The Effect of Soil Bulk Density on Nursery Sweetgum Seedling Growth

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A highly significant inverse relationship exists between soil bulk density and sweetgum seedling height growth. Best sweetgum seedling height growth occurred in nursery areas of low soil bulk density.

The success of a tree improvement or reforestation program depends on the production of quality tree seedlings. Although seedling size requirements vary from species to species and with planting conditions, a quality seedling must possess a functional root system that is in balance with the aboveground portion of the tree. In the Southeast, the demand for hardwood seedlings has been increasing. Union Camp Corporation, Franklin, Va., has established a hardwood nursery to meet this demand. Sweetgum (*Liquidambar styraciflua* L.) is one of several hardwood species produced.

The production of sweetgum seedlings of acceptable quality has not been consistent in the Union Camp Corporation Nursery (*3*). Seedling quality varies from year to year and within nursery fields. Several areas of the same field consistently produced inferior seedlings, characterized by small stocky stems with shallow, fibrous root systems.

The development of a root system depends on the genetic potential for root growth and form and the soil environment. The degree of soil compaction greatly influences root growth. A factor that limits the growth of one species may have little or no effect on another species. A significant species-by-soil-bulk-density interaction occurs among several northwestern conifers (*2*), some of which grow well and some of which grow poorly in compact soils.

The objective of this study was to determine the relationship between soil bulk density and sweetgum seedling growth in the Union Camp Nursery.

Materials and Methods

Four 37-square-meter plots were delineated in each of two nursery fields shortly after germination, but before the appearance of any seedling characteristics symptomatic of either good or poor growth. Of the four plots in each field, two were designated as good height growth areas and two as poor height growth areas, based on the patterns of previous sweetgum crops.

Dry soil bulk density (105° C) was obtained from a single core obtained at depths of 13, 26, 39, 52, and 65 centimeters. Soil cores were collected in July and November, using a Lutz bulk density sampler and an average bulk density value was determined for each depth sample. Bulk density values obtained in July were not significantly different from those obtained in November.

At the end of the growing season, all seedlings on a randomly selected 3.7-square-meter sublot of each plot were sampled to determine average seedling height.

Results and Discussion

Soil bulk density ranged from 1.43 to 2.04 grams per cubic centimeter (table 1). Bulk density varied between sites, between fields, and with soil depth. The variation in compaction found in the nurserybed soil is similar to the compaction patterns found in agricultural fields.

The best sweetgum seedling growth occurred on plots F1A and F2A (table 1), with an average height of 50 and 49 centimeters, respectively. Both plots have soil bulk densities below 1.7 grams per cubic centimeter in the first 39 centimeters of soil. All other sites exceed 1.8 grams per cubic centimeter either above or below the 39-centimeter depth. It is suggested by Zimmerman and Kardos (4) that soil bulk density values of 1.8 grams per cubic centimeter or greater hinder plant root growth. Part of the effect of high soil bulk density on root

Table 1.—*Nursery plot mean soil bulk density for each depth sampled and mean seedling height for each plot*

Plot[1]	Mean seedling height	Soil bulk density — Sampled depth 13.0 cm	26.0 cm	39.0 cm	52.0 cm	65.0 cm
	Cm	*G/cms*				
F1A	50.0	1.47	1.52	1.54	1.55	1.54
F1B	23.0	1.68	1.80	1.91	1.73	1.74
F2A	49.0	1.53	1.65	1.65	1.75	1.74
F2B	37.0	1.58	1.71	1.89	1.92	1.87
G1A	33.0	1.43	1.74	1.87	1.84	1.76
G1B	23.0	1.56	1.64	1.76	1.84	1.90
G2A	30.0	1.73	1.83	1.98	1.94	1.85
G2B	29.0	1.72	1.74	1.91	2.04	1.96

[1]F or G = field.
1 or 2 = location in field.
A = expected good seedling growth area.
B = expected poor seedling growth area.

growth is a result of mechanical impedance and low oxygen content.

We observed that the root systems of the seedlings growing on plots F1A and F1B appeared to develop a large taproot with numerous horizontal rootlets. Seedlings growing on all other sites had shallow, fibrous root systems, with either a small taproot or no taproot at all. In a study of loblolly pine (*Pinus taeda* L.) growing on highly compacted soils, lateral roots comprised a larger proportion of the total root system than those in less compact soils (1).

A highly significant inverse correlation was found between sweetgum seedling growth and soil bulk density at the 39-centimeter depth (table 2). A significant inverse correlation was also found between seedling growth and soil bulk density at the 26- and 52-centimeter depths.

Table 2.—*Correlation of height with soil bulk density occurring at various depths*[1]

Soil depth of sample (cm)	13.0	26.0	39.0	52.0	65.0
Seedling height/bulk density correlation	-0.54[ns]	-0.66*	-0.86**	-0.65*	-0.60[ns]

[1] Weighted average of eight samples of soil bulk density taken at each depth.
[2]** = significant at 1-percent level.
* = significant at 10-percent level.
ns = not significant.

Soil bulk density analyses revealed that field G was more compact than field F (table 1). In particular, plots G2A and G2B were nearly identical. The fact that average seedling height growth was poorer in field G and nearly identical in plots G2A and G2B strengthens proof of the relationship between soil bulk density and height growth.

Conclusion

For this nursery, an extremely compacted soil layer occurs at a depth from 26 to 52 centimeters. Sweetgum seedling growth is significantly correlated with soil bulk density in this zone. Seedlings growing on highly compacted plots are characterized by reduced height growth and shallow, fibrous root systems. The best seedling growth occurs on plots that have low soil bulk density and develop root systems with strong taproots and prolific lateral roots. Subsoiling is recommended to reduce soil compaction and improve drainage.

Literature Cited

1. Foil, R. R.; Ralston, C. W. The establishment and growth of loblolly pine seedlings on compacted soils. Proc. Soil Sci. Soc. Amer. 31: 565-568; 1967.
2. Minore, D.; Smith, C. E.; Wollard, R. F. Effects of high soil density on seedling root growth of seven northwestern tree species. Res. Note PNW-112. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1969.
3. Stone, J. M. Hardwood seedling production: What are the fertility requirements. In: Proceedings, North American forest tree nursery soils workshop. 1980. July 28-August 1; Syracuse, NY. Washington, DC: U.S. Department of Agriculture, Forest Service; 1980: 44-51.
4. Zimmerman, R. P.; Kardos, L. T. Effect of bulk density on root growth. Soil Sci. 91: 280-288, 1961.