on survival.

Botanical Gazette 140(Suppl.):S76-S81.
https://doi.org/10.1086/337039

Davidson, W.H. 1979. Results of tree and shrub plantings on low pH strip-mine banks. USDA Forest Service Research Note NE-285. 5 p.

Dietz, D.R., and P.E. Slabaugh. 1974. Caragana arborescens Lam. (Siberian peashrub). p. 262-264. In Seeds of woody plants in the United States. USDA Forest Service Agriculture Handbook 450.

Kost, D.A., J.H. Brown, and J.P. Vimmerstedt. 1992. Effects of coal minesoil surface and herbicide applications on early tree survival and growth. p. 130-145. In Proc. of 9th Annual National Meeting of the Amer. Soc. for Surface Mining and Reclamation. (Duluth, Minn. June 14-18, 1992). Amer. Soc. for Surface Mining and Reclamation, Princeton, West Virginia.
https://doi.org/10.21000/JASMR92010130

Kost, D.A., and J.P. Vimmerstedt. 1994. Ground cover and tree growth on calcareous minesoils: greater influence of soil surface than nitrogen rate or seed mix. p. 295-304. In Inter. Land Reclamation and Mine Drainage Conf. and Third Inter. Conf. on the Abatement of Acidic Drainage. (Pittsburgh, Penn. April 24-29, 1994). Vol. 3. USDI Bur. of Mines Special Publication SP 06C-94, 353 p. Washington, D.C.
https://doi.org/10.21000/JASMR94030295

Lantagne, D.O. 1995. Effects of tree shelters on planted red oaks after six growing seasons. p. 515-521. In Proc. 10th central hardwood forest conference. (Morgantown, West Virginia. March 5-8, 1995). USDA Forest Service General Technical Report NE-197. 577 p. Northeastern Forest Experiment Station.

Mitchell, H.L., and R.F. Chandler. 1939. The nitrogen nutrition and growth of certain deciduous trees of northeastern United States. Black Rock Forest Bulletin 11. Cornwall-on-the-Hudson, NY. 94 p.

SAS Institute Inc. 1987. SAS/STAT guide for personal computers, version 6 edition. SAS Institute Inc., Cary, NC. 1028 p.

Shetron, S.G., and D.A. Carroll. 1977. Performance of trees and shrubs on metallic mine mill wastes. Journal of Soil and Water Conservation 32:222-225.

Vogel, W.G. 1981. A guide for revegetating coal minesoils in the eastern United States. USDA Forest Service General Technical Report NE-68. 190 p.

Wade, G.L., R.L. Thompson, and W.G. Vogel. 1985. Success of trees and shrubs in an 18-year-old planting on mine spoil. USDA Forest Service Research Paper NE-567. 10 p.

Ward, J.S., and G.R. Stephens. 1995. Protection of tree seedlings from deer browsing. p. 507-514. In Proc. 10th central hardwood forest conference. (Morgantown, West Virginia. March 5-8, 1995). USDA Forest Service General Technical Report NE-197. 577 p. Northeastern Forest Experiment Station.

Waters, D.D., and L.E. Roth. 1990. Soil survey of Noble County, Ohio. USDA-SCS. Washington, D.C.