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Effect of Minesoil Compaction on Growth and Yield of KY-31 Tall Fescue and Sericea Lespedeza

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Abstract

Kentucky 31 tall fescue and sericea lespedeza were sown on clay and loam minesoils that had been screened through a No. 10 sieve and compacted to densities of 1.6, 1.8, and 2.0 g/cm^3. Stands of sericea lespedeza were more difficult to establish than fescue on both minesoils and were more susceptible than fescue to increased levels of compaction. Dry matter yields averaged over all densities were greater on the clay than on the loan minesoil.

Introduction

In the reclamation of surface-mined lands, the surface of the restored minesoil is often compacted by the machinery used to transport and shape the various geologic materials. Additional compaction may be caused by equipment used to apply fertilizer and seed. The surface of the restored minesoil may be either a mix of topsoil and overburden materials or primarily topsoil or subsoil materials. Natural vegetation processes can seldom restore surface cover rapidly enough to prevent severe erosion from the compacted surface. The bulk densities of clay, clay loam, and silt loam agricultural soils normally range from 1.00 to as high as 1.6 g/cm^3. They may range from 1.20 to 1.80 g/cm^3 in sands and sandy loam agricultural soils (Brady 1974). This study was conducted to quantify the effects of compaction (1.6 to 2.0 g/cm^3) on establishment, growth, and yield of two species commonly planted on surface-mined areas. The effects of texture on the moisture-supplying capacity of minesoils and on root development patterns also were investigated.

The study showed that sericea lespedeza was difficult to establish on both minesoils at all levels of compaction, but fescue proved comparatively easy to establish. Results also indicate that compaction of a loam minesoil to a density of 2.0 g/cm^3 may not be detrimental to the growth and yield of fescue, but such compaction may drastically reduce the growth of sericea. Texture was found to affect the growth of fescue and sericea significantly. The finer textured minesoil yielded significantly more dry matter, averaged over all densities, than did the coarser textured one.

Methods

One heavy and one medium textured minesoil found in the coal fields of eastern Kentucky were used in the study. Neither minesoil had developed horizon differentiation at time of collection. They were texturally classified as a clay and a loam. The clay was collected from an orphan mine site in Owsley County, where soils had been mapped in the Tilsit soil series before mining began. The loam was collected from an orphan mine site in Jackson County. Before mining, soils on this site had been mapped in the Rigley series.

Minesoils from each site were sieved to separate the particles. These materials measuring 1.3 cm or smaller were saved and crushed to pass a No. 10 sieve; then each was blended to insure textural uniformity.

The minesoils were analyzed for physical and chemical properties (Table 1). Texture was determined by the pipette method (Day 1965). Organic carbon was determined by the Walkley Black procedure (Allison 1965). Potassium, magnesium, and calcium were determined using the North Carolina extractant and phosphorus was determined using the Bray P^1 extractant (Flannery and Markus 1971). Moisture retention characteristics were determined for the sieved minesoils (Figure 1). Fertilizer (15-30-15) was applied to each blended minesoil at a rate equivalent to 1,000 lb/acre furrow slice (6 inch depth). Reagent grade calcium carbonate ($CaCO_3$) was applied at a rate equivalent to 2 tons agricultural grade limestone per acre furrow slice (6 inch depth). The minesoils were wetted to approximately 0.33 bar equivalent suction, wrapped in polyethylene to prevent drying, and then allowed to equilibrate for a week.

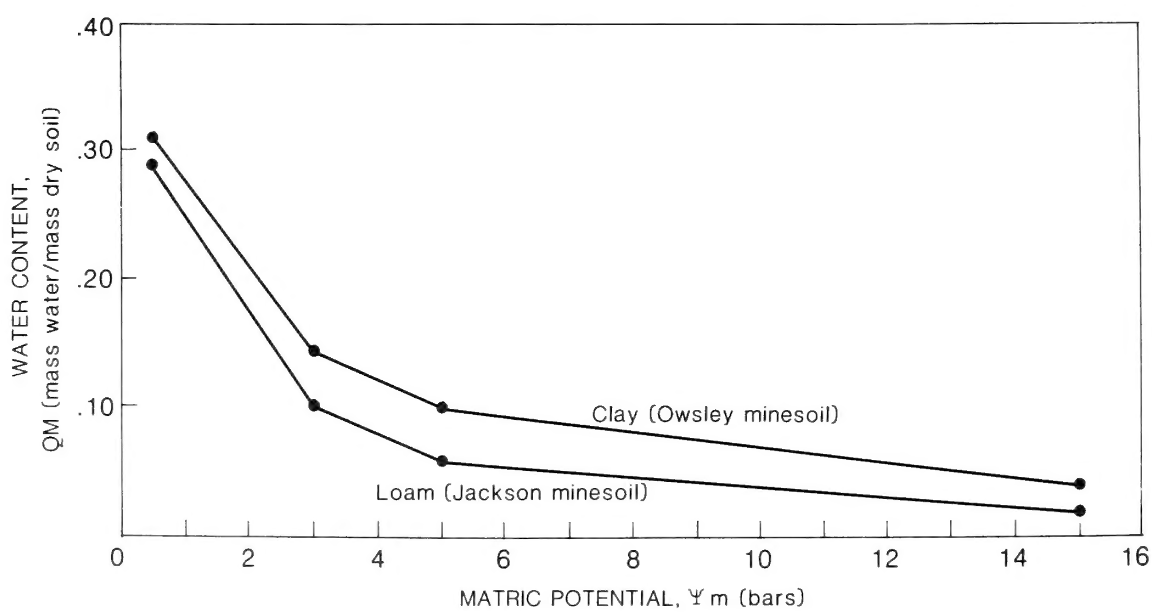
Table 1.—Initial minesoil characteristics

Item	Loam	Clay
Available nutrients		
	——ppm——	
Potassium	81.53	67.24
Magnesium	288.35	298.04
Calcium	395.57	207.31
Phosphorus	36.97	7.23
Texture		
	——percent——	
Sand	40.0	18.9
Silt	33.0	26.6
Clay	27.0	54.6
Other properties		
pH[a]	5.26	5.18
Organic matter (%)[b]	.52	1.45

[a] 1:1 Soil:water

[b] Determined by Walkley Black organic carbon x 1.724 (Van Bremmelin factor)

Figure 1.—Moisture retention curves.



While still moist, the minesoils were packed in plastic greenhouse pots that measured 16.5 cm in diameter at the bottom, 23 cm diameter at the top, and 23 cm tall. The minesoils were compacted in 1 cm increments to create columns of near uniform densities equivalent to 1.6, 1.8, and 2.0 g/cm^3, allowing for the moisture content ($\sim$.30 g water/g minesoil). After all the minesoils were compacted, approximately 100 milliliters of water were added to the columns each day for 3 consecutive days before seeding.

Kentucky 31 tall fescue (*Festuca arundinacea*, Selection Ky-31) and sericea lespedeza (*Lespedeza cuneata*) were selected for the study because these two species are commonly used in reclaiming surface mines. Prior to planting, seed of both species were tested to assure viability. Fifty seeds of each species were sowed on top of the compacted minesoil columns and covered with dampened filter paper to prevent desiccation.

The containers were placed on a greenhouse bench in a randomized complete block design with six treatment combinations (three density levels, two species) with three replications. After a seedling stand was established, pots were watered periodically to recharge the minesoil to near 0.33 bar suction. Plants were allowed to experience moderate moisture stress intermittently. Natural day length was extended by artificial light for about 4 hours at the end of each day during February, March, and April. Ambient air temperature and relative humidity were monitored for the duration of the study.

Fescue was readily established in all pots, but sericea lespedeza required several seedings to establish an adequate stand. Germination of sericea seed was adequate (50%) but seedling radicles did not make adequate growth to penetrate the minesoil surface. An adequate sericea stand was finally established in all containers by mid-March. Warmer spring temperatures and a more friable minesoil surface may have contributed to its eventual establishment. After they were well established, the fescue and sericea seedlings were thinned to 20 plants per pot. Fescue and sericea both were allowed to grow for approximately 180 days after thinning. The fescue was harvested in late July and sericea lespedeza was harvested in mid-October. The tops of both sericea and fescue were dried and weighed immediately after harvest. Root development could not be measured accurately because the minesoil was so compacted, but it was observed for general growth patterns.

Results and Discussion

Growth and yield data for fescue and sericea are shown in Table 2. Plant height of both species generally decreased with increased compaction. Height and growth of sericea were more adversely affected by increased compaction than was the growth of fescue. The yield data for the greenhouse pots were subjected to analysis of variance (Table 3). Treatments were considered to be factorial sets of density and species. A split plot with blocks nested in textural types was used to evaluate the data. Texture and compaction significantly influenced the final dry matter yield of both fescue and sericea. The interaction of texture and compaction also proved to be significant. With one exception, yield of both species decreased at the highest level of compaction (2.0 g/cm^3). Fescue yields on the loam increased with increased compaction (Table 2) even though plant height decreased. With the exception of sericea yield on loam, yields of both species increased at the first increase in compaction (1.6 g/cm^3 to 1.8 g/cm^3). Total dry mass production of both species was greater on clay than on loam (456.3 g vs. 381.2 g).

The moisture retention capability of the loam seemed to improve with increasing compaction to promote better growth of fescue. Increased growth at the highest density (2.0 g/cm^3) indicates that water and nutrients both were available for plant growth. The closely packed loam reduced the normal minesoil porosity and maintained moisture in a form readily available to fescue roots. This agrees with findings of Taylor and Box (1961) that an increase in available soil moisture went with an increase in compaction on a silt loam soil. Fescue yield decreased at the highest level of compaction on clay minesoil. Root development

Table 2.—Plant height and yield data

Species	Compaction	Plant Height[a]		Yield[b]	
		Loam	Clay	Loam	Clay
	g/cm^3	cm		g	
Sericea	1.6	73.5	78.4	51.65	50.74
Sericea	1.8	65.4	61.5	25.37	60.94
Sericea	2.0	21.3	27.1	16.12	23.44
Fescue	1.6	47.4	41.6	81.87	111.59
Fescue	1,8	46.9	39.6	92.01	114.63
Fescue	2.0	40.6	41.6	114.21	91.96

[a]Height is averaged among three replications. Measurements were taken immediately prior to harvest.

[b]Yield is total amount of oven-dry plant material at each compaction rate.

Table 3.—ANOVA table for plant yield

Source	DF	SS	MS	Observed F
Texture (T)	1	11,773.82	11,773.82	115.34*
Block in T (B)	4	408.34	102.08	
Treatment (R)	5	732.78	146.56	4.98*
TR	5	11,457.68	2,291.54	77.86*
BR in T	20	588.69	29.43	

*Significant at the .01 level

of fescue on both minesoils was largely confined to the upper 3 cm of the compacted column. The fescue roots seemingly were not able to fully exploit the clay minesoil at the highest compaction rate.

Sericea yields were reduced drastically at the highest rate of compaction on both minesoils. Sericea yields were greater on the clay than on the loam at 1.8 and 2.0 g/cm^3 compaction levels. The primary roots of sericea were found to extend the full length of the compacted column in both minesoils even at the highest density. At higher compaction rates sericea roots may have failed to branch sufficiently, causing water and nutrient deficits in the plants.

The results of this study suggest that the effects of compaction may vary with the texture of the reclaimed mine surface. The resistance of the minesoil matrix to root penetration is somewhat compensated for by the ability of clay to hold water and thus promote growth. Probably, the increased water holding potential of clay reduces the rate of water loss with increasing compaction. Also, mitigating factors such as selection of plant species assist in offsetting the effects of compaction. The compaction of the loam soil promoted the increased yield of fibrous shallow-rooted fescue. Moderate compaction may be desirable to reduce minesoil porosity and increase the volume water content of the coarser textured soils.

The results of greenhouse evaluations using containers should, of course, be applied with caution to field situations. Even though compaction may reduce or limit infiltration of water into the soil, water added to greenhouse containers will be retained on the soil surface until it can soak in or evaporate, thus supplying water to plants with very shallow root systems. If watered often enough, the plants will be adequately supplied, whereas under field conditions, water may not be retained on compacted soils. Fine-textured minesoils, when moderately compacted, are more subject than coarse-textured soils to the effects of runoff and erosion. However, moderate compaction of coarser textured minesoils may aid the establishment of vegetation.

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