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DROUGHT RESISTANCE OF LODGEPOLE PINE SEEDLINGS IN RELATION TO PROVENANCE AND TREE WATER POTENTIAL

by

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Abstract

Drought resistance during and following moisture stress was evaluated for two-year-old lodgepole pine variants from diverse origin. Shoot height, root volume, fresh weight and survival scores varied among provenances and tree water potentials which indicates that differences exist in drought resistance of variants within lodgepole pine. Further studies of physiological and anatomical variation in relation to genetic and environmental factors will help to explain the variation in lodgepole pine.

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Introduction

The diverse range of climatic conditions in which lodgepole pine (*Pinus contorta* Dougl.) grows may provide, through selection, a difference in drought resistance among provenances. It is known that there are marked differences in morphology and growth among lodgepole pine provenances (Critchfield, 1957). Ferrell and Woodward (1966) and Pharis and Ferrell (1966) found significant differences in drought resistance of Douglas fir seedlings from diverse origins.

Transplanted lodgepole pine nursery stock may be subjected to moisture stress on certain sites and during certain times in the growing season. Because moisture stress may reduce growth and survival, the selection of drought resistant provenances may be an aid on sites where water is a limiting factor.

Growth potential of trees during and following water stress has been little studied. Most often drought resistance has been studied in a restricted sense, in that recovery and growth after water stress has not been emphasized. The objective of this study was to compare the relative drought resistance and growth of lodgepole pine seedlings in relation to provenances of diverse origin and tree water potential. In this investigation, the emphasis is on growth potential following and during moisture stress, therefore the term drought resistance is used in a broad sense as defined by Levitt (1964).

Materials and Methods

The provenances used in this study are shown in Table 1.

Table 1 Lodgepole pine provenances

Form [1]	Provenance No. [2]	Provenance Name	Latitude °N	Longitude °W	Elevation ft.
contorta	94	Sitka	57 04	135 21	100
murrayana	158	Yosemite	37 51	119 40	7900
latifolia	55	Telkwa High	54 38	127 26	3300
latifolia	22	Telkwa Low	54 39	127 03	1700
latifolia	15	Esperon Lake	50 03	119 39	3500
latifolia	39	Redwillow R.	54 56	120 15	3130

1. According to Critchfield's regional forms (1957).
2. B.C. Forest Service, Research Division provenance numbers.

This greenhouse experiment was conducted in two studies because moisture stress treatments were imposed by two different methods. The seedlings were grown under natural daylength at a temperature of approximately 72°F.

Study I - Hopkins (1971) used potted tree seedlings to demonstrate significant differences in drought avoidance and drought tolerance between species, and established a basic approach for studies of drought resistance in forest trees. Hopkins method, slightly modified, is used in this study.

Five 2-0 seedlings were planted in each pot. After the trees had become established, sunflower seeds were sown in each pot and two sunflower seedlings were allowed to grow to a height of six inches. The potting soil was then allowed to dry until the soil reached the permanent wilting point as determined by the permanent wilting of the sunflower seedlings. This provides a fairly sensitive and effective method of drying all treatment units to a common water potential.

The following treatments were then imposed: (1) control, watered daily, (2) permanent wilting (PW) of sunflowers and rewatering, (3) PW + 45 ml H_2O evaporation, (4) PW + 90 ml, (5) PW + 135 ml, (6) PW + 180 ml. The drying treatment was measured in terms of H_2O evaporation from black Bellani plates. Eight days were required to reach PW + 180 ml of H_2O evaporation.

Before rewatering, a seedling was taken from each pot and the tree water potential determined with a pressure bomb (Waring and Cleary, 1967). The height of the four remaining trees was measured, the pots were rewatered and the seedlings were allowed to recover for two months. At the end of the two month period, survival scores were determined on the following basis: 5 points - tree healthy, 4 points - slight needle damage, 3 points - dead tip, 2 points - dead tip plus needle damage, 1 point - tree dead. Hopkins (1971) found that the survival scores, although subjective, were of sound precision when assessed by several different persons and that information is lost if some type of scoring is not used.

Six replications were used per treatment combination.

Study II. - In the second study, the tree water potential was maintained at a given level throughout the duration of the study. The root volume, shoot height and fresh weight of the seedlings were measured before planting. Root volume was measured by the volume of displaced water. Plastic bags were placed around the pots and tied tightly around the stem of the tree. The soil was allowed to dry out until the desired percentage water content was attained. The pots were weighed daily and brought up to treatment weight by the addition of water to the soil.

It is recognized that the addition of water to the top of a soil does not bring the entire soil to a given water percentage. However, in a preliminary study, it was found that a given tree water potential could be maintained by this method if temperature and irradiance did not vary. Moisture treatments were imposed for two months and then root volume, shoot height, and fresh and dry weights were measured. Six replications were used per treatment combination.

A linear function was used to relate shoot height to water potential. A hyperbolic function of the form $Y = B_0 + B_1 X_1 + B_2 1/X_1$ was used to relate root volume and fresh weight growth to water potential. Survival scores were related to tree water potential by a function of the form $Y = B_0 + B_1 X_1 + B_2 X_1^2$. Covariance analysis was used to test the homogeneity of regression coefficients. The correlation coefficients and standard errors of estimate for regression are in table 1 of the appendix.

Results

Study 1 - Tree water potential decreased from approximately -2 to -27 bars in relation to soil water treatment. Shoot height growth (Fig. 1) and survival scores (Fig. 2) decreased significantly in relation to decreased tree water potential. Seedlings from provenance 158 had the highest survival score at all tree water potential values. The survival scores at approximately -25 bars are significantly different among all provenances except 22 and 94 which are not different at any tree water potential. Shoot height growth was significantly different among all provenances at all tree water potentials.

Study 2 - The moisture stress imposed in this study was not as severe as that in study I. Tree water potentials ranged from -2 to -15.5 bars in relation to soil water treatment. The relationship of shoot height growth among provenances and tree water potentials was similar to that in study I and is therefore not presented here. Root volume growth (Fig. 3) and fresh weight growth (Fig. 4) varied significantly in relation to provenance and tree water potential. Seedlings from provenance 158 decreased the least in root volume and fresh weight growth with decreased tree water potential. Seedlings from provenance 15, 22 and 94 made the greatest root volume and fresh weight growth at -2 bars, but decreased the most with decreasing tree water potential. Seedlings from provenance 39 and 55 decreased at an intermediate rate in root volume and fresh weight growth with decreasing tree water potential. Only seedlings from provenance 158 were able to grow at -15 bars. Seedlings from all other provenances ceased root volume and fresh weight growth at tree water potentials ranging from -10 to -15 bars.

Discussion

Growth, distribution of assimilate and survival scores of two-year-old lodgepole pine seedlings vary among provenances ranging from Alaska to California. In this study the provenances can be delineated into three groups according to seedling response in relation to tree water potential. The groups are, by provenance: (1) 158, (2) 39 and 55, and (3) 15, 22 and 94.

Seedlings from provenance 158 were the most drought resistant. The ability to grow at -15 bars of tree water potential is perhaps an adaptive mechanism of ecological importance where physiological dryness and shorter growing seasons are common.

Provenances 39 and 55 are from approximately the same latitude and elevation and demonstrated a similar growth and survival response. The close relationship among provenances 15, 22 and 94 cannot be explained on the basis of latitude or elevation.

Pharis and Ferrell (1966) found that Douglas fir seedlings from inland sources were consistently more drought resistant than Pacific coast sources. This study shows that some inland lodgepole pine variants have a genetic potential for drought resistance similar to that of coastal variant 94. The extent of genetic variation in drought resistance of lodgepole pine in relation to provenance is similar to that demonstrated by growth, photoperiodic response (Jensen and Gatherum, 1965) and physiological processes (Dykstra and Gatherum, 1967) of Scotch pine from diverse origin.

Growth, distribution of assimilate and survival scores vary with tree water potential. Shoot height, root volume and fresh weight growth decreased continuously when tree water potential was decreased from -2 to -15 bars. At -15 bars seedling growth of all provenances except 158 had ceased and all provenances had suffered needle damage.

Water stress can reduce growth directly by reducing photosynthesis, translocation and turgor. Hodges (1967) found that photosynthesis in Douglas fir was correlated with changes in leaf water potential. Brix (1962) showed that loblolly pine had zero rates of photosynthesis at -12 bars of potential. Rutter and Sands (1958) found a large decline in the transpiration rate of Scotch pine seedlings at a soil matrix potential of -1 to -2 bars. Water stress may also have indirect effects on growth. Kaufmann (1968), working with loblolly and white pine, found that root tips matured and became dormant with repeated periods of stress or after single periods of severe stress.

Physiological processes, growth and survival will undoubtedly vary with the manner in which water stress treatments are imposed. The use of potted seedlings will prevent natural root ramification which is an important factor in drought avoidance. Therefore, differences in drought resistance can only be compared on a relative basis.

In this greenhouse study, the marked variation in growth, distribution of assimilate and survival among provenances and tree water potentials indicates that differences exist in drought resistance of variants within lodgepole pine. Therefore, studies of physiological and anatomical variation in relation to genetic and environmental factors will help to explain the variation in lodgepole pine.

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APPENDIX

Table 1 Correlation coefficients and standard errors of estimate for regression lines.

	Shoot Height		Survival score		Root volume		Fresh weight	
Provenance	r	S.E.	r	S.E.	r	S.E.	r	S.E.
15	.98	.71	.96	.52	.98	2.00	.99	2.30
22	.99	.67	.95	.48	.99	1.51	.99	.87
39	.99	.83	.96	.39	.99	.82	.99	.52
55	.99	.79	.94	.47	.98	1.19	.99	.54
94	.98	.92	.96	.44	.98	1.65	.98	2.03
158	.99	.66	.97	.37	.98	.72	.96	.64

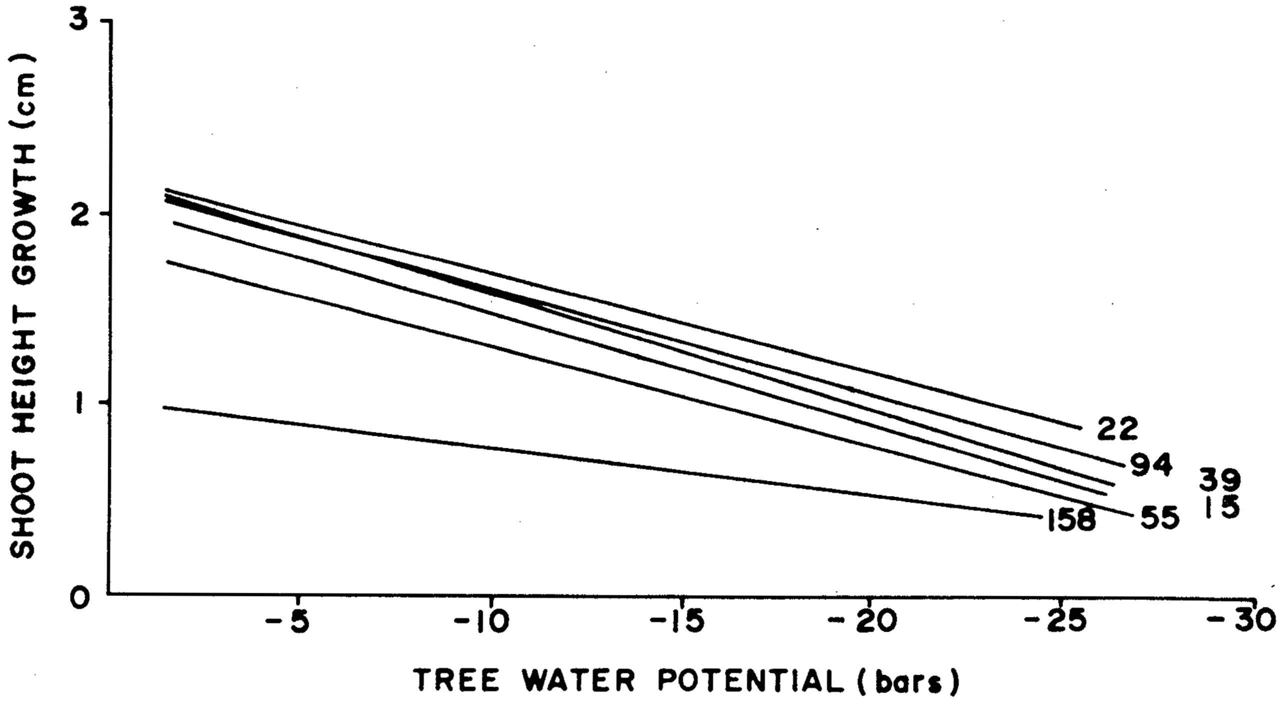

Figure 1. Shoot height growth of lodgepole pine seedlings in relation to provenance and tree water potential.

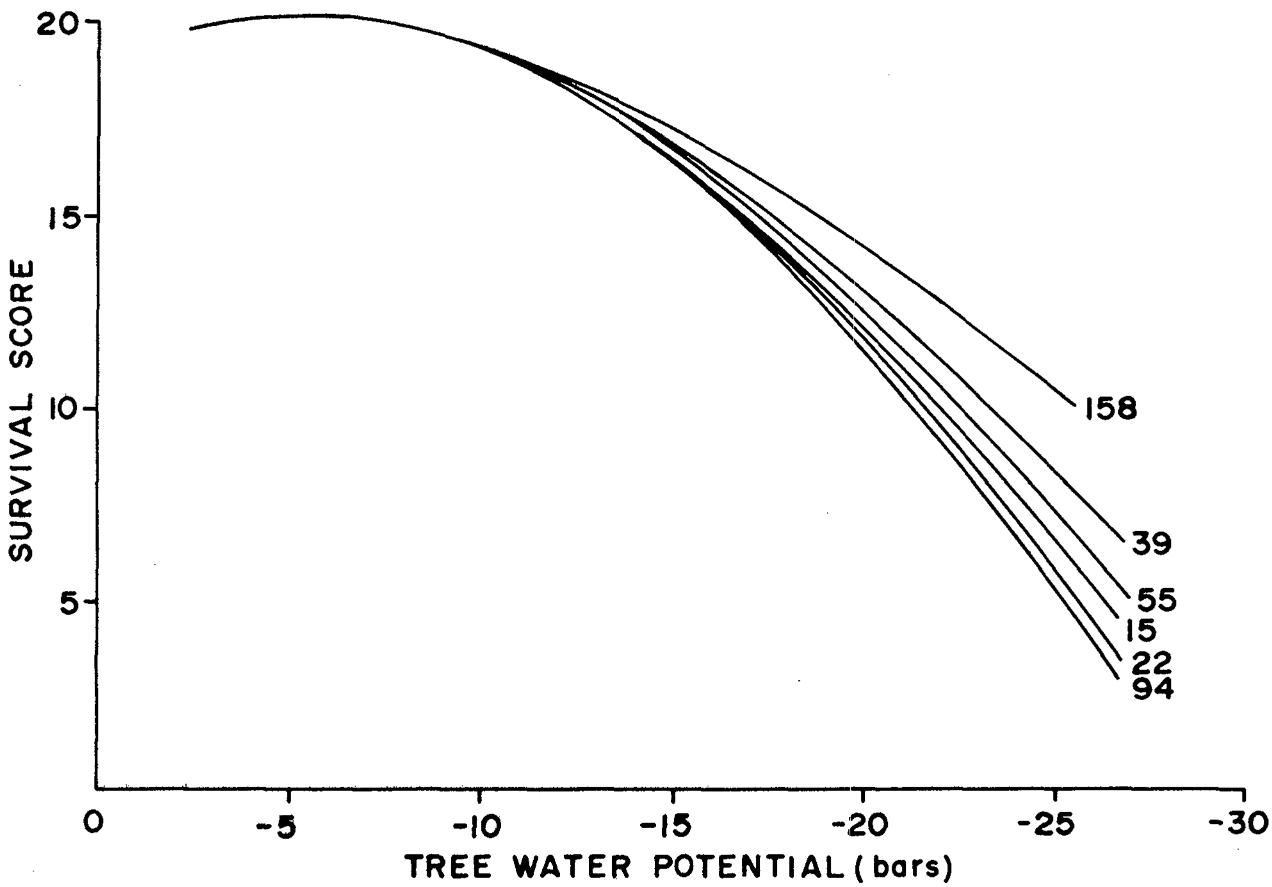

Figure 2. Survival scores of lodgepole pine seedlings in relation to provenance and tree water potential.

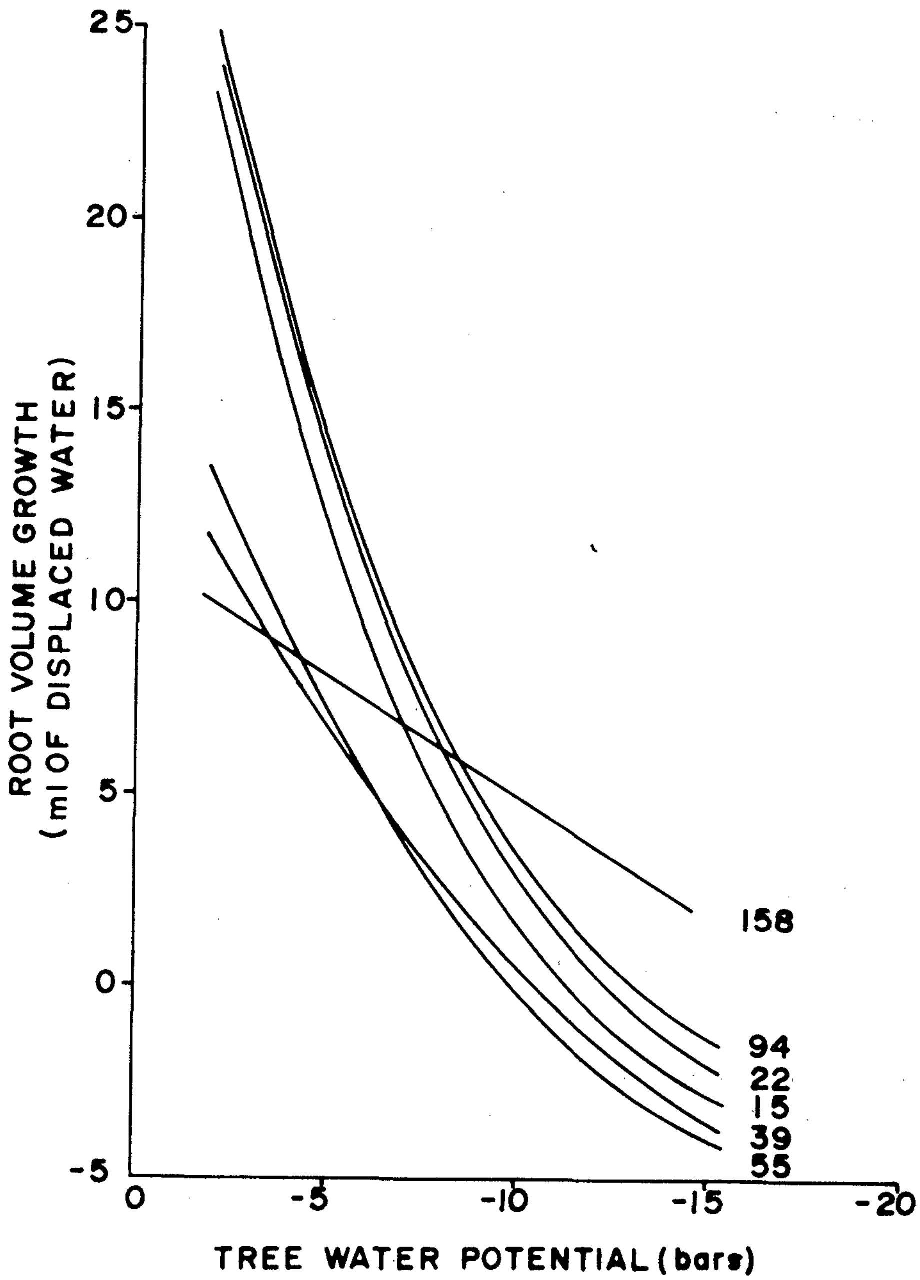

Figure 3. Root volume growth of lodgepole pine seedlings in relation to provenance and tree water potential.

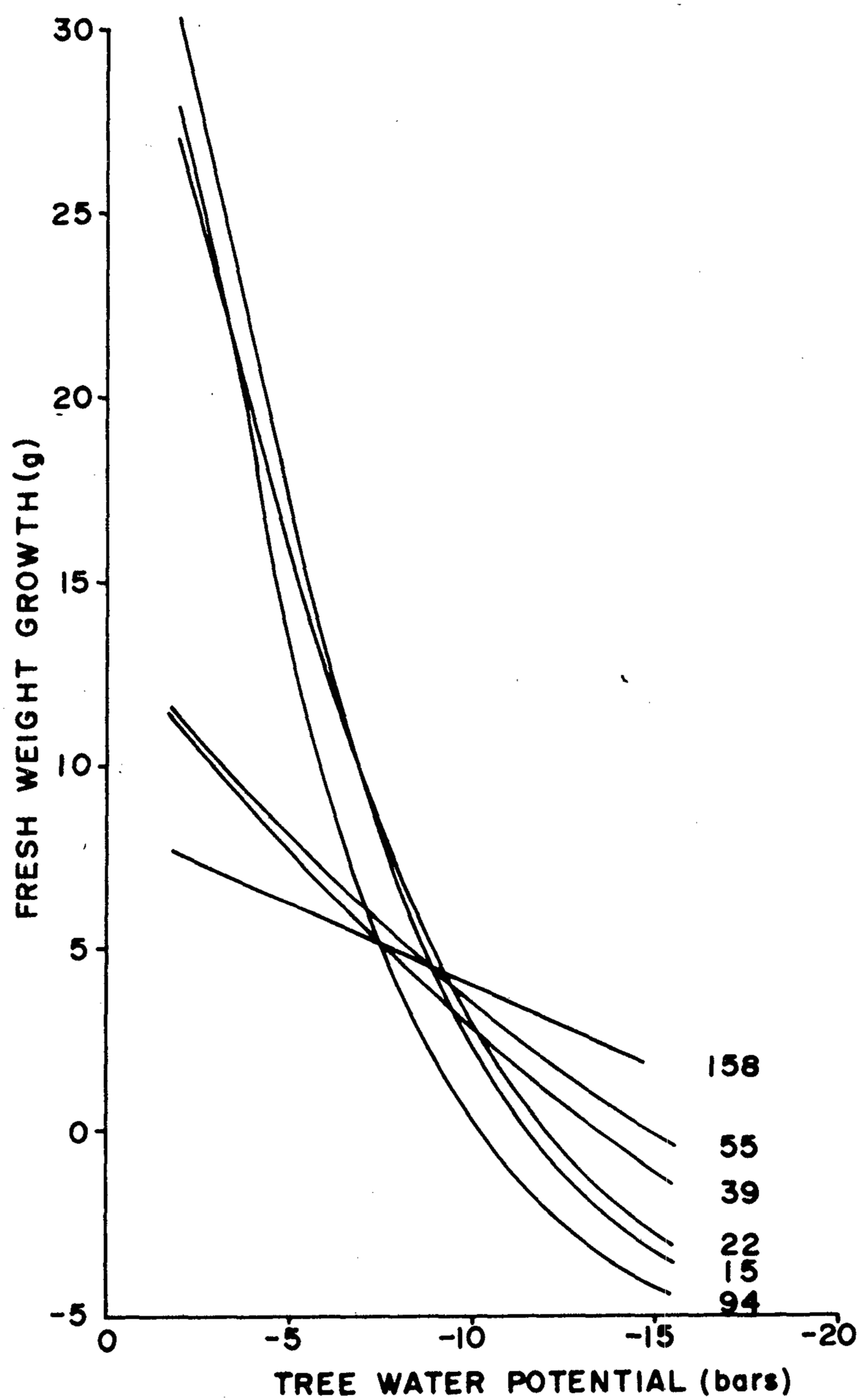

Figure 4. Fresh weight growth of lodgepole pine seedlings in relation to provenance and tree water potential.