The Potential of Poplars in the Boreal Regions
I. Survival and Growth

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(Received 26th January 1983)

Summary

The paper presents the results of a two-stage trial of 32 clones of poplar species and their hybrids in a nursery from 1972 to 1974 and four replicated field experiments during 1978—81 in the boreal region of Canada in Newfoundland. Analysis of variance, S-N-K test among clones and single degree of freedom contrasts among classes, formed on the basis of one common parent, were conducted for survival and height in the nursery. Survival was 70—86%, 54—70% and 38—54% respectively in the high, medium and low survival clones. The good, medium and poor growing clones achieved heights of 174.4—216.0 cm, 170.1—174.0 cm and 136.7—166.8 cm respectively after the root system had been established. The classes were heterogeneous but the clones were fairly homogeneous. Heterosis in growth was noticed in several cases. Good as well as poor rooting ability of the parent species was found in the hybrids.

The four sites for field experiments were selected in the productivity class I and II areas after detailed chemical and physical soil analysis. One-year old rooted cuttings were planted in six-replicated randomized complete block design experiments. Analyses of variance by locations were conducted on the survival and growth data at four-year age. This was followed by Bonferroni t-tests among clones ang single degrees of freedom contrasts among classes. Use of rooted cuttings, combined with scarification, weed eradication and liming of the field planting sites is essential for success as well as achieving uniformity of growth within clones. The best time for field planting appears to be the last week of June to the first week of July. Sites vary considerably in survival as well as growth and the good, medium and poor performers in all characters are different at different sites, details of which have been provided. The results provide guidelines for selection of clones best suited for the boreal environments represented by the four sites studied.

Key words: *Populus* spp., boreal regions survival and growth of poplars, potential of poplars.

Résumé

Sont présentées les résultats d'une expérience effectuée de 1972 à 1974 en deux étapes portant sur 32 clones de peupliers et d'hybrides de peupliers dans une pépinière et de quatre expériences sur le terrain avec répétitions, réalisées de 1978 à 1981 dans la région boréale de Terre-Neuve. Les données sur la survie et la hauteur dans la pépinière ont été soumises à l'analyse de la variance, au test de Student-Newman-Keul de comparaison des clones et à des comparaisons interclasses avec un degré de liberté, les classes étant formées sur la base d'un des parents communs. Les pourcentages de survie ont été de 70 à 86%, de 54 à 70% et de 38 à 54% pour les clones dont le taux de survie est élevé, moyen et faible, respectivement. Les clones à croissance bonne, moyenne et lente ont atteint une hauteur de 174,4 à 216,0 cm, de 170,1 à 174,0 cm et de 136,7 à 166,8 cm respectivement, après l'enracinement. Les classes étaient hétérogènes, mais les clones se sont montrés assez homogènes. L'hétérosis en ce qui concerne la croissance a été observé dans plusieurs cas. L'aptitude à l'enracinement, bonne ou mauvaise, des parents a été retrouvée chez les hybrides.

Les quatre emplacements des expériences sur le terrain ont été choisis dans les classes de productivité I et II après une analyse chimique et physique détaillée des sols. Des boutures racinées d'un an ont été plantées suivant un plan en blocs aléatoires completes avec six répétitions. Les données sur la survie et la croissance à quatre ans ont été soumises à des analyses de la variance pour chaque emplacement. Elles ont ensuite été soumises à des tests t de Bonferroni de comparaison des clones et à des comparaisons interclasses avec un degré de liberté. L'emploi de boutures racinées, combiné à la scarification, au désherbage et au chaulage du terrain de plantation, est essentiel pour la réussite et pour assurer l'uniformité de la croissance au sein des clones. La meilleure période pour la plantation sur le terrain semble la dernière semaine de juin et la première de juillet. Les emplacements diffèrent considérablement en ce qui concerne la survie et aussi en ce qui concerne la croissance, et les clones dont la performance a été bonne, moyenne et médiocre pour tous les caractères varient d'un emplacement à l'autre; des détails sont fournis dans le rapport. Les résultats apportent des indications utiles en vue du choix des clones les mieux adaptés aux conditions boréales représentées par les quatre emplacements d'étude.

Zusammenfassung

Dieser Bericht behandelt die Ergebnisse eines bifaktoriellen Versuchs mit 32 Klonen von Pappelarten und ihrer Bastarde in einer Baumschule von 1972 bis 1974 und in Freilandversuchen mit vier Wiederholungen von 1978 bis 1981 in der nördlichen Forstregion Kanadas in Neufundland. Varianzanalyse, S-N-K-Test zwischen den Klonen und ein Vergleich des einfachen Freiheitsgrades zwischen den auf einem gemeinsamen Elter beruhenden Klassen wurden für Überlebensrate und Höhenwuchs in der Baumschule durchgeführt. Die Überlebensrate der besten Klone war 70—86%, der mittleren 54—70% und der schlechtesten 38—54%. Die schnellwüchsigen Klone erreichten Höhen von 174,4—216,0 cm, die mittelwüchsigen 170,1—174,0 cm und die langsamwüchsigen 136,7—166,8 cm nach Anwurzelung. Die Klassen waren heterogen, die Klone ziemlich homogen. Heterosis im Wuchs wurde verschiedentlich beobachtet. Gute und schlechte Bewurzelungseigenschaften der Elternarten vererbten sich auf die Bastarde.

Nach eingehender chemischer und physikalischer Analyse wurden vier Standorte der Güteklassen I und II für die Freilandversuche ausgewählt. Einjährige bewurzelte Stecklinge wurden in randomisierten vollständigen Blockversuchen mit sechs Wiederholungen ausgepflanzt. Im Alter von vier Jahren wurden standörtliche Varianzanalysen der Überlebensraten und Wuchsdaten durchgeführt, gefolgt von Bonferroni t-Tests zwischen den Klonen und Vergleichen der einfachen Freiheitsgrade zwischen den Klassen. Der Einsatz von bewurzelten Stecklingen im Verein mit Bodenauflockerung, Unkrautvertilgung und Kalkung der Standorte ist unerläßlich für den Erfolg der Pflanzung und für einheitlichen Wuchs innerhalb der Klone. Die günstigste Auspflanzzeit ist offensichtlich die letzte Juni-

und die erste Juliwoche. Überlebens- und Wuchsraten auf den verschiedenen Standorten schwanken beträchtlich; die Leistungen der guten, mittleren und schlechten Klone waren in allen Eigenschaften auf den einzelnen Standorten unterschiedlich — diesbezügliche Einzelheiten werden aufgezeigt. Die Ergebnisse bieten Richtlinien für die Auswahl von Klonen, die sich am besten für die nördliche Umwelt eignen, wie sie durch die vier untersuchten Standorte verkörpert wird.

Introduction

Boreal regions are characterized by simple floristics with only a few widespread species which indicates the need for increased use of exotics for ecological and economic reasons. However, exotic species have not been considered advisable and forest management has emphasized native species almost exclusively. In Newfoundland, which is completely in the boreal region, forest management faces the additional problems of low yields from and inadequate natural regeneration of native species. Artificial regeneration is being phased in as an important component of the recently started intensive management and forest improvement program. Thus, a challenge as well as an opportunity was recently created for use of exotics as a tool in forest improvement. Increasing use of hardwoods in this program would ameliorate forest sites as well as diversify forest industry. Hybrid poplars would be an obvious choice for future reforestation in Newfoundland due to their fast growth, adaptability to varied sites, easy vegetative propagation of intact superior genotypes and potential for multiple use. As experience of poplar culture under boreal conditions was lacking a feasibility study was conducted by Dr. Louis Zsuffa, Ontario Ministry of Natural Resources in 1970 (Zsuffa 1971). Research on the potential of poplars in this part of the boreal region of Canada was planned and started in 1972 (Khalil 1973). This paper summarizes the results of this research during the past ten years.

Material and Methods

Initially 34 clones, listed in *Table 1* were selected as possible candidates. The research was conducted in two stages, the nursery and the field trial stages.

The Nursery Stage

Unrooted and, in some cases, rooted cuttings were planted on June 2, 1972 in the nursery at Pasadena, Newfoundland (lat. 49° 00' N, long. 57° 35' W) for vegetative multiplication of the planting stock and preliminary observations on performance under boreal conditions. The important elements of the climate of Pasadena include a mean frost-free period of 96 days (June 10—September 15), an average of 164 growing days (May 5—October 20) with the mean temperature above 5.6° C, 1 100 degree-days above 5.6° C, mean temperature and rainfall of 12.8° C and 432 mm respectively in the May—September period (Rowe 1972). Thus, the climate of Pasadena is harsh for poplars.

Site preparation had been done earlier consisting of an application of dolomitic limestone (MgO 16%, CaO 33%) at 3 337 $kg.ha^{-1}$, worked into the soil, in the summer of 1971, followed in the spring of 1972, by cultivation, sterilization of the soil with 5.4 $l.m^{-2}$ solution of 1.9% formaldehyde and addition of 305 $m^3.ha^{-1}$ of sterilized sphagnum peat. The area was fertilized three weeks before planting with 205 kg P_2O_5, 117 kg K_2O, 63 kg NH_4 and 83 kg NO_3 per hectare.

Table 1. — The clones.

Clone No.	Origin
A.546, A.547	*Populus alba*. Grand Falls, Newfoundland, lat. 48°55'N. long. 55°40'W.
AK.28, AK.30	*P. alba* Brampton (A.69) x *davidiana* v. *glandulosa* (gl.1). Korea (gl.1) selected from full-sib population 363 produced at Maple.
AS.34	*P. alba* (A.69) x *sieboldii* (S2). Japan (S2). Selected from full-sib population 431 produced at Maple.
AT.42*	*P. alba* Brampton (A.69) x *tremuloides* (T.18) Port Bolster. Selected from full-sib population 274 produced at Maple.
TAC.23*	*P. balsamifera* L. Deer Lake, Newfoundland, lat. 49° 07'N. long. 57°25'W.
C.147	*P. canescens* Ingolstadt. Munden, West Germany.
CAG. 23, CAG. 25, CAG. 26, CAG. 77	*P. canescens* Czechoslovakia (C.18) x (*alba* x *grandidentata*) AG.7. Toronto, Ontario (AG.7). Selected from full-sib population 406 produced at Maple.
CAG.118	*P. canescens* Czechoslovakia (C.18) x (*alba* x *grandidentata*) AG.7. Toronto, Ontario (AG.7). Selected from full-sib population 355 produced at Maple.
D.38	*P. deltoides* Bartr. Belleville, Ontario, lat. 44° 06'N. long. 77°20'W.
D.89*	*P. deltoides* Bartr. Norris Arm, Newfoundland, lat. 49°05'N. long. 55°12'W.
DN.2	*P. euramericana* Cv. Baden 437. Munden, West Germany.
DN.5	*P. euramericana* Cv. Gelrica. Munden, West Germany.
DN.7	*P. euramericana* Cv. Heidemij. Munden, West Germany.
DN.16*	*P. euramericana* Cv. Regenerata Batard d'Hauterive France.
DN.17	*P. euramericana* Cv. Robusta, France.
DN.28	*P. euramericana* Cv. Ostia. Munden, West Germany via Novi Sad, Yugoslavia.
DN.30	*P. euramericana* Cv. Canada Blanc. France var. Novi Sad, Yugoslavia.
DN.41, DN.42	*P. euramericana*. Grand Falls, Newfoundland, lat. 48° 55'N. long. 55°40'W.
IH.45/51	*P. euramericana* Cv. I.45/51. Casale. Monferrato, Italy.
IH.78B	*P. euramericana* Cv. "Jacometti 78B" Italy via Oxford, England No. 46/1015 of T.R. Peace.
GA.87, GA.88	*P. grandidentata* (Maple) x *alba* (A.321). Selected from full-sib population 436 produced at Maple.
Jac. 4	*P. balsamifera* x *deltoides*. Spontaneous hybrid Gore Bay, Manitoulin Island, Ontario, lat. 45°55'N, long. 82°30'W.
Jac. 6	*P. balsamifera* x *deltoides*. Spontaneous hybrid, 1.6 km north of Walkerton, Ontario.
Jac. 14*, Jac. 15*, Jac. 16*, Jac. 17*	*P. balsamifera* x *deltoides*. Spontaneous hybrid, Grand Falls, Newfoundland, lat. 48°55'N, long. 55°40'W.

* Rooted cuttings included.

The cuttings were planted randomly in rows 1.2 m apart with a spacing of 30 cm within rows. The sprouts were cut back to about 3 cm above ground successively in the first weeks of June 1973 and 1974. The cuttings so obtained were planted randomly in additional row plots for multiplication of planting stock and for evaluation of their rooting ability and growth.

The Field Experiments

The field experiments were also conducted in two stages to determine the degree of essential site preparation needed. In the first stage the four areas selected were Millertown Junction Road (lat. 48° 58' N, long. 56° 18' W), New Bay Pond (lat. 49° 05' N, long. 55° 36' W), Robinson River (lat 48° 14' N, long. 58° 36' W) and South Brook Valley (lat. 48° 55' N, long. 57° 38'W). They were recent cutovers with a substantial proportion of trembling aspen (*Populus tremuloides* (Michx.)), which was considered a good indication of their suitability for poplars. The test sites were partially cleared of slash. The Robinson River area was sprayed with a 1.125% aqueous solution of 2,4-D at 1.1 kg.ha^{-1} in summer 1975. The experiments were planted between June 9 and 30, 1976 in six-replicated randomized complete block design with four-tree square plots, using a spacing of 3 × 3 m. Survival was very poor by September 1976 (Millertown Junction Road 48%, New Bay Pond 26%, Robinson River 10%, South Brook Valley 0%). All the surviving plants died by fall 1977.

Four new experiments were planted in the second stage in June—July, 1978. Millertown Junction Road and Robinson River sites were retained and two new sites were selected at Goose Arm (lat. 49° 09' N, long. 57° 31' W) and Wooddale (lat. 49° 09' N, long. 55° 36' W). The original statistical design and spacing were retained. All competing vegetation was removed and the test sites were scarified and treated with dolomitic limestone at 7.4 metric t.ha^{-1}. Rooted cuttings were used. Due to inadequate planting material some clones were excluded from some test sites. The number of clones planted were Goose Arm 30, Millertown Junction Road 28, Robinson River 32 and Wooddale 20.

In view of the great importance of soil nutrient status and physical conditions of the planting site for establishment and good growth of poplars (Zsuffa *et al.* 1977; Czapowskyj 1978) detailed soil analyses were conducted in 1977 on samples from two soil pits at each site with samples collected on a horizon basis. Jackson's methods were used (Jackson 1960). Although all macronutrients are important for tree growth, recent studies on fertilization of poplars have shown nitrogen and potassium to be most effective in increasing and maintaining growth (Einspahr and Wyckoff 1978). Consequently, these elements were estimated together with phosphorus, calcium, magnesium and sodium. The data from the two samples from each horizon at each site were averaged. Soil pH was measured in 1978 and again in 1979 and 1980 summers at six places in each location and the data averaged.

Data and Analysis

The Nursery Stage

The 1972 and 1973 plantings were considered together and treated as a two-replicated randomized complete block experiment for rooting ability and the 1972—1974 plantings as a three-replicated randomized complete block experiment for height growth. Years were used as replications in both cases.

Table 2. — Classes of hybrids and species.

Class		Hybrids or species
Alba	(A)	P. alba (A.546, A.547)
Alba hybrids	(B)	P. alba x davidiana (AK.28, AK.30) P. alba x sieboldii (AS.34) P. alba x tremuloides (AT.42) P. grandidentata x P. alba (GA.87, GA.88)
Balsamifera	(C)	P. balsamifera (TAC.23)
Canescens	(D)	P. canescens (C.147)
Canescens hybrids	(E)	P. canescens x (alba x grandidentata) (CAG. 23, CAG.25, CAG.26, CAG.77, CAG.118)
Deltoides	(F)	P. deltoides (D.38, D.89)
Euramericana	(G)	P. euramericana (DN.2, DN.5, DN.7, DN.16, DN.17, DN.28, DN.30, DN.41, DN.42, IH.45/51, IH.78B).
Jackii	(H)	P. balsamifera x deltoides (Jac.4, Jac.6, Jac. 14, Jac. 15, Jac. 16, Jac. 17).

The 1972 and 1973 plantings were tallied for rooting in September 1974. Survival percent of each clone in both years was calculated. Heights of 1974 shoots were measured on each sapling of the 1972 planting by which time the root system had become fully established. One-year height of 10 randomly selected saplings was measured in each clone in the 1972—1974 plantings.

The 34 clones were grouped into eight classes on the basis of one common parent species, as listed in *Table 2.*

Bartlett's tests of homogeneity of variances were conducted on survival and height data (Steel and Torrie 1980). Analysis of variance, Student-Newman-Keul's multiple range tests and all possible contrasts among the above classes were conducted on the survival percentage data after transformation to arcsin (percentage)$^{1/2}$ and on the one-year height data of the 1972—1974 plantings. All possible contrasts among the above classes were also made for one-year height of the 1972 plantings in 1974, using Bonferroni t-test (Douglas 1979).

The Field Experiments Stage

The sites were evaluated on the basis of forest types, confirmed by chemical soil analyses. Robinson River is in productivity Class I and the remaining three in productivity class II (Bajzak, Bouzane and Page, 1968, Damman 1964). The chemical evaluation was based on the upper organic and B horizons for the total exchangeable bases (TEB), cation exchange capacity (CEC) the total and available percentages of nitrogen, phosphorus, potassium and calcium. The nutrient contents of the upper B horizon were considered to be a critical factor in evaluation of the sites because of the moderately deep rooting systems of hybrid poplars. The percentage of total nutrients in this horizon was also considered important because the test sites were to be limed to raise the pH and increase the quantity of available nutrients.

Survival was tallied and heights and diameters at 0.3 m of all trees were measured in fall 1981, four growing seasons after planting. The analyses of variance for survival, height and diameter were performed by locations covering the clones planted therein, using plot means, as the analyses taking into account the unequal numbers of observations per plot performed in a test case did not alter the conclusions drawn. Variance in height and diameter, pooled over clones was calculated for each location to estimate within-plot variance as a substitute for the estimate of sampling error lost by performing the analyses of variance by locations on plot means. The clones and clone classes were ranked for survival to evaluate their relative performance. Bonferroni t-tests (Douglas 1979) and single degree of freedom contrasts among classes were made for height and diameter (Steel and Torrie 1980). These tests were not made for survival due to small plot size.

Results and Discussion

Nursery Stage

Clones A.546 and DN.41 not survive. *Table 3* summarizes the results of the remaining 32 clones.

Survival

Analysis of variance of survival percent of the unrooted cuttings shows the variance due to years of planting (MS = 3 176, F = 8.9**) to be statistically significant ($P \leq 0.01$) as is that due to clones (MS = 670, F = 1.9* $P \leq 0.05$). The high variation in survival between the two years, with

Table 3. — Summary of the results of the nursery stage.

Clone	Survival percent 1972	Survival percent 1973	Mean annual height growth in the 1972-74 period: Height (cm)	Rank	Mean height growth of 1972 plantings in 1974: Height (cm)	Rank
			Unrooted cuttings			
A.546	63	23	26.2 ghi	24	155.3	24
AK.28	70	31	29.0 fgh	18	198.9*	2
AK.30	80	0	35.4 cdef	11	173.0	10
AS.34	50	47	28.7 fgh	20	160.6	21
AT.42	NP	14	35.6 cdef	9	216.0*	1
GA.87	20	NP	27.2 fghi	21	172.0	12
GA.88	25	55	21.7 hij	30	186.2*	4
TAC.23	NP	64	15.5 jk	32	136.7	31
C 147	55	57	24.7 ghij	27	150.8	28
CAG.23	50	18	17.2 ijk	31	148.9	29
CAG.25	35	0	28.8 fgh	19	174.0	9
CAG.26	70	36	25.6 ghi	25	179.1	6
CAG.77	50	NP	23.3 hij	29	163.8	20
CAG.118	30	NP	26.9 fghi	22	166.8	17
D.38	90	94*	26.6 ghi	23	159.4	22
D.89	93	75	25.5 ghi	26	143.5	30
DN.2	85	88	35.6 cdef	10	174.4	8
DN.5	100*	98*	49.1* a	2	171.4	13
DN.7	95	75	34.9 defg	13	159.0	23
DN.16	95	80	39.0 bcde	7	165.7	18
DN.17	100*	91*	31.7 efgh	15	164.8	19
DN.28	90	62	46.1*ab	3	155.2	25
DN.30	100*	56	41.2 bcde	6	176.1	7
DN.42	NP	82	24.6 ghij	28	153.0	27
IH.45/51	95	59	37.6 bcdef	8	172.7	11
IH 78B	95	89	31.1 efgh	16	153.7	26
Jac. 4	100*	47	57.8* a	1	184.8	5
Jac. 6	100*	0	32.4 defg	14	198.6*	3
Jac. 14	NP	29	29.4 efgh	17	NP	NP
Jac. 15	83	86	35.1 cdefg	12	170.5	15
Jac. 16	67	95	44.9* bc	4	170.1	16
Jac. 17	67	100*	41.3 bcd	5	170.8	14
Mean	73.0	56.9	32.2		168.6	
S.D.	± 25.4	± 32.0	± 9.2		± 16.7	
			Rooted cuttings			
TAC.23	100				136.7	8
D.89	100				171.0	3
DN.16	100				165.7	4
DN.42	100				153.0	7
Jac. 14	100				162.7	5
Jac. 15	100				178.3*	2
Jac. 16	100				162.8	6
Jac. 17	100				182.3*	1
Mean					164.3 ± 13.5	

Clones followed by the same letter are nonsignificantly different from each other (P ⩽ 0.95).
NP = Not planted.
* = Clones one standard deviation above the mean.

marked reduction from 1972 to 1973, is attributable to differences in environmental conditions, like weather, which affected all clones adversely, with some minor exceptions. The S-N-K multiple range test did not show statistically significant differences between any pairs of individual clones. However, the results of single degree of freedom contrasts among the classes are presented in *Table 4* and show significant differences among them. The results in *Tables 3* and *4* indicate the relative rooting ability of clones and classes respectively.

These results are interesting in that they indicate the retention of the high rooting ability of *P. deltoides* Bartr. in its hybrids *P.* × *euramericana*. On the other hand, the low rooting ability of *P. canescens* (Ait.) and *P. alba* (L.) is inherited in their hybrids. Survival was 100 percent in the eight clones whose rooted cuttings had been planted.

Height Growth

The analysis of variance of one-year mean height shows that the variance due to years as well as clones is statistically significant. Variation due to years constitutes 5.0 percent of the total with MS = 350.93, F = 2.96* (⩽ 0.05) and that due to clones is 56.8 percent, with MS = 255.46, F = 2.16** (P ⩽ 0.01). The variation due to experimental error is 38.2 percent of the total, with MS = 118.45.

The statistically significant contribution of years to variance is attributable to differences in environmental conditions, such as meteorological factors as well as increase in vigour due to establishment of the root system. *Table 3* shows the results of the S-N-K multiple range test and identifies promising clones. *Table 5* summarizes the results of single degree of freedom contrasts among the eight classes and identifies promising ones.

Several hybrids showed heterosis. The species *P. balsamifera* L. and *P. deltoides* are slow growing but several clones of the class *Jackii*, which are hybrids of these two species, are fast growing. Similarly *P. alba* is slow growing but several of its hybrids (classes *alba* hybrids and *canescens* hybrids) are fast-growing.

Table 3, column 4 shows the mean of one-year height growth of unrooted cuttings of each clone planted annually from 1972 to 1974 and column 6 shows one-year height of the same clone in 1974, which had been planted in 1972 and had got their root system established. Comparison of these two sets of data shows marked improvement in the growth of all clones by planting the cuttings after the root system had been fully formed. However, the lower part of *Table 3* shows the mean one-year height growth of the rooted cuttings in 1972. Comparison of these figures with those in column 6 in the upper part of the table shows no advantage of root establishment over three years compared to one year. These results indicate that rooting of cuttings for one year improves survival and growth but their retention in the nursery for three years is not necessary.

The Field Experiment Stage

The mortality in the first series of experiments appears to be due to one or more of the following factors:

1. Deep humus layer and low pH of 3.5—4.5.
2. Strong competition from weeds. Even the herbicide treatment with 2,4-D in the Robinson River area was

Table 4. — Summary of contrasts among classes for survival.

Class		Mean survival %	Non-significant differences
High survival	Euramericana	86.1	
	Deltoides	84.6	
	Jackii	78.1	
Medium survival	Balsamifera	64.3	
	Canescens	55.6	
Low survival	Alba	44.8	
	Canescens hybrids	41.2	
	Alba hybrids	38.5	

Note - Classes covered by the same vertical lines are non-significantly different from each other (0.05 level).

Table 5. — Summary of contrasts among classes (1-year height).

Class		Mean height (cm)	Non-significant differences
Good	Jackii	178.7	
	Alba hybrids	178.5	
Medium	Canescens hybrids	167.5	
	Euramericana	165.6	
	Alba	155.3	
Poor	Deltoides	152.5	
	Canescens	150.8	
	Balsamifera	136.7	

Note: Classes covered by the same vertical lines are non-significantly different from each other (0.05 level).

inadequate for their effective eradication. The residual effect of the herbicide itself must have contributed to the mortality as has been experienced in Ontario, Canada (ZSUFFA, L. (1982) Ont. Tree Impr. and Forest Biomass Inst., Ont. Min. Nat. Res. Personal Communication).

3. Late spring and early fall frost. Minimum temperatures of 1.1°—2.8° C were recorded at Deer Lake and Corner Brook, both within 24 km of the South Brook Valley test site on June 12—14, 1976, during the first week after planting. Severe frost must have occurred at this test site which was in the valley bottom. Similarly, minimum temperatures of 2.3°—5.4° C occurred on August 18—19, 1976 at Corner Brook, Stephenville Airport and Port aux Basques all on the coast. Subfreezing temperatures must have occurred in the inland area of Robinson River test site. Frost was recorded in June, August and September 1976 throughout insular Newfoundland, which caused damage at all the four locations.

Tables 6—10 present the results of the second planting. The results of soil and site assessment of the planting sites have been published separately (ROBERTS and KHALIL 1980). The nutrient contents and texture of the soils were comparable with those generally considered suitable for planting hybrid poplars. Only pH was lower than the optimum but it was improved by liming. The sites ranked in the decreasing order as: Robinson River, Wooddale, Goose Arm and Millertown Junction Road. The first three sites have a more favourable soil texture for the growth of poplars than the fourth. Because of the expected increase in pH by liming, Millertown Junction Road area was expected to move above Goose Arm and all sites were expected to improve by release of increased amounts of available nutrients. All sites except Goose Arm have adequate quantities of available moisture. The latter has a fragipan also in the lower B horizon which could adversely affect growth by retarding root penetration in a few years.

The increase in pH at both levels varied with location, with the largest increase in the Robinson River area *(Table 6)*.

The analyses of variance by locations show the statistical significance of both replications and clones as sources of variation for all locations and characters *(Table 7)*. The only exceptions are survival at Goose Arm and Wooddale. The mortality at Goose Arm was mainly due to the dry and hot period soon after planting in 1978, aggravated by the sandy nature of the soil. This affected all replications equally and masked the effect of replications on this character. The mortality at Wooddale resulted from late planting in the summer (third week of July), which affected all replications. However, clones had differential response to the factors leading to mortality at all locations, including Goose Arm and Wooddale, which resulted in the statistical

Table 6. — Summary of pH in 1979 and 1980.

Sample	Goose Arm 1979 sample 5-15 cm depth	Goose Arm 1979 sample 15-25 cm depth	Goose Arm 1980 sample 0-15 cm depth	Goose Arm 1980 sample 15-25 cm depth	Millertown Junction Road 1980 sample 0-15 cm depth	Millertown Junction Road 1980 sample 15-25 cm depth	Robinson River 1979 sample 5-15 cm depth	Robinson River 1979 sample 15-25 cm depth	Robinson River 1980 sample 0-15 cm depth	Robinson River 1980 sample 15-25 cm depth	Wooddale 1980 sample 0-15 cm depth	Wooddale 1980 sample 15-25 cm depth
1	4.3	4.4	4.4	4.9	5.5	5.1	4.4	4.6	4.8	5.0	5.9	5.8
2	4.4	4.6	5.9	5.2	5.6	5.3	4.4	4.5	5.1	5.0	5.1	5.6
3	5.2	4.9	5.8	5.8	4.7	4.7	4.5	4.0	4.6	4.9	6.5	6.3
4	4.4	4.8	4.0	4.3	4.8	4.5	4.5	4.5	4.0	4.0	4.3	5.0
5	5.2	5.2	4.2	4.7	4.6	4.8	4.2	4.8	5.0	6.0	6.2	5.6
6	4.9	4.8	4.6	4.4	4.9	4.7	4.4	4.9	5.6	5.0	5.2	5.6

Table 7. — Summary of analyses of variance by locations.

Source of variation	Goose Arm D.F.	Goose Arm % var.	Goose Arm F	Millertown Junction Road D.F.	Millertown Junction Road % var.	Millertown Junction Road F	Robinson River D.F.	Robinson River % var.	Robinson River F	Wooddale D.F.	Wooddale % var.	Wooddale F
Survival												
Replications	5	2.9	1.53 (> 0.05)	5	9.7	5.36 (0.001)	4	9.4	5.01 (0.001)	5	4.4	1.17 (> 0.05)
Clones	29	47.9	4.39 (0.001)	27	49.3	5.04 (0.001)	31	34.0	2.34 (0.005)	19	24.6	1.73 (0.05)
Experimental error	131	49.2		113	41.0		121	56.6		95	71.0	
Height												
Replications	5	5.7	2.67 (0.05)	5	15.7	8.39 (0.001)	4	13.0	8.54 (0.001)	5	4.5	2.82 (0.05)
Clones	29	38.7	3.14 (0.001)	27	41.9	4.13 (0.001)	31	40.9	3.46 (0.001)	19	64.9	10.63 (0.001)
Experimental error	131	55.6		113	42.4		121	46.1		95	30.6	
Diameter at 0.3 m												
Replications	5	7.4	3.73 (0.005)	5	16.3	11.54 (0.005)	4	12.3	9.24 (0.001)	5	69.2	63.38 (0.001)
Clones	29	40.8	3.56 (0.001)	27	51.9	6.81 (0.001)	31	47.5	4.61 (0.001)	19	10.1	2.42 (0.005)
Experimental error	131	51.8		113	31.8		121	40.2		95	20.7	

The figures in parentheses in F columns indicate the level of significance.

Table 8. — **Summary of ranking for survival percent in field experiments.**

Clone	Goose Arm		Millertown Junction Road		Robinson River		Wooddale	
	% Survival	Rank	% Survival	Rank	% Survival	Rank	% Survival	Rank
A.546	33.9	19	Not planted		72.4	8	Not planted	
AK.28	45.4	16	66.7	8	78.6	6	" "	
AK.30	52.7	14	66.7	8	95.0	2	" "	
AS.34	44.0	18	65.0	9	85.0	4	" "	
AT.42	87.5	4	29.8	21	90.0	3	" "	
GA.87	75.0	9	Not planted		75.0	7	" "	
GA.88	54.2	13	50.0	16	70.0	9	91.7	3
TAC.23	Not planted		Not planted		100.0*	1	Not planted	
C.147	78.9	8	68.3	7	85.0	4	100.0*	1
CAG.23	83.3	5	38.7	18	100.0*	1	100.0*	1
CAG.25	Not planted		Not planted		85.0	4	Not planted	
CAG.26	64.1	12	35.8	20	60.0	11	83.3	4
CAG.77	51.5	15	29.7	22	75.0	7	Not planted	
CAG.118	91.7	3	58.3	14	100.0*	1	" "	
D.38	95.8*	2	61.8	12	100.0*	1	100.0*	1
D.89	50.0	17	41.0	17	80.0	5	95.8	2
DN.2	87.5	4	68.3	7	100.0*	1	83.3	4
DN.5	87.5	4	83.3	5	100.0*	1	95.8	2
DN.7	83.3	5	78.7	6	100.0*	1	95.8	2
DN.16	100.0*	1	62.5	11	100.0*	1	100.0*	1
DN.17	87.5	4	64.1	10	100.0*	1	95.8	2
DN.28	83.3	5	54.1	15	90.0	3	95.8	2
DN.30	73.9	10	37.5	19	85.0	4	100.0*	1
DN.42	66.7	11	94.1*	2	95.0	2	100.0*	1
IH.45/51	54.2	13	59.1	13	90.0	3	83.3	4
IH.78B	95.8*	2	95.8*	1	100.0*	1	95.8	2
Jac. 4	79.2	7	50.0	16	75.0	7	91.7	3
Jac. 6	83.3	5	87.5*	4	95.0	2	Not planted	
Jac. 14	83.3	5	83.3	5	100.0*	1	" "	
Jac. 15	100.0*	1	95.8*	1	95.0	2	91.7	3
Jac. 16	80.9	6	91.7*	3	90.0	3	100.0*	1
Jac. 17	87.5	4	95.8*	1	100.0*	1	100.0*	1
Mean	74.7		64.8		89.6		95.0	
S.D.	18.4		± 20.9		± 11.2		± 5.8	

Note: Clones marked with an asterisk are one standard deviation above the mean.

significance of clones as a source of variation. This indicates the need to avoid late planting after the first week of July.

The variance pooled over plots and clones within locations is usually fairly high as shown below:

	Goose Arm	Millertown Jct. Road	Robinson River	Wooddale
Height	39.9%	28.0%	45.5%	40.0%
Diameter	37.7%	24.3%	43.4%	12.9%

This indicates high within-plot variation which can be attributed to small differences in the size of cuttings and the micro-environmental differences within plots. This emphasizes the need for intensive site preparation in the nursery as well as the planting sites for quality control of the planting stock and minimizing micro-environmental differences in the planting site respectively.

There is very little variation among clones in survival in the Robinson River and Wooddale areas, which have

Table 9. — **Summary of ranking for potential volume by locations.**

Clone	Goose Arm				Millertown Junction Road				Robinson River				Wooddale			
	Ht. (cm)	Diam. (cm)	HD^2	Rank	Ht. (cm)	Diam. (cm)	HD^2	Rank	Ht. (cm)	Diam. (cm)	HD^2	Rank	Ht. (cm)	Diam. (cm)	HD^2	Rank
A.546	167.1	21.9	8.0193	5	Not planted				91.0	12.0	1.3104	18	Not planted			
AK.28	154.9	19.6	5.9506	14	70.5	7.6	0.4072	19	116.7*	13.8	2.2224	9	"	"		
AK.30	161.1	21.3	7.3089	6	90.1	9.4	0.7961	12	100.5	11.3	1.2833	20	"	"		
AS.34	169.8*	24.9*	10.5278*	3	54.8	3.4	0.0633	28	112.9	14.0	2.2128	10	"	"		
AT.42	191.6*	21.3	8.6927	4	65.8	6.0	0.2369	24	125.6*	13.0	2.1226	11	"	"		
GA.87	117.1	14.7	2.5304	22	Not planted				71.6	7.5	0.4028	31	"	"		
GA.88	175.5*	24.8*	10.7940*	2	102.1	15.0	2.2973	5	107.3	13.7	2.0139	13	150.2*	8.7*	1.1369*	3
TAC.23	Not planted				Not planted				88.8	13.4	1.5945	15	Not planted			
C.147	104.7	9.2	0.8862	29	80.7	7.4	0.4419	18	76.5	6.8	0.3537	32	114.6	5.2	0.3099	8
CAG.23	159.0	19.9	6.2966	11	73.3	6.3	0.2909	22	103.3	11.2	1.2958	19	125.3	5.2	0.3388	5
CAG.25	Not planted				Not planted				102.0	12.8	1.6712	14	Not planted			
CAG.26	111.0	13.4	1.9931	24	69.5	6.8	0.3214	20	79.6	7.6	0.4598	30	89.6	5.3	0.2517	10
CAG.77	166.9	20.6	7.0826	8	54.0	5.8	0.1817	25	88.1	10.4	0.9529	24	Not planted			
CAG.118	160.7	19.5	6.1106	13	109.9*	16.9*	3.1389	3	116.7*	14.9	2.5909*	5	"	"		
D.38	114.0	12.5	1.7813	27	60.6	6.5	0.2560	23	111.3	14.6	2.3725	7	96.9	4.0	0.1550	14
D.89	100.7	11.5	1.3318	28	58.0	5.3	0.1629	26	89.1	8.8	0.6900	27	89.6	3.2	0.0918	19
DN.2	138.4	17.1	4.4070	16	75.6	8.1	0.4960	17	94.6	10.8	1.1034	22	89.1	3.5	0.1091	18
DN.5	169.1*	20.5	7.1064	7	90.6	11.0	1.0963	9	98.7	11.6	1.3281	17	120.6	5.4	0.3517	6
DN.7	120.6	13.2	2.1013	23	78.8	11.1	0.9709	11	96.7	10.6	1.0865	23	113.1	3.8	0.1633	13
DN.16	149.3	20.9	6.5216	10	89.0	10.9	1.0574	10	115.4*	16.1*	2.9913*	4	107.4	5.1	0.2793	9
DN.17	153.0	20.1	6.1814	12	76.2	8.3	0.5249	16	97.2	11.3	1.2411	21	104.1	4.6	0.2203	12
DN.28	139.4	18.0	4.5166	15	65.6	6.9	0.3123	21	85.3	8.2	0.5736	28	82.7	5.2	0.2236	11
DN.30	131.2	14.6	2.7967	20	52.1	4.4	0.1009	27	77.5	7.8	0.4715	29	81.5	3.9	0.1240	17
DN.42	89.6	8.9	0.7097	30	92.0	11.6	1.2380	7	107.4	14.7	2.3208	8	116.1	5.3	0.3261	7
IH 45/51	121.3	17.7	3.8002	17	87.9	8.9	0.6963	14	75.8	9.8	0.7280	26	70.3	2.6	0.0475	20
IH.78B	122.5	16.7	3.4164	19	76.0	9.9	0.7449	13	97.3	12.0	1.4011	16	84.5	4.1	0.1420	15
Jac. 4	140.2	16.1	3.6341	18	83.1	13.3	1.4700	6	84.3	9.9	0.8262	25	88.5	3.9	0.1346	16
Jac. 6	163.3	20.3	6.7294	9	72.8	9.1	0.6029	15	109.2	13.8	2.0796	12	Not planted			
Jac. 14	99.0	14.1	1.9682	25	123.2*	21.6*	5.7480*	2	107.5	17.2*	3.1803*	2	"	"		
Jac. 15	172.1*	32.6*	18.2901*	1	143.6*	26.5*	10.0843*	1	101.8	17.3*	3.0468*	3	145.5*	9.7*	1.3690*	2
Jac. 16	114.0	12.9	1.8971	26	108.0*	16.6*	2.9760	4	116.9*	14.7	2.5261	6	119.6	5.7	0.3886	4
Jac. 17	127.5	14.3	2.6072	21	96.4	11.3	1.2309	8	127.3*	18.1*	4.1705*	1	143.1*	10.1*	1.4598*	1
Mean	140.2	17.8	5.1995		82.2	10.2	1.3552		99.2	12.2	1.6445		106.6	5.2	0.3812	
S.D.	± 27.2	± 5.1	± 3.7389		± 21.5	± 5.2	2.1009		± 14.9	3.0	0.9456		± 22.9	± 2.0	0.4200	

Note: Clones marked with an asterisk are one standard deviation above the mean.

Table 10. — **Summary of single degree of freedom contrasts between classes of clones.**

Class	Goose Arm			Millertown Jct. Road			Robinson River			Wooddale		
		Sign.diff.classes			Sign.diff.classes			Sign.diff.classes			Sign.diff.classes	
	Mean	P ≥ 0.95	P ≥ 0.99	Mean	P ≥ 0.95	P ≥ 0.99	Mean	P ≥ 0.95	P ≥ 0.99	Mean	P ≥ 0.95	P ≥ 0.99
				Survival (percent)								
Alba (A)	33.9	Nil	Nil	Not planted	Nil	Nil	72.4	Nil	Nil	Not planted	Nil	Nil
Alba hybrids (B)	59.8			55.6			82.3			91.7		
Balsamifera (C)	Not planted			Not planted			100.0			Not planted		
Canescens (D)	78.9			68.3			85.0			100.0		
Canescens hybrids (E)	72.7			40.6			84.0			91.7		
Deltoides (F)	72.9			51.4			90.0			97.9		
Euramericana (G)	82.0			69.8			96.0			94.6		
Jackii (H)	85.7			84.0			92.5			95.9		
				Height (cm)								
Alba (A)	167.1	B:F	Nil	Not planted			91.0	Nil	Nil	Not planted		
					G:H	G:H					B:E	B:E
Alba hybrids (B)	161.7			76.7			105.8			150.2	B:F	B:F
Balsamifera (C)	Not planted			Not planted			88.8			Not planted		
Canescens (D)	104.7			80.7			76.5			114.6	B:G	B:G
Canescens hybrids (E)	149.4			76.7			97.9			107.5	F:H	F:H
Deltoides (F)	107.4			59.3			100.2			93.3	G:H	G:H
Euramericana (G)	133.4			78.4			94.6			96.9		
Jackii (H)	136.0			104.5			107.8			124.2		
				Diameter (cm)								
Alba (A)	21.9	Nil	Nil	Not planted			12.0	D:H	D:H	Not planted		
Alba hybrids (B)	21.1			8.3	B:H	B:H	12.2	E:H	G:H	8.7	G:H	Nil
Balsamifera (C)	Not planted			Not planted			13.4	G:H		Not planted		
Canescens (D)	9.2			7.4	E:H	E:H	6.8			5.2		
Canescens hybrids (E)	18.4			9.0	F:H	F:H	11.4			5.3		
Deltoides (F)	12.0			5.9	G:H	G:H	11.7			3.6		
Euramericana (G)	16.8			9.1			11.3			4.4		
Jackii (H)	18.4			16.4			15.2			7.4		

only nine and four ranks respectively *(Table 8)*. While the classes of clones differ little in rank for survival at different locations, the individual clones differ greatly *(Tables 8, 10)*. This indicates the need for selection of individual clones rather than classes for best survival.

There is considerable variation among locations in the ranking of clones as well as classes of clones for height and diameter. *Table 9* shows the potential of each clone for height and diameter growth as well as potential stemwood volume at each location, calculated as HD^2. Clones marked with an asterisk appear suitable for the respective locations on the basis of survival and juvenile growth *(Tables 8, 9)*.

Table 11. — **Comparison of expected and actual relative suitability of test sites.**

Test site	Expected rank	Actual rank: Survival	Actual rank: Potential stemwood production
Robinson River	1	2	2
Wooddale	2	1	3
Goose Arm	3	3	1
Millertown Junction Road	4	4	4

The relative suitability of the four test sites for poplars is in close agreement with the expected suitability *(Table 11)*. There is only one exception for survival as well as potential stemwood production. These deviations have resulted from differences in meteorological conditions and their interaction with soil. *Table 12* summarizes the meteorological conditions during the 1978—1981 period. In the first place there appear to be differences in the speed with which the pH has increased at various locations, resulting in the differences with which the unavailable nutrients were released and became available. In 1978 the snowfall was lowest and the average mean temperatures were highest at Wooddale which provided fast warming up of the soil with earlier release of nutrients than at other locations. The temperature regime, and consequently the

Table 12. — **Summary of meteorological conditions at test sites*.**

	Goose Arm				Millertown Junction Road				Robinson River				Wooddale			
	1978	1979	1980	1981	1978	1979	1980	1981	1978	1979	1980	1981	1978	1979	1980	1981
Average maximum temperature, May-Oct. (°C)	17.0	18.4	14.7	17.1	15.3	16.7	13.9	15.7	15.3	16.3	14.8	16.3	16.5	18.7	16.5	17.9
Average minimum temperature May-Oct. (°C)	4.5	6.4	4.2	5.4	6.2	6.6	5.9	7.0	7.4	8.1	7.2	8.4	6.9	9.5	7.8	8.1
Average mean temperature, May-October (°C)	10 7	12.4	9.5	11.3	10.7	12.1	9.9	11.4	11.4	12.4	11.0	12.4	11.7	14.1	12.2	13.0
Degree-days (°C)	985.1	1 250.8	756.9	1 041.5	957.0	1 172.9	852.1	1 063.2	1 058.2	1 248.3	993.2	1 250.0	1 127.8	1 553.7	1 206.8	1 366.7
Total rainfall, May-Oct. (mm)	427.5	525.4	683.3	591.0	395.7	490.9	636.8	738.1	573.1	850.5	779.8	635.8	322.6	413.9	686.0	624.3
Total annual snowfall	447.9	284.9	325.8	224.4	254.0	134.3	181.1	175.0	522.0	278.3	425.4	323.1	260.2	187.6	212.9	181.4

Note: These figures are based on the data collected from the nearest meteorological stations.

* **Anon. 1978, 1979, 1980, 1981.**

energy provided by solar radiation, as indicated by degree-days, was highest at Wooddale in 1978 and 1979, followed progressively by Robinson River, Goose Arm and Millertown Junction Road. This combination of higher percentage of available nutrients and solar energy with their interaction appears to be conducive to best survival at Wooddale. Temperature regime appears to be critical for survival under boreal conditions.

For juvenile growth a combination of several factors is important. The annual snowfall in the 1979—1981 period has been the highest at Goose Arm, providing maximum protection against winter damage, The solar radiation, as reflected by degree-days in 1979, was slightly higher at Goose Arm than other sites which resulted in better growth there than elsewhere. The better growth at Goose Arm over the four year period is a carryover of the faster growth of 1979.

Conclusions

The important conclusions are summarized below.

1. Rooting ability and growth are inherited by the hybrids, which also show heterosis in growth.
2. Use of rooted cuttings, scarification, weed eradication and liming of the planting site are essential for success in field planting as well as for minimizing within-plot variation in growth.
3. The best time for field planting is the last week of June to the first week of July.
4. *Table 8* and *9* provide guidelines for selection of clones best suited for the locations represented by the four test sites under study.

Acknowledgements

The help received from the Applied Statistics and Scientific Computing Branch, Computing and Applied Statistics Directorate, Environment Canada, Ottawa for statistical analyses of the data of the field stage is acknowledged. Acknowledgement is also made of the help provided by Dr. A. W. Douglas, Director of the above Institution, Dr. L. Zsuffa, Principal Scientist, Ontario Tree Improvement and Forest Biomass Institute, Ontario Ministry of Natural Resources, Maple, Ontario, Canada and Dr. B. A. Roberts, Canadian Forestry Service for their review of the manuscript and valuable suggestions. Technical assistance was provided by Mr. L. May, Canadian Forestry Service, which is also acknowledged.

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The Potential of Poplars in the Boreal Regions II. Genotypic Stability and Productive Quality of Clones

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(Received 26th January 1983)

Summary

The data from a six-replicated four-location clonal trial of hybrid and exotic poplars was analysed to verify and quantify locations × clones interaction and to identify superior clones on the basis of genotypic stability and productive quality of the tested clones. Analyses of variance over locations were performed for survival, height and diameter at 0.3 m at four years after field planting. Locations × clones interaction was 14.9%, 14.7% and 12.4% for survival, height and diameter respectively and was statistically significant in each case (0.005 or 0.001 level). Superior clones have been identified for the environmental conditions represented by each test site on the basis of genotypic stability and productive quality. It is recommended that genotypic stability should be given more weight than productive quality if the environmental conditions at the planting site are not known. Superior clones on this basis have also been identified.

Key words: Poplars, locations × clones interaction, genotypic stability, productive quality.

Zusammenfassung

Auf vier Standorten wurden Versuche mit Klonen von Pappelbastarden und exotischen Pappeln mit sechs Wiederholungen durchgeführt. Die Daten aus diesen Versuchen wurden analysiert, um die Wechselwirkung Standort—Klon