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Hardwood Seedling Growth on Different Mine Spoil Types with and without Topsoil Amendment

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The goal of many owners of reclaimed mined land in the Appalachian region is to restore the diverse native hardwood forest for environmental, economic, and cultural reasons. However, native hardwoods often grow poorly on mined sites because they are planted in unsuitable spoils devoid of native topsoil. In a greenhouse experiment, we examined the suitability of four growth media available for use on many mined sites in the central Appalachians—forest topsoil (FT), weathered sandstone (WS), unweathered sandstone (US), and unweathered shale (UH)—as well as the effects of topsoil amendment (none vs. amended) on the growth of three native hardwood species: *Fraxinus americana*, *Quercus rubra*, and *Liriodendron tulipifera*. A 4 × 2 × 3 factorial greenhouse experiment was conducted with planted 1-yr-old seedlings. Tree growth, foliar nutrients, and soil properties were measured and characterized. The WS was the spoil most conducive to growth for *F. americana* and *Q. rubra*. *Liriodendron tulipifera* did not respond to any treatments. Tree growth was highly correlated with mineralizable soil nitrogen and extractable soil phosphorus. Topsoil amendment significantly increased growth on the UH but not on the US or WS. Topsoil amendment increased the number of native herbaceous plants growing in the pots and improved foliar nutrient content in *F. americana* and *L. tulipifera*. Many properties of the WS, such as pH, microbial activity, and water availability, more closely approximated the control soil than the US or UH. This study showed that trees are sensitive to spoil type and that certain spoil types that are conducive to good growth of native trees should be used during the reclamation process, particularly if forest topsoil is not applied. Forest topsoil amendment improved tree growth on some spoil materials, improved tree nutrition, and helped restore the native soil organisms and plants that were present before mining.

THE NATIVE HARDWOOD FOREST of Appalachia consists of a rich collection of vegetation that plays an essential role in the economy, aesthetics, environmental biodiversity, and culture of the Appalachian Mountains. Many of the late-successional hardwoods are valuable timber species that play an important role in the timber economy of the area, while other tree and herbaceous species are important for local crafts, medicines, specialty foods, and wildlife habitat (Duke, 1997; Jones and Lynch, 2002; Alexander et al., 2002). The mixed mesophytic forest in Kanawha County, West Virginia, from which mine spoils were taken for this study, consists of 15 major species, with another 22 species occurring occasionally in different regions (Braun, 1950). This forest is unique in its diversity and is an invaluable asset to the people of the region.

The mixed mesophytic forests are being eliminated over large areas by surface mining. Over 800,000 ha have been affected by strip mining in the Appalachian region since the implementation of SMCRA in 1977 (Office of Surface Mining, 2006). Since 1978, these areas have been commonly graded and hydroseeded with non-native herbaceous vegetation, reclaiming them to grassland. There has been a recent shift toward reforestation of reclaimed mined land using native species (Office of Surface Mining, 2006), but these reforestation efforts have not always been successful (Angel et al., 2005). Current reclamation practices for reforestation use a variety of spoil types for topsoil substitutes, grading to approximate original contour, planting with nonnative, common agricultural grasses and legumes, and planting a variety of tree species.

Most of the mid- to late-successional species that occur in the mixed mesophytic forest do not volunteer on compacted mined spoils with variable chemistry and fertility, and, if they are planted, do not grow well because they cannot tolerate raw mine spoil conditions (Angel, 2008).

During reclamation operations, the original soil is seldom applied to reclaimed mined sites in the central Appalachians, even though it is required in state and federal regulations unless a waiver is obtained. Coal operators usually obtain topsoil waivers because soils are often shallow and difficult to preserve on steep

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Abbreviations: ATP, adenosine triphosphate; FT, forest topsoil; UH, unweathered shale; US, unweathered sandstone; WS, weathered sandstone.