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Fifteen-year growth of tamarack planted at six spacings on an upland site

W.M. Stiell

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Petawawa National Forestry Institute

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ABSTRACT

Development of tamarack (Larix laricina [Du Roi] K. Koch) established at six spacings, from 1.25 x 1.25 m to 4.25 x 4.25 m, on an upland site, is reported to age 15 years from planting. Data were collected by remeasurement of permanent sample plots located in each spacing, which included observations of dbh, height, crown size, and stem taper. Comparisons between spacings for individual tree growth were made for a subsample representing the modal dbh class present at the time of the first measurement (nine years from planting). Per hectare development was obtained from stand tables compiled for the individual plots. Relations of stand values to spacing were determined by stepwise regression. The combined effect of height and spacing on various parameters was demonstrated.

RÉSUMÉ

Sont présentés des détails sur le développement du mélèze laricin (Larix laricina [Du Roi] K. Koch) en terrain élevé, à six espacements (de 1,25 sur 1,25 m à 4,25 sur 4,25 m), au cours des 15 premières années suivant la plantation. Les données ont été obtenues dans des placettes d'échantillonnage permanentes pour chacun des espacements où on a mesuré le diamètre à hauteur de poitrine (dhp), la hauteur, l'étendue de la cime et le défilement. Des comparaisons de la croissance d'arbres individuels aux divers espacements ont été effectuées pour un sous-échantillon représentant la classe modale de dhp au moment du premier contrôle (neuf ans après la plantation). Les chiffres pour le développement par hectare ont été obtenus à partir des tableaux d'inventaire produits pour les placettes. L'influence de l'espacement a été déterminée par régression pas à pas. L'influence combinée de la hauteur et de l'espacement sur divers paramètres a été mise en évidence.

FIFTEEN-YEAR GROWTH OF TAMARACK PLANTED AT SIX SPACINGS ON AN UPLAND SITE

INTRODUCTION

Tamarack, or eastern larch (*Larix laricina* [Du Roi] K. Koch), is widely distributed in all provinces east of the Rocky Mountains and in the Northwest Territories, and has limited occurrence in the Yukon and northeastern and central B.C. (Hosie 1969). The value of tamarack to forestry is limited by several inherent disadvantages, but progress has been made in overcoming some of these. Seed supply is erratic owing both to small seed yields per cone and infrequent seed years (Campbell 1983, Duncan 1954) and collection is expensive even in good years because the small cones are distributed over the crown. As well, tamarack has scattered occurrence in a stand. The establishment of seed orchards (Rauter and Graham 1983) to provide high-quality seed would also allow more concentrated and economical sources of supply. Tamarack is chronically subject to devastating attacks by the larch sawfly (*Pristiphora erichsonii* Htg.) and larch casebearer (*Coleophora laricella* Hbn.); control with insecticides is feasible and necessary in plantations if they are to achieve merchantable production (Howse 1983). Tamarack has been unpopular at pulp mills since low wood supplies necessitate inconveniently frequent process changes to accommodate batches of the species. However Holder (1983) has recently reported that tamarack can be mixed with spruce for satisfactory Kraft pulping.

Despite these shortcomings, foresters in central and eastern Canada have in recent years shown considerable interest in tamarack for planting. This is due to the extremely rapid juvenile height growth observed in natural regeneration, and in trial plantations, where it surpasses other eastern Canadian species at an early age (Vallée and Stipanicic 1983). In this respect tamarack performs best on well-drained sites (MacGillivray 1969) but can grow well under moderately wet soil conditions, where it is said to be the most productive native conifer within its natural range. Operational planting in the east is increasing and expected to reach about 12 million seedlings per annum within a few years --- ca. 85% in Quebec, 8% in New Brunswick, 4% in Ontario, 2% in Prince Edward Island, and 1% in Nova Scotia. In these circumstances it is appropriate to accumulate information on potential plantation yields under various growing conditions.

Concerning the latter, knowledge of tree growth as affected by stocking level is of fundamental importance in forecasting yields, and is essential to making decisions regarding numbers of trees to plant per hectare, whether or not to thin and, if so, the proper timing. The objectives of this study, then, are to determine in detail the effects of initial spacing on individual tree and per hectare development in tamarack plantations on an upland site at the Petawawa National Forestry Institute.

METHODS AND MATERIALS

Site and site preparation

The spacing trial occupies about 3.7 ha on land previously supporting 50-year-old poplar (Populus) and mixedwood stands. The site was undulating, with soil consisting mainly of about 80 cm of fine sand over a boulder pavement. The moisture regime varies from 1 to 2, or somewhat dry to fresh (sensu Hills 1952).

The area was clear-cut in 1967, and the slash burnt in piles. All remaining vegetation was killed with Dybar (pelletted 25% fenuron) broadcast at 33.6 kg/ha in August of that year. Incipient hardwood growth was sprayed with 2,4-D in 1969. The planting site was staked out according to a randomized block design for six spacings, each replicated twice. These were 4 x 4, 6 x 6, 8 x 8, 10 x 10, 12 x 12, and 14 x 14 ft, equivalent to 1.25 x 1.25, 1.75 x 1.75, 2.50 x 2.50, 3.00 x 3.00, 3.75 x 3.75, and 4.25 x 4.25 m respectively, in the 0.25-m interval module (Table 1).

Table 1. Spacing equivalents

Spacing m	Tree/ha Mean	Tree/ha Range
1.25 x 1.25	6 400	5 289 - 7 900
1.75 x 1.75	3 265	2 844 - 3 786
2.50 x 2.50	1 600	1 451 - 1 772
3.00 x 3.00	1 111	1 024 - 1 209
3.75 x 3.75	711	666 - 760
4.25 x 4.25	554	522 - 587

Planting and initial treatment

Tamarack seedlings, received from the Ontario Ministry of Natural Resources at Midhurst, were hand-planted during the first week of May, 1970. Their provenance is presumed to be Ontario Seed Collection Zone 5E, i.e. the same ecological region as the test site. Refilling, from the original stock shipment, was carried out in the spring of 1971 and 1972 for 9% and 8% mortality respectively.

In 1976, 1977, and 1978 a skidder-mounted mistblower was used to spray young trees in early summer with malathion, thereby effectively controlling outbreaks of larch sawfly.

Sampling

Plot establishment

In 1978 the blocks were examined with a view to establishing permanent sample plots and setting up a measurement program. Rate of survival at some spacings was sufficient to allow plot location within the designated spacing class. In other blocks rather high mortality (some caused by root rot) had left large openings, precluding the establishment of normal plots which would contain the nominal number of trees required for the spacings in question.

In these cases constant-density, variable-area plots were established as follows. The height distribution within the block was determined by 1-m classes, and sufficient trees, each with at least a 4-tree complement of adjacent competitors, were selected according to that distribution to make up the number corresponding to the particular spacing on a fractional hectare basis. Even by this method it was possible to provide only one plot at 3.00 x 3.00 m. All other spacings were sampled by two plots.

On each plot all trees were tagged at 1.3 m (metric breast height), and mapped. About 30 sample trees per plot were selected according to the 1-m height distribution.

Measurement

In the fall of 1978 the following measurements were taken on every plot: the dbh in centimetres and height in metres of every tree; the maximum crown width (two observations, one made along the row and one at right angles to the row) in metres, on every sample tree. In 1980 height to the base of the live crown, crown width, and dbh and height were measured on all sample trees.

In 1984 the previous procedures were repeated except that height measurements on non-sample trees were confined to sufficient individuals over the range of diameters to allow the preparation of a height/dbh curve for each plot. On sample trees diameters were measured at stump height (0.15 m), 0.70 m, breast height (1.30 m), at 1.5-m intervals above the latter, and at half-height above breast height.

Compilation

Mean dbh (tree of mean b.a.), mean height (height of that tree, read from the parabolic height/diameter curve), dominant height (height corresponding to average of largest 10% of diameters), and crown length (tree height minus height to crown) were calculated.

Volumes were estimated from stem measurements taken on the sample trees, so as to differentiate changes in stem form associated with spacing. Outside bark measurements were used in the calculations, and the resulting volumes reduced by 9.8% for inside bark values (Doucet, Poliquin, and Verville 1983). For each plot a regression of the form $v = a + b + cd^2$, where v is total stem volume and d is dbh, was derived and applied to the means of plot diameter classes to produce volumes per hectare. A stand table for 1984 was prepared for each plot, showing tree numbers, basal area, and total volume by 2-cm diameter classes.

Analysis and presentation

The height-spacing relationship has been found to control various aspects of tree and stand development in plantations of white spruce (Picea glauca (Moench) Voss) and red pine (Pinus resinosa Ait.) (Stiell 1967, Stiell and Berry 1973, 1977) and was used in the following analysis of tamarack growth. This involved using height rather than age as the independent variable where data are presented graphically according to spacing. In these figures the plotted points are shown for 1978, 1980, and 1984, so that ages can be deduced.

Two sets of data are presented. The first is for the 1978 modal diameter class (4-cm trees) as represented by the sample trees in that class, and indicates the change in individual parameters for the same trees over the study period. The second data set is for stand average and per hectare values as determined from the whole plots in 1978 and 1984. The data presented in Table 2 are the means of the two plots for each spacing (except for that at 3.00 x 3.00 m). However, data from all individual plots were used in running stepwise regressions of stand values on spacing (expressed as trees per hectare), with F-tests for significance.

The following conventions have been adopted. Only one dimension is used to indicate a spacing, e.g. "2.50 m" for "2.50 x 2.50 m", and "spacing" and "density" are used interchangeably with wider spacing implying lower density. Age is taken as the number of years since planting. "Significant" refers to P=0.95; "Highly significant" to P=0.99; and "Very highly significant" to P>0.99.

RESULTS

Damage

Besides attacks by the larch sawfly referred to above, the plantations were subject to damage by the larch shoot moth (Argyresthia laricella Kearfott) which killed a small number of leaders. More serious was the occurrence of root rot caused by the fungus Armillaria mellea (Vahl ex Fr.) Kummer, resulting in variable mortality.

Sample trees

Height

Curves of mean height growth for four spacings are shown in Figure 1. Growth rates had not declined by 1984 for any spacing, except perhaps at 4.25 m, which had the lowest height at that date. Ranking was not consistent from one date to another, however.

Diameter

Dbh of sample trees had stratified according to spacing by 1984, with wider spacings showing the greater values (Figure 2). Except at 3.00 m, growth rate had begun to slow down by 1980.

Crowns

Crown width similarly showed a direct association with height and spacing by 1984 (Figure 3). Trees at all spacings had full-length crowns in 1978, but

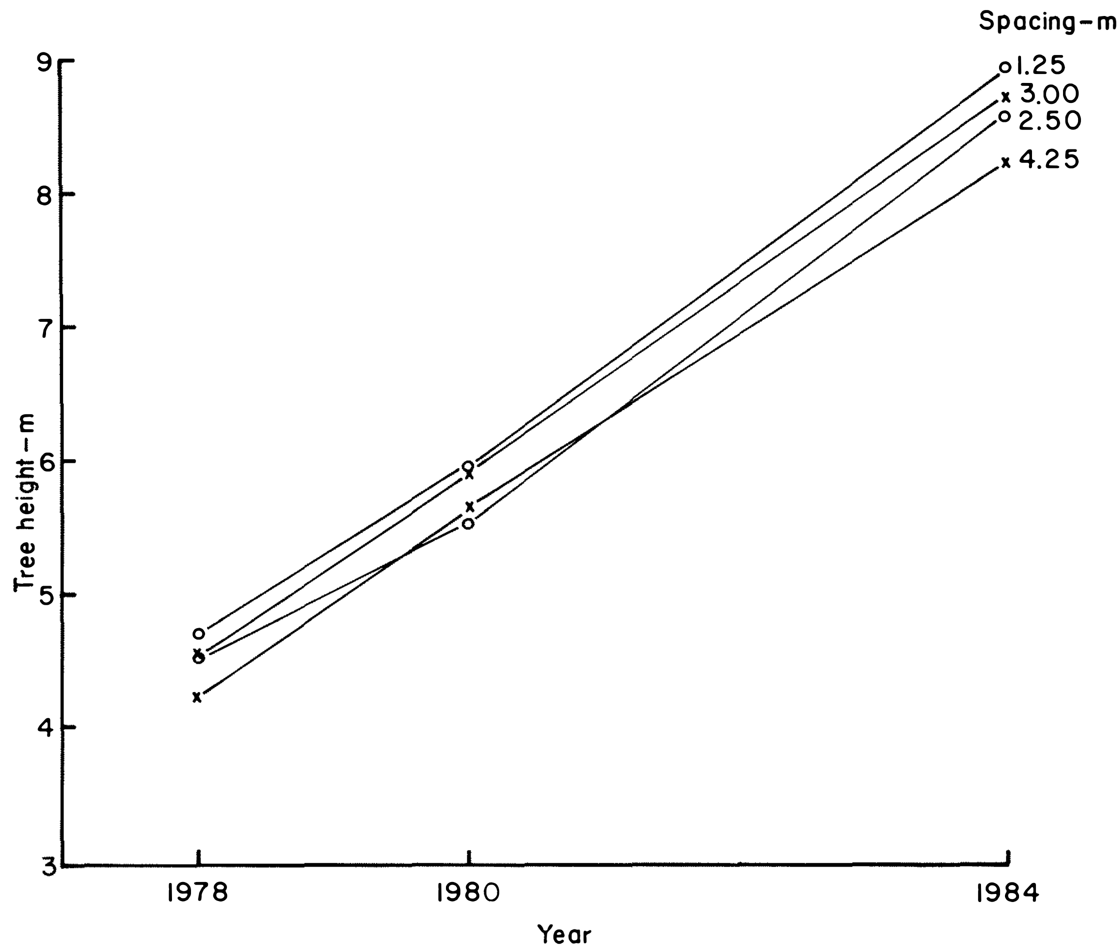

Figure 1. Height growth, for selected spacings, of sample trees in 1978 modal dbh class.

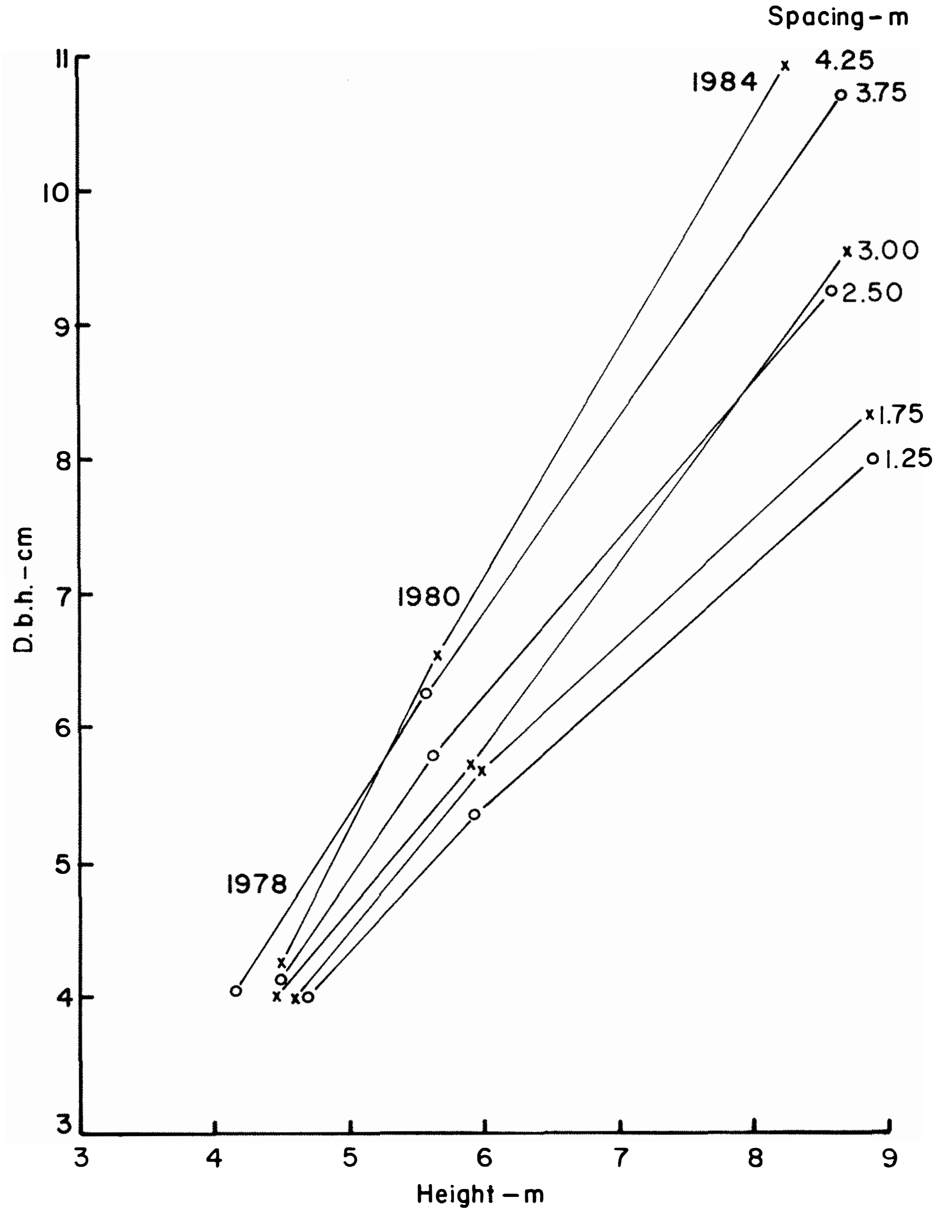

Figure 2. Dbh/height relations of sample trees in 1978 modal dbh class.

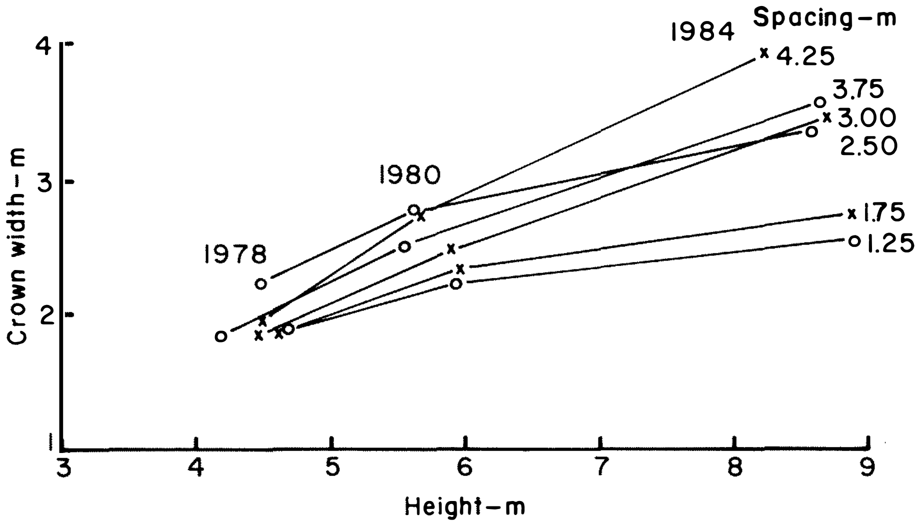

Figure 3. Crown width development of sample trees in 1978 modal dbh class.

recession at the base was underway by 1980 and, by 1984, height to the live crown was inversely associated with spacing (Figure 4). Rate of recession was slower during 1980 to 1984. By contrast, crown length increased more rapidly during 1980 to 1984. It had stratified according to spacing by the latter date, when longer crowns were associated with wider spacings except at 4.25 m (Figure 5).

Stand values

Mean values, together with significance of their relation to numbers of trees per hectare, are summarized in Table 2. All these relations are straight-line, although some (dbh, form quotient, basal area) approached F-values indicating curvilinearity.

Mean height
Mean heights varied between plots by as much as 1.4 m in 1978 and 2.0 m in 1984, but no significant association was found for this parameter (or for dominant height) with spacing in either year.

Diameter breast height
There was no significant relation between plot mean dbh and spacing in 1978, but by 1984 a strong association of greater dbh with lower density had developed (Figure 6).

Diameter distributions for 1978 and 1984 are shown in Table 3. Virtually the same dbh classes were represented by every spacing in 1978, with 4 cm the modal class in each case. By 1984 the range of diameters had been

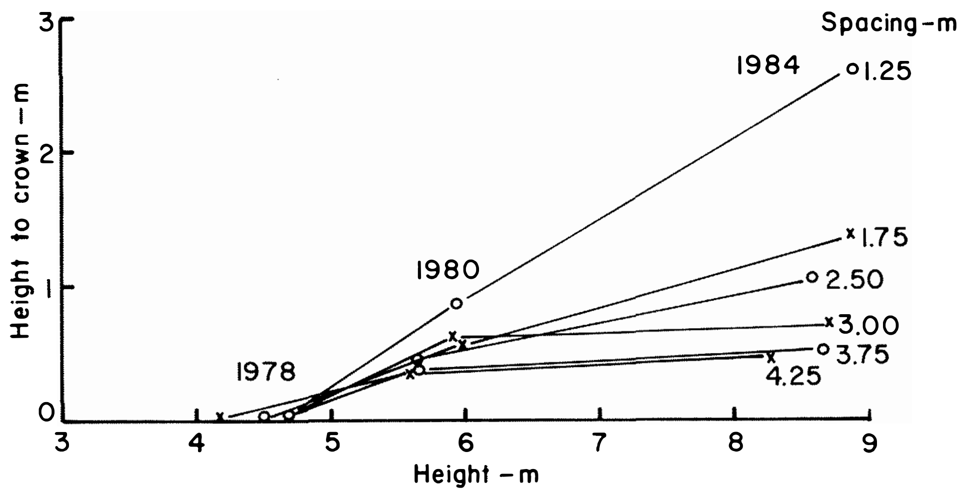

Figure 4. Recession of crowns at the base of sample trees in 1978 modal dbh class.

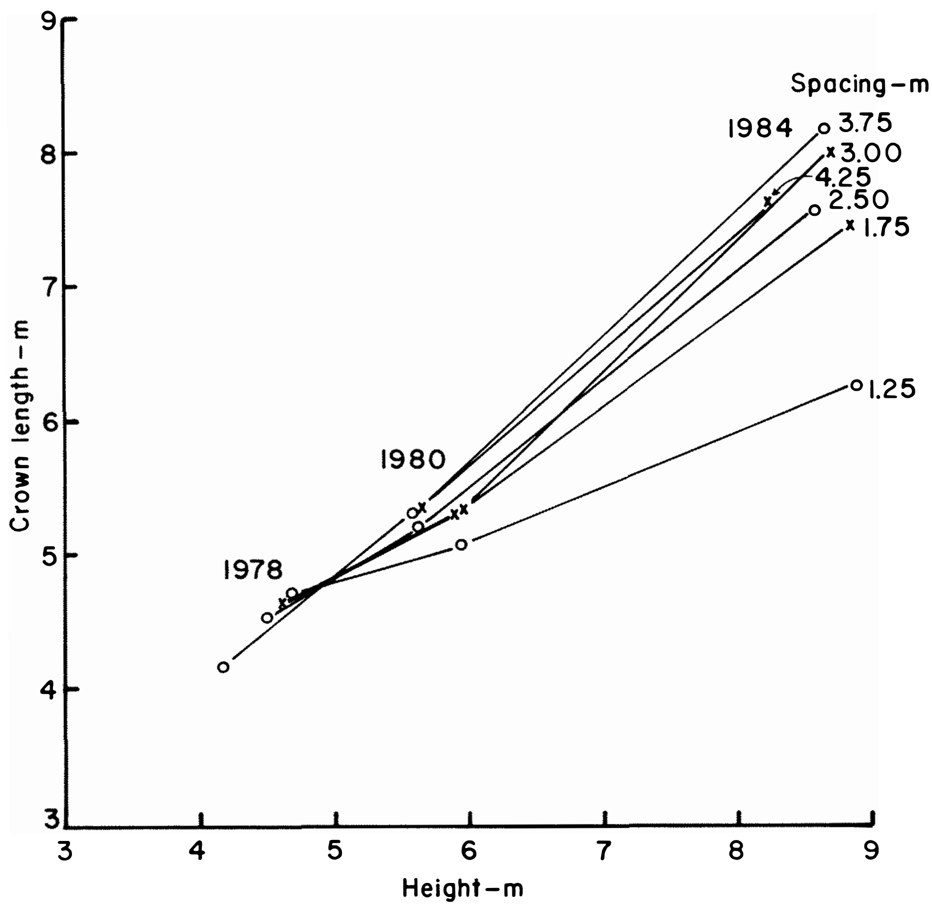

Figure 5. Crown length development of sample trees in 1978 modal dbh class.

Table 2. Average stand parameters

Stand value	Date	Nominal planted spacing, m 1.25	1.75	2.50	3.00	3.75	4.25	Significance of relation to numbers trees/ha
Basis, number plots		2	2	2	1	2	2	
Plot size, ha		0.020	0.040	0.073	0.069	0.081	0.122	
Trees/ha	1978	5250	2488	1467	1058	741	550	
	1984	4825	2262	1460	1043	728	532	
Annual mortality	1978-84	70.8	37.6	1.2	2.5	2.2	3.0	
Mean dbh, cm	1978	3.5	3.7	4.5	4.2	3.8	4.6	NS
	1984	6.6	8.0	9.8	10.0	9.8	11.3	VHS
Annual growth	1978-84	0.5	0.7	0.9	1.0	1.0	1.1	
Mean height, m	1978	4.3	4.4	4.8	4.6	4.0	4.6	NS
	1984	8.3	8.4	8.8	8.7	7.8	8.5	NS
Annual growth	1978-84	0.7	0.7	0.7	0.7	0.6	0.6	
Dominant height, m	1978	5.2	5.8	5.8	5.8	5.2	5.9	NS
	1984	9.4	10.0	9.8	9.6	9.4	9.8	NS
Crown length, %	1984	67.1	82.8	80.6	82.8	88.9	88.7	
Form quotient, %	1984	63.8	59.2	57.2	57.7	52.8	52.8	VHS
Basal area, m^2/ha	1978	4.7	2.6	2.4	1.5	0.8	0.9	VHS
	1984	16.9	11.0	11.1	8.2	5.5	5.4	VHS
Annual growth	1978-84	2.0	1.4	1.4	1.1	0.8	0.7	
Total volume, m^3/ha	1984	73.9	46.1	48.2	35.1	21.4	21.4	VHS

NS = Not significant; VHS = Very highly significant.

Table 3. Diameter frequency (%)

Year	Spacing	Under 1 cm	2-cm dbh class 2	4	6	8	10	12	14	16	18	20	Total
1978	1.25 m	4	43	47	6	0	0	0	0	0	0	0	100
	1.75	3	41	43	12	1	0	0	0	0	0	0	100
	2.50	2	26	42	26	4	0	0	0	0	0	0	100
	3.00	1	26	51	18	4	0	0	0	0	0	0	100
	3.75	6	30	51	11	2	0	0	0	0	0	0	100
	4.25	1	21	47	26	5	0	0	0	0	0	0	100
1984	1.25 m	1	6	21	32	26	14	0	0	0	0	0	100
	1.75	1	3	11	29	27	20	8	1	0	0	0	100
	2.50	0	1	4	10	23	32	23	6	1	0	0	100
	3.00	0	1	4	10	24	26	25	10	0	0	0	100
	3.75	0	1	8	8	22	31	22	6	2	0	0	100
	4.25	0	0	2	6	11	29	33	11	7	1	0	100

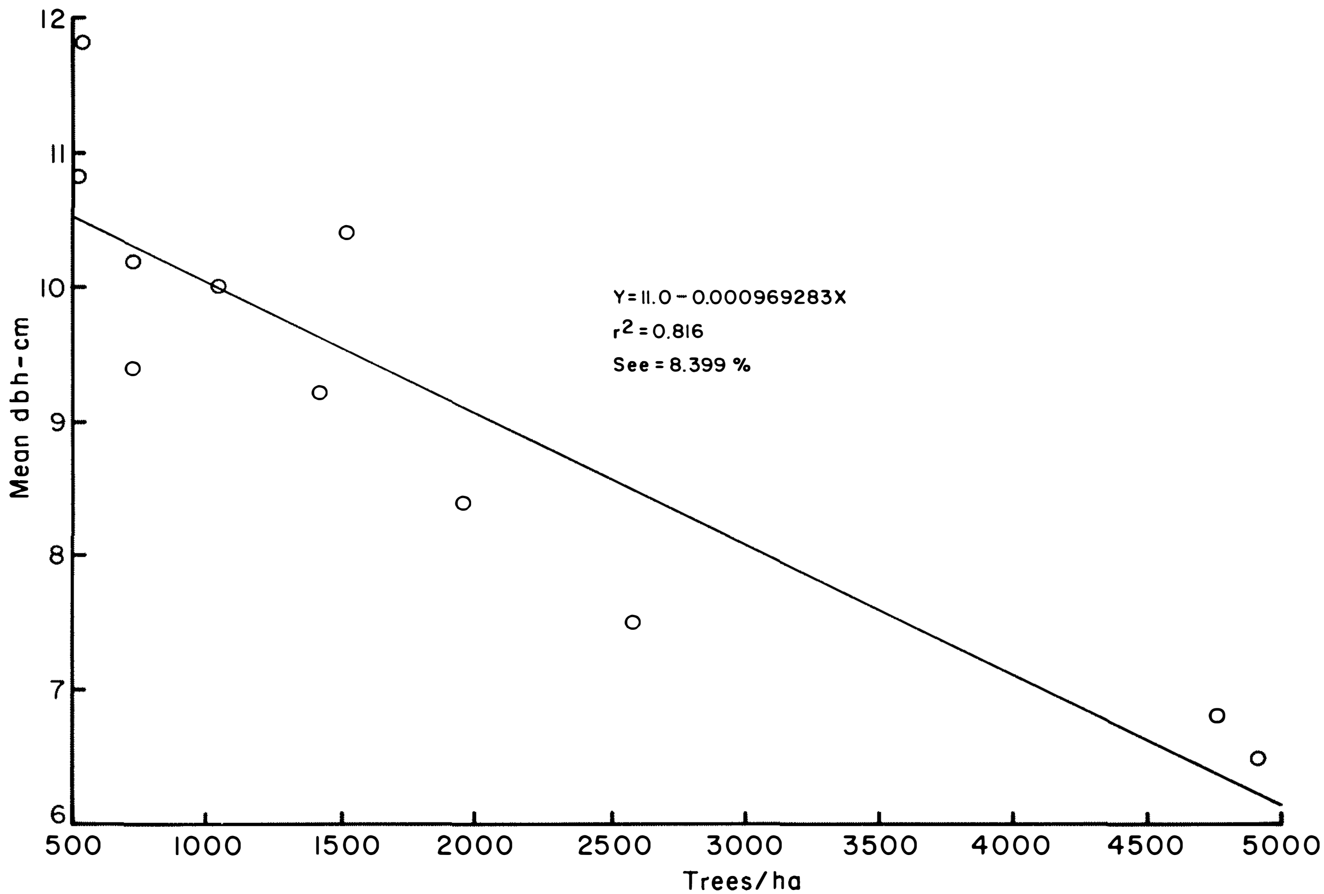

Figure 6. Mean stand dbh/spacing relations 1984.

considerably extended --- to as many as eight classes from the original five, with the shift to larger sizes more pronounced at wider spacings.

Form quotient
Mean form quotient (ratio diameter at half-height above breast height to dbh) was inversely related to spacing (Figure 7), with values ranging from 52.8% at 4.25 m to 63.8% at 1.25 m.

Crown projection
Stand crown projection area (CPA) represents the sum of individual crown cross-sections, and is a measure of canopy closure and of ground coverage. Theoretically, with circular crowns and evenly spaced trees, the CPA would be 0.78 ha at closure, i.e. when adjacent crowns just touched. This value can be considerably exceeded when crowns overlap. In Figure 8, CPA can be seen to increase with greater height and closer spacing. In 1978 closure had already occurred at 1.25 m, and in 1984 at all but the widest spacings. Increase during 1980-84 was similar at all spacings and less than for 1978-80.

Mortality
Few trees at the four widest spacings died in the period 1978-1984 (Table 4). The much higher average mortality at 1.75 m was due to the fairly high incidence of Armillaria on one of the two plots at that spacing; the other showing about the same low rate as in the lower densities. The high rate at 1.25 m was exhibited by both plots and was evidently due to suppression.

Table 4. Mortality 1978-84 (trees/ha)

		2-cm dbh class				Total	
Spacing	<1 cm	2	4	6	8	Trees /ha	% of 1978
1.25 m	50	125	175	75		425	8.1
1.75		75	101	50		226	9.1
2.50		7				7	0.5
3.00			15			15	1.4
3.75	7		6			13	1.8
4.25		4	9	5		18	3.3

Basal area
A strong, inverse relation of basal area to spacing had been established by 1978 and continued in 1984 (Figure 9). Growth rate in the period showed a similar trend. The two widest spacings had the lowest, and about equal, values for all those variables.

Volume
Total volume in 1984 showed a similar relation with spacing to that of basal area (Figure 10). The volume at 1.25 m exceeded the next highest value by over 50%.

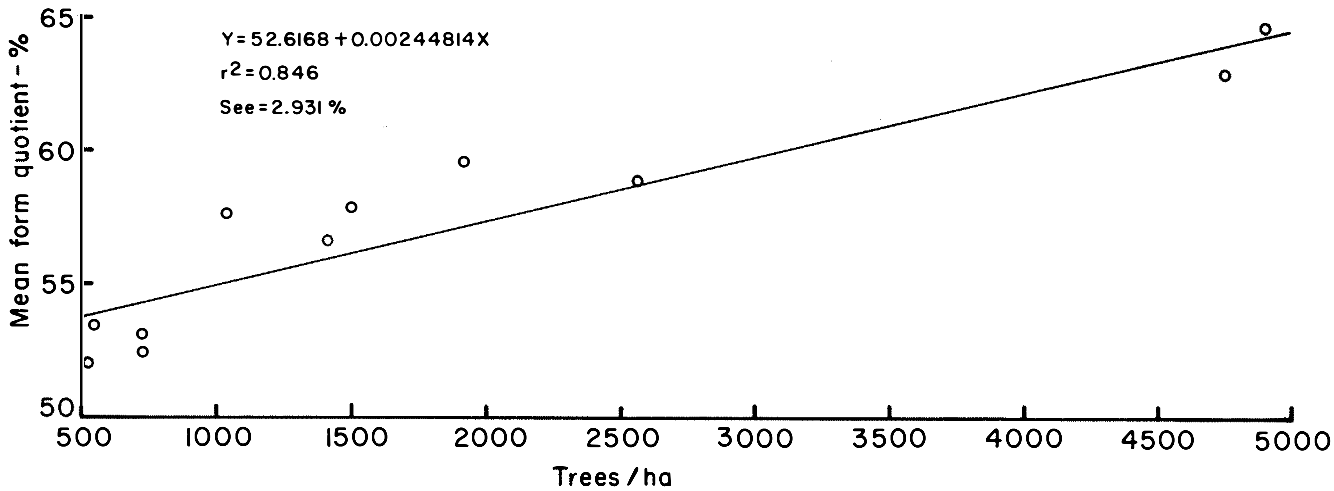

Figure 7. Mean form quotient/spacing relations 1984.

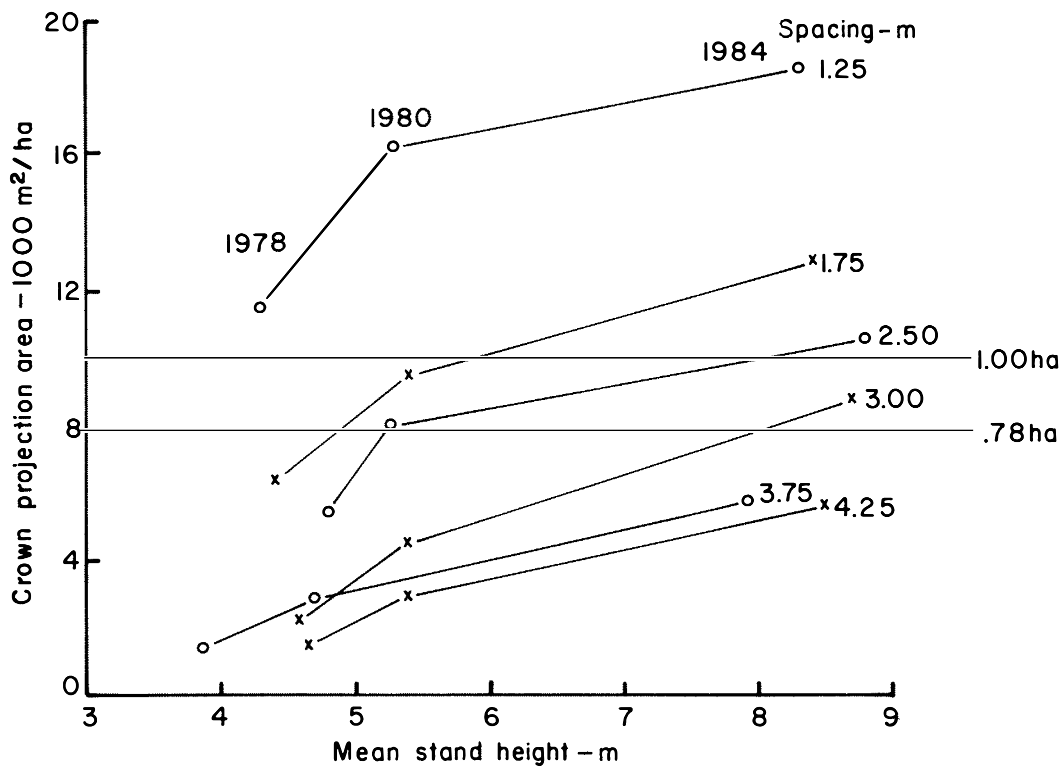

Figure 8. Relation of crown projection area to height and spacing 1984.

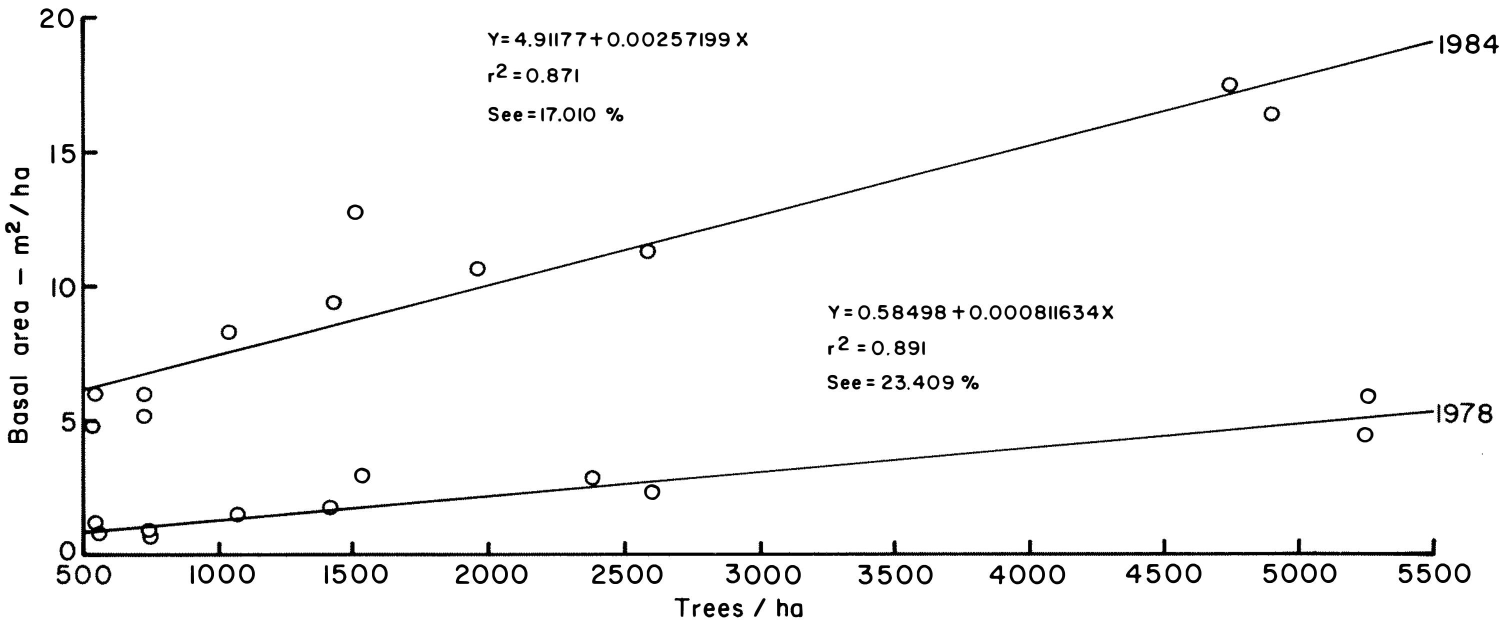

Figure 9. Stand basal area/spacing relations 1978 and 1984.

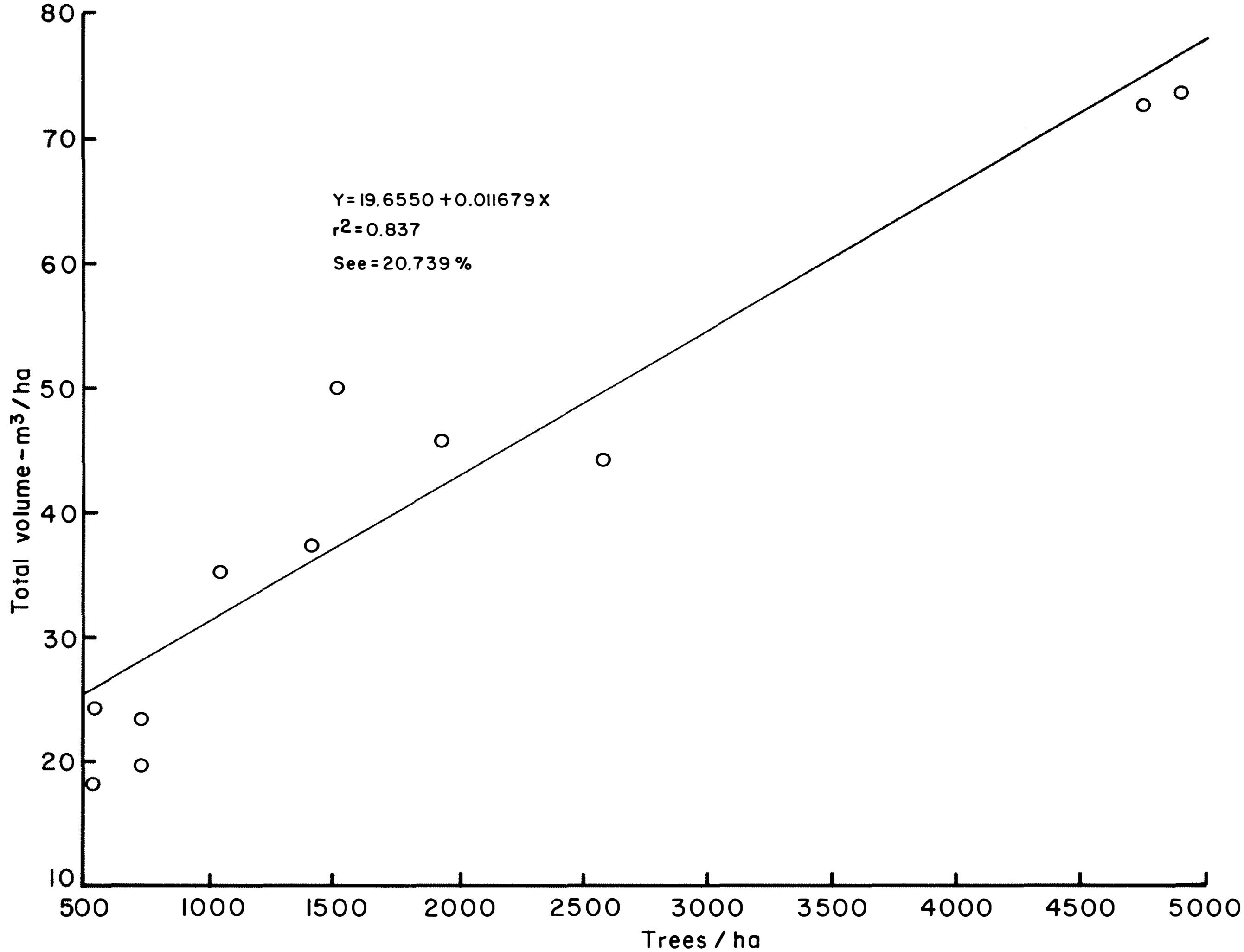

Figure 10. Stand total volume/spacing relations 1984.

DISCUSSION

Lack of height growth response to variations in spacing is not unexpected, as most other conifers show similar behaviour --- especially within this range of densities and at this early stage of development (Evert 1971). However, there is little published information on spacing effects for the species in question. Bolghari and Bertrand (1984), dealing with tamarack plantations in Quebec, indicate the same dominant height for all densities at a given site index in their spacing yield tables which extend up to 35 years of age, and 19 m tall on their best sites.

In terms of actual growth, height of the Petawawa tamarack places these plantations approximately in Site Class 13 m at total age 25 years, according to the dominant height/age curves of Bolghari and Bertrand (1984), or about average for the range of sites presented therein. Height growth appears to equal or exceed values of those few other plantations of similar age[1] reported in the literature (Hall 1983 (Newfoundland), McGillivray 1969 (New Brunswick), Riemenschneider and Jeffers 1980 (Wisconsin), Vallée and Stipanicic 1983 (Quebec)).

Unlike height, a number of variables were clearly associated with spacing, at least at the closer spacings by 1984 when mutual competition had been established. This was not yet the case in 1978, as indicated by the full-length crowns then prevailing at all spacings. Still, at 1.25 m, the large crown projection area developed by that date suggested that high density effects would be imminent for that spacing. The crown, as the photosynthesizing agent, directly controls diameter growth, and spacing is related to dbh and form quotient only through its immediate influence on crown growth.

Crown width, one component of crown size, shows the strongest association with height and spacing in 1984. Crown length, the other component, is not so clearly associated because it is dependent on both recession at the base and height growth, which can proceed at different rates. Relative crown development is shown schematically in Figure 11.

Highest total volume production, occurring at 1.25 m, is a result of greatest number of trees, highest form quotient, and similar height (in comparison to wider spacings), which combine to offset lower mean diameter. This behaviour derives from earlier occupancy of the site by denser stands, and is almost invariably shown for total volume in conifer spacing studies (Evert 1971).

A stand is only "dense" or "close-spaced" in terms of its height, and obviously what is considered a wide spacing when height is only 3 m will not be so considered when height is 20 m. Height and spacing together, then, appear to be the determinants of many stand variables and can be combined mathematically for predictive purposes. This has been demonstrated, for example, with red pine (Stiell and Berry 1977) and jack pine (<u>Pinus banksiana</u> Lamb.) (Stiell 1980). Such regressions were developed for estimating tamarack basal area per hectare and total volume per hectare (Figures 12 and 13).

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[1]Whether plantation age is "from seed" or "from planting" is not always specified.

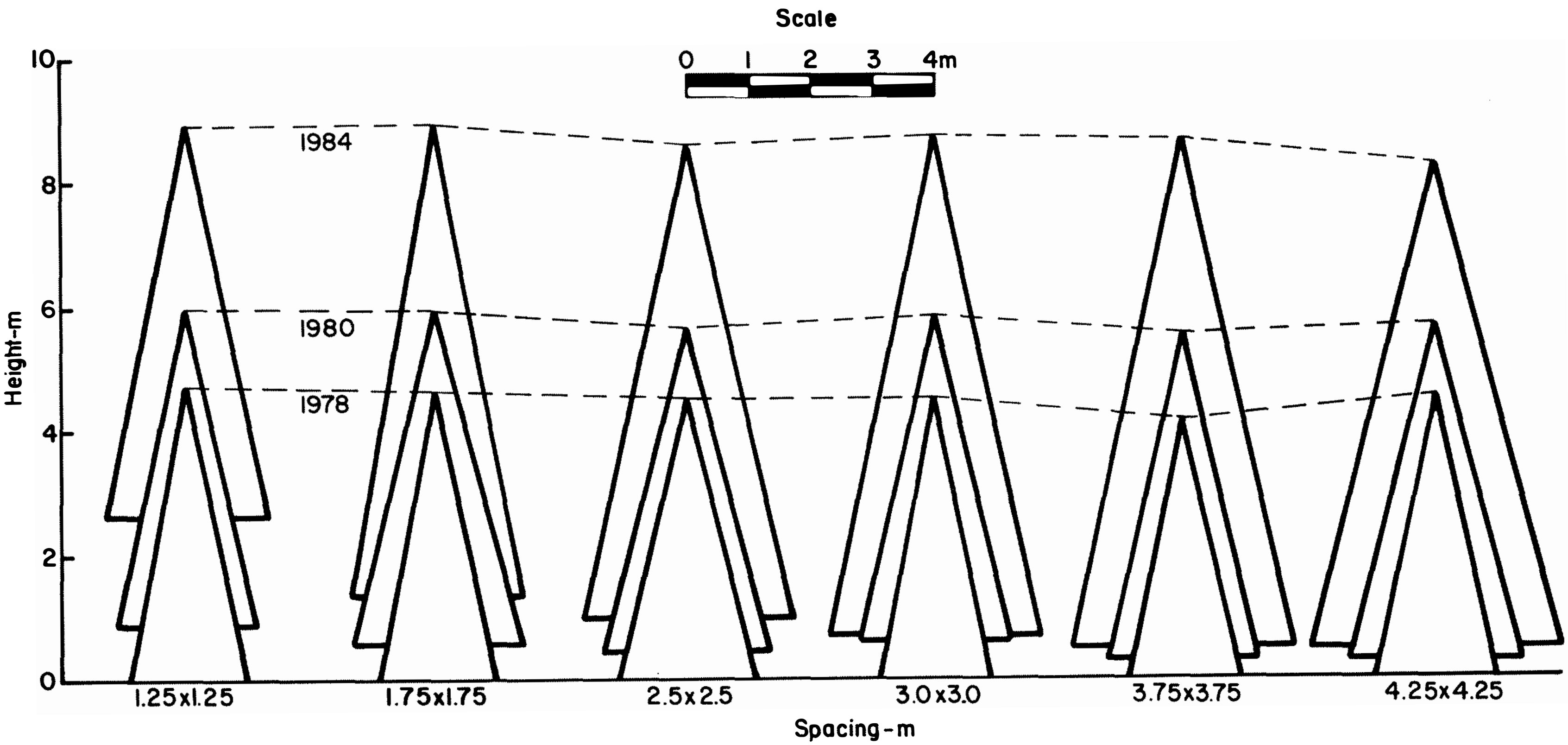

Figure 11. Relative crown development of sample trees in 1978 modal dbh class.

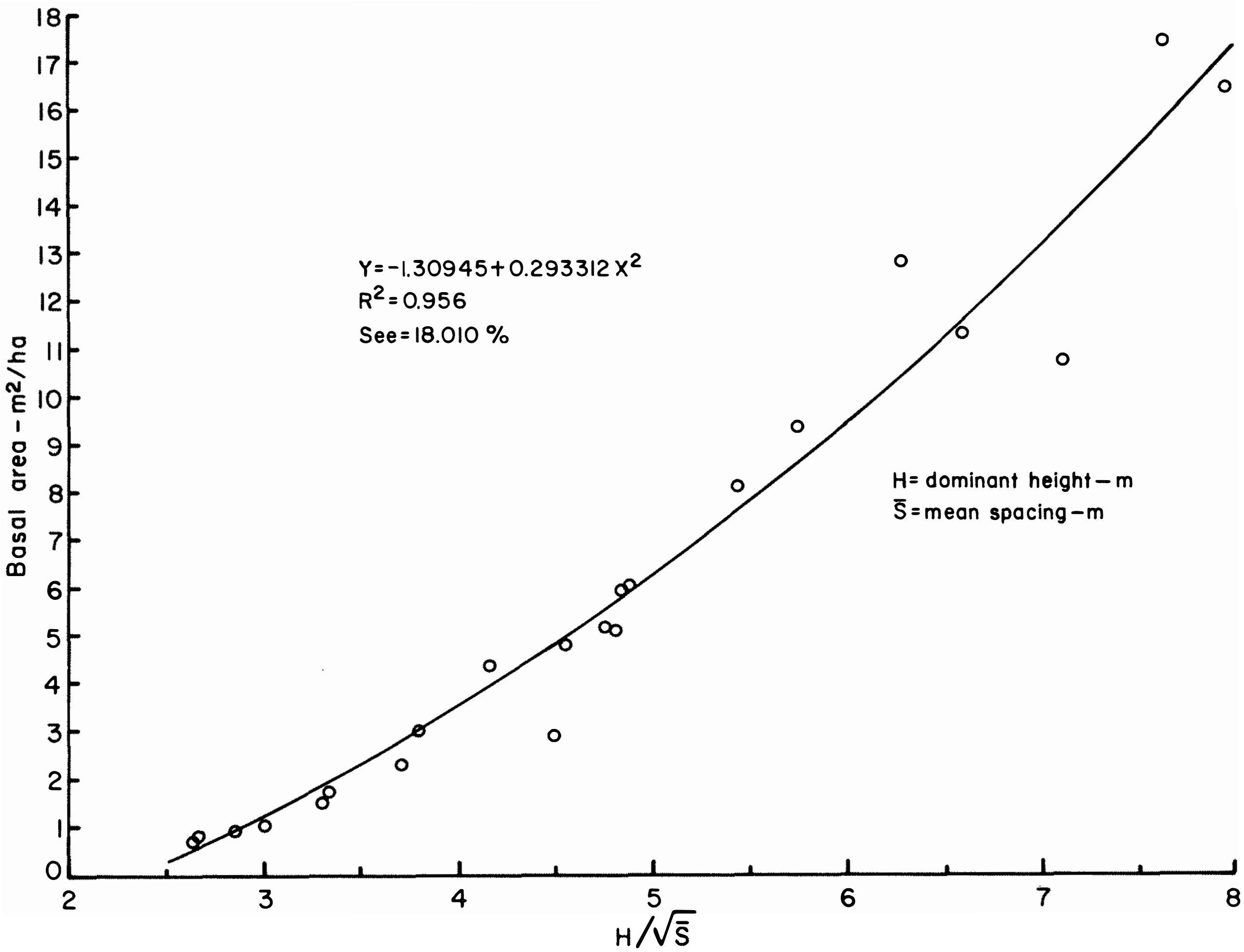

Figure 12. Relation of stand basal area to height and spacing 1978 and 1984.

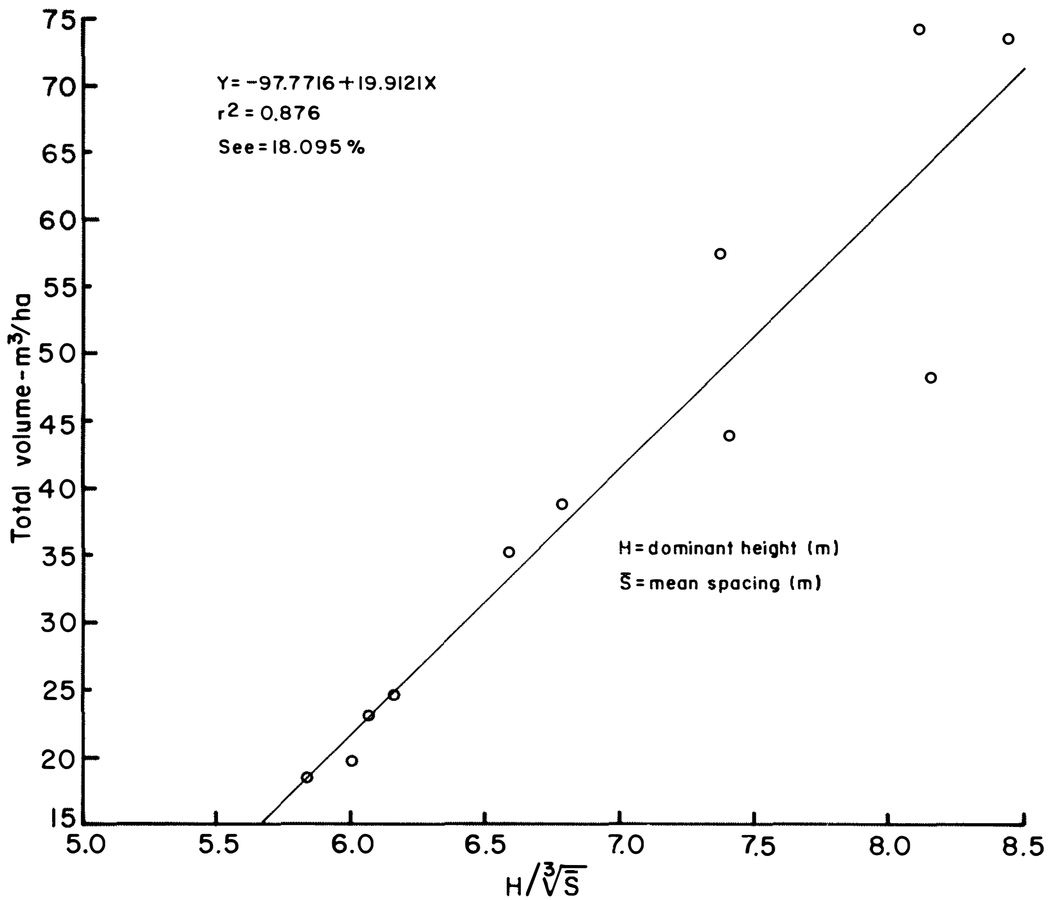

Figure 13. Relation of total stand volume to height and spacing 1984.

In comparison with the tamarack, a red pine spacing trial on a similar site at Petawawa (Stiell and Berry 1977) averaged 20% less in mean height at 15 years from planting. On the other hand, the red pine had similar form quotients but larger mean dbh, basal area, and total volume at that age.

A common assumption is that tamarack will be grown for fibre production on short rotations, variously estimated as 20 years (Wright 1978), less than 30 years (Vallée and Stipanicic 1983), 25 to 30 years (Puttock 1983), and 30 to 40 years (Bolghari and Bertrand 1984). The spacing trial discussed here is too young to give evidence on this point.

CONCLUSIONS

1. Tamarack's individual tree and stand responses to spacing are similar in nature, if not in degree, to those usually evinced by other conifer species.
2. A more pronounced stratification at the wider spacings can be expected as crown closure intensifies intertree competition.
3. When that occurs some stand parameters will show definite curvilinear relations with spacing.
4. At present there is no evidence that tamarack will outproduce red pine, despite its better height growth on a similar site.
5. Further periodic observations, at least to 30 years will be necessary to define growth patterns and fix the culmination of mean annual increment.

ACKNOWLEDGMENTS

Mr. D.J. McGuire was responsible for plantation establishment and pest control, plot maintenance and measurement, and data processing. He also drafted the figures for this report. Mr. C. Robinson took part in the remeasurement and carried out the computer analysis of data.

REFERENCES

Bolghari, H.A.; Bertrand, V. 1984. Tables préliminaires de production des principales essences résineuses plantées dans la partie centrale du sud du Québec. Gouvernement du Québec, Ministère de l'Énergie et des Ressources, Service de la recherche (Terres et Forêts), memoire n° 79.

Campbell, A.J. 1983. Nursery practice and early establishment of larch. Pages 27-34 in Graham, C.M. et al. eds. Larch Symposium, Potential for the Future. Proc. Symp. sponsored by Ont. Min. Nat. Res. and Fac. For., Univ. Toronto, Toronto, Ont., Nov. 9, 1982.

Doucet, J.; Poliquin, J.; Verville, A. 1983. Density variability of planted larch in Québec, and their potential for use as waferboard. Pages 81-113 in Graham, C.M. et al. eds. Larch Symposium, Potential for the Future. Proc. Symp. sponsored by Ont. Min. Nat. Res. and Fac. For., Univ. Toronto, Toronto, Ont., Nov. 9, 1982.

Duncan, D.P. 1954. A study of some of the factors affecting the natural regeneration of tamarack (Larix laricina) in Minnesota. Ecology 35: 498-521.

Evert, F. 1971. Spacing studies - a review. Dept. Environ., Can. For. Serv., Ottawa, Ont. Inf. Rep. FMR-X-37.

Hall, J.P. 1983. Comparison of the growth of larch with other conifers on reforested and afforested sites in Newfoundland. For. Chron. 59: 14-16.

Hills, G.A. 1952. The classification and evaluation of sites for forestry. Ont. Dept. Lands & Forests, Res. Div., Toronto, Ont. Res. Rep. 23.

Holder, D.A. 1983. The potential of larch for the Kraft and refiner mechanical pulping processes. Pages 137-152 in Graham, C.M. et al. eds. Larch Symposium, Potential for the Future. Proc. Symp. sponsored by Ont. Min. Nat. Res. and Fac. For., Univ. Toronto, Toronto, Ont., Nov. 9, 1982.

Hosie, R.C. 1979. Native trees of Canada. 8th ed. Fitzhenry and Whiteside, Don Mills, Ont.

Howse, G.M. 1983. Pests of larch: biology, damage and control. Pages 35-45 in Graham, C.M. et al. eds. Larch Symposium, Potential for the Future. Proc. Symp. sponsored by Ont. Min. Nat. Res. and Fac. For. Univ. Toronto, Toronto, Ont., Nov. 9, 1982.

MacGillivray, H.G. 1969. Larches for reforestation and tree improvement in eastern Canada. For. Chron. 45: 440-444.

Puttock, G.D. 1983. An evaluation of the economics of the production of larch and jack pine in plantations. Pages 153-167 in Graham, C.M. et al. eds. Larch Symposium, Potential for the Future. Proc. Symp. sponsored by Ont. Min. Nat. Res. and Fac. For., Univ. Toronto, Toronto, Ont., Nov. 9, 1982.

Rauter, R.M.; Graham, B.J. 1983. The genetics and tree improvement potential of larches in Ontario. Pages 11-26 in Graham, C.M. et al. eds. Larch Symposium, Potential for the Future. Proc. Symp. sponsored by Ont. Min. Nat. Res. and Fac. For., Univ. Toronto, Toronto, Ont., Nov. 9, 1982.

Riemenschneider, D.E.; Jeffers, R.M. 1980. Height and diameter of tamarack seed sources in northern Wisconsin. USDA Forest Serv., North Cent. For. Exp. Stn., St. Paul, Minn. Res. Pap. NC-190.

Stiell, W.M. 1967. Plantation volume estimates from two stand parameters. Can. Dept. For. Rural Dev., For. Branch, Ottawa, Ont. Dep. Publ. 1199.

Stiell, W.M. 1980. Stand volume estimates for natural jack pine stands. Dept. Environ., Can. For. Serv., Bi-mon. Res. Notes 36: 7.

Stiell, W.M.; Berry, A.B. 1973. Yield of unthinned red pine plantations at the Petawawa Forest Experiment Station. Dept. Environ., Can. For. Serv., Ottawa, Ont. Publ. 1320.

Stiell, W.M.; Berry, A.B. 1977. A 20-year trial of red pine planted at seven spacings. Dept. Environ., Can. For. Serv., Ottawa, Ont. Inf. Rep. FMR-X-97.

Vallée, G.; Stipanicic, A. 1983. Growth and performance of larch plantations. Pages 47-63 in Graham, C.M. et al. eds. Larch Symposium, Potential for the Future. Proc. Symp. sponsored by Ont. Min. Nat. Res. and Fac. For., Univ. Toronto, Toronto, Ont., Nov. 9, 1982.

Wright, L.H. 1978. Industry/government cooperation and forest management in the Gaspé. Pulp Pap. Can. 79: 54-60.