minimizing damage from the disease. Using seed from slightly south of the intended planting site has been recommended as trees of southern origin have performed better than those of northern origin in several tests (COOPER *et al.*, 1977; COGGESHALL *et al.*, 1981).

Seed collection and planting zones. — Most provenance tests of sycamore in the southeastern United States are young, but trends are emerging, and at least tentative seed collection areas and planting zones can be proposed at this point. The growth trait in the present study, 5-year height, does not show close adaptive matching of genotype and environment over short distances in the southern Coastal Plain. Trees from southern Georgia and Louisiana were moved about 800 km north in the present study and suffered no obvious cold damage. In fact they were the fastest growing of the seed sources tested in the northern plantings, just as they were in plantings where they were the local seed source. This is not to recommend that such seed movement be done — GE interaction may be better expressed as the tests mature and better sample the vicissitudes of their environments. Given the present state of knowledge, a reasonable rule of thumb would be to collect seed up to 250 to 300 km south of the intended planting sites for planting south of the 34th parallel of latitude (northern boundary of Mississippi). This would be conservative enough to avoid cold damage, and it would take advantage of the generally faster growth rate of trees of southern origin. Most important, it would minimize the risk of incurring stem canker disease.

Most provenance tests of sycamore, including the present one, have shown substantial amounts of heritable tree-to-tree variation in growth rate within the provenances sampled. Genetic improvement through selection and progeny testing would most likely proceed at a rapid rate in sycamore if commitment to this task were to be made by forest industry and other firms that plant sycamore. Material from tests such as those reported here are logical starting points for such improvement programs, as selection has already been carried on for one complete generation.

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Stand-Volume Prediction of Improved Trees Based on the Realized Gain in Progeny Tests of HINOKI (Chamaecyparis obtusa Endl.)

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Summary

Stand-volume prediction based strictly on the realized gain in thirteen progeny-tests of HINOKI (*Chamaecyparis obtusa* ENDL.) were made by using a reciprocal-equation of yield-density effect connected with site-index curves. In this study, height-growth superiorities of plus-tree progenies over commercial-checks are regarded as the realized gain of correlated-responses by plus-tree tree selection, and it is found to be equivalent in the mathematical form to the site-index formula if its standard-deviation equation is derived from within stand variation of individual tree height.

2.6% increase in site-index of improved trees at the base age of forty years was calculated based on the 5.7% gain in progeny-tests at five years old, and it is expected to bring 6 to 8% increase in stand volume for this species. Then the proof of this estimate as the lower-limit value was given in relation to the difference between heritability and coheritability used to express the correlated response found in progeny-tests. Furthermore, a possibility of over-estimation on future breeding gain which was reported by other scientists with the use of conventional site-index formulae was pointed out by contrasting the standard-deviation curve of between stands height variation with that of within stand variation.

Key words: Plus-tree selection, progeny test, genetic gain, correlated response, yield-density effect, stand-volume prediction, site index curves.

Zusammenfassung

Auf der Grundlage der realisierten Züchtungsfortschritte in 13 Nachkommenschaftsprüfungen bei Hinoki (*Chamaecyparis obtusa* ENDL.) wurden Voraussagen über das Bestandesvolumen gemacht. Dabei wurden in Verbindung mit Bonitäts-Index-Kurven eine reziproke Gleichung des Ertragsdichteeffektes benutzt. In dieser Studie wird die Überlegenheit im Höhenwachstum von Plusbaum-Nachkommenschaften über kommerzielle Vergleichsproben als der

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realisierte Gewinn bezüglich des korrelierten Response bei Plusbaumauslese betrachtet. Es wurde festgestellt, daß er in seiner mathematischen Form zur Bonitäts-Index-Formel äquivalent ist, wenn die Gleichung seiner Standardabweichung von der Variation der individuellen Baumhöhe innerhalb des Bestandes abgeleitet wird.

Es wurde ein Anstieg des Bonitätsindex im Alter von 40 Jahren von 2,6% errechnet, wobei die Berechnungen auf einem genetischen Gewinn von 5,7% bei den 5 Jahre alten Nachkommenschaftsprüfungen beruhen. Es wird erwartet, daß bei dieser Art eine Erhöhung des Bestandesvolumens um 6 bis 8% erreicht werden kann.

Es wird ferner nachgewiesen, daß der Schätzwert einen unteren Grenzwert darstellt, bezogen auf die Differenz zwischen Heritabilität und Koheritabilität, die benutzt wurde, um den in den Nachkommenschaftsprüfungen gefundenen korrelierten Response auszudrücken. Schlechthin wird die Möglichkeit der Überschätzung von zukünftigen Züchtungsfortschritten herausgestrichen, wenn mit den üblichen Bonitäts-Index-Formeln gearbeitet wird. In der vorliegenden Arbeit wird die Schätzmethode verbessert, indem die Variation innerhalb von Beständen berücksichtigt wird.

Introduction

A rational method for stand-volume prediction of genetically improved trees are of primary importance in evaluating tree-improvement programs. In many cases, estimates of volume gain are extrapolated values of the relative performances of improved stocks over unimproved ones in progeny tests at far younger stages than final harvest ages (Dutrow and Row, 1976; Talbert, 1981). Therefore to get the unbiased prediction, estimation procedure should be satisfied not only with genetical aspect but also with silvicultural point of view.

In Japan, standard forest management systems for production of logs are characterized by its relatively long rotations with its intensive thinnings before the final harvest. Studies on yield-density effects during a rotation were developed in several species in Japan (Tadaki, 1964; Ando, 1968). And also applied to the species grown outside Japan (Drew and Flewelling, 1977, 1979). Recently those yield-density effect equations were combined with site-index equations as yield models which describe stand development under several optional silvicultural treatments (Manabe, 1982).

In this study the equivalence was pointed out between the conventional theories of site-index curves and formulae to estimate correlated responses found in the progeny-tests by initial plus-tree selection. Stand-volume predictions based on progeny-test performances, although they are still in younger age of only five years old, were made using above-mentioned yield-models in HINOKI cypress and its genetical interpretations are discussed.

Mathematical procedures

Equivalence in the method of site-index theory and correlated response

Growth superiorities of improved trees measured in the progeny tests are regarded as the realized gain resulted from plus-tree selection. However the selection and the measurements are made far different in age, the selected trait X and that of measured Y are treated as different. Thus the relation between them is given by (Falconer, 1960),

$$CR_y = i \cdot h_x \cdot h_y \cdot r_g \cdot \sigma_y \quad \text{------} \quad (1),$$

where CR_y refers to the correlated response in trait Y, and i is the selection intensity on trait X, σ_y is the phenotypic standard deviation of trait Y, h_x, h_y, r_g are square root heritabilities of X, Y and genetic correlation between both traits, respectively.

If the plus-tree selection were made around the index age, estimates of increase in site index of improved trees based on the realized gain in progeny tests can be approximated by the following equation (2), derived from formula (1).

$$i \cdot \sigma_x \cdot h_x \cdot h_y \cdot r_g = CR_y \cdot (\sigma x / \sigma_y) \quad \text{------} \quad (2),$$

where σ_x is a phenotypic standard-deviation in trait X.

On the other hand, site-index S is computed from the following formula (Osborne and Shumacher, 1935).

$$S = h_1(A) + (H_t - h_1(t)) \cdot (h_2(t)/h_2(A)) \quad \text{------} \quad (3),$$

where H_t = average height of dominant trees at age t (t = age/5 — 1), A = reference age (= 40 years) and h_1 = guide-curve equation being given as,

$$h_1(t) = K_1 - a_1 (c_1)^t \quad \text{------} \quad (4),$$

h_2 = equation of standard deviation among stand at age t (t = age/5 — 1) being given,

$$\log h_2(t) = K_2 - a_2 (c_2)^t \quad \text{------} \quad (5).$$

Equation (4), (5) are log-Micherlich curves and K_1, K_2, a_1, a_2, b_1, b_2 were obtained by fitting to the data.

If the estimates of increase in site index of improved trees are regarded as deviation from the guide curve of unimproved trees, it is clear that the right-hand side of equation (2) is equivalent to the second term in the same side of equation (3). That is CR_y in equation (2) correspond to $(H_t - h_1(t))$ in (3), while the phenotypic standard-deviation in (2) is different from that of stand height variation used in (3).

In forest tree breeding, plus-trees are selected based upon their phenotypic superiorities which are judged in comparison with the neighboring trees. Thus we might say even in equation (3) the increase in site index of improved trees should be measured by standard deviations within stands instead of those of stand-height variation, because gains by plus-tree selection mainly come from the variation within stands.

Toda (1961) expressed the change of phenotypic standard-deviation in relation to the size of the mean value by the following regression equation,

$$\sigma_x = a_2' \cdot (\bar{x})^{c_2'} \quad \text{------} \quad (6),$$

where σ_x and $\bar{x}$ represent the standard deviation and mean, respectively, a_2' and c_2' are parameters. This equation is easily combined with site-index formula (3), and it is as follows,

$$h_2'(t) = a_2' \cdot (h_1(t))^{c_2'} \quad \text{------} \quad (7).$$

From now on the estimation for site-index of improved trees based on the realized gain in progeny test is made by applying equation (3), (4) and (7) instead of applying (5).

Stand-volume prediction

Stand-volume having mean height H_t and number of stems with stand density p is calculated by the following reciprocal-equation of yield-density effect given by Ando (1968),

$$V = (b_1 \cdot H_t^{b_2} + b_3 \cdot H_t^{b_4} / \rho)^{-1} \text{ ------------- } (8),$$

where V = stand volume and b_1, b_2, b_3, b_4 are constants.

As regard to the stand height of improved trees at given age t (t = age/5 — 1), it is calculated by the following equation (9), which is the solution of formula (3) for H_t.

$$H_t = h_1(t) + [S - h_1(A)] \cdot h_2'(t)/h_2'(A) \text{ ----- } (9),$$

where S = the site index of improved trees computed by formula (3) based on the realized gain in progeny tests.

Meanwhile the course of self-thinning in even-aged stand which started from initial density p_0 is given by TADAKI (1964) as,

$$1/\rho = 1/\rho_0 \cdot v / \{K_3 \cdot (\rho_0)^{1+K_1}\} \text{ --------- } (10),$$

where v = single-tree volume, K_1, K_3 are constants and p is the same as in equation (8). Moreover, initial densities after successive thinnings are recalculated by inserting their dominant-tree height and number of remaining trees into the following equation (MANABE, 1982),

$$v \cdot (1/\rho_0 - 1/\rho) - 1/[K_3 \cdot (\rho_0)^{1+K_1}] = 0 \text{ ---------- } (11).$$

By these procedures, realized gain in height growth and in survival ratio in progeny tests are converted to the increase in site index and in initial density. Then the predicted values of improved trees are calculated by equation (9) for stand height and by (10) for stand density. Further, they are incorporated into equation (8) to estimate the stand volume at given age t.

Materials

Progeny test

The 13 progeny tests used in this report was established during 1974 to 1978 (*Table 1*). All were planted in a randomized complete block design with 29 to 34 open-pollinated families from a single fixed clonal plus-tree seed-orchard and with an extra 2 to 4 commercial-checks from different seed sources. In each test, square plot of 30 to 50 plants per family were replicated three. All seedlots planted in these progeny tests were sown and raised up in the same nursery of Kyushu Forest Tree Breeding Institute. Thus the field performances probably reflect the genetic quality of the seed themselves.

After five growing seasons from field planting, each test was measured for height and survival-ratio. In the following analysis, test-site mean of each families were used.

Table 1. — Five years' performances on thirteen progeny tests of HINOKI grown in Kumamoto prefecture in Kyushu.

Test	Established	Number of seedlots tested		Five years' height (m)			Five years' survival(arcsin%)		
code	year/month	Plus-tree	Check	Plus-tree	Check	(%)	Plus-tree	Check	(%)
Kuma13	1974.3	33	4	1.95	1.91	△ 2.1	1.02	0.99	△ 3.3
Kuma14	1974.3	34	4	2.58	2.47	△ 4.8	0.92	0.90	△ 2.4
Kuma15	1974.3	34	3	2.59	2.44	△ 5.8	1.14	1.04	△ 9.9
Kuma18	1975.3	27	2	1.76	1.61	△ 9.8	1.09	1.05	△ 4.0
Kuma19	1975.3	28	2	2.54	2.23	△14.1	1.12	1.07	△ 5.3
Kuma21	1976.3	35	2	2.16	2.06	△ 5.1	1.14	1.10	△ 3.7
Kuma22	1976.3	33	3	1.69	1.48	△14.5	1.31	1.29	△ 2.1
Kuma23	1976.3	34	3	2.23	2.05	△ 8.6	1.32	1.26	△ 5.3
Kuma24	1977.3	30	3	1.83	1.74	△ 5.1	0.97	1.00	▼ 2.9
Kuma26	1977.3	28	3	2.08	1.89	△ 9.7	1.25	1.21	△ 3.6
Kuma27	1978.3	28	3	1.86	1.78	△ 4.3	0.87	0.76	△13.8
Kuma28	1978.3	28	3	2.81	2.82	▼ 0.3	0.90	0.94	▼ 4.7
Kuma29	1978.3	28	3	3.04	2.83	△ 7.3	1.25	1.06	△18.1

Note) (%) = Percent superiority of Plus-tree progeny mean over commercial-check mean on each progeny-tests.

Legend) △ ; Plus-tree progeny mean > commercial-check mean,
▼ ; Plus-tree progeny mean < commercial-check mean.

Table 2. — Analysis of variance table across thirteen progeny-test data combined.

Source of variation	Degree of freedom	Five years' height	Five years' survival	Expected components
Family	82	0.05212**	0.01652**	$\sigma_e^2 + 4.90\sigma_f^2$
Error	320	0.01499	0.00814	σ_e^2

Note) Only the mean squares are given.
Analysis of variances were made by least-square method (Searle 1971), assuming the following linear-model.
$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$,
where Y_{ij}; i-th family-mean on j-th progeny-test, α_i; i-th family's effect, β_j; j-th progeny-test site's effect, ε_{ij}; error with Y_{ij}, μ; population mean.

Legend) **; Significant at 1% probability.

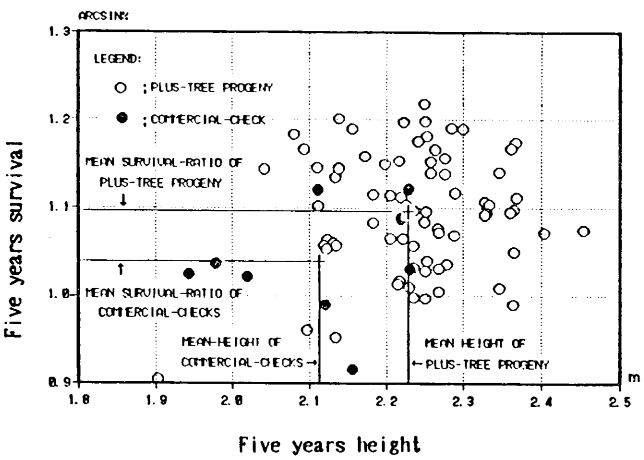

Figure 1. — Correlation between least square estimates for height and those for survival-ratio. The estimate on both traits were computed based on the linear model (12) for each plus-tree families and for checks tested more than one sites.

Realized gain

Since the family × progeny-test array across all sites is highly incomplete, least square estimates of height and survival ratio were computed based on the following linear model for each plus-tree family and checks tested at more than one site.

$$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \text{ ------------------ } (12),$$

where Y_{ij} = i th family or check mean on j th site, μ = population mean, α_i, β_j, and ε_{ij} are effect of i th family or check, that of j th site, and error with y_{ij}, respectively. In addition to this estimation, analysis of variance assuming the above described model was made (SEARLE, 1970). There were 1% level of significant differences among families and/or checks in height as well as survival ratio (*Table 2.*)

Then the realized gain on both traits was calculated by subtracting the mean of least-square estimate for commercial checks from that of plus-tree progenies. In this study the comparison between 74 plus-tree progeny performances versus those of 9 commercial checks gave 0.12m (5.7%) gain in height and 4.7% (6.3%) in survival ratio (*Fig. 1*). The differences were both significant at 1% level in height and 5% in survival ratio.

Silvicultural treatment

In this study two types of tending regimes were assumed. One is the conventional tending systems to produce

Table 3. — Tending regimes assumed in this study.

Tending type	Production purpose	Planting density(ha)	Rotation age(years)	Thinning Frequen.	Thinning Ratio(%)	Thinning Age
Type 1	General	3300	45	2	30	30,40
Type 2	Hi-quality	4500	60	3	30	28,36,48

logs for general purposes, while the other is relatively intensive systems aiming to produce high quality products. Thus they are different in their planting density, frequency of thinnings and rotations, as shown in *Table 3*.

As regard to the thinning, relatively faster growth and higher survival of improved trees would prompt an earlier start to thinning than the ordinary schedule. Thus the start of thinning of improved trees was set a little earlier than ordinary ones under the condition that total amount of yield by thinning was equal to that of unimproved ones.

Results

Site index of improved trees

A guide-curve equation (4) was fitted to the dominant tree height from 5 to 60 years of age on middle-site class in yield table of HINOKI in Kyushu area (Forest Agency and For. Prod. Res. Inst. 1962), and it is as follows,

$$h_1(t) = 33.462 - 31.41 \cdot (0.9327)^t \quad \text{------} \quad (4').$$

On the other hand, equation (7) was given by YAHATA *et al.* (1973) as below,

$$h_2(t) = 0.2274 \cdot (h_1(t))^{0.6005} \quad \text{------} \quad (7').$$

Thus the site index of improved trees were calculated by inserting 0.12 m into (Ht—h_1 (t)) in equation (3) which is connected with (4') and (7'). As a result 14.54 m was calculated for the site index of improved trees, while that of ordinary ones was 14.17 m; that is the height given by guide-curve itself at age 40. Therefore, an increase of 0.37 m in site index of improved trees is estimated for this species (*Fig. 2*).

Stand volume of improved trees

A "Stand density control diagram" for HINOKI in Kyushu area which is based on the yield density effect rule (KIRA *et al.*, 1953) has already been published (FOREST AGENCY, 1982). Thus the coefficients in the following equations are taken from it. A reciprocal-equation of yield-density effect used in this study is given as follows,

$$v = (0.0295501 \cdot H_t^{-1.123886} + 6421.8 \cdot H_t^{-3.039492} / \rho)^{-1} \quad \text{---} \quad (8'),$$

and the course of self-thinning is expressed as,

$$\rho = 1/\rho_0 + v / [(151250 \cdot \rho_0^{-0.5867})] \quad \text{------} \quad (10').$$

Moreover, relative yield R_y and diameter at breast height D in relation to the above equations are given as follows,

$$R_y = \rho / [(1 - R_f) \cdot (b_3 \cdot H_t^{b_4 - b_2/b_1} + \rho)] \quad \text{------} \quad (13),$$

where $R_f = 0.2978$ = full density coefficient,

$$D = 0.126801 + 0.99823 \cdot D_g - 0.038556 \cdot \sqrt{\rho} \cdot H_t/100,$$

$$HF = 0.577825 + 0.40953 \cdot H_t + 0.147286 \cdot \sqrt{\rho} \cdot H_t/100,$$

$$G = H_t / HF, \quad D_g = 200 \cdot \sqrt{G/(\pi \cdot \rho)}.$$

The predicted stand volume and other factors for improved trees as well as for ordinary ones at the time of final harvest under the two types of silvicultural treatments are summarized in *Table 4*. In case of HINOKI, volume gain by plus-tree selection amounts to 25 m^3/ha under the conventional tending system and 28 m^3/ha under the intensive one. If they are expressed by percentage gain, 6 to 8% increase in stand volume is expected by utilizing the first generation planting stocks (*Fig. 3*).

According to the above-described model, percentage gain in height at age five of 5.7% reduced to 2.4—2.5% at the

Table 4. — Predicted stand-volume and other stand-factors at the final-harvest ages.

Stand charactristics	Type 1 (45 years rotation) Improved trees	Ordinary trees	Ratio (%)	Type 2 (60 years rotation) Improved trees	Ordinary trees	Ratio (%)
Height (m)	15.8	15.4	2.6	19.2	18.7	2.4
Diameter (cm)	24.3	24.1	0.8	28.7	28.5	0.7
Num.of stems(ha)	947	914	3.6	776	756	2.6
Stem-volume (m^3)	350	325	7.7	473	445	6.4
Relative-yield	0.66	0.63	-	0.72	0.70	-

Note) Ratio(%) = Percent superiority of improved tree over ordinary tree.

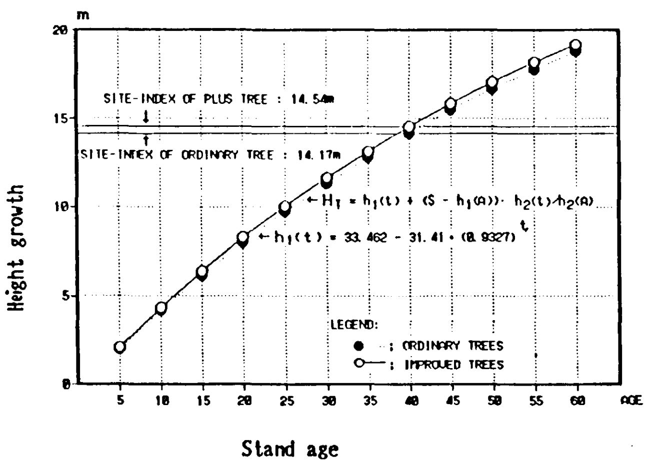

Figure 2. — Predicted height growth of improved trees. The height growth of ordinary trees are from the dominant tree height on medium site class in yield table of HINOKI in Kyushu area. And that of improved trees are derived assuming it as a guide-curve.

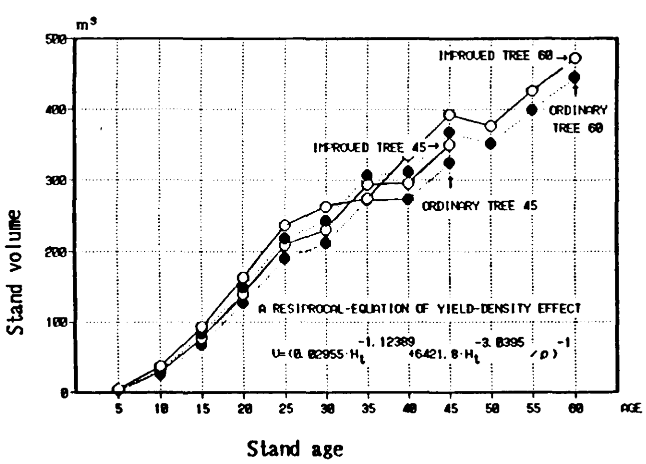

Figure 3. — Predicted stand-volume growth of improved trees. Stand-volume growth are estimated under the two types of tending regimes (see *Table 3*). Improved trees 45/Ordinary trees 45 = Type 1. Improved trees 60/Ordinary trees 60 = Type 2.

final harvest ages, while the gain in absolute scale enlarged from 0.12 m to 0.37 m. On the other hand, superiorities of improved trees over ordinary ones in stand density and in diameter growth were almost diminished due to the density effect employed in this model. Therefore the estimates of increase in stand volume of improved trees were mainly caused from the increase in stand height.

Discussion

The predicted stand-volume of improved trees in this study will have to be revised when the progeny-test results closer to the final harvest ages become available. This is because coheritability ($h_x \cdot h_y \cdot r_g$) and selection differential of the initial mass selection in the left-hand side of equation (2) cannot be specified by progeny-test data especially in the juvenile stage. However the assumption that $h_x \doteqdot h_y$ and $r < 1.0$ might be possible from the previous studies on older progeny tests (Franklin, 1979; Lambeth *et al.*, 1983), thus juvenile coheritability for height is probably lower than the heritability at the stage of plus-tree selection. Therefore the predicted stand-volume obtained in this study are considered to be the lower limit value to be attained by plus-tree selection.

Beside above-described problem, there are two points to be discussed in connection with the prediction method of stand volume of improved trees. One is on stand-volume equations and the other is on the site-index curves. Talbert (1981) pointed out that two possible ways to increase stand-volume by forest tree breeding are improvement in carrying capacity and that on growth ratio, which correspond to the above-mentioned two points.

With regard to the stand-volume equation, the reciprocal equation of yield-density effect was used in this study. However we are not certain that it is directly applicable to the improved trees because it was derived from the actually existing stands of unimproved trees. Thus further examinations are necessary to determine if it is applicable or whether it needs some modifications to be applied to stands of improved trees.

As for the growth ratio of improved trees, it is possible to assess their superiorities in comparison with the growth of ordinary trees under the same condition, such as progeny tests, by the time when the measurement was made. In the case of HINOKI, this factor is expressed by the increase in site index of improved trees, assuming the growth of ordinary trees as its guide curve. The following are assumptions and/or problems involved in this method to be discussed.

1) Growth pattern of improved trees are assumed to be similar to that of present ones.
2) Five years results can be extrapolated by site-index curves.
3) Genetical interpretation of the extrapolated results.

The first problem may become a problem under the condition that the growth pattern of improved trees is much different from that of unimproved trees. If it is true, the increase in site index of improved trees cannot be specified. Because its guide curve is derived from unimproved trees, the height growth of improved trees cannot be expressed by these site-index curves. According to the study on height growth in loblolly-pine provenance-trials, only a minor difference in the form of site-index curves between seed sources was found (Warren and Wells, 1981). Moreover the average selection age of HINOKI plus-trees coincides with the base age of site index 40 years old. Thus the method used in this study is probably safe with regard to the first assumption. However it would be necessary to check the growth of improved trees with unselected ones by the successive measurements.

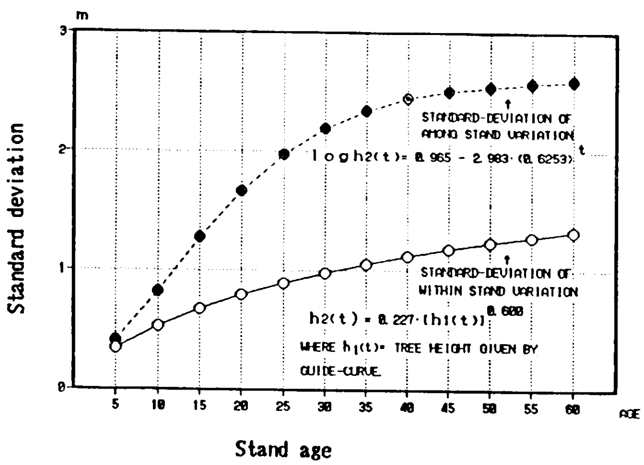

Figure 4. — The difference in increase of standard deviation with age among stands, and within stands. Equation which shows within stand variation is from Yahata *et al.* (1973), and the other is derived from the sample-stand heights in yield table of HINOKI.

The second problem stems from the nature of site-index equations itself. The accuracy of the estimate on marginal age classes are much lower than those around the mean age-classe; true for equation (4) as well as (7). Nevertheless, site-index estimation of improved trees was made by inserting the absolute difference between plus-tree progeny-mean and controll-mean into equation (4). Thus the above-mentioned bias does not directly influence the estimates in site index of improved trees.

As the third point has already been described, only the comparison of conventional equation (5') used to derive site-index curves and suggested equation (7') for estimating site index of improved trees are shown (*Fig. 4*). Equation (5') was drawn from the over-hundred sample-stand's height being used to construct the above-mentioned yield tables of HINOKI, and it is given as follows,

$$\log h_2(t) = 0.965 - 2.983 \cdot (0.6253)^t \quad (5').$$

There is a marked difference in increase with age between the variation among stands and within stands. That is the standard deviation of base age 40 ($t = 7$) given by equation (5') is two times larger than that given by (7'), while at age five they are much the same. Thus the extrapolations of juvenile results by conventional site-index formulae as made by several authors such as Dutrow 1976, Talbert 1981, would probably lead to the over-estimates on future gain by forest tree breeding as far as it is said to be the extrapolates based only on the realized gain in younger stages. Therefore, a new procedure reported here will result in more correct and reasonable estimation on genetic gain in the first plus-tree selection.

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Genetic Variation in Red Spruce (Picea rubens Sarg.)

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Summary

The paper discusses the nature, magnitude and trends of variation in red spruce (*Picea rubens* (Sarg.)) on the basis of twenty-year results of growth, phenology and crown form and recommends provenances most suitable for Newfoundland. Provenances are a significant source of variation in characters of growth, phenology and crown form, except branch angle. Inter- and intra-provenance variation is significant in all characters and is clinal with geographic coordinates. Characters of crown form appear to be closely associated with growth characters. Intra-provenance variation in all characters is partly due to introgression with black spruce (*Picea mariana* (Mill.) B. S. P.). Putative natural hybrids from the lowlands of New Brunswick have shown positive heterosis at the test site rather than the negative heterosis in artificial hybrids, reported earlier.

Red spruce is potentially promising for Newfoundland. The provenances in the top quartile are from the lowlands of New Brunswick and Nova Scotia. Family selection from superior provenances is advocated for best genetic gains. Early selection of superior provenances at ten-year age is possible in red spruce.

Key words: Red spruce; *Picea rubens* Sarg.; Provenance study; Variation; Phenology; Growth; Crown form; **Clinal** variation.

Résumé

La nature, l'ampleur et les tendances des variations de la croissance, de la phénologie et de la forme de la cime de l'épinette rouge (*Picea rubens*) sont examinées à partir des résultats de vingt années, et les provenances les mieux adaptées à Terre-Neuve sont recommandées Les provenances sont une source importante de variation pour les caractères de croissance, de phénologie et de forme de la cime, sauf pour l'angel des branches. La variation inter provenance et intraprovenance est importante pour tous les caractères et est clinale suivant les coordannées géographiques. Les caractères de forme de la cime semblent étroitement associés à ceux de croissance. La variation intraprovenance pour tous les caractères est due en partie à l'introgression avec l'épinette noire (*Picea mariana* Mill. B.S.P.). Des hybrides supposés naturels des basses-terres du Nouveau-Brunswick ont démonstré une hétérosis positive dans du lieu d'expérience et non l'hétérosis négative des hybrides artificiels dont il a été fait état.

L'épinette rouge semble une espèce prometteuse pour Terre-Neuve Les meilleures provenances dans le quartile supérieur proviennent des basses-terres du Nouveau-Brunswick et de la Nouvelle-Écosse. La sélection de familles des provenances supérieures est recommandée pour obtenir les meilleurs gains génétiques Une sélection précoce des provenances supérieures à dix ans est possible dans le cas de l'épinette rouge.

Zusammenfassung

Das Manuskript diskutiert die Natur, den Umfang und die Trends der Variation bei *Picea rubens* (Sarg.) auf der Basis der Wachstumsergebnisse, der Phänologie und Kronenform und empfiehlt die geeignetsten Herkünfte für Neufundland. Abgesehen vom Astwinkel sind die Herkünfte eine signifikante Variationsursache bei den Merkmalen Wachstum, Phänologie und Kronenform. Die Variation zwischen den Herkünften sowie innerhalb der Herkünfte ist bei allen Merkmalen signifikant und erweist sich in Bezug auf die geographischen Koordinaten als klinal. Die Merkmale der Kronenform scheinen am engsten mit den Wachstumsmerkmalen gekoppelt zu sein. Die Variation innerhalb der Provenienzen ist bei allen Merkmalen zum Teil der Introgression mit *Picea mariana* (Mill.) B. S P. zuzuschreiben. Vermeintliche natürliche Hybriden aus dem