

# EFFECTS OF SOIL MORPHOLOGY ON THE PRESENCE OF ALDER WITHIN A MATURE JACK PINE FOREST

T.A. Nerbas and D.W. Anderson  
Department of Soil Science, University of Saskatchewan  
Saskatoon, Saskatchewan, CANADA S7N 5A8

## Abstract

Soil morphological differences have resulted in a distinct pattern of Green Alder growth within a predominately Jack Pine forest. Alder growth occurred mainly in an area of finer textured parent materials. After a rain these finer textured layers result in a temporary or perched zone of saturation. Materials with fine sandy loam to silty clay loam textures have volumetric moisture contents  $> 35\%$ . The ability of Alder to fix  $N_2$  results in a considerably greater accumulation of N than that found under pure Jack Pine forests. Textural bands act as a barrier to N leaching. Elevated levels of P within the finer textured materials may have caused the microsite to be more suitable for Alder growth. It appears that a dominance of fine and very fine sand, coupled with finer textured bands in the subsoil results in a more moist soil, with high P supplies, all contributing to more alder and eventually a more productive site. The greatest volume of merchantable timber corresponds to the same area where Alder growth is most significant.

## Introduction

Forests cover about one-third of the earth's land surface (Dasmann 1968). Trees, the dominant feature of forest ecosystems, interact with their physical environment by altering both the soil on which they grow, and, to a lesser extent, their microclimate. Conversely, tree growth is affected by the soil, the climate and other factors of each environmental niche.

Rowe (1978) described ecosystems as being linear, which acknowledges that all parts of an ecosystem are interactive. Differences in the soils, the topography, the hydrology, the climate, and the time since the last major disturbance, are but a few of the factors which influence the population and pattern of plants. The plant colonization of an area is based on the species tolerance of the local climate and the soil substrate (Rowe, 1984). Thus microsites most suitable for a species will tend to become more densely populated with that species. A different set of environmental conditions will not only affect the abundance and distribution of the individuals, but it will also change the growth rate, the branching pattern, the root area, and the size of the individuals.

Thus a habitat which is perceived as homogeneous at a macroenvironmental level may, at a more detailed level, consist of many microsites which promote the establishment of species with varying degrees of success. Once established, the species can have a pronounced effect on site quality.

This study was conducted to examine the soil characteristics beneath the patterns of Alder growth in mature Jack Pine forests, and compare them to areas devoid of Alder.

## Materials and Methods

### Site Selection and Characterization

The research area is located west of Highway #106, 53 Km north of Smeaton, Sk. This area is on the edge of the Lower Torch River Plain, part of the Carrot River Lowlands physiographic area. It is a gently to roughly undulating plain composed of sandy glacio-fluvial, glacial-lacustrine, and aeolian deposits (Anderson and Ellis, 1976).

The sands are generally dominated by medium and coarse fractions, with finer sands in some areas. The sands are coarse textured and composed almost wholly of resistant quartz and feldspar minerals. The parent materials are weakly to non-calcareous, containing little clay.

### Grid Sampling

In June 1994 an area 100 by 100 m was selected within an old Jack Pine forest where dense Alder understory is present. A rectangular grid (40 by 70 m) composed of 40 sampling points, separated by 10 m spacing, was placed on the surface. Soil cores were taken and characterized in the field, at each of the sampling points, using a backsaver probe to 100 cm (to maintain an intact core) and a Dutch auger to a depth of 250 cm (to examine the parent material). Soils were classified according to The Canadian System of Soil Classification.

Within the grid, coniferous and deciduous tree locations were marked. Alder (*Alnus crispa*) size was simply indicated on a relative scale: small, medium, and large. The diameter of Jack Pine (*Pinus banksiana* Lamb.) at breast height (DBH) was measured and used to calculate basal area. Tree height was measured using an optical reading clinometer, PM - 5. The total merchantable volume of wood (assuming a 30.48 cm stump to a 7.62 cm top diameter) was calculated for each tree using the following equation:

$$V = (bD^2H)/10000$$

Where:      **V:** merchantable volume ( $m^3$ )  
               **D:** DBH outside bark (cm)  
               **H:** total tree height (m)  
               **b:** volume factor  
                       =  $a + bX + cX^2$       Where: X = ln DBH

Soil moisture was measured along a transect in the middle of the grid. A neutron moisture gauge (CPN 503 DR Hydroprobe) was used to monitor soil moisture two to three times per week from mid-June to mid-September. One measurement was taken in November of 1994. Volumetric soil moisture was measured using 10-cm increments starting at 15 cm from the surface and extending to 165 cm.

Tissue sampling of the Jack Pine foliage occurred in August 1995. Samples from the Jack Pine in both the open Jack Pine and the Alder-Jack Pine areas were taken in triplicate at all four grid locations. Tree branches were gathered by shooting the limbs off with a 12 gauge shotgun. Needles from the 1995 growth were sampled. Samples were oven-dried (48 hrs @ 45°C), ground (tine tissue grinder; #40 mesh), and analyzed for total N and P.

### Pit Sampling

There were two pits, one in each of the open Jack Pine and Alder-Jack Pine areas. The location of pits was based on information from the grid survey. Areas were chosen which were characteristic of each micro-site as a whole. Pits were dug 1.5 by 1.5 m to a depth of 2.0 m for ease in profile sampling. Samples were extracted along one wall of the pit; each horizon or textural change was sampled individually.

Samples were brought back to the lab, air-dried, ground, and analyzed for total N and P, and particle size. Total N and P of the soil and plant material were determined in the digestion with  $H_2SO_4$  and  $H_2O_2$  (Thomas et al., 1967). The products  $NH_4^+$  and P were measured colorimetrically by the ammonia salicylate method (Technicon, 1973) and acid-molybdate blue method (Murphy and Riley, 1962), respectively. Particle size was measured by the pipette method after pretreatment to remove organic matter and carbonates (McKeague, 1978).

## Results and Discussion

### Alder Pattern

There is a distinct pattern of Alder growth represented in cells 3A-3D, 4A-4D, 5A-5D, and 6B-6D (Fig. 1). The pattern of Alder growth corresponds closely to the texture of the upper 100cm of the soil (Fig. 2), where the finest mineral textures are found. The parent material appears to be a controlling factor in the ability of Alder to thrive in certain locations of this forest.

### Soil Moisture

Soil moisture was measured across the landscape along grid C1-C8 (Fig. 3). Measurements at C1 and C2 show a relatively low moisture holding capacity which remains constant through the measuring period at  $\approx 10$ cm of water stored in the 10 - 170cm depth. Even after a 15cm rain on DOY 200, little evidence of this precipitation remains five days after the storm. This reflects how rapidly these coarse sand textured sediments drain.

At C3 and C4, there was an increase in the amount of water stored. Initial moisture content early in the year showed  $> 20$ cm of water stored within the measurement profile, with a large percentage of the water stored in the 60 - 110cm depth. Moisture stored in the 110 - 170cm depth remained relatively constant throughout the year ( $\approx 6$ cm).

**Figure 1.** Spatial pattern of Alder growth.

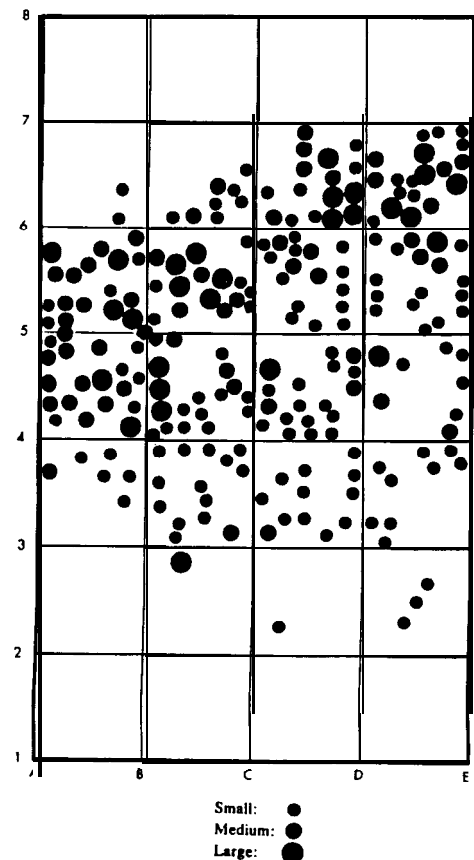


Figure 2. A 3-Dimensional Cross-section of sediments.

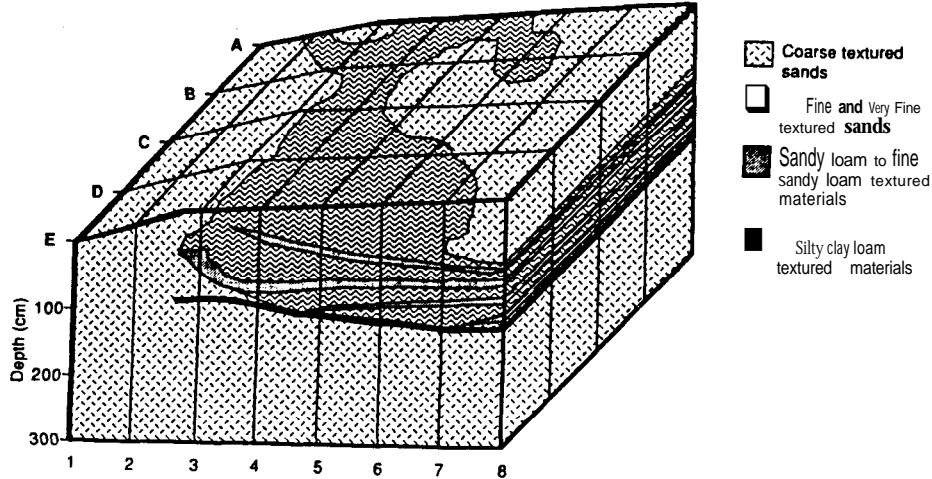
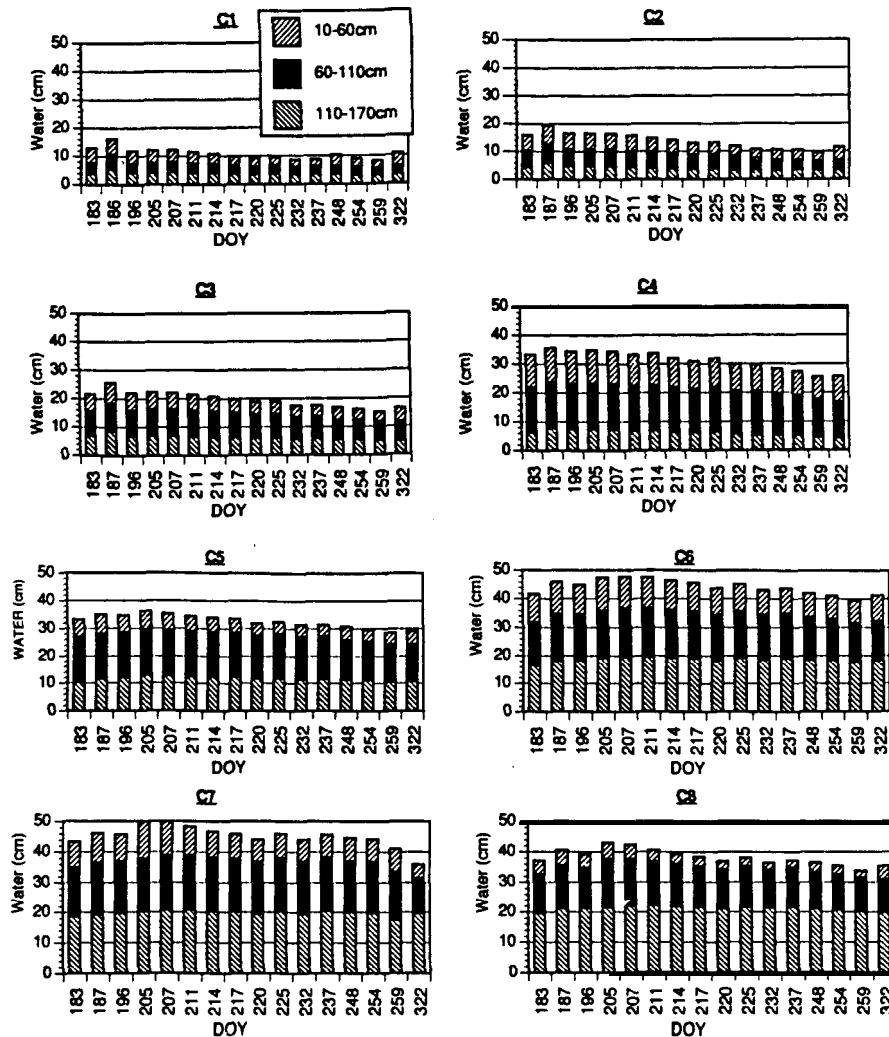


Figure 3. Volumetric soil moisture expressed in cm of water for three depth ranges (10-60, 60-110, 110-170cm) for grid locations C1, C2, C3, C4, C5, C6, C7 and C8.



At C5, a greater percentage of the water is stored in the 110 - 170cm depth than at the 10 - 60cm depth. The amount of water stored deeper in the profile (60 - 110; 110 - 170cm) continues to increase at C6 and C7, although there is a significant amount of water in the 10 - 60cm depth. Within the latter depth increment, a fine sand layer is present at C6 and C7.

At C8, the volume of water stored declines, but this is largely because less water is stored at the 10 - 60cm depth. From 60 - 110cm and 110 - 170cm the amount of water stored is similar to C6 and C7.

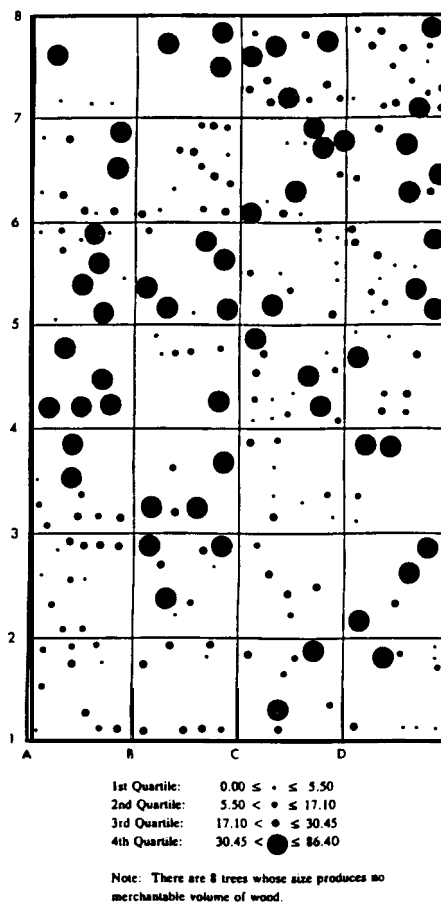
The redistribution of water in the profiles reflects an ever-thickening layer of coarse sediments overlying the fine textured bands. C5, C6 and C7 show some evidence of the 15cm ram on DOY 200 (July 18, 1994). Each of these locations showed an increase in the overall water stored at the 10 - 170cm depth. However prior to this rain storm, these soils had relatively high moisture contents. Layers of stratification within the profile restrict the downward movement of water. This results in much higher moisture contents above these layers than that which is encountered in freely drained soils. The water from the rain may have increased the moisture content of the overlying material to a moisture tension of 0.5 atmosphere or less. Therefore there would have been a movement of moisture beyond the depth of measurement.

### Overstory Patterns

This site is predominately Jack Pine, with White Spruce (*Picea glauca* (Moench) Voss), Paper Birch (*Betula papyrifera* Marsh.), and Trembling Aspen (*Populus tremuloides* Michx.) in areas of Green Alder growth. The greatest vegetative productivity is concentrated within cells 3A-3D to 7A-7D (Fig. 4). Within this area of the grid, there is a large percentage of trees with the greatest volume of merchantable timber.

This pattern of vegetative productivity corresponds closely with the area of the grid where finer textured sediments are located (Fig. 2). Where a finer textured band or bands occur within 1.2 m of the surface, there are a significant number of trees with the most merchantable timber. However the pattern of Alder corresponds to an area in which finer textured layers are within 80cm of the surface. Where bands are within 80cm of the surface, there are also fine sand to loam textured sediments at the soil surface. In cells 6A-6B, and 7A-7D, finer textured layers are still within 120cm of the surface, but there is up to 100cm of coarser textured sands

**Figure 4.** Spatial pattern of overstory productivity. Each dot represents a single tree. The total merchantable volume of wood for each tree was separated into four quartiles.



overlying these bands. The growth of Alder in these cells is significantly reduced, but the growth of Jack Pine remains high. The greatest growth of pine occurs where there is a fine textured layer to impede moisture drainage (Barnes and Ralston, 1955).

Because of increased N and ample water for growth, nearly all trees with  $> 40\text{m}^3$  of merchantable timber are found within the pattern of Alder in this landscape.

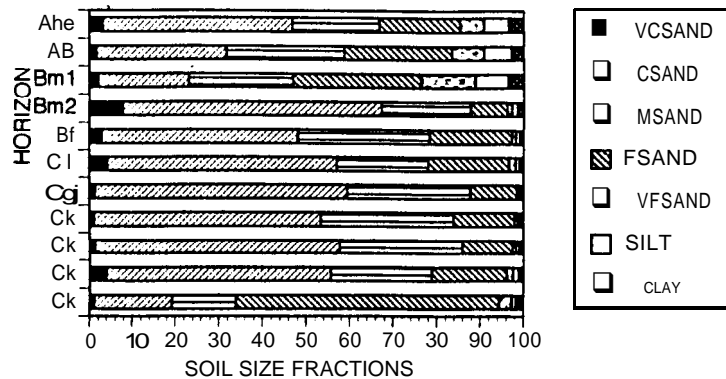
**Parent Material Differences**

**Particle size**

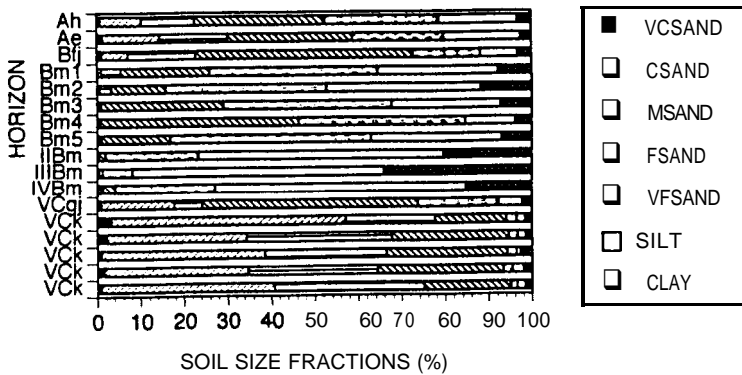
There are significant differences between the parent materials beneath the open Jack Pine and the Alder-Jack Pine areas. (Fig. 5). Within the open Jack Pine, coarse sandy materials are present either throughout the profile or as an overlay over finer textured bands. Conversely, the pattern of Alder growth occurs where significant textural differences are present in the upper 120cm. In the open Jack Pine (Pit A), textures range from sand to coarse sand. In the Alder-Conifer areas (Pit B), textures range from loamy sand to silty clay loam in the upper 120cm with coarse sand below this depth (Fig. 5).

**Figure 5.** Comparison of particle size analyses with depth from soils within the open Jack Pine (Pit A) vs soils within the Alder-Jack Pine (Pit B) designated areas.

Pit A:



Pit B:



Finer sediments in the upper 40 cm of pit "A" reflect either changes in the sediment load during deposition by water or changes in the composition as a result of aeolian processes. However, there may have been some physical weathering of sand-sized particles (of the Ahe horizon) into silt-sized particles (Santos et al., 1985). The latter researchers report only a minor physical breakdown of sand into silt-sized particles in the B horizons of Gray Luvisol soils. Therefore changes in the silt-sized particles at the 14 - 40cm depth should be considered a result of deposition. Below 40cm, < 3% of the particles (on a weight basis) are < 0.05mm in diameter.

Conversely, the upper 120cm of pit "B" (Alder-Jack Pine) contains a greater percentage of silt and clay. The low percentage of sands > 0.5mm likely reflects a lacustrine mode of deposition.

These finer textured layers play an important role in the downward movement of water. A temporary zone of saturation (perched water table) develops above these layers.

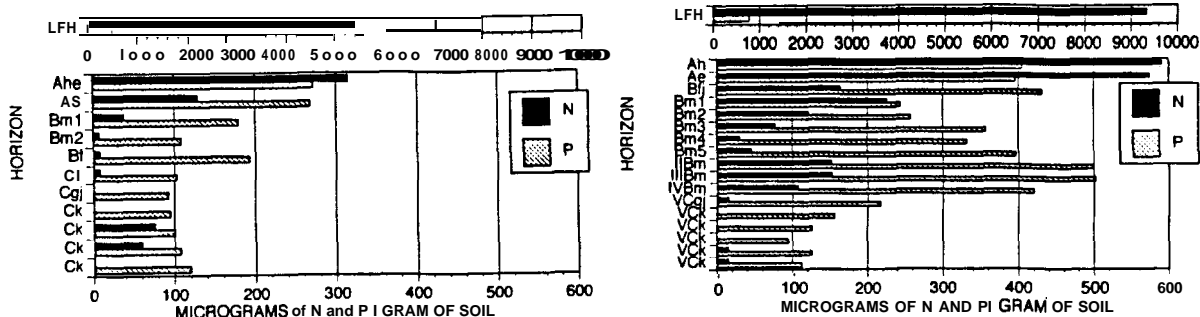
### Nitrogen and Phosphorus

Within the study area, N in the both the litter layer and the mineral horizons varies greatly between pits "A" and "B" (Fig. 6). In the upper mineral layers, pit "B" has a significantly greater concentration of N than pit "A". However, differences in the N concentration between pits becomes more pronounced with increasing depth.

**Figure 6.** A comparison of changes in the concentration of both total N and P between soil profiles at pit "A" and pit "B", with depth.

Pit A:

Pit B:



For pit "A", the level of N declines to nil within the upper 170 cm of soil. At 170 - 330 cm, the N concentration increases. However, below this depth no level of N was measurable. The low N concentration at 40 - 170 cm is indicative of the low ability these coarse sands have to retain N. Within the 170 - 330 cm layer, increased N is likely the result of N leaching and not a consequence of organic matter leaching (OC content ranges from 0.01 - 0.02%).

Conversely, in pit "B" the concentration of N varies between 121 - 226 $\mu\text{g/g}$  at 8 - 56 cm. The finer textured sediments within pit "B" have a much greater ability to retain N. From 56 - 104 cm the level of N in the materials declines reflecting the coarser textured sediments within this layer. However the concentration of N remains much

greater than pit “A” at similar depth increment. The significantly finer textures in the 104 - 121 cm depth provide a major barrier to not only the movement of water but also N leaching. N concentrations increase in this layer. Below this depth, the N level drops quickly to near zero, reflecting the significant role the finer textured materials (104 - 121 cm) play in the N cycling in this area. Significantly greater N in upper mineral soil beneath Alder reflects previous research (Van Miegroet et al., 1990) and demonstrates the strong positive correlation between soil moisture content and N concentration (Voigt and Steucek, 1969).

· Within the litter layer, N-enriched litterfall beneath the Alder-Conifer forests results in a greater N accumulation than that found under pure conifer stands. However the significantly greater litter accumulation at pit "B" (6 - 11 cm) vs that at pit “A” (2 - 4 cm), accentuates the N accumulation at pit “B”.

The P content of the litter layer follows the same pattern as that of N. The higher foliar level of P in Green Alder vs Jack Pine (data not shown), explains the increased P concentration of the litter.

Within the mineral soil, the concentration of P (Pit “A”) varies between 110 - 250  $\mu\text{g}\text{g}^{-1}$  in the upper horizons. At a similar depth in Pit "B" significantly greater levels of P are present (220 to 500  $\mu\text{g}\text{g}^{-1}$ ). Small increases in P availability, particularly in areas of very low P concentrations, may enable other species (i.e. N-fixing species) to establish and compete with other species present (Walker et al., 1959). However, Wurtz (1995) reported lower soil P beneath Alder.

Below a depth of 135cm at pit "B", the P concentration quickly drops. These P levels below 185cm are similar to those at pit “A” at similar depths.

### **Foliar Comparisons**

Jack Pine tissue samples from both open Jack Pine and Alder-Jack Pine areas were compared for Total N and P content (Table 1). The foliar level of N and P was significantly different at  $p < 0.10$  and  $0.05$  levels, respectively. Higher mean foliar levels of Jack Pine in association with the Alder, reflects the greater soil supply of these nutrients.

**Table 1.** Comparison of Jack Pine tissue samples analyzed for Total N and P ( $\mu\text{g}/\text{g}$ ) taken from open Jack Pine vs Alder-Jack Pine areas (Samples taken in triplicate).

	Nitrogen		Phosphorus	
	open Jack Pine	Alder-Jack Pine	open Jack Pine	Alder-Jack Pine
Mean	10,952.0	12,698.8	1039.6	1189.1
STD	544.9	1183.7	17.7	73.5
Range	1058.3	2052.7	31.6	146.2
t	2.32 <sup>**</sup>		3.43 <sup>***</sup>	

\*\* Significant at  $p < 0.10$  level

\*\*\* Significant at  $p < 0.05$  level



## Conclusions

Alder growth and site selection are strongly influenced by the soil substrate. Microsites which are most suitable for a species tend to become more densely populated with that species (Rowe, 1984). Consequently parent material changes within the landscape have resulted in distinct patterns of Alder growth.

Beneath Alder, increased levels of P were found. The highest mean foliar levels of N and P are associated with the soils that have the highest concentration of N, and P in the parent materials.

The ability of Alder to fix N has resulted in significantly more N stored in the soil where Alder is present. Soils which have fine textured layers have substantially higher levels of N to the depth where the banding ceases. The fine textured layers provide a barrier to downward leaching, retaining N which may otherwise be lost from the profile. In soils with no impeding layer, small N bulges at depths > 150cm are indicative of leached N.

Layers of stratification within the profile restrict the downward movement of water. This results in much higher moisture contents above these layers than that which is encountered in freely drained soils.

## References

- Anderson, D.W. and J.G. Ellis. 1976. The Soils of the Provincial Forest Reserves in the Prince Albert Map Area. S.I.P. Publ. SF3, University of Saskatchewan, Extension Division, Saskatoon. 126p.
- Barnes, R.L., and C.W. Ralston. 1955. Soil factors related to the growth and yield of slash pine plantations. Fla. Agr. Exp. Sta. Bull. 559. 23p.
- Dasmann, R.F. 1968. Environmental Conservation. John Wiley and Sons, Inc., New York. 375p.
- McKeague, J.A. 1978. Manual on Soil Sampling and Methods of Analysis. 2nd Edition. Can. Soc. Soil Sci., Ottawa, Ontario.
- Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chem. Acta 27:31-36.
- Rowe, J.S. 1984. Forestland Classification: Limitations of the use of vegetation. Pages 132-147 in J.B. Bockheim, editor. Forest Land Classification: Experience, Problems, Perspectives. Proceedings of a symposium held at the University of Wisconsin at Madison on March 18-20, 1984.
- Rowe, J.S. 1978. Revised working paper on Methodology/Philosophy of Ecological Land Classification in Canada. Proceedings Second Meeting Canadian Community of Ecological Land Classification.

- Santos, M.C.D., A.R. Mermut, D.W. Anderson, and R.J. St. Arnaud. 1985. Micromorphology of three gray luvisols in east-central Saskatchewan. *Can. J. Soil Sci.* 65:717-726.
- Technicon Industrial Systems. 1973. Nitrate and nitrite in water and wastewater. Industrial Method No. 100-70W. Technicon Industrial Systems, Tarrytown, N.Y.
- Thomas, R.L., R.W. Sheard, and J.P. Moyer. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorus, and potassium analysis of plant material using a single digest. *Agron. J.* 59:240-243.
- Van Miegroet, H., D.W. Johnson and D.W. Cole. 1990. Soil nitrification as affected by N fertility and changes in forest floor C/N ratio in four forest soils. *Can. J. For. Res.* 20:1012-1019.
- Voigt, G.K. and G.L. Steucek. 1969. Nitrogen distribution and accretion in an alder ecosystem. *Soil Sci. Soc. Amer. Proc.* 33:946-949.
- Walker, T.W., B.K. Thapa, and A.F.R. Adams. 1959. Studies on soil organic matter: 3. Accumulation of carbon, nitrogen, sulfur, organic, and total phosphorus in improved grassland soils. *Soil Sci.* 87: 135-140.
- Wurtz, T.L. 1995: Understory alder in three boreal forests of Alaska: local distribution and effects on soil fertility. *Can. J. For. Res.* 25:987-996.