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SILVICULTURE

Evaluation of Several Competition Indices for Prediction of Balsam Fir Tree Growth.—In the past 15 yr or so, a large number of computer-based models of forest stand growth have been developed to aid our understanding of stand dynamics and to provide forest managers with better decision-making tools.

One approach often used in these models is that of explicitly describing the growth of each tree in the simulated stand and then using the resulting tree statistics to calculate a set of stand statistics. Examples of this approach are those models developed by Arney for Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) (Arney, Ph.D. Thesis, School For., Oreg. State Univ., Corvallis, 1971), Hegyi for jack pine (*Pinus banksiana* Lamb.) (Hegyi, *in* Growth models for tree and stand simulation, Proc. IUFRO Work. Party S4.01-4, Vancouver, 1973), and Mitchell for white spruce (*Picea glauca* [Moench] Voss) (Mitchell, Yale Univ. School For. Bull. 75, 1969).

Since competition between trees for moisture, nutrients, and light plays an important role in determining tree growth and mortality, these models usually incorporate some form of competition submodel that provides, given information on the size of a tree and the sizes and locations of its neighbors, an index that can be interpreted as a measure of the relative share of resources available to the tree for growth. This competition index can then be used, along with other information about the tree, to predict its growth and to assess the probability of mortality.

There are two basic criteria for selecting a competition index for use in a tree and stand model: (1) high correlation with diameter growth, and (2) computational simplicity. The second criterion is important because much of the computer time involved in running these models is spent in computing competition indices. Thus, to help keep the costs of computer time down to reasonable levels, competition indices that require a minimum of computational effort are preferred.

This note describes the results of an evaluation of several competition indices that was done to select a competition index for use in developing a computer model of balsam fir (*Abies balsamea* [L.] Mill.) tree and stand growth.

The specific indices tested were those defined by Arney (1971), Hegyi (1973), Newnham (Ph.D. Thesis, Fac. For., Univ. B.C., 1964), Quenet (Hegyi and Oxtoby, A set of FORTRAN algorithms for evaluating inter-tree competition indices, unpubl. Rep. Can. For. Serv., Pac. Forest Res. Cent., 1976), and Staebler (M.F. Thesis, School For., Univ. Mich., 1951). Data used in this study were from a set of spacing trials located in the Green River watershed in northwestern New Brunswick. Data from four 0.08 ha plots were used, one from each of four spacings: control, 1.2 × 1.2 m, 1.8 × 1.8 m, and 2.4 × 2.4 m. Competition indices were calculated for each tree within an inner plot whose dimensions were 21 × 21 m (0.04 ha). Some of these competition indices make use of the relationship between crown width and dbh in open-grown trees. The crown-width equation used in this study, derived from open-grown fir at Green River, was $CW = 0.5078 + 0.2718\ D - 0.00301\ D^2$, where CW and D are crown width (m) and diameter at breast height (cm), respectively. Characteristics of each stand at the beginning of the 15-yr growth period used in this study are given in Table 1. The computer software used for this evaluation was developed at the Pacific Forest Research Centre by Hegyi and Oxtoby (1976) and provides, among other things, plots of diameter growth vs. competition index and the correlation coefficient of diameter growth vs. competition index for each index tested.

TABLE 1
Characteristics of stands used in testing competition indices (all trees with dbh >1 cm)

Plot no.	1	2	3	4
Nominal spacing (m)	Control	1.2 × 1.2	1.8 × 1.8	2.4 × 2.4
No. years since spacing	10	10	10	10
Average dbh (cm)	6.7	7.2	10.2	8.4
Basal area (m²/ha)	19.3	24.0	21.5	9.8
No. stems/ha	4,645	4,830	2,347	1,556
Quadratic mean diameter (cm)	7.3	8.0	10.8	8.9
Total volume (m³/ha)	74.5	93.5	89.6	34.0
Dominant height (m)	10.5	11.2	10.6	8.7

TABLE 2
Correlations between 5-yr diameter growth and five competition indices for balsam fir

Plot no.	1	2	3	4
Nominal spacing (m)	control	1.2 × 1.2	1.8 × 1.8	2.4 × 2.4
ARNEY	-0.313	-0.237	-0.064	-0.085
HEGYI	-0.525	-0.533	-0.654	-0.660
NEWNHAM	-0.612	-0.497	-0.531	-0.549
QUENET	-0.530	-0.424	-0.326	-0.470
STAEBLER	-0.247	-0.031	-0.054	-0.130

Table 2 summarizes the correlation coefficients of diameter growth vs. competition index for each of the four plots. Hegyi's index showed the highest correlation with 5-yr diameter growth in three of the four plots. Newnham's index was best in the control plot and consistently second to Hegyi's in the other plots. Quenet's index generally ranked third followed by those of Arney and Staebler. If we derive an overall ranking for each index by assigning five points to the index with the highest correlation coefficient in a given plot, four points to the index with the second highest coefficient, and so on, and adding the points for each index, we arrive at the following ranking: (1) Hegyi's, 18 points; (2) Newnham's, 17; (3) Quenet's, 13; (4) Arney's, 7; and (5) Staebler's, 5. Hegyi's index has the additional advantage of being one of the simpler indices to compute, since it does not involve any of the overlap area calculations common to some other indices.

One interesting feature of this ranking is that it is identical with that shown by the same indices in a more extensive comparison of eight competition indices made by Alemdag, Forest Manage. Inst. Inf. Rep. FMR-X-108, 1978, Table 10). Alemdag's study was done with plantation white spruce data, and its main performance criterion was the multiple coefficient of determination (R^2) associated with a regression equation relating diameter growth to initial diameter and competition index.—M.F. Ker, Maritimes Forest Research Centre, Fredericton, N.B.

Urea Fertilization of Five 60-year-old Balsam Fir Stands in Quebec: 10-year Results on Growth Response and Ammonium-nitrogen Changes.—Merchantable volume, diameter growth, and changes in various properties of the humus horizon of five natural balsam fir stands were observed for 10 yr following the additon of 112, 224, and 336 kg/ha of nitrogen as urea. With the 112 kg/ha of nitrogen

TABLE 1

Ten years' growth in merchantable volume (m^3/ha) due to urea addition in five 60-yr-old balsam fir stands in Quebec.

Treatment (kg/ha)	Fran-quelin	Huit Chutes	Parc des Lauren-tides	Lac Made-leine	Grande Vallée	Average
112 N	13	19	9	30	24	19
224 N	12	-3	4	26	26	13
336 N	—	—	10	35	32	26

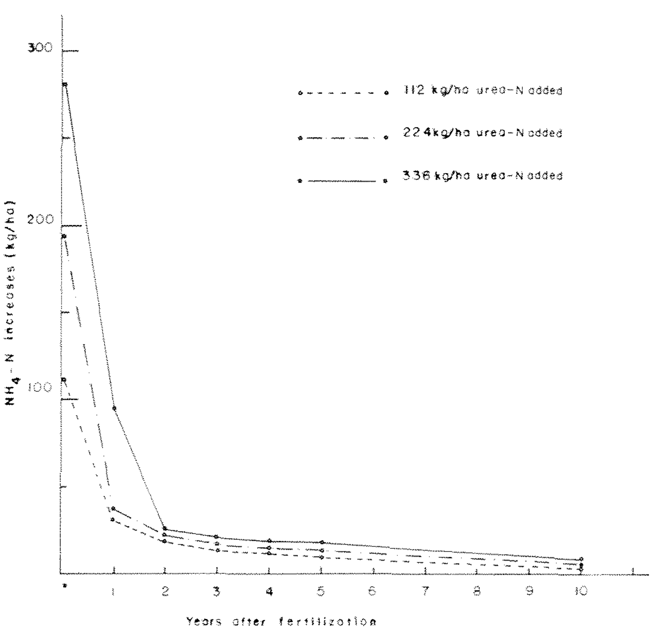
TABLE 2

Ten years' growth in diameter (cm) due to urea addition in five 60-yr-old balsam fir stands in Quebec

Treatment (kg/ha)	Fran-quelin	Huit Chutes	Parc des Lauren-tides	Lac Made-leine	Grande Vallée	Average
112 N	0.5	0.4	0.3	0.5	0.8	0.5
224 N	0.5	0.0	0.3	0.3	0.5	0.3
336 N	—	—	0.1	0.4	0.2	0.2

the average growth in merchantable volume was 19 m^3/ha, which was 32% higher than in the control. With 336 kg/ha of nitrogen the average (26 m^3/ha) was slightly higher (Table 1). Diameter growth was maximum with 112 kg/ha of nitrogen, reaching 0.5 cm, or 38% more than in the control (Table 2). The NH_4-N levels of the humus horizon were increasingly improved with the larger amounts of nitrogen added, and the improvement was still easily observed 10 yr after fertilization (Fig. 1). The results indicated that the optimum amount of nitrogen to add as urea for maximum growth would be less than 224 kg/ha but that for optimum improvement in the humus properties it should probably not be more than 336 kg/ha.

The initial effect of urea addition was to shift the pH of the humus horizon to greater alkalinity (Roberge, pages 42-68 *in* Laurentian Forest Res. Cent. Inf. Rep. Q-F-X-14, 1971) but not to the point where an oxidation of ammonium ions to nitrates could occur and where nitrites and ammonia would accumulate. After this point, the pH decreased but was still higher in fertilized than in control plots 10 yr after fertilization (Gagnon et al., Laurentian Forest Res. Cent. Inf. Rep. LAU-X-36, 1979).



* Two days after fertilization

Figure 1. Trends in the amounts of available nitrogen due to urea addition found in the humus horizon in various years after fertilization in five 60-yr-old balsam fir stands in Quebec.

The NH_4-N and total N contained in the humus horizon were increased at the time of fertilization by the amount added as urea-N (Fig. 1). During the first 3 yr after treatment, the levels of NH_4-N decreased rapidly, most of the NH_4-N having become organic nitrogen. It was not leached or volatilized because it was recovered in the total-N fraction (Roberge et al., Can. J. Forest Res., in press). After 5 yr, the NH_4-N content approached an equilibrium value approximately 30% higher than in the control plots. After 10 yr, the difference in the total-N content of the humus horizons of the fertilized and control plots was still near 60 kg/ha (for the 112 kg/ha dosage).

It is interesting to speculate on why such stands, growing on a large accumulation of organic N, are N-deficient. Some insight can be obtained from the following estimates of the cycling of N.

	kg/ha
Mean annual accumulation in trees	5
Mean annual accumulation in shrubs, herbs, and mosses	0.5
Total	5.5
Mean annual return by trees in litterfall	16
Mean annual return by shrubs, herbs, and mosses in litterfall	4
Total	20
Mean annual uptake by trees	21
Mean annual uptake by shrubs, herbs, and mosses	4.5
Total	25.5

The mean annual requirements of the trees, shrubs, herbs, and mosses are relatively modest. This nitrogen may come from

	kg/ha
a) organic nitrogen through mycorrhiza	1
b) rainfall	4
c) mineralization of the organic N in the humus	15
d) fertilization	5
Total	25

The reason for believing that some nitrogen comes from fertilization is the observed tree-growth response. This nitrogen, however, must be low because the tree-growth response was almost equal to increases of 5 to 15 kg/ha NH_4-N that occurred from the 5th to the 10th yr after fertilization (Fig. 1). The NH_4-N increase is low , but it is important because it represents 20 to 60% of the mean annual requirements of the trees, shrubs, herbs, and mosses.

The potential for humus-N mineralization was always higher in the humus horizons of the urea-fertilized plots than in those of the unfertilized. The C/N ratios were smaller and the actual rates of humus-N mineralization were greater (Gagnon et al, Can. J. Forest Res., in press).

Whenever the humus was sampled, the potential for total biological activity was found to be greater in fertilized plots. This was indicated by the difference in the total number of bacteria and fungi in the O_2-demand (Roberge et al., Can. J. Forest Res., in press).

In summary, in the 10 yr following fertilization of balsam fir stands with urea there was an increase in merchantable volume, tree growth, potential for humus-N mineralization, and potential for total biological activity. Apparently, two factors contributed to tree and microbe responses: first, the occurrence of available N; second, the increase in pH brought about by the mineralization of urea.

Urea-N fertilization, with an optimum amount of less than 224 kg/ha, may be recommended for stimulating growth of 60-yr-old balsam fir trees.—M.R. Roberge and J.D. Gagnon, Laurentian Forest Research Centre, Sainte-Foy, Que.

SOILS AND FERTILIZER

Detailed Soil and Site Assessment of Hybrid-poplar Planting Areas in Newfoundland.—An experiment was started in 1972 to identify hybrid-poplar clones suitable for large-scale planting as a source of fast-growing wood and fiber in Newfoundland. Thirty-four clones were tested for rooting ability and growth and, by the end of

TABLE 1

Site characteristics of the hybrid poplar experimental areas and total nutrients, percent ovendry basis

Location	Forest type (former)	Horizon	Depth (cm)	pH	Texture	Soil drainage	OM%[1]	N	P	K	Ca	Mg	Na	Mn
Robinsons K5	Dryopteris -bF	LF(H)	8-0	3.35		2-3		1.9000	0.0875	0.1207	0.7609	0.2151	0.0330	0.0682
		Ae	0-7	3.40			1.3	0.0300	0.0031	0.2887	0.2257	0.0682	0.0117	0.0689
		Bhf	7-23	3.79	Loam		14.4	0.1520	0.0544	0.3255	0.5355	0.9397	0.0402	0.0787
		Bf	23-41	3.79	Sandy loam		—	0.1125	0.0506	0.3355	0.4666	0.8075	0.0279	0.0733
		C	41+	4.13	Sandy loam		2.2	0.0305	0.0506	0.5344	0.6602	1.6296	0.0439	0.0837
South Brook K4	Dryopteris hylocomium - bF	LF(H)	8-0	3.98		2-3	81.1	1.5550	0.1300	0.1837	0.8712	0.1312	0.2309	0.0577
		A_e	0-3	3.36			—	0.0110	0.0119	0.3937	0.1049	1.4288	0.0075	0.0735
		Bhf	3-20	3.94	Silt loam		6.7	0.0650	0.0263	0.6811	0.1204	0.4558	0.0242	0.0733
		Bf	20-42	4.52	Loam		4.9	0.0750	0.0194	0.6247	0.0892	0.4620	0.0307	0.0682
		C	42+	4.62	Sandy loam		2.3	0.0420	0.0419	0.6930	0.1417	0.7560	0.0179	0.0787
Goose Arm K3	Pleurozium - bF	F + H	5-0	4.12		2	93.8	1.5150	0.0831	0.0577	0.7295	0.1102	0.1417	0.0577
		A_e	0-25	4.31	Sandy loam		0.4	0.0150	—	0.0943	0.0261	0.0051	0.0052	0.0733
		Bhf	25-37	4.94	Sandy loam		9.0	0.1390	0.0769	0.2408	0.0837	0.2513	0.0239	0.0785
		Bfc	37-49	4.85	Fragipan		5.0	0.0720	0.0563	0.2357	0.0837	0.2514	0.0686	0.0733
		C	49+	5.00	Sandy loam		1.5	0.0305	0.0706	0.4731	0.1205	0.6449	0.0469	0.0786
Millertown Jet. K2	Pleurozium - bF	F + H	8-0	3.71		3	87.9	1.1140	0.0706	0.0577	0.4565	0.0735	0.0270	0.0525
		A_e	0-3	3.92			3.9	0.0895	0.0119	0.1310	0.4194	0.0366	0.0197	0.0838
		Bhf	3-9	4.85	Silty sand		16.7	0.1190	0.0544	0.1785	0.6300	0.2782	0.0275	0.0682
		Bfgj	9-26	4.99	Fine sandy loam		—	0.1160	0.0375	0.2357	0.7431	0.4243	0.0272	0.0837
		BC	26-46	4.80	Sandy loam		—	0.2135	0.0563	0.2205	0.7140	0.4462	0.0425	0.0787
		C	46+	5.27	Sandy loam		3.1	0.0740	0.0288	0.2357	0.8330	0.3510	0.0317	0.0890
Clarenville Lethbridge K1	Dryopteris lycopodium - bF	LF(H)	7-0	4.39		3	87.2	1.4000	0.1250	0.2047	0.6719	0.1470	0.0597	0.0630
		Ae	0-2	4.65	Silt loam		—	—	0.0419	0.5026	0.6021	0.1570	0.0691	0.1204
		Bf_1	2-15	5.09	Silt loam		3.0	0.0550	0.0375	0.5086	0.4719	0.3041	0.0846	0.1048
		Bf_2	15-30	5.30	Silt loam		1.9	0.0295	0.0300	0.8340	0.8085	0.5618	0.0402	0.2047
		BC	30-50	5.39	Loam		1.9	0.0260	0.0419	0.9397	0.7615	0.5932	0.0362	0.1837
		C	50-80+	5.17	Sandy loam		1.7	0.0265	0.0625	1.0395	0.8295	0.6195	0.0339	0.2100
Wooddale K0	Black spruce moss on sandy loam	Bf		5.1	Sandy loam	2	3.5	0.0870	0.0561	0.3653	0.5282	0.6221		

K5, K4, K3, K2 soils are classified as Orthic Ferro-Humic podzols and K1, K0 as Orthic Humo-Ferric podzols (Canada Soil Survey Committee, The Canadian system of soil classification, Can. Dep. Agric. Publ. 1646, 1978).

[1]OM = organic matter.

TABLE 2

Available nutrients, CEC, and base saturation for each site

			Available nutrients		Exchangeable cations (Meq/100 g)						
Location	Horizon	Depth (cm)	N%	P%	K	Ca	Mg	Na	TEB	CEC Meq/100 g	Base saturation %
Robinsons K5	LF(H)	8-0	0.00070	0.00293	0.5621	8.4331	2.3026	1.1739	12.4717	195.54	
	A_e	0-7	0.00073	0.00003	0.0469	0.7485	0.3056	0.1594	1.2604	5.96	21.2
	Bhf	7-23	0.0042	—	0.1394	0.6820	0.2851	0.2319	1.3384	41.72	3.2
	Bf	23-41	0.0175	0.00015	0.0758	0.3159	0.0836	0.1883	0.6636	27.78	2.4
	C	41+	0.0007	0.00013	0.0784	0.3326	0.1822	0.1739	0.7671	7.35	10.4
South Brook K4	LF(H)	8-0	0.00238	0.01610	0.4859	10.3293	2.1382	1.0870	14.0404	122.12	11.5
	A_e	0-3	0.00175	0.00042	0.0886	1.7456	0.9316	0.2028	2.9686	16.50	18.0
	Bhf	3-20	0.00297	—	0.0145	0.0832	0.0110	0.1304	0.2391	14.76	1.6
	Bf	20-42	0.00105	—	0.0938	0.0998	0.0260	0.1739	0.3935	17.35	2.3
	C	42+	0.00070	—	0.0669	0.0998	0.0192	0.2029	0.3888	8.90	4.4
Goose Arm K3	F + H	5-0	0.00063	0.00063	0.5624	7.8803	1.8905	0.9995	11.3327	111.36	10.2
	A_e	0-25	0.00117	0.00003	0.0264	0.1829	0.0712	0.3621	0.6426	1.52	42.3
	Bhf	25-37	0.00205	0.00007	0.0601	0.0998	0.0397	0.1884	0.3880	38.67	1.0
	Bfc	37-49	0.00110	0.00006	0.0401	0.1995	0.0301	0.1304	0.4001	24.33	1.6
	C	49+	0.00101	0.00013	0.0332	0.1164	0.0274	0.2028	0.3798	7.04	5.4
Millertown Jet. K2	F + H	8-0	0.00058	0.00331	0.4599	4.0378	1.1502	0.9556	6.6035	198.26	3.3
	A_e	0-3	0.00149	0.00023	0.1497	0.0793	0.1069	0.2174	0.5533	13.46	4.1
	Bhf	3-9	0.00583	—	0.1074	0.1829	0.0822	0.1738	0.5463	59.93	0.9
	Bfg	9-26	0.00227	—	0.0443	0.1164	0.0233	0.1884	0.3724	21.28	1.8
	BC	26-46	0.00402	—	0.0652	0.1497	0.0480	0.1739	0.4368	36.07	1.2
	C	46+	0.00114	—	0.0401	0.0832	0.0151	0.2029	0.3413	13.46	2.5
Clarenville Lethbridge K1	LF(H)	7-0	0.00051	0.01167	1.1759	6.9825	2.3837	1.2602	11.8023	127.66	9.2
	A_e	0-2	—	—	—	—	—	—	—	—	—
	Bf_1	2-15	0.00070	0.00003	0.0754	0.5822	0.2193	0.1884	1.0653	15.20	7.0
	Bf_2	15-30	0.00058	—	0.0511	0.4987	0.1904	0.1883	0.9285	7.30	12.7
	BC	30-50	0.00044	—	0.0648	1.0308	0.4041	0.2028	1.7025	8.91	19.1
	C	50-80+	0.00026	0.00013	0.1053	4.7397	2.1926	0.2029	7.2405	15.17	47.7
Wooddale K0	Bf		0.00500	tr	0.0487	0.5240					

1977, disease-free planting stock of rooted cuttings was available from 32 of them (Khalil, Nfld. Forest Res. Cent. Inf. Rep. N-X-142, 1976).

Soil-nutrient status and physical condition at the planting site are important for the establishment and good growth of hybrid poplars. Soil quality and weed competition have been found to greatly influence early growth of hybrid poplars in Ontario (Zsuffa et al., For. Chron. 53:195-200, 1977), and in Pennsylvania (Czapowskyj, USDA Forest Serv. Res. Note NE-267, 1978).

Concern has recently been expressed at the lack of detailed soil-chemical and physical data related to forest productivity (Rennie, Utilization of northern soils, pages 305-331 *in* Proc. 11th Int. Congr. Soil Sci., Edmonton, Alta., 1978). In this study we consequently felt the need to obtain detailed vegetation and soil data for the six selected areas representing the range of common Boreal Forest soils in Newfoundland that were tentatively selected for poplar field trials.

Chemical and physical data on forest soils from Newfoundland are inadequate at this time, notwithstanding the availability of the results of some chemical analyses (Page, Can. J. Forest Res. 1:174-192, 1971) for western and eastern Newfoundland. With the exception of data from a 1 300 km^2 area covered in a soil survey (Wells and Heringa, Can. Dep. Agric., Nfld. Soil Surv. Rep. 1, 1972) few data on the nutrient content of forest soils exist for central Newfoundland. Several reports (Damman, Soc. Am. For. Forest Sci. Monogr. 8, 1964; Wells et al., Nfld. Forest Res. Cent. Inf. Rep. N-X-83, 1972; Wells and Roberts, Nfld. Forest Res. Cent. Inf. Rep. N-X-101, 1973) give detailed soil descriptions and classification but report very few chemical data.

Although all macronutrients are important for tree growth, recent studies in fertilization of poplars have shown that nitrogen and potassium are most effective in increasing and maintaining growth (Einspahr and Wyckoff, Tappi 61(3):49-52, 1978). In the present study, these elements were analyzed together with phosphorus, calcium, magnesium, and sodium. Table 1 summarizes the site characteristics and the total nutrient contents of the soils of the proposed experimental areas. Table 2 shows the available nutrients, cation exchange capacity (CEC), and base saturation for each of the soils. The analytical methods used were those of Jackson (Soil chemical analyses, Prentice-Hall Inc., Englewood, N.J., 1958). Two soil pits were dug at each site and soil samples were collected on a horizon basis. The results are the averages of each set of duplicate samples from each horizon. The sites were then evaluated on the basis of the upper organic and B horizons for the total exchangeable bases (TEB), CEC, and the total and available percentages of nitrogen, phosphorus, potassium, and calcium. The nutrient content of the upper B horizon was considered to be a critical factor in selection of sites because of the moderately deep rooting system of hybrid poplars. The percentage of total nutrients in this horizon was also considered important because the planting sites were to be limed to raise the pH to 5.5-6.0 and increase the quantities of available nutrients.

In addition to the chemical data collected, our knowledge of the former forest types helped in evaluation of the sites. Sites K5, K4, and K1 are in productivity class I and K3, K2, and K0 are in productivity class II (Bajzák et al., Nfld. Forest Res. Cent. Inf. Rep. N-X-7, 1968; Damman, 1964). This information provided the initial site grouping for hybrid poplar planting and the chemical data were used for the further evaluation of each site. The sites rank in decreasing order as K5, K1, K4, K0, K3, and K2 on the basis of the soil analyses (Table 1). The first three sites have more favorable soil texture for the growth of poplars than the others. Because of the expected increase in pH by liming, K2 is expected to move above K3 and all sites are expected to improve by release of increased amounts of available nutrients.

All sites except K3 should have adequate quantities of available moisture. Site K3 also has a fragipan in the lower B horizon that may adversely affect growth by retarding root penetration. Czapowskyj (1978) reported good growth of hybrid poplar on coal mine sites derived from glacial till with similar levels of available nutrients. He reported mean values of 0.08% N, and 2.40, 1.55, and 0.10 meq/100 g for Ca, Mg, and K respectively; the average CEC was 4.85. His pH values were 1-2 units higher than those for local sites investigated.

Correct assessment of site quality is particularly important for areas selected for planting hybrid poplars where an annual height growth of more than 2 m is expected under favorable conditions. Our results show that the nutrient contents and texture of the soils on the proposed planting sites are comparable to those generally prescribed for growing hybrid poplars. The nutrient contents of Newfoundland Boreal Forest soils are generally low in all essential elements, but the limiting factor in the growth of hybrid poplars may be the excessive soil acidity. This could be improved by liming. We recommend that, in future, detailed soil-site studies be a major basis for selecting suitable areas for plantations of fast-growing species. Hybrid poplars have now been outplanted on all six sites in replicated experiments. Future growth measurements will test our site ranking. Our detailed chemical results provide a summary of the major properties of predominant forest soils of Newfoundland.—B.A. Roberts and M.A.K. Khalil, Newfoundland Forest Research Centre, St. John's, Nfld.

PATHOLOGY

Influence of Splash Cones on Outplanted Conifer Seedlings.—Rain splashes mud and light debris that often encrust needles and stems of seedlings to form splash cones (Fig. 1). Splash cones are an important factor in frost heaving and injury to seedlings under freeze-thaw conditions (Schramm, Repr. Proc. Am. Philos. Soc. 102(4):333-50, 1958). Persistent splash cones may also be a hazard to seedlings during the growing season. This paper discusses some effects of such splash cones on the early development of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and white spruce (*Picea glauca* [*Moench*] Voss) outplanted in 1976-78 in north-central Alberta.

The mean height of seedlings before outplanting ranged from 5 to 9 cm (Table 1). The 5- and 13-wk-old lodgepole pine seedlings were in the early epicotyl stage without secondary needles or a terminal bud, while the 45-wk-old seedlings usually had a fully developed terminal bud and secondary needles. The 41- and 55-wk-old white spruce seedlings had fully developed terminal buds. The seedlings were outplanted between 13 May and 22 June, 1976, in two adjacent

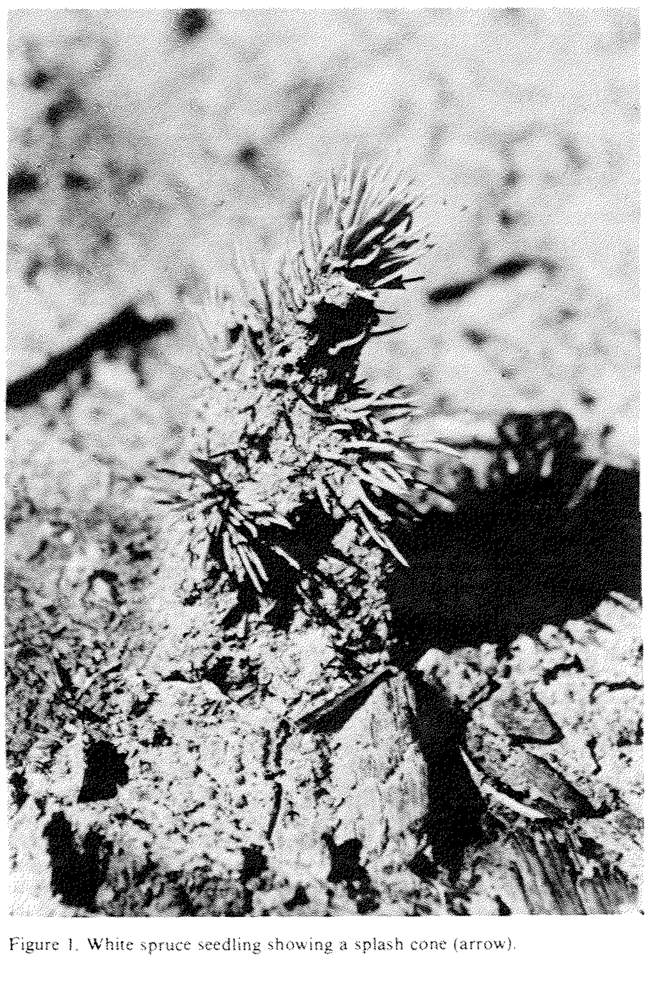


Figure 1. White spruce seedling showing a splash cone (arrow).

TABLE 1

Occurrence of splash cones on outplanted lodgepole pine and white spruce on two cutover areas

Species and numbers of outplanted seedlings	Age (wk)	Mean height (cm)	Percent of total seedlings with splash cones					
			Cutblock 36			Cutblock 38		
			1976	1977	1978	1976	1977	1978
Lodgepole pine								
50	5	5	24	0	36	100	56	50
75	13	7	28	0	32	100	49	60
125	45	9	19	5	26	98	31	51
White spruce								
75	41	8	5	12	52	98	23	50
50	55	8	0	24	44	100	70	46

cutblocks (36 and 38) at latitude 54°40′ and longitude 118°53′, 81 km south of Grande Prairie Alta.

The weakly to moderately calcareous soil of both cutblocks belongs to the Smoky soil group (Gleysol), although cutblock 38 is overlaid with a shallow cover of the Edson group (Orthic Gray Luvisol). The mineral soils involved in splash-cone production were clay loam (30% clay, 35% silt, and 35% sand) within cutblock 36 and clay (48% clay, 35% silt, and 17% sand) within cutblock 38. Twardy and Corns (Alta. Inst. Pedol. Rep. 39, in press) have described the Smoky soil group as poorly drained Gleysolic soils associated with significant amounts of moderately well drained Orthic and Brunisolic Gray Luvisols developed on Edson continental till parent material.

The two cutblocks differed in the amount of mechanical disturbance at the time of planting. In 1976, cutblock 36 was mostly undisturbed, with little or no exposure of mineral soil or loss of vegetation cover. In contrast, cutblock 38 was severely disturbed: it had lost its 8-15 cm humus layer and most of its herbaceous shrub cover because of churning and compaction that occurred during logging under conditions of wetness. Its ground cover rejuvenated very gradually from 1975 to 1978. Originally the stand consisted of lodgepole pine and black spruce *Picea mariana* [Mill.] B.S.P.). Labrador tea (*Ledum groenlandicum* Oeder) and tall bilberry (*Vaccinium membranaceum* Dougl.) were the main species of ground vegetation (Corns, Growth prediction in Alberta foothills, Ph.D. Thesis, Univ. Alta., 1978). The timber was cut between May 1974 and July 1975.

Rain in the experimental area usually came in short, heavy cloudbursts or as a steady drizzle lasting for a day or more. According to our May-to-October data for 1976-78 and those of Schultz and Co. Ltd. (Environmental effects of timber harvesting in Alberta, vol. 1, Alta. Dep. Lands Forests, 1973), the seasonal precipitation in this area varied from 53 to 63 cm. Heavy showers were most frequent during August 1976, May and July 1977, and September 1978; 1977 was the wettest season. During wet months the water table rose above the surface in some parts of cutblock 36, where the soil is underlaid with impervious bedrock. When rainfall was not abundant, as in 1976, the churned soil in cutblock 38 tended to dry into hard clods.

Observations on splash cones affecting bud size, needle color, and growth were made from 1976 to 1978. Fully and partly developed splash cones were recorded.

A substantial number of splash cones were recorded during these first 3 yr after the seedlings were outplanted. They occurred on seedlings planted on mineral-soil microsites within cutblock 36 and were particularly prevalent on those planted in churned soils within cutblock 38. Lodgepole pine and white spruce were equally susceptible to splash cones. Cutblock 36, with considerably less scarification and better ground cover, had fewer splash cones than cutblock 38 (Table 1). Splash-cone production on lodgepole pine decreased in 1977 within cutblock 36 because the water table rising there that year obliterated most splash cones except the ones that were not standing in water. Spruce seedlings were not affected to the same extent because they were planted on higher ground. In 1978 splash-cone production within cutblock 36 increased over the 1976 level because many seedlings were stunted from frost damage and frost heave and had a bushy-growth habit, which was more common in spruce than in pine. Bushy seedlings trapped more soil than nonbushy seedlings. The percentage of seedlings affected by splash cones increased gradually from May to August-September. Differences in cutblock 38 between seedlings with decreasing and fluctuating percentages of splash cones were due to small differences in recovery from frost damage and frost heave.

In severe cases the splash cone covered the seedling entirely or almost to the tip of the leading shoot, with the columns measuring 8-10 cm (Fig. 1). Lodgepole pine with long needles fared better than pine or spruce with short needles. Spruce and pine measuring 4 cm were generally covered entirely and were devoid of light until drizzle washed off the encrusted needles. Seedlings taller than 4 cm were bent over by the weight of their soil-encrusted stem tips. Encrusted needles were bleached but regained some of the chlorophyll as they became free of encrustation. The older needles tended to be pale in the first year after planting.

Seedlings with persistent splash cones rooted poorly and usually formed smaller terminal buds, particularly noticeable in white spruce. Seedlings with small splash cones or none developed reasonably good roots and tops. Splash cones on second-year and succeeding growth interfered with flushing. New shoots were small and spindly and had short needles. Affected seedlings lost vigor and had little or no top development.

Splash cones can be prevented by confining logging activity to winter months, when saturated soils are frozen, and by using proper silvicultural measures for most fine-textured soils. Cutblocks that have intact ground covers can be outplanted within a year of clear-cutting because the soil has better aggregation and structure. Cutblocks with bare, unstable, mineral soil may have to be left for a few years after clear-cutting to allow establishment of ground cover, which would protect the disturbed soil from compaction and leaching by pounding rains and help to bind soil particles into aggregates. As soil structure improves, seedlings root better (Perry, Tree Plant. Notes 69:9, 1964).

Conifer seedlings must not be planted too deep (i.e., past the root collar) on disturbed microsites, because deep planting slows rooting. The rooting process is hindered even more by persistent splash cones, which smother and weaken seedlings by denying them most of the light, aeration, and means to produce chlorophyll and starch. Observations suggest that weak seedlings are prime targets of frost damage and frost heave.—H. Zalasky, Northern Forest Research Centre, Edmonton, Alta.

ENTOMOLOGY

Web-spinning in Spiders Is Unaffected by the Molt-inhibiting Insect-growth Regulator BAY SIR 8514.—Upon ingestion, N-[[[4-(trifluoromethoxy) phenyl] amino] carbonyl]-2-chlorobenzamide, or BAY SIR 8514, selectively inhibits chitin synthesis in larval instars of Lepidoptera. After extensive laboratory and greenhouse studies, this material was field-tested on 40 ha (100 acre) plots of spruce-fir forest infested with spruce budworm near Wawa, Ont., in June 1979. Four different dosages, 280, 210, 140, and 70 g in 4.7 L/ha (4, 3, 2, and 1 oz in 0.5 U.S. gal/acre) were sprayed from an aircraft, and at the highest concentration the budworm population reduction due to treatment was 83 and 60% in balsam fir and white spruce, respectively (Retnakaran, J. Econ. Entomol., in press). Examination of this particular plot soon after spraying revealed that very few spider webs were present. A preliminary experiment to determine whether or not BAY SIR 8514 had any deleterious effect on web-spinning in spiders was conducted, and the results are presented in this report.

Twenty spiders of varying ages belonging to the genus *Aranea* were collected locally and maintained individually at 22°C, 60% RH, under continuous light in 5 L jars covered with cheesecloth, 10 of which served as controls and the other 10 as treatment. Each spider was fed one sixth-instar budworm at 2-day intervals for 1 mo before the start of the experiment. For the test CO_2 anesthetized sixth-instar budworm were each injected with 2 μL of a 4% aqueous suspension of BAY SIR 8514 and fed to the treatment spiders; control spiders were fed untreated budworm. After a period of 24-48 h, when the spiders had consumed the budworm larvae, the webs in all the jars were removed. Within 2 days all the spiders had spun new webs that appeared normal. One spider that had fed on a treated larva attempted to molt within 48 h after feeding and died during the process, showing evidence of molt inhibition (Fig. 1). Four other spiders that had fed on treated budworm molted

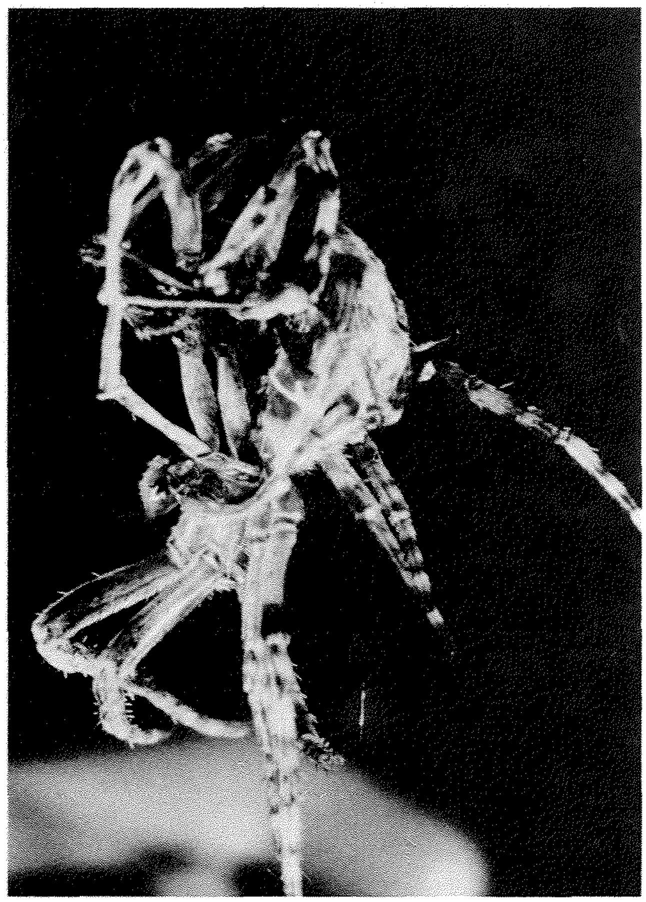


Figure 1. Molt inhibition in a spider (*Aranea* sp.) that attempted to molt within 48 h after consuming a sixth-instar budworm injected with BAY SIR 8514.

normally 7 to 10 days after feeding. These preliminary results indicate that web-spinning in spiders is unaffected by BAY SIR 8514, but there is some suggestion that molt inhibition can occur if molting takes place shortly after a treated larva is consumed.—Arthur Retnakaran and Larry Smith, Forest Pest Management Institute, Sault Ste. Marie, Ont.

WRONG CODE NUMBERS

Because an old negative was not discarded, the May-June addresses and code numbers listed on the outside back cover for recent publications were all incorrect. These addresses and numbers were changed last summer, and the new ones have been appearing since. The old negative, however, got into the works when the May-June issue was going to press. As the addresses and code numbers are supposed to be standing matter, it did not occur to anyone to check them. Hence the error.

For the publications listed in the May-June issue, use the address and code list that appears in the present issue and in those published from July-August 1979 to March-April 1980, inclusive.

RECENT PUBLICATIONS—JULY-AUGUST 1980

3 **Bonga, J.M. 1980.** Plant propagation through tissue culture, emphasizing woody species. Pages 253-264 *in* Plant cell cultures: results and perspectives. Elsevier/North-Holland Biomedical Press.

7 **Dyer, E.D.A, and P.M. Hall. 1980.** Effect of the living host tree (*Picea*) on the response of *Dendroctonus rufipennis* (Coleoptera: Scolytidae) and a predator *Thanasimus undatulus* (Coleoptera: Cleridae) to frontalin and seudenol. Can. Entomol. 112:167-171.

7 **Funk, A. 1980.** The sclerophomas associated with dieback of Douglas-fir. Eur. J. Forest Pathol. 10:53-57.

7 **Harris, J.W.E., and A.F. Dawson. 1979.** Predator release program for balsam woolly aphid, *Adelges piceae* (Homoptera: Adelgidae) in British Columbia, 1960-1969. J. Entomol. Soc. B.C. 76:21-26.

7 **Harris, J.W.E., and A.F. Dawson. 1979.** Parasitoids of the western spruce budworm, *Choristoneura occidentalis* (Lepidoptera: Tortricidae), in British Columbia 1977-78. J. Entomol. Soc. B.C. 76:30-38.

7 **Nijholt, W.W. 1980.** Pine oil and oleic acid delay and reduce attacks on logs by ambrosia beetles (Coleoptera: Scolytidae). Can. Entomol. 112:199-204.

7 **Ruth, D.S., and A.F. Hedlin. 1979.** Observations on a twigminer, *Argyresthia pseudotsuga* Freeman (Lepidoptera: Yponomeutidae), in Douglas-fir seed orchards. J. Entomol. Soc. B.C. 76:26-29.

7 **Sahota, T.S., and S.H. Farris. 1980.** Inhibition of flight muscle degeneration by precocene II in the spruce bark beetle, *Dendroctonus rufipennis* (Kirby) (Coleoptera: Scolytidae). Can. J. Zool. 58:378-381.

5 **Takai, S. 1980.** Relationship of the production of the toxin, cerato-ulmin, to synnemata formation, pathogenicity, mycelial habit, and growth of *Ceratocystis ulmi* isolates. Can. J. Bot. 58:658-662.

5 **Takai, S., and Y. Hiratsuka. 1980.** Accumulation of the material containing the toxin cerato-ulmin on the hyphal surface of *Ceratocystis ulmi*. Can. J. Bot. 68:663-668.

5 **Takai, S., W.C. Richards, Y.D. Davies, Y. Hiratsuka, and J. Krywienczyk. 1980.** Evidence for the presence of the toxin cerato-ulmin in the synnema head fluid of *Ceratocystis ulmi*. Can. J. Bot. 58:669-675.

3 **Thomas, A.W. 1980.** New records for some Canadian horse flies and deer flies (Diptera: Tabanidae). Entomol. News 91(2):59-60.

recent publications

Addresses of the Canadian Forestry Service

Requests for recent publications should be addressed as shown by the code.

1 Information Directorate,
Department of the Environment,
Ottawa, Ontario,
K1A 0E7

2 Newfoundland Forest Research Centre,
Department of the Environment,
Building 305, Pleasantville,
P.O. Box 6028,
St John's, Newfoundland,
A1C 5X8

3 Maritimes Forest Research Centre,
Department of the Environment,
P.O. Box 4000,
Fredericton, New Brunswick,
E3B 5P7

4 Laurentian Forest Research Centre,
Department of the Environment,
P.O. Box 3800,
Ste. Foy, Quebec,
G1V 4C7

5 Great Lakes Forest Research Centre,
Department of the Environment,
P.O. Box 490,
Sault Ste. Marie, Ontario,
P6A 5M7

6 Northern Forest Research Centre,
Department of the Environment,
5320 - 122nd Street,
Edmonton, Alberta,
T6H 3S5

7 Pacifc Forest Research Centre,
Department of the Environment,
506 West Burnside Road,
Victoria, British Columbia,
V8Z 1M5

8 Petawawa National Forestry Institute,
Department of the Environment,
Chalk River, Ontario,
K0J 1J0

9 Forest Pest Management Institute,
Department of the Environment,
P.O. Box 490,
Sault Ste. Marie, Ontario,
P6A 5M7