WINTER HARDINESS ASSESSMENT IN SEEDLINGS OF PURE AND HYBRID PITCH PINE

by George P. Buchert
Ontario Ministry of Natural Resources,
Ontario Tree Improvement and Forest Biomass Institute,
Maple, Ontario, Canada LOJ 1E0

ABSTRACT.--One hundred and forty-six open-pollinated families from 25 stands in 15 geographic areas throughout the northern part of pitch pine's range and various F_1, F_2 and backcross combinations of pitch x southern pines were assessed for winter survival in southern Ontario. Survival differences among trees in natural stands accounted for 74% of total genetic variability, while differences among geographic areas accounted for 25% of variability. Between-stand differences were not detectable.

Large differences among various hybrid combinations were due in part to a/ choice of species combination, and b/ hardiness of individual pitch pine clones. Progenies having pitch x shortleaf as one parent were quite winter hardy. Implications for tree breeding are discussed.

INTRODUCTION

Development of *Pinus rigida* (Mill.) x *taeda* L. hybrids to incorporate the fast growth rate of *taeda* with the winter hardiness of *rigida* has been going on for some time in the northeastern United States and adjacent Canada (Little and Trew 1979, Zsuffa 1975, Heimburger 1969). Results in Ontario have been encouraging, but have been hampered by a limited genetic base of *rigida* materials to work with. Of utmost importance to Ontario's hybrid hard pine development program is the addition of diverse *rigida* sources from which to select well-adapted genotypes exhibiting both winter hardiness and fast growth. Information on how winter hardiness is inherited and the contribution that each parent makes to the hardiness of hybrid progeny is essential for rapid breeding progress.

In fall 1979, open-pollinated *rigida* cones were obtained from a number of locations in the northeastern U.S., Ontario and Quebec for testing in southern Ontario. In addition, control-pollinated and wind-pollinated seedlots from *rigida* and hybrid clones in breeding arboreta were available for investigation of variability and inheritance in winter hardiness. In the following report we present the results of this initial study.

MATERIALS AND METHODS

Open-pollinated cones from 146 individual trees across the northern portion of pitch pine distribution were collected in 1979. A minimum of five trees from each of 25 stands in 15 geographical areas were sampled, with the only selection criteria being a harvestable cone crop. Seeds were germinated in moist sand and transplanted into Leach super cells in January 1981. Family blocks consisting of 98 seedlings per family were grouped on greenhouse benches under natural light. In June 1981, 48 seedlings were randomly selected from each family block and grouped into three replicated plantation units, each unit consisting of 16 randomized complete single-tree blocks. These plantation units, still in containers, were overwintered in a lath house under ambient winter temperatures. In spring 1982, those seedlings which were not flushed out by June 6 were considered dead. All plantation units were scored. Live trees received a score of 1 and dead trees were scored 0. Analysis of variance was performed on this data and variance components were estimated for geographic areas, stands within areas and families within stands.

Control-pollinated seed of F_2 and backcross combinations, and open-pollinated seed from hybrid trees growing at the Maple and Turkey Point hard pine breeding arboreta were treated in the same manner as above and included in the replicated plantation units. Two seedlots each of Ontario red and white pine were included as controls. Winter hardiness was scored as above.

RESULTS AND DISCUSSION

Pitch pine.--Individual families were highly variable in their ability to survive their first winter at Maple. Analysis of variance indicated that 74% of the total treatment variation was due to differences among trees within stands, with the remaining 26% attributable to differences among geographical areas (Table 1). Stand to stand differences were not apparent. The red and white pine controls were virtually undamaged (97% and 100% survival respectively). Survival of pitch pine families ranged from 90% (family 3P218, Malletts Bay, Vt.) to 17% (family 3P119, Dansville, N.Y.).

TABLE 1 Analysis of variance in winter survival among 146 open-pollinated pitch pine families

Source	df	ms	% of treatment variance
Blocks	47	3.08	
Treatments	145	1.07	
Among geographic areas	13	3.89	26
Between stands within areas	11	0.32	0
Among trees within stands	121	0.84	74
Error	6760	0.20	

Two interesting facts emerged from the data:

a/ Cold hardiness as measured by first year seedling survival was rather randomly distributed over a broad geographical area, and

b/ variability among trees in any given stand was extreme.

The only clear pattern of geographic variation showed up as lower winter hardiness in western New York populations, where survival ranged from17% to 66%. When winter survival was expressed as a mean value for geographic area of origin, the Cairnside, Quebec population appeared to be hardiest, followed by Fryeburg, Maine and Lake Champlain western shore stands (Table 2, Figure 1). However, when all seedlots with 75% survival or better were ranked, the 23 qualifying families came from 17 different stands (Table 3). Furthermore, these 17 stand were distributed among 12 different geographic areas. This magnitude of tree-to-tree variability was unexpectedly high. We had assumed the selective forces in the form of winter temperature would result in fairly uniform levels of winter hardiness among families within a stand. However, two-to-threefold differences among families from the same stand were measured (Table 4).

These differences suggest that selection for winter-hardy individuals will make it necessary to screen a large number of families. Inheritance patterns of cold hardiness in pitch pine are as yet unkown. Variability in early seedling growth of pitch pine appears to be negligible among trees within stands (Ledig et al. 1976), suggesting little or no relationship between growth and hardiness. However, variation in wood characters of pitch pine is similar to the patterns we found in winter hardiness, e.g. most variation in tracheid length and specific gravity was among trees within stands, with substantial variation among geographic areas, but not among stands within areas (Ledig et al. 1975). If this abundant variability acts as a buffer against environmental fluctuations, as has been suggested for *Picea abies* L. (Kleinschmidt and Sauer 1976), and P. *glauca* (Moench) Voss (Pollard and Ying 1979), then what effects will intensive selection fcr

TABLE 2 Geographic areas of pitch pine ranked by mean winter survival

Location	survival	Location	survival
1. Cairnside, Quebec	74	8. Thousand Islands, Ontario	63
. Freyburg, ME	72	9. Oxford, ME	[illegible]
3. Ausable Chasm, NY	72	10. Black Moshannon, PA	58
4. Ossipee, NH	69	11. Chestertown, ME	57
5. Essex Junction, VT	67	12. Miller's Falls, MA	56
6. Concord, NH	65	13. Poconos, PA	56
7. Clear Lake, NY	63	14. Waverly, NY	[illegible]
		15. Dansville, NY	[illegible]

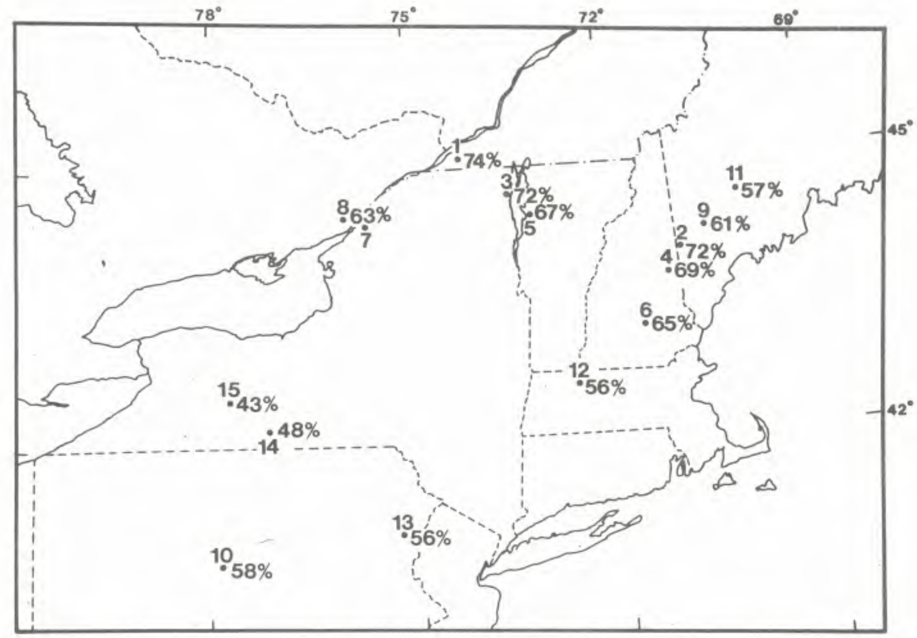

Figure 1 Location map and mean winter survival of pitch pine from 15 geographic areas.

winter hardiness have on the synthetic breeding population? At present we don't know, but analysis of winter hardiness data for a number of rigida hybrid combinations gives some interesting clues.

Rigida hybrids.--Winter hardiness ranged from 90% survival for (rigida x echinata) x rigida to 10% for (rigida x taeda) x (rigida x taeda). Families of rigida x taeda parentage generally had poor winter survival (Table 5). Two F_2 rigida x taeda families were tested and both had low winter hardiness. Backcross progenies of rigida x (rigida x taeda) also had fairly low winter hardiness. However, survival of these backcross families must be interpreted with caution, however, because the backcross female parents were themselves not very hardy. Rigida mother trees of two backcross families (3P 307, 3P 308) came from Dansville, NY, an area of relatively low hardiness, as already mentioned. Furthermore, the Cairnside, Quebec parent in family 3P 303 performed poorly in most other combinations, when compared with Ontario rigida parents (Table 6). This is interesting in light of the fact that the Cairnside population was, in general, quite hardy (Table 2). However, open-pollinated seedlings from clone 3-26, the rigida parent in question, was much less hardy than the Cairnside stand mean (46% versus 74%), although still within the range of variability (43% to 85%) detected in that population. It seems reasonable to assume that clone 3-26 from the Cairnside population is a relatively non-hardy genotype selected by random chance from a very heterogeneous population. Furthermore, without winter hardiness assessment, it may have

TABLE 3 Pitch pine families with 75% or better survival

Family	Geographic area	Stand	% survival
3P 218	5	Malletts Bay, VT	90
3P 177	11	Chestertown, ME	88
3P 227	3	West Plattsburg, NY	88
3P 198	4	West Ossipee, NH	87
3P 172	6	Canterbury, NH	85
3P 188	2	Freyburg, ME	85
3P 221	3	Ausable Chasm, NY	85
3P 229	1	Cairnside, Quebec	85
3P 232	1	Cairnside, Quebec	85
3P 254	8	Charleston Lake, Ont.	85
3P 212	5	Essex Junction, VT	83
3P 230	1	Cairnside, Quebec	81
3P 245	8	Thousand Islands, Ont.	81
3P 140	13	Poconos, PA	79
3P 203	4	Ossipee, NH	79
3P 236	7	Clear Lake, NY	79
3P 275	10	The Barrens, PA	79
3P 233	1	Cairnside, Quebec	78
3P 145	13	Big Pocono, PA	77
3P 169	6	Concord, NH	77
3P 202	4	Ossipee, NH	77
3P 211	5	Essex Junction, VT	77
3P 226	3	West Plattsburg, NY	77
3P 167	6	Concord, NH	75
3P [illegible]	2	Freyburg, ME	75

TABLE 4 Range of winter survival within selected pitch pine stands

Family	Geographic area	Stand	% survival
3P 177	11	Chestertown, ME	88
3P 178	11	Chestertown, ME	27
3P 218	5	Malletts Bay, VT	90
3P 217	5	Malletts Bay, VT	48
3P 254	8	Charleston Lake, Ontario	85
1P 255	8	Charleston Lake, Ontario	32
3P 140	13	Pocono, PA	79
3P 142	13	Pocono, PA	42
3P 127	15	Dansville, NY	65
3P 119	15	Dansville, NY	17
3P 263	10	Black Moshannon, PA	73
3P 268	10	Black Moshannon, PA	31

TABLE 5 Winter survival of P. rigida x taeda combinations

		% survival
rigida x (rigida x taeda)		
3P 303	Cairnside, Quebec x (Korea)	28
3P 307	Dansville, NY x (Korea)	42
3P 308	Dansville, NY x (Korea)	35
(rigida x taeda) x (rigida x taeda)		
3P 380	(Ont x NJ) x (Ont x NJ)	25
3P 383	(Ont x NJ) x (Korea)	10
(rigida x radiata) x (rigida x taeda)		
3P 328	(Korea) x (Korea)	58
(rigida x taeda) x wind		
3P 309	(Korea) x wind	33
3P 310	(Korea) x wind	35
3P 313	(Korea) x wind	48
3P 314	(Korea) x wind	44
3P 315	(Korea) x wind	13
3P 316	(Korea) x wind	38
3P 319	(Ont x NJ) x wind, 1978	38
3P 320	(Ont x NJ) x wind, 1978	31
3P 387	(Ont x NJ) x wind, 1979	51

TABLE 6 Comparative performance of crosses involving Quebec clone 3-26

		survival
rigida x wind		
3P 285	3-11 (Thousand Islands, Ontario) x wind	77
3P 289	3-26 (Cairnside, Quebec) x wind	46
(rigida x radiata) x rigida		
3P 331	3-176 (Korea) x 3-11 (Thousand Islands, Ontario)	81
3P 332	3-176 (Korea) x 3-14 (Thousand Islands, Ontario)	79
3P 333	3-176 (Korea) x 3-26 (Cairnside, Quebec)	60
rigida x (rigida x taeda)		
3P 303	3-26 (Cairnside, Quebec) x (Korea)	28
3P 307	3-60 (Dansville, NY) x (Korea)	42
3P 308	3-64 (Dansville, NY) x (Korea)	35

TABLE 7 Winter survival of seedling families from (*rigida* x *echinata*) crosses

		% survival
(*rigida* x *echinata*) x wind		
3P 283	3-41 (PA) x wind, 1978, ramet 1	79
3P 284	3-41 (PA) x wind, 1978, ramet 2	81
rigida x (*rigida* x *echinata*)		
3P 297	3-26 (Cairnside, Que.) x 3-41	79
3P 298	3-53 (Seneca Co. NY) x 3-41	74
3P 300	3-60 (Dansville NY) x 3-41	69
(*rigida* x *echinata*) x *rigida*		
3P 281	3-41 (PA) x 3-11 (Thousand Islands, Ont.)	90
(*rigida* x *radiata*) x (*rigida* x *echinata*)		
3P 325	3-176 (Korea) x 3-41 (PA)	83

continued to be used as a parent in F_1 hybridization and backcross breeding due to its desirable phenotypic appearance and the assumption that as a northern seed source, it is cold-hardy.

Winter survival of a *rigida* x *echinata* clone by assessment of its open-pollinated progeny, backcross progeny and in combination with other F_1 hybrids was surprisingly good (Table 7). When backcrossed to Quebec clone 3-26 the progeny survival rate was 79%, as good as open-pollinated seed from the hybrid parent. We cannot explain the hardiness of hybrid clone 3-41. Our records indicate that it is a natural hybrid, direction of cross unknown, parental seed sources unknown, probably from central Pennsylvania. Scions were received from Pennsylvania State University and are growing moderately well at the Turkey Point arboretum. Assuming a central Pennsylvania origin for the parents, our data for the limited Pennsylvania sources or *rigida* we tested (10 trees from two Pocono stands, 20 trees from two central Pennsylvania stands) gave winter survival ranging from 38% to 79% (Pocono sources) and 31% to 79% (Barrens and Black Moshannon sources). Hardiness contribution from an Allegheney *echinata* source is unknown; a single collection from an inland New Jersey stand (five trees from Hunterdon county) indicated winter survival ranges from 21% to 40%.

Do these first winter survival measurements accurately estimate winter hardiness? To answer this question we are establishing a series of provenance/progeny trials using families included in this study. In addition, we will monitor cold hardiness development throughout fall and winter by artificial freezing tests and electrolytic conductivity measurements of 2-year-old nursery seedlings. We also plan to investigate plant-soil moisture relations to elucidate effects on winter hardiness, because successful large-scale cultivation of fast-growing *rigida* x *taeda* hybrids in Ontario will depend on achieving a satisfactory level of winter hardiness.

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