pour un individu issu d'une autofécondation:
F = 1/2
d'où:

$$Cov(A, X) = 3/2.\sigma_A^2 + \sigma_{ADo}$$

* frères-soeurs issus d'une autofécondation:
(parents non consanguins)

$\delta_2 = \delta_9 = 1/4$;

$\delta_1 = \delta_4 = \delta_5 = \delta_6 = 1/8$;

$\delta_3 = \delta_7 = \delta_8 = \delta_{10} = \delta_{11} = \delta_{12} = \delta_{13} = \delta_{14} = \delta_{15} = 0$

$(\Sigma \delta_i = 1)$

d'où : $Cov(A, X') = \sigma_A^2 + 1/2.\sigma_{ADo}$

Effects of Clones, Primary Ramets, and Age of Stock Plants on Tamarack Rooting

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Summary

Genetic variance in the rooting potential of tamarack was estimated using greenwood cuttings of 2, 3 and 5-year-old primary ramets of clones developed from wildling ortets in northern Ontario. After eight weeks under mist, average rooting percent was 57% to 75% for cuttings from primary ramets of all three ages, and clone means ranged from 17% to 98%. Clone means for number of roots per cutting ranged from <1 to 7. Together, provenance and clones/provenance accounted for 42% of variance in rooting percent and 41% of variance in number of roots per cutting. Correlations of clone means for rooting characteristics among the three ages of ramets had coefficients ranging from 0.52 to 0.68. Environmental preconditioning (C effects) associated with primary ramets was a minor source of variance in rooting.

Key words: Genetic variance, environmental preconditioning, *Larix laricina*.

Introduction

The limited availability and generally poor quality of tamarack (*Larix laricina* Du Roi) K. Koch) seed has accelerated the development and use of vegetative propagation techniques for this species. Operationally successful mist propagation methods have been described by Farmer et al. (1986) and Morgenstern (1987). The likelihood of using vegetative progagules in plantation establishment has led to genetic improvement strategies centering around selection of clones. Information on clonal variance in rooting capability is therefore essential to breeding programs.

In an assessment of cuttings taken directly from 40 wildling ortets ranging in age from 3 to 10 years, Morgenstern et al. (1984) noted that the ratio of ortet variance to total variance in rooting percent ranged from 0.27 to 0.40, depending upon collection time; ratios of ortet variance in number of major roots per cutting ranged from 0.13 to 0.31. Farmer et al. (1986) reported ortet rooting percentages ranging from 0% to 100% in a study of cuttings from 221 wildling ortets collected throughout northwestern Ontario. In both of these studies cuttings were treated with indolebutyric acid to promote rooting, thus possibly masking genetic variation in natural rooting potential. Moreover, estimates of ortet variance in rooting are not necessarily good estimates of genetic variance, since physiological condition of the ortet is confounded with genetic potential. In this study we estimated genetic variance using untreated cuttings from clones which were represented by several previously propagated primary ramets. Because previous work (Carter, 1984; Morgenstern et al., 1984) suggests that propagation capability may not be rapidly lost with aging, we examined rooting of cuttings from ramets at two, three and five years of age to further confirm this relationship.

Methods

In the spring of 1985, 37 clones were randomly selected from two provenances included in a 1984 collection made to evaluate genetic variation in northern Ontario. The clones in this collection were developed from young(<5 yr.) wildling ortets transplanted from natural stands and propagated as described by Farmer et al. (1986). Sixteen were from the Timmins area (Lat 48°N, Long. 80°W) and 21 from Pickle Lake (Lat. 50°N, Long. 90°W). The primary ramets for the study were four cuttings rooted from each clone in 1984 and planted in 3-liter pots filled with a commercial peatvermiculite growing mix supplemented with liquid fertilizer (20:20:20) with micronutrients. They were then grown out-of-doors for one season (1985). Shoot and root growth were normal, and there was no evidence of nutrient deficiency. Plants were overwintered in a lathhouse and forced to break buds in the greenhouse in February 1986.

On July 21, 1986, twelve 4-to 6-cm-long cuttings were taken from each of the four ramets of each clone. Needles were stripped from the basal 2 cm of the cuttings. Cuttings were then soaked in a benomyl solution (1 g/l) for several minutes before being stuck in Spencer-Lemaire containers (size 170 cm^3, 140 cm^3) filled with a peat-

Table 1. — Analyses of variance in rooting characters of tamarack cuttings.

Source of Variation	1986 Degrees of Freedom	1986 Mean Square	1986 Variance[1] Component	1987 Degrees of Freedom	1987 Mean Square	1987 Variance Component	1989 Degrees of Freedom	1989 Mean Square	1989 Variance Component
				Number Roots per Cutting				Length of Longest Root	
Replication (B)	2	55.16	-	2	7.75	-	5	10.80	-
Provenance (P)	1	193.88**	19	1	0.28 NS	±0	1	230.00*	11
Clones/Provenance (C)	35	18.57	30	35	9.21**	39	21	44.95**	25
Primary Ramets/Clones (R)	108	2.61	2	106	1.15NS	4	44	6.27	2
Error	267	2.32	49	283	0.95	57	325	5.19	62
Total	413			427			395		
				Percent of Cuttings Rooted (Arcsin Transformation)					
Replication (B)	2	12,170.00	-	2	1,266.50	-	2	1266.50	-
Provenance (P)	1	10,068.00 NS	5	1	312.00NS	±0	1	3701.00NS	14
Clones/Provenance (C)	34	3,300.06**	34	30	3,756.98**	31	20	994.55**	43
Primary Ramets/Clones (R)	106	366.43 NS	±0	91	771.14**	11	-	-	-
Error	261	494.78	61	242	487.45	58	42	245.86	43
Total	404			366			66		

Source of Variation	Expected Mean Square
Replication (B)	$\sigma^2 + b\sigma^2_R + rb\sigma^2_C + rbc\sigma^2_P$
Provenance (P)	$\sigma^2 + b\sigma^2_R + rb\sigma^2_C$
Clones/Provenance (C)	$\sigma^2 + b\sigma^2_R + r\sigma^2_C$
Primary Ramets/Clones (R)	$\sigma^2 + b\sigma^2_R$
Error	σ^2

*) Statistically significant at 0.05 level of probability.
**) Statistically significant at 0.01 level of probability.
NS — Not statistically significant at 0.05 level of probability.
1) Variance components expressed as percent of total variance less replication variance.

vermiculite (50:40) rooting medium. Containers of cuttings were placed on a greenhouse "misting" bench where cycles were 4 to 6 seconds of mist every 4 minutes during daylight hours. Air temperature was 15°C to 25°C, and cuttings were exposed to natural photoperiods. This system had been previously used to successfully propagate primary ramets, with rooting of over 90% (FARMER et. al., 1986).

Four-cutting plots were used in a nested design with three replications arranged as randomized complete blocks (*Table 1*). This standard nested design (see STEEL and TORRIE, 1980, for linear model and computation procedures) allowed for evaluation of variance due to provenance, clones within provenance, and primary ramets within clones. Primary ramet variance is an estimate of environmental preconditioning ("C" effects) associated with growing ramets in separate pots. Three clones were represented by only three primary ramets, and several ramets provided only enough cuttings for two replications; this accounted for lower than expected degrees of freedom for primary ramets and for error (*Table 1*).

After eight weeks, cuttings were removed from the medium and number of roots longer than 2 mm. recorded for each cutting. Average number of roots per cutting and rooting percent were determined for plots, and the analysis of variance was performed on these plot means after arcsin transformation of rooting percent. Variance components were based on expected mean squares shown in *table 1* after adjusting coefficients (SNEDECOR and COCHRAN, 1980) for some inequalities in number of ramets within clones and plots per ramet.

Primary ramets were placed out-of-doors during the 1986 growing season, stored over winter in a lath-house, and greenhouse forced in March 1987. On June 4, 1987 the propagation test described above was repeated following the same general design used in 1986. Primary ramets were then planted at 2 m x 2 m spacing on a sandy-loam old-field site in four replications of a randomized complete block design, with one primary ramet from each clone per block.

In 1989, twelve clones from the Timmins provenance and ten from Pickle Lake were chosen for a third rooting evaluation. These clones were all represented in at least three replications of the field test, and their ramets were 0.6 m to 1.5 m in height. On June 26, six 4-to 6-cm-long cuttings were taken from tips of upper lateral branches on each ramet in three replications. They were treated as in previous years and planted under mist in the experimental design outlined in *table 1*, with six replications of single-cutting plots arranged as randomized complete blocks. After eight weeks under mist, number of roots per cutting and length of the longest root on rooted cuttings were recorded. The analysis of variance outlined in *table 1* was used to evaluate roots per cutting. The effect of ramets within clones was not evaluated in the analysis of the length of longest root (*Table 1*) since numerous unrooted cuttings prevented proper assessment of this factor. Rooting percent was analyzed without evaluation of ramets within clones using a synthesis of data from two adjacent blocks to give three replications of six cuttings per clone (*Table 1*).

Results

Average rooting percent ranged from 57% to 75% in the three years, and clone means ranged from 17% to 98%

Table 2. — **Rooting characteristics of tamarack cuttings propagated in 1986, 1987, and 1989.**

Item	Provenance	1986 Test Mean	1986 Range of Clone Means	1987 Test Mean	1987 Range of Clone Means	1989 Test Mean	1989 Range of Clone Means
Number roots per cutting	Timmins	3.1	0.6-6.9	1.6	0.4-3.3	3.5	0.8-6.2
	Pickle Lake	1.7	0.3-3.4	1.6	0.5-3.9	1.9	0.5-4.9
Percent of cuttings rooted	Timmins	74	31-96	60	17-90	75	33-94
	Pickle Lake	60	20-86	63	23-98	57	22-94
Length of longest root,mm	Timmins	---	-----	---	-----	24	8 - 40
	Pickle Lake	---	-----	---	-----	24	13-48

Table 3. — **Coefficients of correlation between tamarack clonal rooting characteristics in 1986, 1987, and 1989.**

	Rooting Percent		Number Roots per Cutting	
	1987	1989	1987	1989
1986	.52**	.68**	.52**	.58**
1987		.34		.66**

**) Statistically significant at the 0.01 level of probability.

(*Table 2*). In 1986 and 1989, material from Timmins had respectively 14% and 18% better rooting than Pickle Lake clones, but the difference was not significant in 1987, when provenance means were almost identical. Average number of roots per cutting at eight weeks ranged between 1.7 and 3.5, but the better rooting clones had 6 to 7 roots per cutting; provenance differences were significant in 1986 and 1989 (*Tables 1, 2*). Over the three years, clones within provenance accounted for an average of 31% of variance in roots per cutting and 36% of variance in rooting percent. Clonal variance was also predominant with respect to length of longest root when it was evaluated in 1989, with clone means ranging from 8 mm to 48 mm. Effect of primary ramets within clones was significant only for rooting percent in 1987, when it accounted for 11% of variance (*Table 1*). There was no evidence of a trend toward decreased rooting with age of stock plants (i.e. primary ramets).

Clone means for rooting percent were moderately to strongly correlated with clone means for number of roots per cutting (r = 0.82, 0.89 and 0.61 in 1986, 1987, and 1989, respectively). In 1989, root length was moderately correlated with number of roots per cutting (r = 0.51). Of more interest, however, are correlations of clone means among years for rooting percent and number of roots per cutting (*Table 3*). With the exception of the low correlation of rooting percent between 1987 and 1989 (r = 0.34), the coefficients of these correlations ranged from 0.52 to 0.68.

Discussion

The major finding of this study is that there is relatively strong genetic control over rooting percent and number of roots per cutting, both of which vary widely among clones. Had the propagation period been longer than eight weeks, the degree of rooting would probably have been generally greater. Our estimates of clonal variance in root number and degree of rooting are similar to those for western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) made by Foster et al. (1984, 1985). Morgenstern's et al. (1984) estimate of ortet variance in rooting of tamarack is also similar to our estimates of clonal variance.

The negligible effect of primary ramets within clones (C effects) in our study may be partly due to the fact that all ramets were grown under similar conditions in a situation comparable to a cutting nursery. While the study results suggest that C effects will not be a problem under these conditions, they do not generally demonstrate that environmental preconditioning will be negligible.

The reasonably good year-to-year correlation of clonal rooting characteristics further strengthens the utility of selection to improve rooting. However, it must be noted that in our study, material with very poor rooting potential was eliminated in initial trials, thus biasing the test mean as well as the range of clone means reported here. Use of rooting hormones may also allow the selection of some clones with only modest rooting potential but good growth characteristics. In fact, general use of chemical rooting promoters may be advisable to obtain quicker and more abundant rooting.

As suggested by Morgenstern's et al. (1984) work, there appears to be little problem with early (three to five years) loss of juvenile rootability in tamarack though one can expect a decrease in rooting potential as trees approach ten years of age. There is also a likelihood that problems associated with plagiotrophic effects may emerge at this age. On balance, however, the rooting characteristics observed to date lend themselves to development and operational use of tamarack clones with genetically improved growth potential, the major goal of propagation techniques. Clones developed using the above described rooting procedure are currently in field tests.

While our data suggest that the sampled southeastern provenance may contain material with better rooting characteristics than that from the northwest, the sample is too small from the standpoint of provenance testing to make even a tentative general statement about geographical relationships. The data do, however, indicate that because of wide clonal variation within provenances, a substantial number of genotypes per provenance (> 20) must be used to adequately characterize geographical trends.

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