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Soil Texture and Bulk Density Affect Early Growth of White Oak Seedlings

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Recently germinated white oak seedlings were grown under three bulk densities and five soil textures. Root growth was significantly reduced at the highest bulk density. White oak regeneration from seed may therefore be hindered where sites are compacted from logging or other operations.

Abundant oak regeneration must be present in an understory if a future stand is to be predominantly oak (*3*). Beck (*2*) suggested a three-cut shelterwood may be effective in establishing such regeneration. However, more entries into a stand by logging equipment may increase soil compaction and thereby hinder root growth of young seedlings. When bulk densities exceed 1.55 grams per cubic centimeter in coarse soils or 1.75 grams per cubic centimeter in fine-textured soils, root penetration may be impeded (*12*). Shale and sandstone-derived soils common to upland hardwood forests of the Eastern United States tend to be droughty during portions of the growing season (*13*), making vigorous root growth vital for survival and growth of young hardwood seedlings.

In addition to bulk density, differences in soil texture can cause varying root growth patterns. For example, roots of fruit trees penetrated to a depth of 30 feet in coarse-textured soils but only 3 feet in high clay soils (*7*). The objectives of this study were to determine the effects of compaction and growing-medium texture on the early growth of white oak seedlings.

Materials and Methods

The A_1 horizon of a Calvin silt loam, a clayey, mixed, mesic, Typic Hapludult, was collected from a forested site in Montgomery County, Va., air dried and passed through a 2-millimeter screen. Fifty-five lengths of plastic PVC pipe (each 7.7 cm in diameter and 43 cm long) were plugged at one end to allow drainage, but prevent soil loss. These long containers were used as pots to allow ample room for taproot growth. The inside walls of all containers were swathed with an adhesive casting resin;[1] soil was added to the container and shaken so that a thin film of soil became "glued" to the inside walls. The containers were allowed to dry for 1 week to insure that the resin was completely dry and free of vapor. The walls were thus roughened to minimize taproot spiralling. Containers and soil were then randomly divided into two groups for the bulk density and soil texture experiments.

The desired bulk density was attained by repeatedly pouring a small amount of soil into a container, followed by tamping. When a container was filled, it was weighed and the bulk density calculated. This procedure was repeated until five replications (containers) were attained for each treatment level (1.0, 1.2, and 1.5 g/cm^3).

[1]Chemco, San Leandro, Calif.

Five soil texture treatments were administered across five replications (25 containers). The silt loam soil was mixed with coarse sand (0.5-1.0 mm) in various percentages (volume/volume): 100 soil/0 sand, 75 soil/25 sand, 50 soil/50 sand, 25 soil/75 sand, 0 soil /100 sand. In addition, a treatment with Pro-mix BX2 (60-percent peat, 20-percent vermiculite, and 20-percent perlite) as the growth medium was used.

White oak seeds were collected from several trees in Blacksburg, Montgomery County, Va., and composited to form a single seedlot. One white oak *(Quercus alba* L.) acorn was placed in each container; and in one replication, red oak *(Quercus rubra* L.) acorns were placed alongside the white oak acorns. The red oak acorns had been in cold storage for 1 year and were included to compare freshly germinated red and white (unstored) oak seeds. Seedlings were placed in a growth chamber with 15° C nights and 25° C days under a 12-hour daylength regime. Plants were watered to field capacity at intervals of 3 to 5 days.

Seedlings were harvested 40 days after planting. Soil was washed from root systems, and shoots were separated from roots at the root collar (just below the point of acorn attachment to epicotyl). The following measurements were taken: shoot height and dry weight (including stem, leaves, and acorn); taproot

[2]Bonar-Bennis Ltd., Canada.

length and dry weight; and primary and secondary lateral root number, length, and dry weight.

The bulk density experiment was a completely randomized design with three treatments and four replications. The soil texture experiment was of similar design, but with five treatments and four replications. An analysis of variance was used to test significance of treatments. Treatment means were compared and results are reported on the basis of least significant difference at the 0.05-probability level. The single replication containing red oaks was not used in the statistical analysis.

Results and Discussion

Root growth of white oak was significantly reduced at a bulk density of 1.5 grams per cubic centimeter (table 1). Similar reduced growth was also found with Sitka spruce *(Picea sitchensis* (Boug.) Carr), western hemlock *(Tsuga heterophylla* (Raf.) Sarg.), and western red cedar *(Thuja plicata* Donn) (*11*); Scots pine (*Pinus sylvestris* L.) (*5*); and yellow-poplar *(Liriodendron tulipifera* L.) (*9*). Root growth may therefore be adversely affected on intensively used recreation sites where bulk densities may increase to 1.5 grams per cubic centimeter or higher (*8*) and on forest sites subjected to heavy equipment traffic. Bulk density may increase by 35 percent because of tractor skidding (*4, 14*), with the greatest compaction resulting from the first few tractor passes (*1, 10*). Since more than two cutting operations may be necessary to successfully regenerate oak (2), site compaction may become a problem for establishment of young white oak seedlings as advanced regeneration and as postharvest regeneration. In addition, a bulk density of 1.5 grams per cubic centimeter significantly decreased the taproot length of white oak. Because early establishment of a long taproot is essential for drought tolerance (*6*), high bulk density is likely to lower white oak seedling tolerance to water stress. This would be critical on xeric sites typical of south and southwest

Table 1.—*Growth responses of container grown white oak seedlings at three bulk densities and five soil textures*[1]

	Root length			Root number[2]		Dry weight		Shoot height
Treatment	Tap	Prim.	Sec.	Prim.	Sec.	Root	Shoot	
Sulk density (g/cm^3)	- - - - - *Cm* - - - - -					- - - - *G* - - - -		*Cm*
1.0	20	88	18	47	4	0.5	1.4	10.6
1.2	22	133	29	57	1	.7	1.6	10.2
1.5	9	43	13	19	3	.4	1.7	9.4
Least significant difference (.05)[3]	8	58	NS	21	NS	NS	NS	NS
Growing medium (% v / v)								
100 silt loam soil 0 sand	20	88	18	47	4	.5	1.4	10.6
75 silt loam soil 25 sand	22	98	38	52	4	.6	1.7	11.3
50 silt loam soil 50 sand	20	133	66	57	1	.5	1.7	9.9
0 silt loam soil 100 sand	24	244	296	93	58	.7	1.4	9.2
Pro-mix	36	92	12	65	3	.6	1.4	9.9
Least significant difference (.05)	NS	95	NS	NS	40	NS	NS	NS

[1]Values are means tar four replications.

[2]Roots 0.5 centimeter or longer were counted.

[3]Differences between two means that exceed the least significant difference are significant, NS indicates treatment means do not differ significantly.

aspects in the central Appalachians and most upland soils of the Piedmont where fine-textured soils are prevalent.

Generally, with an increasing percentage of sand, root growth of white oak increased. The number of secondary and length of primary and secondary roots grown in 100-percent sand were significantly greater than those growing in other soil media (table 1). The large pores and low mechanical resistance in this sandy soil enabled rapid development of the large root system. Such large root systems allow plants to exploit greater soil volumes, which may be critical, since less moisture and fewer nutrients are available with decreasing amounts of silt and clay (*12*). Differences in root growth because of soil texture also have implications for root growth studies that use different types of soil media. Because of different growth responses, such as those observed in this study, the texture of the growing medium must be considered when conclusions and recommendations are made.

Red oak growing in Pro-mix had a larger number of roots per unit volume (intensive root system) than red oaks grown in soil mixtures (table 2). Also, white oaks growing in Pro-mix were found to have longer taproots than those growing in soil mixtures (table 1). This greater root growth may have resulted from greater total porosity, better aeration, and resultant ease of root penetration. Although results are based on only one replication, it would appear that additional work should be done with intensively rooted species such as red oak and yellow-poplar to more clearly understand root growth patterns that occur in an artificial growing medium such as Pro-mix. It is evident that large numbers or lengths of new roots in Pro-mix do not indicate similar growth in soil mixtures.

Red oak responses to treatments were similar to white oak. However, red oak had 20 times the number and 4 times the length of secondary roots. Such growth may be because of greater food reserves stored in the larger red oak acorn. This early establishment of a large root system could enable red oak seedlings to compete more effectively than white oaks and may partly account for the faster growth rate of red oak.

Table 2.—*Growth responses of container-grown red oak seedlings at three bulk densities and five soil textures*

Treatment	Root length			Root number[2]		Dry weight		Shoot height
	Tap	Prim.	Sec.	Prim.	Sec.	Root	Shoot	
Sulk density (g/cm^3)	- - - - - *Cm* - - - - -					- - - - *G* - - - -		*Cm*
1.0	24	189	238	63	47	1.1	3.6	19.5
1.2	23	212	54	49	19	1.0	4.6	20.3
1.5	18	193	65	27	24	.5	3.0	10.0
Growing medium (% v / v)								
100 silt loam soil 0 sand	24	189	238	63	47	1.1	3.6	19.5
75 silt loam soil 25 sand	18	366	518	66	215	.9	4.2	20.5
50 silt loam soil 50 sand	19	208	374	56	96	1.0	3.9	12.5
0 silt loam soil 100 sand	29	308	509	308	509	1.1	3.7	13.1
Pro-mix	22	455	951	58	429	1.2	1.8	18.2

[1]Values represent one tree per treatment.

[2] Roots 0.5 centimeter or longer were counted.

Summary and Conclusion

Compaction, which may result from several logging operations, such as in a three-cut shelterwood, may inhibit root growth of young white oak seedlings. Root growth of freshly germinated white oak seedlings was severely curtailed in silt loam soil that had a bulk density of 1.5 grams per cubic centimeter. The inability of roots to penetrate fine-textured soils that have been compacted can therefore reduce white oak establishment on upland hardwood sites. Root growth was also found to vary at different soil textures and was notably large with seedlings grown in 100-percent sand. The significance of the soil texture used in an experiment must then be considered, particularly where new root growth is used as an index of a seedling's physiological condition and its ability to survive outplanting.

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