Correlation of Juvenile Height Growth with Cone Morphology and Seed Weight in White Spruce

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Abstract

A nursery experiment in the randomized complete block design on the early growth of progenies of "plus" and "ordinary" trees of two provenances of white spruce in central Newfoundland began in spring 1972, using open-pollinated seed of trees of each class from each location. Heights of 10 randomly selected seedlings were measured in each plot in the falls of 1973 and 1975 at the ages of two and four years. Multiple regression and correlation analyses of height with nine characters of cone morphology and 1 000-seed weight were conducted to determine the existence of any correlation between them which could be used to select genetically superior trees. Statistically significant positive correlation and regression were found only between 1 000-seed weight and four-year height. Similar relationship was found between 1 000-seed weight and annual growth of the terminal shoot at the ages of two and four years. It appears possible to include seed weight among the criteria for early selection of genetically superior white spruce trees in a family selection program.

Key words: Picea glauca (Moench) Voss., predictive value of characters.

Résumé

Au printemps de 1972, une expérience a été entreprise en pépinière selon le plan en blocs aléatoires sur la croissance précoce de la descendance d'arbres „plus“ et „ordinaires“ de deux provenances d'épinette blanche du centre de Terre-Neuve, à l'aide de graines obtenues par pollinisation libre des arbres de chaque catégorie à chaque endroit. La hauteur de 10 semis choisis au hasard dans chaque parcelle a été mesurée à l'automne de 1973 et de 1975, soit à l'âge de 2 et de 4 ans. Des analyses par régression et corrélation multiples de la hauteur en fonction de neuf caractéristiques morphologiques de cônes et du poids de 1 000 graines ont été réalisées afin de déterminer s'il existe une corrélation qui pourrait servir à la sélection d'arbres génétiquement supérieurs. On n'a pu établir une corrélation et une régression statistiquement significatives qu'entre le poids de 1 000 graines et la hauteur à 4 ans. Une relation similaire a été trouvée entre le poids de 1 000 graines et la croissance annuelle de la pousse terminale à 2 et à 4 ans. Il semble possible d'inclure le poids des graines parmi les critères de sélection précoce des sujets génétiquement supérieurs épinette blanche dans un programme de sélection des familles.

Zusammenfassung

Um das Jugendwachstum von Nachkommenschaften von Plus- und Durchschnittsbäumen von zwei Herkünften zu untersuchen, wurde in Zentral-Neufundland im Frühjahr 1972 ein Baumschulexperiment mit *Picea glauca* Moench in Form eines vollständigen randomisierten Blockversuchs begonnen. Zum Vergleich dienten Nachkommenschaften aus freier Abblüte. Im Herbst 1973 und 1975, im Alter von 2 und 4 Jahren, wurden in jeder Parzelle die Höhen von je 10 zufällig ausgelesenen Sämlingen gemessen. Es wurden multiple Regressions- und Korrelationsanalysen zwischen Höhe und 9 morphologischen Zapfenmerkmalen und dem 1000-Korn-Gewicht durchgeführt und benutzt, um die genetisch besten Bäume herauszufinden. Statistisch signifikante positive Korrelationen und Regressionen wurden zwischen dem 1000-Korn-Gewicht und der Höhe im Alter 4 gefunden. Ähnliche Beziehungen wurden zwischen 1000-Korn-Gewicht und dem jährlichen Wachstum des Terminaltriebes im Alter von 2 und 4 Jahren festgestellt. Es erscheint deshalb möglich, das Samengewicht in einem Familien-Selektionsprogramm mit als Kriterium für eine frühe Selektion von genetisch überlegenem Material einzubeziehen.

Introduction

Research on the genetics of white spruce [*Picea glauca* (Moench) Voss], including methods of early identification of superior provenances is currently in progress at the Newfoundland Forest Research Centre. In one study Khalil (1974) reported that though characters of cone morphology and seed weight in white spruce are under very strong genetic control they do not appear to be associated with the growth of the mother trees and cannot be used for identification of trees genetically superior in growth. Though the effect of seed size and weight on juvenile growth in tree species has been known for over 50 years (Aldrich-Blake 1930, Baldwin 1942, Champion 1928, Gast 1937 and Korstian 1927) the information on North American species is scanty. Righter (1945) found that in the genus *Pinus* the positive correlation between seed weight and seedling height was temporary and disappeared with the growing age of seedlings. However, a recent study on loblolly pine (*Pinus taeda* L.) has shown that a statistically significant positive correlation between seed weight and height persists till at least 15 years (Robinson and van Buijtenen 1979). Morgenstern (1969) found statistically significant positive correlation between seed weight and two-year height in black spruce (*Picea mariana* (Mill.) B.S.P.). In white spruce only a broad association has been found between seed size and germination, survival and one-year height (Burgar 1964). Consequently, the data of the four-year height growth of progenies of individual trees in the study would also establish the groundwork from which determine the correlation between characters of cone morphology and seed weight with juvenile growth. This study would also establish the groundwork from which the correlations between the characters of cone morphology and seed weight, together with juvenile characters in the nursery with later volume growth could be established at a later date. This paper reports the results of the current analysis.

Material and Methods

The Progenies

The study is based on open-pollinated progenies of 20 individual trees from two stands about 80 km apart selected in the Frenchman's Pond (lat. 48°53'N; long. 55°40'W) and Lake Douglas (lat. 48°30'N; long. 56°40'W) areas in central Newfoundland. Both stands are second growth, even-aged and of natural origin, resulting from the clear-cutting of 1942—45. Trees are designated as "ordinary" (mean height $= \bar{X} \pm 1\ \sigma$)*, "plus" (mean height $> \bar{X} + 1\ \sigma$)*) and "minus" (mean height $< \bar{X} - 1\ \sigma$)* on the basis of height.

Open-pollinated single-tree seed was collected in the fall of 1971 from five "plus" and five "ordinary" trees in each stand. The seed was sown in June 1972 in a five-replicated randomized complete block design experiment in the nursery at Pasadena in western Newfoundland (lat. 49°00'N; long. 57°35'W).

The Data

Heights of 10 randomly selected (or all that were available if less than 10) half-sib seedlings in each experimental unit were measured in October 1973 and 1975. The following variables were measured on an oven-dry sample of 20 randomly selected female cones of each mother tree out of a large number of cones of each:

(1) Weight (g)

(2—3) Length and diameter at the widest point (cm)

(4—6) Length of a randomly selected scale from the apex, the middle and the base of the cone (cm), respectively.

(7—9) Width, at the widest point, of a randomly selected scale from the apex, the middle and the base of the cone (cm), respectively.

(10) Weight of 1 000 cleaned, air dry, full seeds from each tree (g).

Means of all variables by mother trees, except (10) were calculated. Mean height in the fall of 1975 and the length of the terminal shoot in 1975 were used in the current study.

*) $\bar{X}$ = mean height of stand
σ = standard deviation in height

The Statistical Analyses

Multiple regression analysis was conducted using the mathematical model for the prediction regression equation shown at (1):

$$\hat{Y} = \alpha + \Sigma\, \beta_i X_i \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (1)$$

where $\hat{Y}$ is the predicted value of the dependent variable Y, (cm), α is the intercept of Y and β_i is the coefficient of partial regression of the independent variable X_i (where $i = 1 \ . \ . \ . \ . \ . \ . \ . \ . \ 10$).

The mean height of the seedlings for the progeny of each tree was used as the dependent variable (Y) and the 10 variables listed above were used as the independent variables, which were designated as X_1—X_{10} respectively.

The prediction equation established for the experiment is shown at (2):

$$\hat{Y} = a + b_1X_1 \ . \ . \ . \ . \ . \ + b_{10}X_{10} \ . \ . \ . \ . \ . \quad (2)$$

where $\hat{Y}$ is the predicted value of the dependent variable, a is the intercept of Y and b_1—b_{10} are the respective partial regression coefficients of the respective independent variables X_1—X_{10}.

The simple correlations between the dependent variable and each of the independent variables were found to be statistically significant ($P \geqq 0.95$) only for 1 000-seed weight. Consequently, multiple regression analysis was performed using the step-wise regression procedure to include only the above, possibly with a few more independent variables, which may have significant partial regression coefficients with the dependent variable (DRAPER and SMITH 1966).

The regression equation so obtained is shown at (3), which includes only one independent variable, viz. 1 000-seed weight:

$$\hat{Y} = 6.4306 + 3.2531\ X_{10} \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (3)$$

The intercept was found to a statistically non-significant with a t- value of 1.43 ($P < 0.95$). This, together with the fact that on theoretical grounds this regression should pass through the origin, the simple regression equation without the intercept was established and is represented by equation (4).

Table 1. — Correlation matrix.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1.000									
X_2	0.484**									
X_3	0.672**	0.453*								
X_4	0.782**	0.382	0.546*							
X_5	0.686**	0.505*	0.919**	0.682**						
X_6	0.639**	0.404	0.945**	0.584**	0.943**					
X_7	0.504*	0.302	0.085	0.644**	0.165	0.054				
X_8	0.657**	0.425	0.605**	0.595**	0.629**	0.541*	0.659**			
X_9	0.570**	0.465*	0.679**	0.598**	0.754**	0.726**	0.514*	0.842**		
X_{10}	0.553**	0.688**	0.527**	0.256	0.542*	0.519*	-0.042	0.231	0.335	
Y	0.134	0.217	0.307	-0.211	0.084	0.148	-0.287	-0.062	0.021	0.452*

**- Statistically significant ($P \geq 0.99$)

*- Statistically significant ($P \geq 0.95$)

Rest - statistically non-significant ($P < 0.95$)

Table 2. — Analyses of variance.

Source of variation	of freedom	Height in 1973			1975 shoot			Height in 1975		
		Sum of squares	Mean squares	F	Sum of squares	Mean squares	F	Sum of squares	Mean squares	F
Regression	1	4.7474 (22.8)	4.7474	5.3109*	20.0708 (31.1%)	20.0708	8.1137*	36.9859 (22.1%)	36.9859	5.1113*
Deviation from regression	18	16.0893 (77.2%)	0.8939		44.5257 (68.9%)	2.4737		130.2499 (77.9%)	7.2361	
Total	19	20.8367			64.5965			167.2357		

*Statistically significant (P > 0.95)

$$\hat{Y} = 5.7103\ X_{10} \quad (4)$$

The t- value of the coefficient of regression is 3.8567*** ($P \geqq 0.999$). This equation describes the relationship between seed weight and four-year height. Similar equations were established between seed weight and two-year height in 1973 and seed weight and length of the terminal shoot in the fourth year in 1975. They are presented in equations (5) and (6) respectively.

$$\hat{Y} = 1.8009\ X_{10} \quad (5)$$

$$\hat{Y} = 3.0020\ X_{10} \quad (6)$$

Results and Discussion

Tables 1 and *2* show the correlation matrix and the analyses of variance of the regression equations respectively. They show that (1) out of the 10 independent variables tested only seed weight is significantly correlated with four-year height, (2) the seed weight height regression accounts for 22% variation for two-year as well as four-year height and is statistically significant ($P \geqq 0.95$), (3) the seed weight-current annual height growth in the fourth-year is associated with 31% variation.

Righter (1945) attributed the temporary nature of the seed weight-height correlation in the genus *Pinus* to the endosperm and seed coat constituting 90% of the seed weight in that genus. Endosperm and seed coat should be regarded as environmental factors whose effect disappears with increasing age of the seedlings. That relationship has been modified for loblolly pine (Robinson and van Buijtenen 1979) and does not appear to apply to white spruce. Notwithstanding the lack of knowledge about the proportion of endosperm and seed coat in white spruce seed the results of the present study indicate that seed weight is positively correlated with annual height growth up to four years and is not a mere carryover of the initial effect in the first year resulting from the favourable effect produced by the endosperm. The seed weight-annual height growth relationship appears to be genetically correlated and controlled pleiotropically or by linkage. For this reason it appears safe to include seed weight among the criteria for selection of plus trees.

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