GUIDELINES FOR ESTABLISHING PRODUCTIVE FOREST LAND ON RECLAIMED SURFACE MINES IN THE CENTRAL APPALACHIANS[1]

J.L. Torbert and J.A. Burger[2]

Abstract. This paper presents an overview of forestry reclamation research conducted within the Forestry Department at Virginia Polytechnic Institute and State University since 1980. Research indicates that coal mining and subsequent reclamation in the Central Appalachian region of Virginia, West Virginia, and Kentucky presents a good opportunity to create productive forests on land that is often too steep or remote to be used for crop production, grazing, or commercial development. Unfortunately, coal companies seldom reclaim these lands in a fashion that will result in productive forest land. Overburden selection, surface grading, and ground cover establishment are usually oriented towards producing a hayland/pasture land-use. In order to develop productive forest land, special considerations need to be given to the requirements of forest tree species as opposed to agronomic forages. Preliminary results from our research program indicate that for best tree establishment and long-term growth, moderately-acidic sandstone overburdens should be used as topsoil substitutes when real topsoil is not recoverable, grading and tracking-in should be minimized to avoid compaction, and a tree-compatible ground cover of acid-tolerant, short grasses and legumes should be used for revegetation.

Introduction

Forestry is a logical land-use for most of the reclaimed mined land in the Appalachian Mountains because most reclaimed sites are too steep or remote to be used for grazing, crops, or commercial development. Consequently, more than 80% of the coal mining permits issued in Virginia during the last few years have specified "forest land" as the designated post mining land-use (Virginia Division Mined Land Reclamation, personal communication). According to PL 95-87, the Surface Mining Control and Reclamation Act of 1977 (SMCRA), mined lands are supposed to be reclaimed in a fashion that promotes their intended land-use. Unfortunately, most land designated as forest land is not reclaimed in a way that favors tree establishment or (more importantly) long-term forest productivity.

A research program was started by the Forestry Department of Virginia Polytechnic Institute and State University (VPI&SU) in 1980 with initial funding from the Powell River Project, an industry-university research cooperative, to study reforestation of surface mined land. Early emphasis was placed on studying the establishment of trees on land reclaimed before 1977 (pre-SMCRA). A trial of fifteen species was established along with a study to evaluate the effects of a mycorrhizal fungus (*Pisolithus tinctorius*), fertilizer planting tablets, and chemical weed-control on the establishment and development of three species of containerized pine. Although these studies have yielded valuable results (Schoenholtz and Burger 1984; Torbert et al. 1985, and Schoenholtz et al., 1987), research emphasis shifted in subsequent years to concerns of site productivity and techniques for modifying reclamation processes to create better sites for tree establishment.

Our studies show that in many cases excellent sites can be created during reclamation such that tree growth often exceeds the pre-mining level of productivity. When a site is properly reclaimed and revegetated, virtually any tree species suitable to the climate can be established without the need for containerized seedlings,

[1]Paper presented at the 1990 Mining and Reclamation Conference and Exhibition, Charleston, WV,. April 23-26, 1990.

[2] John L. Torbert is Forest Soils Research Associate, and James A. Burger is Associate Professor of Forest Soil Science at the School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, Blacksburg, VA. 24061-0324.

Proceedings America Society of Mining and Reclamation, 1990 pp 273-278
DOI: 10.21000/JASMR90010273

https://doi.org/10.21000/JASMR90010273

mycorrhizal inoculation, fertilizer tablets, or chemical weed-control.

The objective of this paper is to outline the forestry reclamation research conducted at VPI&SU since 1980, and to present our research-based recommendations for reclaiming forest land in Virginia and surrounding states. Our results show that the greatest constraints to tree establishment and long-term growth in this region are 1) the use of inappropriate overburden for topsoil substitutes, 2) compaction from final grading and "tracking-in", 3) excessive levels of herbaceous ground cover during the year that trees are planted, and 4) improper planting techniques.

Overburden selection

Proper minesoil construction is essential for long-term productivity of forest land. The inherent productivity of much forest land in the Appalachians is limited by shallow soils. Even though the area receives abundant rainfall, inadequate soil-water storage limits forest production in this region. Surface mining offers the opportunity to replace shallow and infertile soils, with carefully constructed minesoils that are deeper and often more fertile.

In order to take advantage of the deeper soils that can result from surface mining, overburden strata must have desirable physical and chemical properties for trees. Overburden strata differ in many important ways that influence plant growth. These properties include coarse fragment content, resistance to weathering, texture of the fine-earth fraction (<2mm), pH, soluble salt concentrations, and fertility. Forest tree species have different minesoil requirements than forage grasses and legumes, both in terms of quality and depth. Frequently, coal companies select finely textured overburden materials with a pH near neutral in order to maximize the production of ground covers without realizing the adverse effect that such overburden types can have on tree establishment and growth.

Several studies have been conducted to evaluate the effects of various overburden types on tree growth. In a greenhouse study, pine seed germination was significantly higher on a siltstone spoil than a sandstone spoil because the soil fraction associated with the siltstone was more finely textured and had greater water retention. However, seedling growth was greatest in the moderately acid sandstone (Preve et al. 1984). Many tree species grow poorly in soils with a high pH and prefer soils with a pH of 5 to 6.

In the field, an overburden-type study was established to evaluate the effect of various overburden mixes on tree establishment and growth. Treatment plots consisting of sandstone, siltstone, and different proportions of the two were carefully constructed to produce four feet of uncompacted growth media. Half of each plot was seeded with Ky-31 tall fescue (*Festuca arundinacea* Schreb.) and the other side was planted with pitch x loblolly hybrid pine (*Pinus xrigitaeda*) seedlings. After five years, the rock type had no effect on tree survival, but it had a large effect on tree growth. The average height of trees in the pure sandstone plots was 50% greater than the height of trees in pure siltstone (75 inches vs. 51 inches), and stem volume was five times greater (113 in^3 vs 23 in^3); (Torbert et al. 1990a). The sandstone spoil used in this study was a better growth medium for trees largely because it had a lower pH (5.7 vs 7.1) and lower levels of soluble salts (0.4 vs 1.3 $dS\ m^{-1}$). In contrast, the fescue performed better in the siltstone spoil during the first three years and was unaffected by spoil type by the fifth year (Roberts et al. 1988). It is important to note that selection of a spoil for maximum first-year ground cover performance in this case would have resulted in a significant sacrifice of tree performance. Furthermore, the early enhancement of ground cover growth did not persist through the entire bond period.

A minesoil-quality study (Torbert et al. 1988) was conducted to evaluate the relationship between minesoil properties and the growth of ten-year-old eastern white pines (*Pinus strobus* L.) that were planted across an area of several thousand acres in southwestern Virginia. Based on the height of trees at age ten and the use of Beck's (1971) equation for white pine polymorphic site index curves, the site index (base age 50) for each site was estimated and found to range from 40 ft to 110 ft. Based on this study, the minesoil properties most influential on tree growth were rooting volume and level of soluble salts. These results corroborate those of Ashby et al. (1984) who reported excellent tree growth on minesoils in Illinois, and who attributed the performance of those trees to the presence of a deep, uncompacted, non-toxic minesoil. Plass (1979) summarized results of several studies that found a negative relationship between soluble salt levels and performance of various pine species.

In our minesoil-quality study, the best tree growth was found on acidic, sandy minesoils derived from oxidized sandstone overburden found near the surface before mining. In addition to results obtained from our studies, observations across numerous sites in Virginia, West Virginia, and Kentucky, indicate that, with few exceptions, whenever excellent tree growth is found on minesoils, the trees are growing in an oxidized (brown) moderately acid, sandstone-derived minesoil. Oxidized sandstone is usually highly fractured and tends to produce more soil-sized particles during the blasting process than the harder sandstone, siltstone, and shale strate that occurs further below the surface. Furthermore, oxidized sandstone weathers more rapidly; rocks have been observed to weather completely to a loamy sand within a few years.

Unfortunately, even though oxidized sandstone is abundant in Virginia and is a superior growth medium for trees, reclamationists often avoid using this material as a topsoil substitute. Oxidized sandstone in southwestern Virginia and much of West Virginia and Kentucky has a pH of

4.5 to 5.5 and a high phosphorus fixing capacity that renders this material less suitable for agronomic grasses and legumes. However, this problem can be overcome by using a mixture of tree-compatible grasses and legumes that are tolerant of the chemical and physical minesoil properties that maximize tree growth.

Surface grading

Prior to revegetation, the final surface is typically cleared of large boulders, gullies are filled, and the surface is graded smooth and "tracked-in" with bulldozer cleats to improve seed bed conditions. These practices promote the establishment of a uniform ground cover that facilitates bond release. While these practices may be conducive to grassland establishment, the harmful effects of such practices to trees due to minesoil compaction have been lamented by forestry reclamation researchers for years (Vogel 1981, Larson and Vimmerstedt 1983, Ashby et al. 1984). Poor seedling survival often results on compacted soils because trees are not planted deeply enough, and root growth is restricted by the low moisture holding capacity and high soil strength associated with compacted soils. A more subtle effect of compaction that is not readily recognized is the permanent decrease in minesoil quality and decreased growth rates of surviving trees.

To quantify and demonstrate the effects of compaction on the survival and growth of several tree species caused by final grading and "tracking-in", a compaction study (Torbert et al. 1990b) was established. Bare-root tree seedlings were planted on a sloping site, half of which was graded and tracked-in using standard operational practices, and half of which was left ungraded. Minesoil compaction due to grading was immediately apparent during tree planting. Even during the early spring when soils were relatively moist, it was difficult to make an adequate hole with the tree planting bar on the graded slope. On the ungraded slope, however, deep planting holes were easy to open. Survival and growth was much better on the ungraded slope. Overall, tree survival on the ungraded slope was nearly 70% compared to 42% on the graded and, tracked-in slope (Table 1). The effects of compaction were most severe on the hardwood species. All the black walnuts and sugar maples survived on the ungraded slope, but only about half of both species survived on the graded slope. Seventy percent of the sycamores survived, and some grew to more than four feet tall in two years on the ungraded slope; none survived on the compacted slope. Unfortunately, this study was removed during its third season by re-mining; however, it was observed that compaction effects on growth continued to be very dramatic during the third year. Red oak grew as much as two feet during the third spring on the uncompacted area, but only several inches on the compacted area.

Some compaction is inevitable due to the return-to-contour requirements of SMCRA. On long steep slopes, coal companies must grade and track-in sites to stabilize the site and ensure a uniform ground cover. On these areas there may be no alternative to current reclamation practices. On level, gently sloping, or short slopes, however, where compaction is not required for slope stabilization, grading should be minimized and tracking-in should be eliminated when forestland is the designated post-mining land use. Tree planting will be easier, survival will be greater, and better long-term tree growth and forest development will occur.

Revegetation

Another aspect of post-SMCRA reclamation that conflicts with tree establishment efforts is dense herbaceous ground covers. Forage species commonly used to create hayland/pasture (Ky-31, clovers, etc.) are often not appropriate for reclamation of forest land. If they are successfully established, they grow too tall and dense for trees to emerge. On the other hand, when oxidized, acidic sandstones are used as a topsoil substitute, the ground cover is sometimes too sparse to satisfy ground cover requirements for bond release. When trees are to be planted, a tree-compatible ground cover should be used which protects the surface from erosion but still protects tree establishment (Vogel, 1981).

Our research has shown that a ground cover can be established which provides 90% cover during the first year, protects the surface from erosion, and does not excessively compete with trees (Torbert et al. 1986a,b). Tree compatible ground cover species that have performed well in several research projects and for operational reclamation include annual grasses such as foxtail millet (Setaria italica), rye (Secale cereale), or wheat (Triticum aestivum); less-competitive perennial grasses such as perennial ryegrass (Lolium perenne), redtop (Agrostis gigantea), orchardgrass (Dactylis glomerata), and weeping lovegrass (Eragrostis curvula); and legumes such as birdsfoot trefoil (Lotus corniculatus), kobe lespedeza (Lespedeza striata var 'Kobe') and Appalow lespedeza (Lespedeza cuneata var 'Appalow'). Vogel (1981) recommends a mixture of weeping lovegrass (2 lbs/acre), orchardgrass (5 lbs/acre), kobe lespedeza (10 lbs/acre), and Appalow lespedeza (8 lbs/acre).

These species have been successfully established with seeding and fertilization rates that are lower than typically used for reclamation. Unlike standard hayland/pasture ground covers that are lush during the first year and gradually decline without additional fertilizer, tree-compatible covers that we have tested are comparatively sparse during the first year and become increasingly lush with time. Despite relatively low seeding rates, ground cover establishment during the first year can satisfy the 90% cover requirement for partial bond reduction. Most of this first year-cover results from the annual grasses, while the legumes dominate after several years. In our trials, when birdsfoot trefoil and Appalow lespedeza were seeded at rates of 5 to 10 lbs/Ac, they started slowly by producing only a few plants per square foot which were generally less

Table 1. Tree survival and growth after two years on a minesoil in southwest Virginia as affected by surface grading compaction.

Species	Survival		Tree Height		Height Response
	Graded & Tracked-in	Ungraded	Graded & Tracked-in	Ungraded	
	- - - - (%) - - - -		- - - - (in) - - - -		(%)
Black walnut	55	100	17	22	29
Red oak	40	62	17	17	0
Sugar maple	60	100	23	46	100
Sycamore	0	69	-	51	--
Virginia pine	63	42	18	22	22
White pine	37	43	10	17	70
Average	42	69	17	29	44

than six inches tall after the first season. However, by the third season, they developed into a complete ground cover. Appalow, a relatively new variety of sericea lespedeza, sprawls along the ground rather than growing upright. It has been established on sites with a pH as low as 4.0 and can rapidly invade surrounding bare areas. Despite the aggressiveness of Appalow and birdsfoot trefoil, their short stature during the first few years after seeding allows tree seedlings to grow above them. These legumes will persist beneath the trees, increasing soil nitrogen levels for several years, until they are eventually shaded out.

Another advantage of seeding these tree-compatible species at relatively low seeding rates is that native plant species can more easily invade the site. Dense covers of tall fescue can effectively prevent the establishment of native plants (Wade, 1989). In our ground cover experiments, we observed that native herbaceous and tree species were abundant, even when native topsoil was not replaced. Many of these plants persist in the ground cover above the legumes adding to the diversity of plant species and creating a plant community that resembles a natural forest. Lastly, a problem associated with fescue is its alleleopathic effect on tree growth (Walter and Gilmore 1976, Todhunter and Beineke 1979). This problem can be avoided by using other grass species.

Tree Establishment

After a tree-compatible ground cover is established, tree seedlings can be planted. We use two general categories of trees; "crop trees" and nitrogen-fixing "nurse trees". Crop trees are long-term species that offer economic value to the landowner. Nurse trees are short-lived nitrogen-fixing trees or shrubs that are primarily planted to enhance the N status of the soil and help achieve the minimum number of stems required for bond release. Most nurse trees also provide food and cover for wildlife. Nurse trees are short lived and begin to drop out of the tree stand after 15-20 years, providing additional space for the crop trees as they develop.

Crop tree establishment.

Many important hardwood species (oaks, ash, walnut, yellow-poplar, etc.) will grow on properly constructed minesoils. Ashby et al. (1984) reported that 30-year-old white oaks growing on a minesoil in Illinois were the fastest growing white oaks ever reported in the state. Similarly, yellow-poplar and black walnut grew very well. As a general rule, however, pines are easier and less expensive to establish than hardwood crop tree species. Pines can be harvested in fewer years than most hardwood species and offer more immediate economic opportunities for landowners.

In recent years, the most widely planted pine in the Central Appalachian coal fields has been Eastern white pine. On good sites in the Appalachians, white pine produces more timber per acre than any other species (Doolittle 1958) and can be harvested in thirty years. On properly constructed minesoils, white pines can reach ten feet tall after five years. White pine produces the most merchantable volume when planted on a wide spacing (Balmer and Williston, 1983). For sawlog production on minesoil, white pine should be planted on a 10 x 10 ft to 12 x 12 ft spacing (300-450 trees/acre). If trees are planted more densely, the stand might stagnate after crown closure and result in many low-value pulpwood-sized trees at an otherwise harvestable age.

Other pine species that have performed well in our studies include Virginia pine, loblolly pine, and pitch x loblolly hybrid pine. All of these species grew more rapidly than white pine during the first five years. These species should be planted more densely than white pine. A 6 x 8 ft spacing to an 8 x 8 ft spacing (680-900 trees/acre) is best. There is some concern that loblolly pine may not perform well over the long term because the coal fields are outside the species' natural range. The pitch x loblolly hybrid, which has the growth rate of loblolly pine and the cold-hardiness of pitch pine, has performed very well in our studies. Unfortunately, there is currently no commercial source of hybrid pine seedlings for operational reclamation.

Nurse tree species selection.

Nitrogen-fixing trees and shrubs can increase soil nitrogen levels and improve the growth of interplanted crop trees (Plass, 1977; Vogel 1981, Jencks 1982, Vimmerstedt et al. 1989) Nitrogen-fixing trees appropriate for minesoils in the Central Appalachians include black locust (*Robinia psuedoacacia* L.), European black alder (*Alnus glutinosa* (L.) Gaertn.) and redbud (*Cercis canadensis* L.). Suitable shrub species include bristly locust (*Robinia fertilis* Ashe), autumn olive (*Elaeagnus umbellata* Thunb.), and bicolor lespedeza (*Lespedeza bicolor* Turcz.). Vogel (1981) recommends planting nurse species in every second or third row between crop trees.

Tree Planting Techniques.

A major reason trees die during the first year is due to mishandling before or during planting. Common problems that lead to seedling mortality are: 1) storing seedlings in warm places which breaks their dormancy, 2) allowing trees to dry out during storage or in the field during planting, 3) excessive root pruning, 4) shallow planting or 5) improper planting (not closing the planting hole).

Soil compaction is a contributing cause of poor planting techniques. It is difficult to make a deep planting hole in compacted soils. Because of this, trees are either improperly planted or severely root-pruned so that the root will fit in a small hole. These problems must be minimized by properly constructing the minesoil and properly training and supervising the planting crews. In Virginia, some coal companies have been able to obtain contracts with tree planting crews that guarantee minimum levels of survival.

Direct seeding trees.

We have experimented with direct seeding several pine and nurse tree species. Virginia pine and loblolly pine have been successfully established in several studies (Torbert et al. 1986b). These species can be established at seeding rates of 2 lbs/acre when used in conjunction with a tree-compatible ground cover and nitrogen fertilizer rates below 60 lbs N/acre. The cost of pine seed, however, is fairly high so that the cost of establishing these trees by direct seeding is probably not less than hand planting seedlings. White pine has been a difficult species to establish by direct seeding. White pine growth during the first season is slow, which makes them subject to frost-heaving during the first winter and overtopping by the ground cover during the second summer. Black locust and autumn olive have been successfully established in our studies and we have seen other sites where black alder and bicolor lespedeza were established with an herbaceous ground cover. Most nurse tree and shrub species have inexpensive seed; therefore, it may be most economical to direct seed the nurse species and handplant the crop trees.

Conclusions

Despite the fact that forestry is the most logical land use for much of the surface mined land in the Central Appalachians, most reclamation laws, practices, and guidelines in this region seem to have been designed to reclaim mined land for hayland or pasture with Kentucky-31 tall fescue and other forage species. An important concept that is not well understood by coal companies, regulatory agencies and many researchers is that in order to maximize land use productivity in accordance with PL 95-87, reclamation techniques to reclaim forest land should be different than tehcniques for reclaiming hayland/pasture.

To create productive forest land, a good minesoil for trees must be created during reclamation. An overburden material should be selected for placement at the surface that will maximize tree performance. When forest land is the designated land use, grading should be minimized. A tree-compatible ground cover should be used that will grow well on the site but not hinder tree establishment. On properly reclaimed sites, trees can be planted with ease, and survival and long-term growth will be ensured.

Literature Cited

Ashby, W.C., W.G. Vogel, C.A. Kolar, and G.R. Philo. 1984. Productivity of stony soils on strip mines. p. 31-44. In J.D. Nichols et al. (Ed) Erosion and productivity of soils containing rock fragments. Spec. Pub. No. 13. Soil Sci. Soc. Am. Madison, WI.

Balmer, W.E. and H.L. Williston. 1983. Managing eastern white pine in the southeast. USDA For. Serv. Forestry Rep. R8-FR 1. USDA For. Serv. Southeastern Area, State and Private Forestry, Atlanta, GA.

Beck, D.E., 1971. Polymorphic site index curves for white pine in southern Appalachians. USDA For. Serv. Res. Pap. SE-80. Southeastern For. Exp. Stn. Asheville, NC.

Doolittle, W.T. 1958. Site index comparisons for several forest species in the Southern Appalachians. Soil Sci. Soc. Proc. 22:455-458.
http://dx.doi.org/10.2136/sssaj1958.03615995002200050023x

Jencks, E.M., E.H. Tyron, and M. Contri. 1982. Accumulation of nitrogen in minesoils seeded to black locust. Soi Sci Soc Am J. 46:1290-1293.
http://dx.doi.org/10.2136/sssaj1982.03615995004600060033x

Larson, M.M. and J.P. Vimmerstedt. 1983. Evaluation of 30-year-old plantations on stripmined land in east central Ohio. Research Bulletin No. 1149. Ohio Agric. Res. and Dev. Center. Ohio State Univ. Wooster Ohio. 20pp.

Plass, W.T. 1977. Growth and survival of hardwoods and pine interplanted with European alder. USDA For. Serv. Res. Pap. NE-376. 10pp.

Plass, W.T. 1979. The use of southern pines for surface mine reclamation. pp 176-182. In H.L. Williston and W.E. Balmer (Eds). Proceedings Symposium for the Management of Pines of the Interior South. Nov 7-8, 1978, Knoxville, TN. USDA For. Serv. Southeastern Area State and Private Forestry. Tech. Pub. SA-TP2. mycorrhizae on pines seeded in greenhouse trays. J. Environ. Qual. 13:387-391.

Roberts,J.A., W.L. Daniels, J.C. Bell, and D.C. Martens. 1988. Tall fescue production and nutrient status on southwest Virginia mine soils. J. Environ. Qual. 17:55-62.
http://dx.doi.org/10.2134/jeq1988.00472425001700010009x

Schoenholtz, S.H., and J.A. Burger. 1984. Influence of cultural treatments on survival and growth of pines on strip-mined sites. Reclamation and Revegetation Research. 3:223-237.

Schoenholtz, S.H., J.A. Burger, and J.L. Torbert. 1987. Natural mycorrhizal colonization of pines on reclaimed surface mines in Virginia. J. Environ. Qual. 16:143-146. http://dx.doi.org/10.2134/jeq1987.00472425001600020009x

Todhunter, M.N. and W.F. Beineke. 1979. Effect of fescue on black walnut growth. Tree Planters' Notes 30:20-23.

Torbert, J.L., J.A. Burger, J.N. Lien, and S.H. Schoenholtz. 1985. Results of a tree species trial on a recontoured surface mine in southwestern Virginia. Southern J. Applied Forestry 9:150-153.

Torbert, J.L., J.A. Burger, and T.J. Nichols. 1986a. Reforestation seed mixtures for hydroseeding reclaimed mined land. Va. Coop. Ext. Serv. Pub. 460-112. VPI&SU, Blacksburg VA. 6pp.

Torbert, J.L., J.A. Burger, and R.E. Preve. 1986b. The effect of ground cover species and nitrogen fertilizer rate on the successful establishment of hydroseeded trees. pp83-87. In D.H. Graves (Ed) Proceedings 1986 Symposium on Mining, Hydrology, Sedimentology, and Reclamation. Dec 8-11 1986. Univ. KY, Lexington, KY, UKY BU142.

Torbert, J.L., A.R. Tuladhar, J.A. Burger, and J.C. Bell. 1988. Minesoil property effects on the height of ten-year-old white pine. J. Environ. Qual. 17:189-192. http://dx.doi.org/10.2134/jeq1988.00472425001700020004x

Torbert, J.L., J.A. Burger, and W.L. Daniels. 1990 a . Pine growth variation associated with overburden rock type on a reclaimed surface mine in Virginia. J. Environ. Qual. 19:88-92. http://dx.doi.org/10.2134/jeq1990.00472425001900010011x

Torbert, J.L and J.A. Burger. (1990b). Comparison of tree survival and and growth on a graded and ungraded mine soil after two years. Tree Planters' Notes (In press).

Vimmerstedt, J.P., M.C. House, M.M. Larson, J.D. Kasile, and B.L. Bishop. 1989. Nitrogen and carbon accretion on Ohio coal minesoils: influence of soil-forming factors. Landscape and Urban Planning. 17:99-111.
http://dx.doi.org/10.1016/0169-2046(89)90018-2

Vogel, W.G. 1981. A guide for revegetating coal minesoils in the eastern United States. USDA For. Serv. Gen. Tech. Rep. NE-68. 190 pp.

Wade, G.L. 1989. Grass competition and establishment of native species from forest soil seed banks. Landscape and Urban Planning. 17:135-149.
http://dx.doi.org/10.1016/0169-2046(89)90022-4

Walter, D.T., and A.R. Gilmore. 1976. Allelopathic effects of fescue on the growth of sweetgum. J. Chem. Ecol. 2:469-479.
http://dx.doi.org/10.1007/BF00988812