OPTIMAL SITES FOR CONIFERS IN THE BOREAL FOREST REGION OF ALBERTA

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The study reported in this paper deals with the effects of soil moisture, soil texture and vegetative competition on survival and growth of four coniferous species common to the Boreal Forest Region of Alberta. Tree seedlings were planted in soil boxes, two of sandy loam and two of silty clay soil. Each soil box was split into five zones running perpendicular to the moisture gradient which ranged from poorly to rapidly drained. Measurements were made and data analyzed for species survival, height growth, diameter growth and total root length. Based on survival and height growth, tamarack preferred an imperfectly drained, nonvegetated silty clay soil while lodgepole pine preferred a non-vegetated sandy loam soil with no apparent moisture preference. Black spruce preferred a poorly to imperfectly drained, non-vegetated silty clay soil while white spruce preferred an imperfectly to moderately well-drained, non-vegetated silty clay soil.

INTRODUCTION

Forest managers in Alberta have, presumably for economic reasons, re-established the same tree species on harvested areas without considering the ecological niche requirements of such species. The rationale for this approach is that managers are aware that native cover is well adapted to the site. Whether a foreign species is adapted to the same site is not always certain.

Uniform reforestation treatments are normally applied to entire cutblocks. This minimizes the initial costs of regeneration operations but may lead to later re-treatment costs for fail areas because even small cutblocks may vary in site potential. Rarely can the entire area of a clearcut be considered to have no variation in physical properties such as relief, soil and drainage. Poorly regenerated parts of cutblocks must then be replanted to obtain the proper stocking, thus commonly increasing the cost for reforestation.

Each site should be treated specifically to create a suitable environment for seedlings, and the choice of species should also be varied by site in order to maximize forest yield.

The purpose of this study was to examine the performance of tree species on two different soil textures, on a moisture sequence, and under competitive pressure to determine if generalized statements can be made regarding specific/site preferences.

The four species — tamarack, lodgepole pine, black spruce, and white spruce — are representative of the Boreal Forest Region and were selected because of their economic importance to Alberta (Rowe 1972).

Table I is a compilation of information about the responses of the four species to the various environmental factors considered in the experiment. The empty spaces imply lacking information.

The analysis of the effects of soil texture, soil moisture, and vegetative competition on seedling survival and growth was based on a controlled experiment where the effects of other environmental factors could be minimized. The soil moisture sequence developed in the soil boxes of this experiment (McLeod 1977) are identical to those used by other authors for similar studies (Hewlett 1961; Mueller-Dombois 1963; Cook 1972).

METHODS AND MATERIALS

White spruce and lodgepole pine were grown for 2 yr in Spencer-Lemaire Rootrainers at the provincial government tree nursery at Oliver near Edmonton, Alberta. The seedlings of tamarack and black spruce were 1 yr old at the inception of the experiment.

Textural classes of soils used were obtained from the lower river terrace (sandy loam) and the broad upper terrace (silty clay) of the Athabasca River Valley near Blue Ridge, Alberta. The A and B horizons were mixed, as these horizons are commonly mixed in the field during scarification. Native roots, contained within each soil sample, were not removed.

Rectangular soil boxes with level bottoms and sloping surfaces (1500 mm at one end tapering to 300 mm at the other) were constructed (Fig. 1). A standpipe was attached inside each box to feed tapwater to the bottom, thereby simulating ground-water flow. The water table was controlled at the low end through a tap 15 mm above the bottom of the box.

The boxes were first filled with roofing gravel to a depth of 100 mm. Then a 30-mm layer of coarse sand was added, and the boxes were topped up with the appropriate air-dried soil. Two of the four boxes were filled with the silty clay soil and two with the sandy loam soil. A bulk density of 1.1 g/cm^3 was obtained on both soils.

The surface of each box was divided into five equal sections perpendicular to the slope (Fig. 1). The depth to the water table, measured from the soil surface, ranged from 480 mm at the midpoint of zone 5 (top end) to 0 mm at the midpoint of zone 1 (bottom end of the box). Zone 5 was considered to be rapidly drained, zone 4 was well-drained, zone 3 was moderately well-drained, zone 2 was imperfectly drained, and zone 1 was poorly drained. The water table level was kept constant but water was allowed to flow through the box and out through the tap placed in the lower wall of each box.

Artificial watering of the slope to simulate natural rainfall was carried out by means of an irrigation pipe which enabled a controlled flow of water to be applied along the slope. The rainfall distribution from 1 May to 1 Sept., 1972 for Hinton, Alberta was arbitrarily chosen as the average for the Boreal Forest Region (Canada Atmospheric Environment Service 1972).

Batteries of piezometers, each consisting of three pipes (Fig. 1), were placed at one-third increments along the slope of each box. Within each battery, the terminal end of one piezometer was placed at 152 mm from the bottom of the box, one at 305 mm, and one at 457 mm.

Sets of tensiometers, containing three instruments per set, were placed in the middle of zones 2 and 4. Within each set, the terminal end of one tensiometer was placed at a depth of 152 mm, one at 305 mm, and one at 457 mm level from the soil surface.

A lighting rack was constructed to provide 2,000 ft-c of light at the soil surface. An automatic timer was installed to maintain an 18-h photoperiod. The building was equipped with environmental controls which enabled a constant temperature of 25°C to be maintained. The light levels, photoperiod and temperature were decided in consultation with forestry experts (L. Carlson, personal communication).

Ten seedlings of each species were planted in each of the five moisture zones. In one box containing sandy loam and in one box containing silty clay soil, the native vegetation was allowed to compete with the seedlings.

The height and diameter of each surviving seedling was measured on three occasions during the experiment. The data collected during these three measurement periods provided the information used in determining the effects of soil, competition and moisture regime on the growth of each

TABLE I. LITERATURE REVIEW

Environmental parameters considered in the experiment	Generalized Relationships	White spruce	Lodgepole pine	Black spruce	Tamarack	References
Soil texture	Optimal soil texture	Loam soils	Silty clay to clay loam soils	Loams or sandy loam soils	Heavy clays or coarse sands	(Fowells 1965)
Soil tension	1, 6 and 15 atmospheres atmospheres tension have no effect on height growth	Cessation of photosynthesis occurs at 9 atmospheres tension, transpiration drops to 2-5% of maximum				(Glerum and Pierpoint 1968)
Ligth intensities and shade tolerance	Optimal light intensities	Tolerant — reaches maximum photo-synthesis at 5,000 ft-c to lux.	Intolerant — not light saturated at 12,000 ft-c. to lux.	Tolerant	Very tolerant	(Brix 1972) (Fowells 1965)
Moisture drainage class and moisture regime	Optimal drainage	Imperfectly drained — mesic conditions	Well-drained	Imperfectly drained	Imperfectly drained	(Fowells 1965) (Rowe 1955)
Competition	Vegative competition monopolizes available light, space and soil moisture and may cause mechanical damage	70% or better vegetation canopy reduces height growth considerably	Reduces growth considerably	Seedlings will develop under competition with as little as 10% of full light. Superior development occurs in the open	Very successful in competing with other vegetation	(Crossley 1969) (Fowells 1965) (Mullin 1969) (Place 1955) (Wagg 1973)
Initiation of root and shoot growth and cessation of same		27 April — October		About 1st June in Alberta		(Wheaton 1958) (Horton and Lees 1961)
Rooting patterns		Elongated or monolayered root forms. Elongated taprootform occurs on well-drained soils; monolayered root-forms occurs on Gleysolic soils.	Taproot dominant during seedling and sapling development but becomes less significant as lateral development occurs at maturity	Tolerates excess moisture, hence monolayered root form common, but does not prefer such wet habitats	Shallow compact root systems	(Beeftink 1951) (Mueller-Dombois 1963) (Pfister 1975) (Wagg 1973)

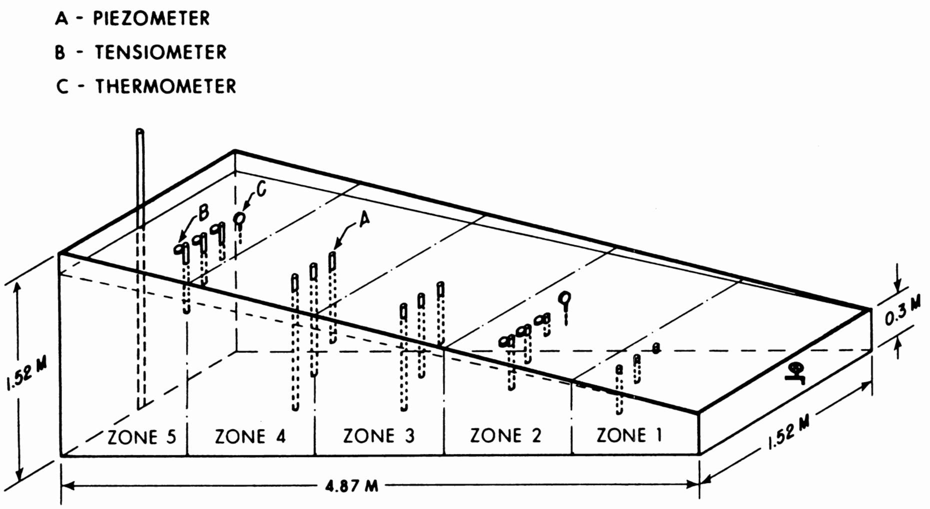

Figure 1. Diagram of soil boxes used in the experiment.

species. The formal experiment was started on 26 February, 1976 and was terminated 1 June, 1976.

RESULTS AND DISCUSSION

Soil texture had a highly significant effect on survival, diameter and height growth but had no significant effect on root length. Higher survival percentages, height and diameter growth occurred consistently on the non-vegetated silty clay soil (Table II). Though the effect of soil texture on root length was statistically non-significant, the trend was for seedlings grown on silty clay soil to have longer roots than seedlings grown on sandy loam soil.

The reason growth and survival was best on silty clay soil may be explained by considering the chemical properties of the soil (Wynnk et al. 1969). The Culp soil series (sandy loam, alluvial) was low in nitrogen, sulfur and phosphorous compared to the Kathleen soil series (silt loam, lacustrine). Therefore, for tree growth, the silty clay soil was more fertile and potentially more productive than the sandy loam soil. Also, the sandy loam soil had a cation exchange capacity one-half that of the silty clay soil.

Vegetative competition had a significant effect on height and diameter growth. Root lengths were measured only for bare slope conditions; therefore no information is available on the effect of competition on root growth. Survival with competition was best on the sandy loam soil (Table II). However, herbaceous growth was observed to be greater on the silty clay soil. The denser vegetation and the resulting vegetation competition reduces light, moisture, and nutrients available for seedlings. The growth (height and diameter) was best on the non-vegetated silty clay soil.

Moisture zones had a highly significant effect on all factors measured, except root length. In zone 5 (rapidly drained) the soil moisture content, for both soil textures, seldomly exceeded field capacity at any level within the rooting zone except immediately following simulated rainfall. The soil moisture in zone 4 (well-drained) was rarely greater than field capacity, even after watering. In zone 3 (moderately well-drained) the soil moisture exceeded field capacity following the addition of surface moisture for a longer time than in zones 4 and 5. In zone 2 (imperfectly drained), the soil moisture in excess of field capacity remained in the lower part of the rooting depth where the groundwater had some effect. In zone 1 (poorly drained), the soil

TABLE II. MEANS OF PERCENT SURVIVAL, HEIGHT GROWTH, DIAMETER GROWTH AND ROOT LENGTH

List of factors that are important in the experiment as determined by analysis of variance	Survival (%)	Height growth (mm)	Diameter growth (mm)	Root length (mm)
Non-vegetated sandy loam soil	61.5	86.8	0.9	123.5
Non-vegetated silty clay soil	80.4	157.0	1.7	166.0
Standard error of the mean	3.15	30.0	0.3	33.5
Vegetated sandy loam soil	74.6	125.1	1.3	
Vegetated silty clay soil	68.0	118.7	1.3	
Standard error of the mean	1.57	1.48	0.1	
Zone 1 (poorly drained)	53.3	46.1	0.90	71.5
Zone 2 (imperfectly drained)	96.3	189.1	1.95	173.3
Zone 3 (moderately well drained)	92.0	165.0	1.60	199.0
Zone 4 (well drained)	59.0	125.1	1.35	167.3
Zone 5 (rapidly drained)	39.2	84.2	0.80	112.4
Standard error of the mean	1.57	1.48	0.10	33.5
Tamarack	50.3	85.0	0.80	86.8
Lodgepole pine	92.3	44.2	1.40	223.0
Black spruce	69.1	47.1	0.60	62.1
White spruce	91.6	47.8	0.75	125.7

TABLE III. OVERALL SITE PREFERENCE OF EACH SPECIES TESTED

Soil†	Parameters measured‡	Tamarack	Lodgepole pine	Black spruce	White spruce
NV-SL	Survival (%)	57.0	93.2	52.4	75.0
	Height growth (mm)	54.0	70.0	24.0	34.0
	Root length (mm)	79.0	200.0	50.0	95.0
NV-SiCl	Survival (%)	44.2	87.6	74.4	89.0
	Height growth (mm)	116.0	46.0	62.0	62.0
	Root length (mm)	95.0	246.0	74.0	156.0
V-SL	Survival (%)	47.0	90.2	64.2	82.0
	Height growth (mm)	104.4	42.0	42.0	42.0
V-SiCl	Survival (%)	54.4	91.2	61.2	55.0
	Height growth (mm)	66.0	42.0	46.0	54.0
Optimum soil moisture level, zone		2	No moisture preference	1-2	2-3
Overall site preference of each species based on survival percentage		SL-NV-2	SL-NV no moisture preference	SiCl-NV-1-2	SiCl-NV-2-3
Effects of competition on height growth		SiCl-NV-2	SL-NV, no moisture preference	SiCl-NV-1-2	SiCl-NV-2-3

†SL = sandy loam soil; SiCl = silty clay soil; NV = non-vegetated; V = vegetated.
Height growth (growth after planting), root length (length of longest root).

moisture was in excess of field capacity throughout the root zone. Generally, survival, height and diameter growth were best overall in zone 2. Apparently zone 2 had an optimal combination of moisture and oxygen content.

Table III shows how each species responded to the combination of factors imposed in the study. No root lengths were measured on the vegetated soils. Optimum soil moisture levels were determined from the multiple comparisons for survival and height growth by comparing the results for the bare slope to the results for the vegetated slope.

Also in Table III, the overall site preference of each species is shown using survival as an indicator of preference. The habitat preference determined for the species here can be related to situations that a forester can recognize in the field. In regenerating a cutover, the most important objective should be to obtain the stocking density required by the local authority. If the area is not stocked to the required density, then usually no matter how rapid the growth of survivors, the ability of the site to yield fibre may fall below the full potential possible.

Excepting lodgepole pine, all other species considered here (Table III) had the best height growth on the non-vegetated silty clay soil. Lodgepole pine grew best on a sandy loam soil with no apparent moisture preference. However, Fowells (1965) has asserted that lodgepole pine survives and grows best on well-drained sites. The means by which lodgepole pine adapts to these very different moisture regimes is not known.

Tamarack survived best on an imperfectly drained non-vegetated sandy loam soil, while maximum height growth occurs on an imperfectly drained non-vegetated silty clay soil.

Survival and height growth of black spruce was best on a poorly to imperfectly drained, non-vegetated silty clay soil. This is in agreement with the results of Fowells (1965).

The best survival and height growth of white spruce occurred on an imperfectly to moderately well-drained, non-vegetated silty clay soil. This accords with the results of other studies (Fowells 1965).

Variability within cutblocks, which result in high reforestation costs due to the monoculture techniques currently being used, could be minimized by planting particular sites with suitable species. However, to plant a cutover with several species in order to obtain good stocking involves increased costs for planting. The increased costs should be offset by increased profits earned by better growth on the cutover.

An alteration of cutblock shape to reflect closer uniformity in site preferences throughout the cutover would possibly lower reforestation costs. Planting several species on a cutover could influence rotation age and method of logging. Only an economic analysis could show whether or not the above changes in current reforestation and logging practices would be profitable.

SUMMARY AND CONCLUSIONS

1. Non-vegetated silty clay soil provided the best survival, height and diameter growth when all four species are considered.
2. Site preferences for each species based on survival and height growth are:
   (a) tamarack — an imperfectly drained, non-vegetated silty clay soil.
   (b) lodgepole pine — a non-vegetated sandy loam soil with no apparent moisture preference.
   (c) black spruce — a poorly to imperfectly drained, non-vegetated silty clay soil.
   (d) white spruce — an imperfectly to moderately well-drained, non-vegetated silty clay soil.

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