contiguous plots, should provide reasonably accurate progeny testing. Little additional accuracy is achieved from testing more offspring and indeed genetic gain and benefit-cost solutions may favour fewer than 10 individuals per family. Of course allowance has to be made for deaths or perhaps artificial thinnings when deciding how many offspring to actually plant when establishing a progeny test.

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The Use of Competition Indices in Advanced-Generation Selection

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Summary

Two first-generation open-pollinated progeny tests of loblolly pine (*Pinus taeda* L.) were used to test the usefulness of four competition indices in advanced-generation selection procedures. In the five-year-old test all competition indices demonstrated an overall lack of competition. However, among the basal area classes within the five-year-old test there were differences in the competitive environment. Below basal area of 4.6 m^2/ha there was no competition among adjacent trees, between basal areas 4.6 and 9.2 m^2/ha competition appeared to stimulate growth, and above basal area 9.2 m^2/ha competition acted to diminish growth. In the 15-year-old test, within all basal area classes, all four indices functioned well as indicators of the past competitive environment. The best overall indicator was the Proportional Area Index; the Weighted Tally appeared to be the most practical. The changes in the competitive environment at age five, and the consistently negative relationship between each of the above four indices and the subject tree measurements indicates that individuals within families could be selected based upon 1) the subject tree's measurements prior to the onset of competition and 2) those individuals, after the onset of competition, whose measurements occur above the regression line of the competition index predicting the subject tree's diameter or height.

Key words: Interspecific-competition, advanced-generation selection, *Pinus taeda*, progeny testing.

Zusammenfassung

Die Ergebnisse aus zwei Nachkommenschaftsprüfungen bei *Pinus taeda* L. der ersten Generation wurden ausgewertet, um zu prüfen, in welcher Weise vier verschiedene Konkurrenzindizes in Selektionsverfahren für die folgenden Generationen nützlich sein können. In der Nachkommenschaftsprüfung im Alter 5 zeigte sich,, daß alle vier Indizes noch keine Konkurrenz aufzeigen konnten. Es konnten jedoch Unterschiede im Konkurrenzverhalten beobachtet werden, wenn die Bäume nach dem Querschnitt am Stammfuß klassifiziert worden waren. Unterhalb eines Stammquerschnittes von 4,6 m^2/ha gab es keine Konkurrenz zwischen benachbarten Bäumen, bei Bäumen mit einem Stammquerschnitt zwischen 4,6 und 9,2 m^2/ha scheint Konkurrenz das Wachstum zu fördern und bei einem Stammquerschnitt über 9,2 m^2/ha vermindert Konkurrenz das Wachstum. In dem Test im Alter 15 konnten die vier Konkurrenzindizes die Konkurrenzsituation früherer Jahre gut beschreiben und zwar innerhalb aller Stammquerschnittsklassen. Der beste Konkurrenzindex war der Proportional Area Index, der Weighted Tally Index erschien aber am praktischsten. Die Änderung in der Konkurrenzsituation bei fünfjährigen Bäumen und die negative Be-

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ziehung zwischen jedem der o. a. vier Indizes und der subjektiven Baummessung zeigt an, daß Einzelbäume innerhalb von Familien wie folgt selektiert werden können,

1) daß die notwendigen Messungen des Baumes vor dem Einsetzen der Konkurrenz durchgeführt werden und
2) daß jene Bäume, die nach Einsetzen der Konkurrenz über der Regressionsfläche mit der die Höhe bzw. der Durchmesser vorhergesagt werden, liegen, selektiert werden.

Introduction

As tree improvement moves through a second generation of breeding, and as progeny testing becomes increasingly more expensive, it will be essential to critically evaluate individuals prior to their use in a breeding program. The phenotypes of such individuals may be beneficially or detrimentally influenced by the competitive environment in which they develop. If the competitive environment could be parameterized, select phenotypes could be screened using models of competitive response.

A number of models exist which evaluate the effects of density on developing trees (Daniels 1976). Some models apply a derived diameter at breast height/crown width regression equation of open-grown trees to plantation grown trees (Krajicek *et al.* 1961). Other models use a circular zone of influence in which different measures of crown overlap are correlated to diameter growth of the subject tree (Staebler 1951, Newnham 1964, and Gerrard 1969). If this correlation is negative, competition has begun to limit growth. Still other models use a vertical projection of crown cross-sectional area through a given volume to determine when potential growing space becomes limited and when competition begins to affect growth (Hamilton 1969).

Applying such models to advanced-generation selection procedures may enhance the effectiveness of choosing superior genotypes, and at the same time reduce the cost of making selections by quantifying the competitive environment of a progeny test. Therefore, the objectives of this study were:

1) To test several competition models for their usefulness in advanced-generation selection procedures, and
2) To make recommendations on the use of competition models in advanced-generation selections.

Materials and Methods

Field Measurements

Two first-generation, open-pollinated progeny tests of loblolly pine (*Pinus taeda* L.), selected for growth rate, were examined. The first plantation, PLT066, was 15-years-old and had a site index 50 of 60 ft. The second plantation, PLT180, was five-years-old and had a site index 50 of 70 ft. Both progeny tests contained 10-tree family row plots PLT066 was planted on a 2.4 m × 1.8 m spacing, PLT180 on a 2.4 m × 2.4 m spacing. At both tests, individuals within the top five families were used to construct the competition indices. Since most advanced-generation selection procedures utilize combined family and within family selection, screening for the top five families eliminated

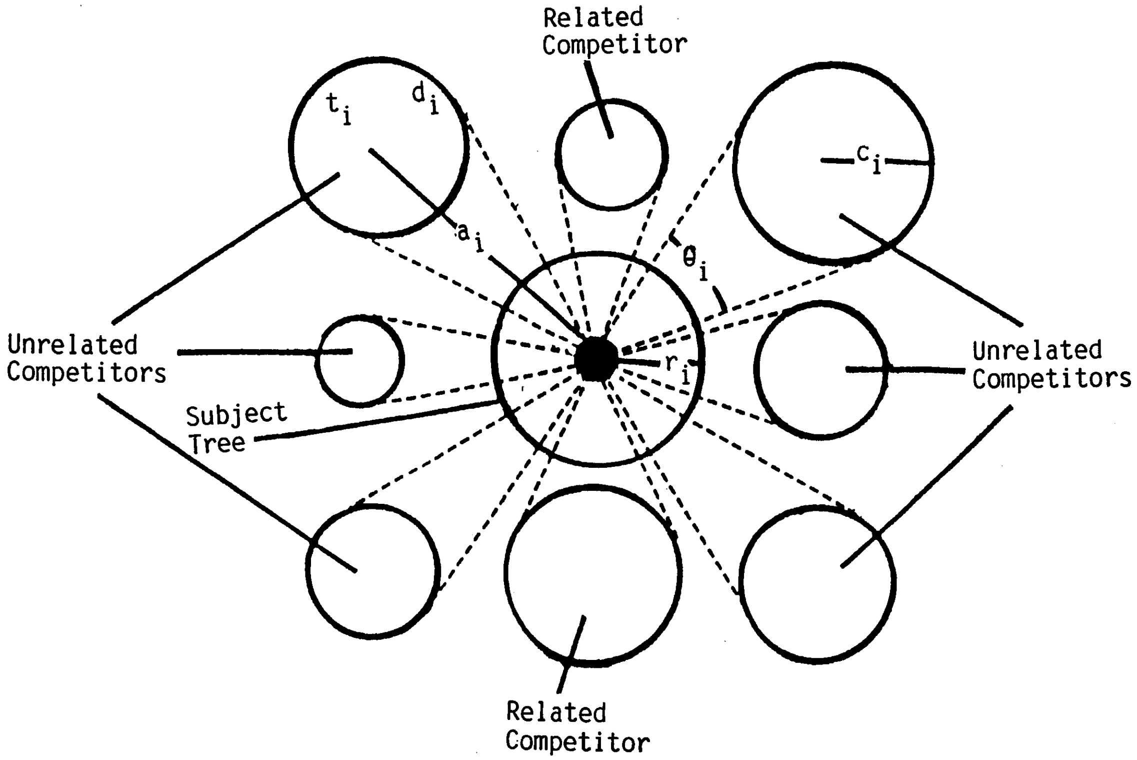

Figure 1. — Geometric representation of the competition models examined in this study.

Perimeter Index = $\sum\Theta_i \sim$ up to 360 degrees

Tally = $\sum t_i$

Proportional Area Index = $\frac{(\pi r_i^2)(\sum\Theta_i/360)}{(\pi r_i^2)} = .278(\sum\Theta_i)$

Weighted Tally = $\sum(dt)_i$

c_i = competitor crown radius
r_i = subject tree crown radius
d_i = competitor diameter at breast height
a_i = distance between the subject tree and the competitors
Θ_i = angle formed by subtended cords (degree)
t_i = numeric tally: 0.5 on the diagonal, otherwise 1.0

those families which would not normally be used to obtain advanced-generation selections. The competition indices could then be used to select individuals within families. Two trees were randomly sampled within each plot. Individuals at the end of each row were not selected as subject trees, nor were trees which were unlikely candidates for advanced-generation selections, i.e., trees with severe fusiform rust *(Cronartium quercuum* f. sp. *fusiforme)*, broken tops, or multiple stems. Total height, diameter at breast height, and four estimates of crown radius were recorded for each subject tree. Similar measurements were recorded for all eight adjacent competitors. In addition to individual tree measurements, basal area was determined with a ten-factor prism at each subject tree plot.

Competition Models

Initially NEWNHAM (1964) proposed an index which was the sum of the angles formed by the subtended cords of overlapping circles. The sum of these angles was then correlated to diameter growth at breast height of the subject tree. That model was modified in this study to facilitate advanced-generation selection procedures. Selection, in most operational tree improvement programs, begins as early as age five before crown closure has occurred. Therefore, NEWNHAM's model was expanded to include non-overlapping crowns. Each intersecting angle within the crown cross-sectional area of the subject tree was then dependent upon the distance to the competitor from the subject tree, and the size of the competitor's crown. These intersecting angles were used to calculate two slightly different indices: the Perimeter Index--the sum of the angles, up to 360 degrees, formed by all subtended cords, and the Proportional Area Index--the sum of the area represented by all intersecting angles divided by the total cross-sectional area of the subject tree's crown *(Fig. 1)*. In addition, a Tally was calculated based on the presence or absence of competing trees. Each competitor on the diagonal received a tally of 0.5. All other competitors received a value of 1.0. If all competitors were present the subject tree received a Tally of 6.0 *(Fig. 1)*. The diameter of the individual competitor was also used to obtain a Weighted Tally. Diameter was selected as a weight because of its sensitivity to competition. The Proportional Area Index, Perimeter Index, Tally, and Weighted Tally each give no weight to subject tree size, and all indices except the Tally vary positively with competitor size; the Tally is constant for competitor size. Similar competition models (DANIELS 1981) could be examined in a similar manner.

Analysis of Data

Once the competition indices had been calculated for each subject tree, correlations, adjusted for families and replications within progeny tests, were calculated between subject tree index values and the subject tree measurements. Spurious variation, due to families or replications, would have artificially inflated the correlation between the index and diameter (NETER and WASSERMAN 1974). The adjusted within-plot correlation thus reflected the true relationship between the index and diameter independent of families and replications. Similar correlations were calculated between each of the four index values and average competitor measurements. Concurrently these correlations indicated whether or not competitive stress was being placed on the subject tree. That is, the correlations among the index values and the competitor measurements should be positive--as the competitors grow larger, competitive stress placed on the subject tree should increase. The correlations between the index values and the subject tree measurements should be negative--as competitive stress increases, subject tree growth should decline. Each index had to satisfy these criteria before it was considered an indicator of the past competitive environment. Note that unlike stand-growth simulators where competition models predict future diameter increments, advanced-generation selection procedures need to use indicators that reveal the past competitive environment. BELLA (1971) states that accumulated diameter and height are such indicators. Therefore the above correlations between the indices and the subject tree diameters and heights were based on cumulative performance.

To further clarify the relationship between competitor measurements, and subject tree measurements, as revealed by the competition indices, competitor averages were calculated based on 1) all competitors present, 2) competitors related to the subject tree, and 3) competitors not related to he subject tree. Competitors within the row were related to the subject tree and those in adjacent rows were not. Separating competitor averages based on the genetic relationship to the subject tree may improve the correlation coefficients among competitor averages and each index. It may also indicate whether or not competitive stress placed on the subject tree varies by competitor predigree. All of the above correlation matrices were calculated separately by progeny test.

Results

The two progeny tests examined in this study were established on comparable sites containing similar growing conditions. At PLT066 average family survival was 78%, slightly lower than the average survival at PLT180 *(Table 1)*. In addition, mean basal area was considerably higher at PLT066 (21.3 m²/ha vs. 5.2 m²/ha), mainly due to the presence of older, larger trees, and more trees per unit area. These larger measurements, plus the lower percent survival caused PLT066 to have a wider range of values for all four competition indices, suggesting that all the indices reflect changes in spacing, survival, and competitor size *(Table 1)*.

At age five, for PLT180, all correlation coefficients between each competition index and the diameter and height measurements from either the competitor averages or subject trees, were positive *(Table 2)*. As the average size of the competitors increased so did the competition index of the subject tree, and as the indices increased so did the subject tree heights and diameters. Microsite effects ac-

Table 1. — Means and ranges for variables measured at two separate progeny tests.

	Plantation 066		Plantation 180	
	Mean + S. E.	Range	Mean + S. E.	Range
Age (yr)	15	-	5	-
Sample Size	70	-	82	-
Survival (%)	78	-	84	-
Basal Area (m^2/ha)	21.3 ± .54	13.8 - 27.6	5.2 ± .37	0.0 - 11.5
Subject Tree Diameter (cm)	14.8 ± .40	8.0 - 22.0	7.6 ± .15	4.5 - 10.8
Subject Tree Height (m)	13.3 ± .26	10.0 - 18.0	4.2 ± .06	3.0 - 5.4
Perimeter Index (deg)	337 ± 7.8	61 - 360	291 ± 6.2	143 - 360
Proportional Area Index (%)	139 ± 6.5	17 - 296	84 ± 2.2	40 - 130
Tally	4.4 ± .14	1.5 - 6.0	4.8 ± .10	2.5 - 6.0
Weighted Tally (cm)	59.7 ± 1.9	23.0 - 83.5	19.3 ± .50	9.0 - 29.0

Table 2. — Correlation coefficients between competition indices and 1) subject tree measurements and 2) average competitor measurements.

	Subject Tree		Average Competitor	
Competition Index	Height	Diameter	Height	Diameter
		PLANTATION 180 (Age 5)		
Perimeter	.34*	.13	.78**	.77**
Proportional Area	.37*	.19	.84**	.85**
Tally	.34*	.22	.82**	.64**
Weighted Tally	.39*	.12	.87**	.84**
		PLANTATION 066 (Age 15)		
Perimeter	-.45**	-.59**	.65**	.66**
Proportional Area	-.45**	-.66**	.56**	.62**
Tally	-.25	-.42*	.87**	.79**
Weighted Tally	-.37*	-.51**	.87**	.87**

*significant at $\alpha \geq 0.05$
**significant at $\alpha \geq 0.01$

count for the positive relationship between subject tree size and competitor size, and the positive correlations indicate that overall there was no measurable competition among adjacent trees at age five.

At age 15, for PLT066, significant negative correlations were displayed between subject tree measurements and each of the four indices (*Table 2*). In addition, all correlations between competitor averages and each of these indices were signficant and positive. In conjunction these correlations indicate that as average competitor size increased, competitive stress increased, resulting in an associated decrease in subject tree measurements. The Proportional Area Index had the largest overall correlation coefficients with the subject tree measurements; the Weighted Tally had the next best, overall group of correlations (*Table 2*). These two indices explain a greater proportion of the variation in growth, and therefore are considered to provide the greatest utility in advanced-generation selection procedures as indicators of the past competitive environment.

In addition to quantifying the competitive environment, the correlations obtained revealed a number of other important relationships. For example, separating competitor averages into those individuals related to the subject tree and those individuals not related to the subject tree did not increase or improve the correlations between competitor averages and the indices. Moreover, a T^2-test (JOHNSON and WICHERN 1982) between the mean vectors containing diameter, height, and crown radius from the related and non-related competitors exhibited no significant difference between the two groups ($T^2 = 8.6$ vs. critical value $= 11.7$). The competitors related to the subject tree were no larger or smaller than the competitor not related to the subject tree, suggesting that competition would occur equally among related and non-related individuals. Subsequently, competitor averages refer only to the average of all competitors (*Table 2*).

Furthermore, the correlations between the subject tree index value and the average competitor measurements were always higher than the corresponding coefficients between the subject tree index value and the subject tree measurements (*Table 2*). Two separate factors contributed to these higher index-average competitor correlations. First, all competition indices, except the Tally, were calculated from individual competitor measurements, increasing the correlation because of the functional relationship between the index value and competitor measurements. Second, variation in subject tree diameter (or height) was affected by the environment in which the tree developed and the genotype of the tree itself. As indicated by each index, and its correlation to subject tree measurements, the past competitive environment contributed only a small portion to the present subject tree phenotypes. On the other hand, narrow-sense heritability from these progeny tests, for diameter ($h^2 = .18$) and height ($h^2 = .20$), indicate that additive genetic variation also contributed to the subject tree phenotypes. Thus, correlation coefficients between each index and the subject tree measurements were restrained below a value of 1.0, and below those coefficients obtained from the competitor averages.

Finally, at age 15, the correlation coefficients between each index and diameter were consistently higher than those between each index ~~and~~ height (*Table 2*). This supports published information suggesting diameter is more sensitive than height to competitive stress (SAKAI *et al.* 1967, ADAMS *et al.* 1973).

An analysis of variance, used to determine whether or not certain families always had large index values while other families had small index values, revealed no significant family variances among any of the four indices (*Table 3*). This lack of family differences was consistent between progeny tests. The homogeneity among family means for each index, particularly the Tally, indicated that the number of competing individuals did not vary significantly among families. With the existence of significant family differences in diameter and height, the uniformity of each index across families suggests that genetic differences in growth are independent of competition, while phenotypic differences among individuals are elements of competition. All four indices also exhibited non-significant replication effects (*Table 3*). The consistency of the index values across families and replications indicates that these indices would be suitable for screening individuals within families under an advanced-generation selection procedure.

Discussion

Since none of the fifth year correlation coefficients among any of the competition indices and the subject tree measurements were negative, a covariance analysis was performed to determine if there were differences among regression coefficients (slopes) within basal area classes. The Tally and Weighted Tally were not examined in this manner because they were highly correlated with basal

Table 3. — Results of analyses of variance to determine family effects within several competition indices.

	F-test Results			
Age 5 (Plantation 180)	Perimeter Index	Proportional Area Index	Tally	Weighted Tally
Replication (R)	NS	NS	NS	NS
Family (F)	NS	NS	NS	NS
R_*F	**	**	**	**
Age 15 (Plantation 066)				
Replication (R)	NS	NS	NS	NS
Family (F)	NS	NS	NS	NS
R_*F	NS	NS	**	**

NS - non-significant

** - significant at $\alpha \geq 0.01$

Table 4. — Variation among regression coefficients between competition indices and subiect tree diameter, within the basal areas classes of plantation 180.

Basal Area (m^2/ha)	Sample Size	Subject Tree Diameters (cm)	Regression Coefficients[1] Perimeter Index	Regression Coefficients[1] Proportional Area Index
0.0	6	4.5 - 9.5	11.20	4.15
2.3	25	4.8 - 8.8	10.79	6.07
4.6	13	4.5 - 9.5	9.64	8.95
6.9	21	6.5 - 10.8	11.91	13.84
9.2	10	5.8 - 10.0	15.48	41.99
11.5	7	8.0 - 10.5	-38.06	-7.99

[1] Competition Index = $\beta_0 + \beta_1$ (Subject Tree Diameter).

All coefficients are significant at $\alpha \geq 0.05$.

area. Comparisons among slopes within basal area classes revealed significant differences in the linear relationship between subject tree diameter and each index *(Table 4)*. Even though the slopes within basal areas 0.0—9.2 m²/ha were all positive, there were differences in the ascent of each regression line. Between basal areas 0.0—4.6 m²/ha, the positive slopes remained relatively equal, while for basal areas 6.9 m²/ha and 9.2 m²/ha the slopes became increasingly positive *(Fig. 2)*. Finally at basal area 11.5 m²/ha the slopes became negative. Despite the fact that basal area and age are confounded when mentioning PLT066 it is noteworthy that the slopes within PLT066's basal area classes were always negative.

The changes in slope associated with basal area indicate that three competitive situations exist, each requiring different sets of selection strategies. Initially at lower basal areas (≦ 4.6 m²/ha) there was no competition between adjacent trees. At these levels of basal area it is impossible to assess the competitive environment of a potential selection. Possibly selections could be delayed until the competitive relationship becomes significant. Alternatively, competition could be disregarded when making selections under these conditions. The absence of one or more competitors seems to yield no advantage to the subject tree; all necessary resources are acquired with or without competitors present. Moreover, this pre-competitive stage of growth is important in determining the mature performance of an individual (Nance *et al.* 1983). Selection for pre-competitive growth and subsequent selection for competitive ability are both requirements for improved second-generation plantation performance. Increasing growth at a pre-competitive stage of development will decrease the time required to capture the site, plus it will give the select trees an advantage in size which its competitors may never overcome (Nance *et al.* 1983). Therefore potential selections should be evaluated at a pre-competitive stage of development, based soley on tree size.

Competition may have begun to play a role in stand development between basal areas 4.6 m²/ha and 9.2 m²/ha, acting to stimulate growth. Increased growth rates for both subject trees and competitors are the result of better microsites at these moderate basal area levels. Yet the additional increase in diameter, associated higher competition index values, indicate that supplemental factors may be operating in conjunction with microsite effects to produce steeper regression lines within these basal area classes *(Fig. 2)*. Competition may trigger a brief growth response; growth which could serve as a means of overcoming competitive stress. A similar response to competition was exhibited in growth curves for loblolly pine seedlings (Adams

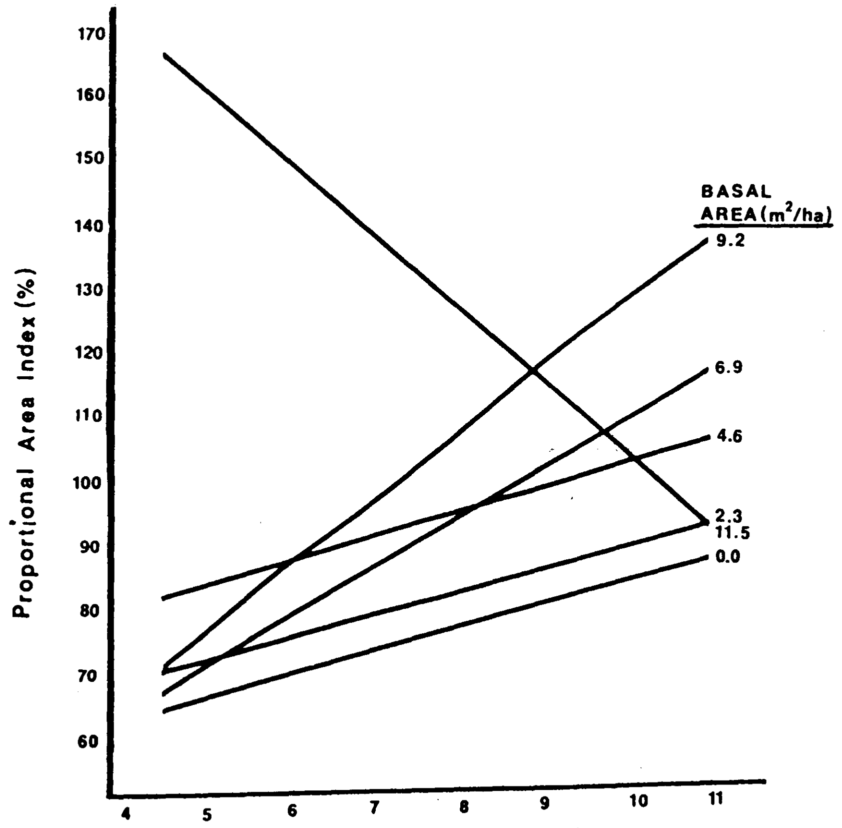

Figure 2. — Changes in the regression equations--competition index = $\beta_0 + \beta_1$ (subject tree diameter), associated with tallied basal area classes.

et al. 1973). Although these authors attributed the initial improved height of seedlings under competition to "cooperative interactions", competition-stimulated growth, as described above, does fit their data. Wareing and Phillips (1981) note that phytochrome is involved in stem elongation and that differences among individuals may confer some competitive advantage. The brief stimulation of growth exhibited in the above regression lines may in fact be a phytochrome regulated action in response to canopy shading and the onset of competition. Since this is a transient stage between a competition-free environment and competitive suppression, and individuals are "vying" for position within the stand, selections should be delayed until the competitive environment can be firmly evaluated.

Finally, for PLT180, at basal area $\geqq 11.5$ m^2/ha, and for all of PLT066, competition suppressed growth. Resources being limited many trees succumb to or are suppressed by the more efficient competitors, eventually resulting in a net reduction in growth rate. Selection strategy under these circumstances can take two forms. Since the indices are indicators of the past competitive environment, trees with higher index values should, on the average, have smaller measurements. Therefore, individuals whose diameter (or height) are significantly larger than those predicted by a linear regression of the competition index onto diameter (or height) should be considered for selection *(Fig. 3).* These individuals would have diameters (or heights) greater than would be expected under a given level of competition. A second approach would be to set minimum requirements for both the index and diameter or height, then selecting only those individuals which satisfy both criteria, provided the intersection of the two culling levels falls above the regression line *(Fig. 3).*

If an equal number of individuals are selected under each alternative Approach One should have the advantage of improving the variation in growth strategies. Individuals at the upper left-hand side of the regression line can exploit environments with little or no competitive stress while individuals at the other extreme are capable of tolerating competitive stress. Cannell (1982) classifies these types of individuals as "isolation" and "crop" ideotypes, respectively. Individuals in the upper central portion of the regression line may be classified as "competition" ideotypes; i.e., individuals which assimilate light, water, and nutrients at the expense of adjacent trees. Planting combinations of "crop" and "competition" ideotypes should diversify a plantation. This practice should also minimize the risk of losing a disproportionate number of trees to competitive suppression, and thus increase the utilization of resources in that environment. In addition, an optimum combination of "crop" and "competition" ideotypes may utilize the resources that become available through the inevitability of mortality more efficiently than a plantation comprised of a single ideotype. The four individuals selected under Approach One in *Figure 3* represent such a combination.

The apparent advantage of Approach Two is the potential for greater genetic gains. Height and diameter differences between selected individuals and the plantation average should be greater when individuals are chosen using Approach Two as opposed to selections using Approach One. This larger selection differential would yield larger predicted gains in individual diameter or height. Claiming a greater proportion of the resources, individuals selected under Approach Two should produce above average individual tree growth. In our example, the difference between Approach One and Approach Two is one individual *(Fig. 3).* This individual, under Approach One, appears to be able to produce growth greater than would be expected under its determined level of competition (10.6 cm predicted vs. 13.0 cm actual). So, the apparent increased gains in size under Approach Two may well be offset by the ability of individuals selected under Approach One to grow under severe competition, i.e. the ability to increase per unit area yield.

In conclusion, the Perimeter Index, Proportional Area Index, Tally, and Weighted Tally function well as indicators of the past competitive environment. The Proportional Area Index has the largest correlation between subject tree index and subject tree measurements, and thus explains

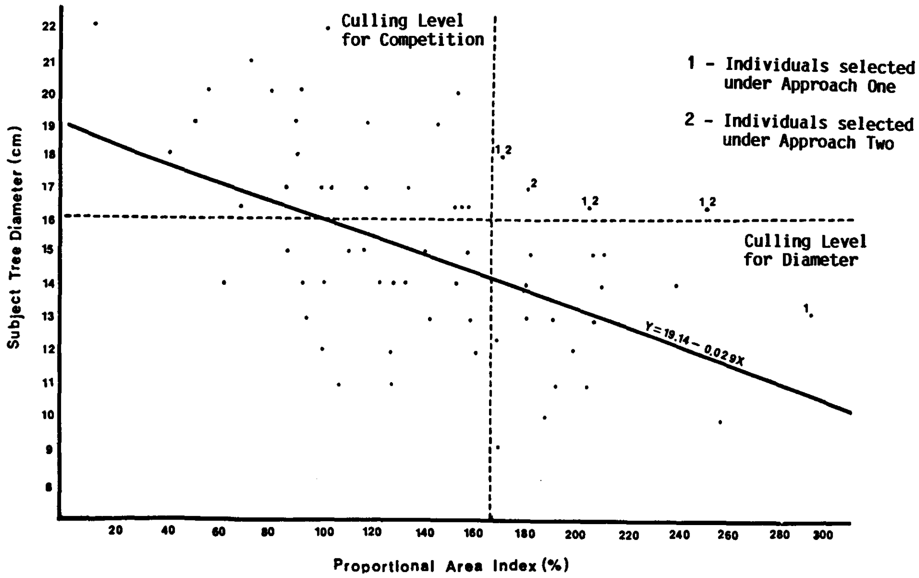

Figure 3. — Selection alternatives based on either 1) the four best individuals whose measurements exceed those predicted by the regression equation--subject tree diameter = $\beta_0 + \beta_1$ (competition index), or 2) individuals whose measurements satisfy culling levels for diameter and competition.

the highest proportion of variation in the subject tree measurements. This is also the most complicated index to calculate, requiring measurements of crown radius from all competitors and the subject tree. The Weighted Tally is one of the simplest indices to calculate, requiring only the diameter of adjacent competitors. And it is also significantly correlated to subject tree measurements. The choice of which index to use will vary; the differences in correlations may well be offset by the time required to obtain measurements necessary to calculate the index. In either case once the index has been selected, simple linear regression models of the index predicting subject tree diameter and height should be generated for each progeny test. Based upon the results of these regression models, individuals within families should be selected based upon 1) the subject tree's measurements alone prior to the onset of competition and 2) those subject trees whose measurements, after the onset of competition, exceed measurements predicted by the derived regression equations.

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Propagation of Norway Spruce Cuttings Free of Topophysis and Cyclophysis Effects

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Abstract

A method is described with which within 14 months from an ortet of *Picea abies* (L.) Karst. about 64 very evenly growing, topophysis-free ramets can be vegetatively propagated at an early developmental phase. This number increases exponentially with a longer propagation period. Starting from a seedling, first stock plants were propagated and repropagated by cuttings and from these the cuttings were taken. At the age of two years, a comparison of clones propagated by this method and clones propagated from 12-year old trees showed that topophysis effects influence many growth characters. Cuttings propagated by this method showed better height growth, more free growth as well as orthotropic growth and a radial arrangement of needles and branches. The growth characters of the clones propagated from the 12-year old trees showed that a complete change of the developmental phase caused by topophysis and cyclophysis back to a seedlings phase is unlikely. Implications for sustained growth potential of repeatedly repropagated clones are discussed.

Key words: Picea abies, cyclophysis, topophysis, repropagation, developmental phase.

Zusammenfassung

Eine Methode wird beschrieben, mit deren Hilfe bei Fichte *(Picea abies* (L.) Karst.) in einer Zeit von 14 Monaten ca. 64 sehr einheitlich gewachsene topophysisfreie Stecklinge pro Klon vegetativ vermehrt werden können. Sie befinden sich in einem frühen Entwicklungsstadium. Die Anzahl der gewonnenen Stecklinge steigt exponentiell mit der Dauer der Vermehrung. Beginnend mit einem Sämling wurden zunächst Ausgangspflanzen in mehreren Vermehrungszyklen hergestellt und von diesen die Stecklinge gewonnen. Ein Vergleich dieser Stecklinge im Alter von zwei Jahren mit gleichalten Stecklingen, die von zwölfjährigen Mutterbäumen gewonnen wurden, zeigt, daß Topophysiseffekte verschiedene Wuchsmerkmale deutlich beeinflussen. Solche topophysisfreien Stecklinge zeigen ein größeres Höhenwachstum, mehr freies Wachstum sowie orthotropes Wachstum und radiärsymmetrisch angeordnete Nadeln und Zweige. Wachstumsmerkmale von Stecklingen zwölfjähriger Mutterbäume lassen ein vollständiges Verschwinden der Topo- bzw. Zyklophysiseffekte durch das von den Mutterbäumen erreichte Entwicklungsstadium nicht erwarten. Diese Stecklinge beginnen also ihre Entwicklung in einem späteren als das Sämlingstadium. Die Auswirkungen einer wiederholten Vermehrung von Klonen auf ein anhaltendes Wuchsvermögen wird diskutiert.

Résumé

Nous décrivons une méthode par laquelle environ 64 ramets de *Picea abies* (L.) Karst. poussés de nature uniforme et sans topophysis, peuvent être propagés végéta-