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EFFECTS OF HIGH SOIL DENSITY ON SEEDLING ROOT GROWTH OF SEVEN NORTHWESTERN TREE SPECIES

by

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ABSTRACT

Seedlings of Douglas-fir, Sitka spruce, western hemlock, western redcedar, lodgepole pine, Pacific silver fir, and red alder were grown over soil columns compacted to bulk densities of 1.32, 1.45, and 1.59 grams per cubic centimeter. In 2 years, the roots of lodgepole pine, Douglas-fir, red alder, and Pacific silver fir penetrated soil columns that the roots of Sitka spruce, western hemlock, and western redcedar did not.

INTRODUCTION

Species differences in regard to the effects of high soil density on seedling root growth are compared here for seven Northwestern tree species: Douglas-fir *(Pseudotsuga menziesii)*, Sitka spruce *(Picea sitchensis)*, western hemlock *(Tsuga heterophylla)*, western redcedar *(Thuja plicata)*, lodgepole pine *(Pinus contorta)*, Pacific silver fir *(Abies amabilis)*, and red alder *(Alnus rubra)*.

Forristall and Gessel (1955),[1/] working in Snohomish County, Washington, concluded that western redcedar roots could grow in a soil bulk density of approximately 1.8 grams per cubic centimeter, and red alder root growth was stopped by a density of approximately 1.5. However, the soil density above which roots do not penetrate varies

[1/] Forristall, Floyd F., and Gessel, S. P. Soil properties related to forest cover type and productivity on the Lee Forest, Snohomish County, Washington. Soil Sci. Soc. Amer. Proc. 19: 384-389. 1955.

with soil texture (Veihmeyer and Hendrickson 1948),[2] and a given bulk density in fine-textured soil limits root growth more than the same density in coarse soil (Lull 1959;[3] Raney *et al.* 1955[4]). Therefore, limiting bulk density values like those given by Forristall and Gessel probably are valid only for the soils in which they were measured.

Youngberg (1959)[5] measured bulk densities of 1.5 to 1.7 on tractor roads where densities in adjacent cutover areas were only 0.87 to 0.98 grams per cubic centimeter. He recorded highly significant differences in height growth of Douglas-fir seedlings planted on and off the roads but did not measure root growth.

MATERIALS AND METHODS

A sandy loam soil (52 percent sand, 31 percent silt, 17 percent clay) was screened, blended, and compacted to three bulk densities in 37-centimeter lengths of plastic sewer pipe 10 centimeters in diameter. A Carver hydraulic press (fig. 1) and small, equal increments of air-dry soil were used to construct a compacted column 30 centimeters deep in each pipe length. The soil in each column was weighed, and weights were converted to an ovendry basis. Pressures of 34.6, 8.0, and 3.5 kilograms per square centimeter were applied to obtain bulk densities of 1.59, 1.45, and 1.32 grams per cubic centimeter. A perforated plastic tile was cemented to the lower end of each pipe section to create a cylindrical pot. Equal amounts of a 4-to-1 mixture of soil and peat moss were then added to each pot above the compacted soil column, forming a loose top layer 6 centimeters deep.

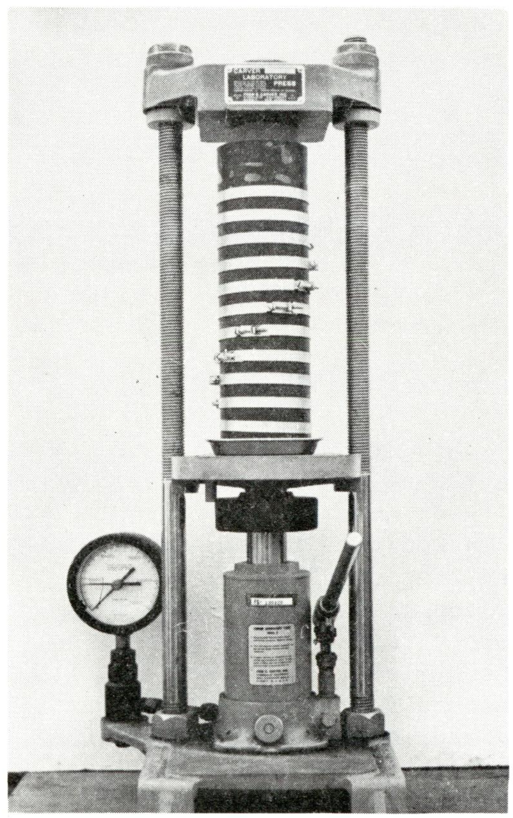

Figure 1.--Carver hydraulic press. A close-fitting wooden cylinder (not shown) compacted soil within the plastic pipe section. Metal rings prevented pipe splitting during compaction.

[2] Veihmeyer, F. J., and Hendrickson, A. H. Soil density and root penetration. Soil Sci. 65: 487-493. 1948.

[3] Lull, H. W. Soil compaction on forest and range lands. U.S. Dep. Agr. Misc. Pub. 768, 33 pp. 1959.

[4] Raney, W. A., Edminster, T. W., and Allaway, W. H. Current status of research in soil compaction. Soil Sci. Soc. Amer. Proc. 19: 423-428. 1955.

[5] Youngberg, C. T. The influence of soil conditions, following tractor logging, on the growth of planted Douglas-fir seedlings. Soil Sci. Soc. Amer. Proc. 23: 76-78. 1959.

Seeds from low-elevation, coastal sources were used. Seeds were stratified and germinated in petri dishes, then planted in the loose layer of top soil in May 1967. Seven seedlings of the same species were planted in each pot, and each species-soil density combination was replicated four times. Species and bulk density treatments were completely randomized on a greenhouse bench. Summer temperatures in the greenhouse varied from 16° to 32° C. Each of the 84 pots was weighed and watered three times each week to bring the soil to 1 atmosphere of soil moisture tension--determined on the Richardson pressure membrane apparatus. During 1967, the amounts of water added were computed on a soil weight basis. During 1968, they were computed on a soil volume basis similar to that used by Flocker and Nielsen (1961).[6/] All pots were fertilized with equal amounts of nutrient solution[7/] at 2- to 3-week intervals throughout the growing seasons of 1967 and 1968.

Seedlings were thinned to four per pot in August 1967. Pots and seedlings were chilled at 0° to 5° C. for 10 weeks during the winter of 1967-68. Seedlings were thinned to two per pot in March 1968, and a final thinning in April 1968 left one seedling in each pot. Overwintering mortality and a watering accident reduced the experiment to three replications in 1968.

The pots were broken in September 1968 and rooting depths measured in each soil column. Many roots were found wedged between the pot wall and the compacted soil column (fig. 2). The depths of these roots were measured in addition to the depths of roots which actually penetrated the column itself. Roots were carefully washed free of soil. Roots and shoots were then oven-dried at 65° C. for 48 hours and weighed. All measurements were subjected to factorial analyses of variance.

RESULTS

Average seedling weights and root depths are listed in table 1. Inherent growth differences between species resulted in significant weight differences regardless of bulk density treatment (red alder was always heavier than western hemlock, for example), but significant species X density interactions occurred. When weights were analyzed separately for each species, only western redcedar weights differed significantly between soil density treatments.

Total western redcedar seedling weights in the 1.32- and 1.45-gram-density treatments were significantly heavier than those in the 1.59. Redcedar shoot and root weights in the 1.32-density treatment were also heavier than those in the 1.59-density treatment.

[6/] Flocker, W. J., and Nielsen, D. R. Relationship between soil moisture and airspace associated with levels of bulk density that influence growth of tomatoes. Seventh Int. Congr. Soil Sci. Trans. (1960)1: 347-353. 1961.

[7/] 1.6 g. $Ca(NO_3)_2$, 1.0 g. KNO_3, 0.5 g. $MgSO_4$, and 0.3 g. KH_2PO_4 per liter H_2O.

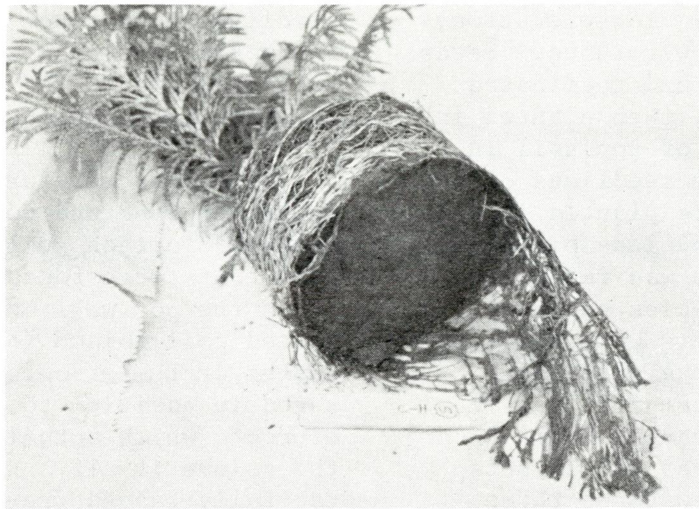

Figure 2.--Western redcedar roots did not penetrate a soil density of 1.59 grams per cubic centimeter. Note root growth around the edge of the compacted soil core, absence of roots in the core itself (which has been almost entirely removed), and the concentration of roots in the loose upper soil layer.

As the root depths recorded in table 1 indicate, the roots of all seven species grew through the 1.32-density soil cores all the way to the pot bottoms. The roots of western redcedar, Sitka spruce, and western hemlock did not penetrate 1.45-density cores, but roots of red alder, lodgepole pine, and Douglas-fir grew entirely through them. No roots penetrated the 1.59-density cores. The maximum root depths recorded in table 1 resulted from root growth between soil cores and pot walls in the 1.59-density treatment.

DISCUSSION

Plastic pots and soil cores expanded and contracted differently, producing a narrow space between each soil core and pot wall. This space should be considered when the data listed in table 1 are interpreted.

Roots near the pot walls were able to grow down the space between pot wall and soil core (fig. 2). Nutrient solution added periodically during the growing season probably flowed through this space faster than it flowed through the soil core itself, and roots growing in this space may have received more nutrients than roots growing within the core.

If the above hypothesis is correct, the total seedling weights, shoot weights, root weights, and maximum root depths listed in table 1 were influenced by differences in nutrient availability. They should not be relied upon to compare species growth in high soil densities. We are left with the root depths within compacted soil cores.

Table 1.--*Average weights and root depths of seedlings grown in three soil densities, by species, with standard errors (sandy loam, artificially compacted soil, in greenhouse)*

Soil density[1/] and species	Total weight	Shoot weight	Root weight	Maximum root depth[2/]	Root depth within soil core
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1.32 density:					
Red alder	97.28 (±6.18)	38.46 (±1.64)	58.82 (±6.74)	36.0 (±0)	36.0 (±0)
Western redcedar	23.94 (±.18)	12.98 (±.69)	10.95 (±.52)	36.0 (±0)	36.0 (±0)
Lodgepole pine	12.50 (±1.18)	6.18 (±.89)	6.32 (±.41)	36.0 (±0)	36.0 (±0)
Douglas-fir	11.65 (±1.18)	6.17 (±.68)	5.48 (±.52)	36.0 (±0)	36.0 (±0)
Sitka spruce	5.36 (±2.04)	3.21 (±1.18)	2.15 (±.88)	36.0 (±0)	36.0 (±0)
Pacific silver fir	1.50 (±.26)	.77 (±.18)	.71 (±.10)	36.0 (±0)	36.0 (±0)
Western hemlock	.72 (±.08)	.42 (±.07)	.30 (±.04)	35.7 (±.3)	26.0 (±10.0)
1.45 density:					
Red alder	72.72 (±2.40)	27.17 (±3.18)	45.54 (±.97)	31.3 (±4.7)	31.3 (±4.7)
Western redcedar	20.45 (±1.54)	10.82 (±.59)	9.63 (±1.82)	36.0 (±0)	6.0 (±0)
Lodgepole pine	16.37 (±1.39)	6.83 (±.43)	9.54 (±1.09)	36.0 (±0)	36.0 (±0)
Douglas-fir	8.33 (±1.03)	3.50 (±.41)	4.83 (±.65)	36.0 (±0)	36.0 (±0)
Sitka spruce	6.17 (±.79)	3.53 (±.38)	2.64 (±.41)	36.0 (±0)	6.0 (±0)
Pacific silver fir	1.39 (±.12)	.74 (±.12)	.65 (±.01)	16.0 (±4.9)	9.7 (±3.7)
Western hemlock	3.21 (±.74)	1.96 (±.57)	1.25 (±.20)	14.3 (±2.3)	6.0 (±0)
1.59 density:					
Red alder	78.02 (±4.44)	34.11 (±2.88)	43.91 (±2.38)	36.0 (±0)	6.0 (±0)
Western redcedar	14.26 (±.41)	8.15 (±.38)	6.11 (±.10)	16.3 (±3.7)	6.0 (±0)
Lodgepole pine	9.44 (±1.14)	4.12 (±.48)	5.32 (±.65)	29.3 (±6.7)	6.0 (±0)
Douglas-fir	5.78 (±.70)	2.58 (±.27)	3.19 (±.44)	26.3 (±4.9)	6.0 (±0)
Sitka spruce	11.23 (±1.85)	6.77 (±1.15)	4.46 (±.73)	26.3 (±4.9)	6.0 (±0)
Pacific silver fir	1.57 (±.35)	.86 (±.25)	.71 (±.05)	12.7 (±2.3)	6.0 (±0)
Western hemlock	1.80 (±.56)	.70 (±.17)	1.10 (±.39)	13.3 (±1.8)	6.0 (±0)

[1/] In grams per cubic centimeter.

[2/] Includes roots growing between soil core and pot wall.

Root depths within compacted soil cores clearly indicate that the roots of some species are able to grow in moderately high soil densities where the roots of other species cannot grow. Absolute soil densities that are associated with measured root growth in greenhouse pots may or may not be associated with the same root growth in the field, even if soils of similar texture are compared--climatic conditions in greenhouse and field are different. The absolute soil density values listed here therefore are not useful in themselves. However, relative differences between the root growth of different species in the same high density soil are useful--these relative differences should be applicable in the field regardless of the absolute soil densities or textures involved.

Lodgepole pine, Douglas-fir, and red alder roots can grow in soil densities that prohibit the growth of Sitka spruce, western hemlock, and western redcedar roots. Pacific silver fir ranks between the above species groups in respect to root penetration of high soil densities.