Performance of Japanese and Hybrid Larch Progenies in Pennsylvania

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ABSTRACT. *Two series of larch progeny tests were established at three locations in Pennsylvania in the spring of 1984. The Penn Orchard series contained progenies of 24 "plus-tree" Japanese larch clones growing in a seed orchard in Pennsylvania, two production seedlots of Japanese larch, and two lots of Japanese × European larch hybrids. The Westvaco test contained 5 hybrid seedlots and 15 seedlots of Japanese larch originating from 9 seed orchards (including Penn "A" Orchard), 5 plantations, and one natural stand. After 7 yr, only one site was clearly ideal for Japanese larch, having produced both rapid growth (0.83 and 0.99 m/yr) and high survival. Survival or growth was considerably lower at the other two sites, probably because of both seasonally excessive and deficient soil moisture. Hybrid lots were significantly shorter than others at the best site; they tended to survive significantly better than Japanese larch at the other two sites, but they did not necessarily grow taller. Progenies from seed orchards were not significantly faster growing than those from plantations or natural stands (Westvaco test); and progenies from select trees in the Penn Orchard test were not significantly faster growing than production lots. Although genetic effects on 7 yr height were significant in most individual plantations, few seedlots could be statistically distinguished as superior or inferior in growth rate. Seedlot pedigree had much less influence on growth rate or survival than did choice of site. North. J. Appl. For. 11(2):53–57.*

Japanese larch is endemic to the island of Honshu, Japan, but has been successfully planted throughout the Northern Hemisphere. Even though its relatively small natural range suggests limited genetic diversity, Japanese larch appears to be adaptable to other environments, and it often outgrows native conifers on certain sites in the Northeastern United States (Ostry and Nicholls 1989, Einspahr et al. 1984, Isebrands et al. 1982). In 71 Pennsylvania plantations ranging from 41 to 84 yr old, European and Japanese larch outgrew all other species in height, and only red pine surpassed them in diameter (Grisez 1968). This and other reports of rapid growth, good krafting ability, potential for rotations of less than 30 yr on good sites, and relative resistance to deer browsing makes it a good candidate for reforestation (Shipman and Fairweather 1989, Carter and Simpson 1985, Park and Fowler 1983). A Japanese larch hybrid, (*Larix leptolepis* × *decidua*), has also shown great promise for similar uses (Zavitovski et al. 1983) and has eclipsed the performance of Japanese larch in some plantings (Riemenschneider and Nienstaedt 1983) and European larch in others (Weiser 1992).

As with any nonnative species, it is important to define which seed sources of Japanese larch are best adapted to local conditions. Unfortunately, provenance studies of this species have shown that seed source origin characteristics such as latitude, longitude, elevation, temperature, and precipitation are not clearly related to performance characteristics such as survival, growth rate, damaging agents, flower production, and stem quality (Park and Fowler 1983, Farnsworth et al. 1972, Genys 1972). Since provenance performance appears to be unpredictable, the purpose of this study was to compare the performance of diverse samples of Japanese and hybrid larch seed sources from local and international stands, plantations, and seed orchards, with the objective of determining which are best suited for plantation use in Pennsylvania.

Materials and Methods

Progenies

Two larch progeny tests consisting of Japanese and hybrid larch seedlots were established adjacent to each other at three Pennsylvania sites in 1984. The "Penn Orchard" test consisted of 24 open-pollinated families (seedlots) from the Pennsylvania Bureau of Forestry's Penn "A" Japanese larch clonal seed orchard of plus-tree selections, two seedlots of putative Japanese × European hybrids, and two production seedlots of Japanese larch (Table 1). The 24 plus-tree genotypes of the clonal orchard were originally selected for superior height and diameter from within well-stocked plantings 20 to 60 yr old in Pennsylvania, New York, and Vermont; replicated scions from these trees were grafted into

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Table 1. Japanese and hybrid larch seedlots represented in the Penn Orchard and Westvaco tests each planted at three sites across Pennsylvania.

Number of seedlots	Seedlot origin groupings
Penn Orchard Test	
24	Penn "A" orchard (families)
2	Production (unselected)
2	Hybrids
Westvaco Test	
9	Seed orchard seedlots (incl. bulk Penn "A")
5	Plantations
1	Provenance
5	Hybrids

the orchard. The two putative hybrid seedlots represented two separate years in which seed was collected from only the Japanese larch clones within a mixed Japanese and European larch seed orchard. The proportion of true hybrids in these seedlots was determined by examining twigs with intact needles collected from the upper third of the crown of each surviving tree at the Black Moshannon test site. One of the putative hybrid seedlots was determined to be 65% hybrid and 35% Japanese and the other was 45% hybrid, 45% Japanese, and 10% European larch (indicating that some seed had been collected from European larch). Although trees from these seedlots were not all hybrids, as may be expected in mixed species open-pollinated seed orchards, to simplify terms they will be referred to as hybrid seedlots. The two production lots consisted of one collection from local Pennsylvania stands and another of Japanese origin purchased from a seed company.

The "Westvaco" test consisted of 20 seedlots of Japanese and putative hybrid larch from diverse origins representing varying levels of tree improvement efforts. Nine seedlots represented collections from Japanese larch seed orchards in various locations around the world including one seedlot bulked from the same Penn "A" seed orchard families represented in the Penn Orchard test. Five seedlots were collected from Japanese larch plantations that were located in West Germany, Holland, and Japan. One seedlot represented a bulk collection from a natural stand in Japan. Five seedlots were putative hybrids from five different mixed Japanese and European larch seed orchards. Determining the proportion of true hybrids in these seedlots was done as described above. For two of the putative hybrid seedlots the seed was collected from only European larch trees. One of these two seedlots was determined to be 100% and the other 82% hybrids. Of the two seedlots collected from only Japanese trees, one was 58% hybrids and the other 33% hybrids. The fifth seedlot had 67% hybrids, 11% Japanese, and 22% European larch. These five seedlots will be referred to as hybrid seedlots.

Planting stock for the Penn Orchard test was raised at The Pennsylvania Bureau of Forestry's Penn Nursery. It was outplanted in April and May of 1984 as dormant 1-0 bareroot seedlings. Stock for the Westvaco test was produced by seeding 163.9 cm^3 "Styroblocks" and growing the germinants in a greenhouse at Pennsylvania State University from January to May 1984, when the containerized seedlings were moved to a unheated shadehouse for 1 month. They were outplanted in June 1984 as 5-month-old "green" containerized stock. Planting bars were used to plant both tests. At all three sites, the planting design was a randomized complete block with 6 blocks and 4-tree plots for each test. Border rows of 1-0 nursery-run Japanese larch were planted around most sides of the plantations to minimize potential edge effects

Sites

Planting sites were selected the previous summer and autumn by cooperators, but only one locality (Black Moshannon) was known by prior experience to be a productive site for Japanese larch. The Black Moshannon site is in Centre County and formerly supported a stand of maple and mixed oak. The understory was treated with glyphosate on Sept. 2, 1983 prior to winter harvest. The herbicide treatment was very effective, and significant weed competition never became established over most of the site. The site is nearly level and has a Clymer sandy loam soil, a deep, well-drained soil formed in sandstone with solum 61 to 102 cm deep and depth to bedrock greater than 150 cm. It is classified as being moderately permeable and moderate in available water capacity (Braker 1981). Spacing was 2.4 × 2.4 m.

The Towanda site is in Bradford County and formerly was an old field with a heavy sod. After planting, glyphosate was spot-sprayed around the trees, and the grass between the rows was mowed periodically to help reduce competition. The soil is classified as a Volusia channery silt loam. The upper 15 cm of subsoil is mottled with a fragipan located at a depth of 36 cm. Though the site slopes gently, it is somewhat poorly drained and was discovered at planting time to have a seasonally high water table as was evidenced by standing water in the planting holes. Permeability is slow to very slow with low to very low available water capacity (Grubb 1986). Spacing was 3.0 × 3.0 m.

The Shade Gap site is in Huntingdon County and had been primarily a Virginia pine stand with some invading mixed hardwoods. It was clearcut in 1983 and root-raked immediately before planting. The soil is a steep Berks-Weikert association Shelly silt loam, moderately deep and well drained with solum at 51 to 81 cm. Permeability is moderate to rapid and available water capacity is considered very low (Merkel 1978). The site slopes moderately steeply to the east. Spacing was 2.4 × 2.4 m. Glyphosate applied around the larch in the summer of 1984 reduced the competition, but established woody vegetation was not killed. In subsequent years maple, oak, hickory, and *Rubus* became competitors with the planted larch.

Data Collection and Analyses

After 7 growing seasons in the field, survival, height (dm), and diameter (mm at 1.3 m above ground) were measured and statistically analyzed for each test at each site. Height and diameter data were subjected to analyses of variance among individual seedlots using plot means weighted by the number of surviving trees per plot. In addition, analyses of variance were performed among seedlot groups of hybrids, seed orchards, natural stands, and plantations to gain insight on comparative performance among groups representing varying levels of genetic improvement effort. Fisher's least significant difference (LSD) was used to test for significant differences among seedlots and among seedlot groups at the $P = 0.05$ level. Variance analyses were not conducted across all sites due to heterogeneity of error variances as established by Bartlett's test (Steel and Torrie 1980). Survival comparisons among seedlots and among seedlot groups were tested using CONTRAST, a computer program developed by Hines and Sauer (1989) based on a Chi-square-related procedure that is weighted by associated survival rate covariances as outlined by Sauer and Williams (1989). One block was omitted from the analyses of height and diameter data in the Westvaco test at the Black Moshannon site, because of unrepresentative patches of herbaceous competition and shading from the bordering stand. In the same test at Towanda, only 2 blocks were subjected to analyses of height and diameter data because of much greater mortality in the other 4 blocks. Though mortality was high in the Penn Nursery test at Towanda, all blocks were included in the variance analyses because mortality was evenly distributed among blocks, and 66% of all seedlot plots were represented by at least one surviving tree. Seedlot rankings and significance of effects for the diameter data were virtually identical to those for height and will not be discussed.

Results

Survival

Seven years after outplanting, survival was extremely variable among sites but consistent between tests at the sites, ranging from 96% and 88% at Black Moshannon, to 44% and 49% at Shade Gap, and 33% and 34% at Towanda for the Penn Orchard and Westvaco tests, respectively. At the best site, Black Moshannon, there were no significant differences in survival among seedlots or seedlot groups. However, on the two poorer sites, the hybrid seedlots had greater survival compared to Japanese seedlots (Table 2).

Height

Plantation mean heights (m) after 7 growing seasons were 6.9 and 5.8 at Black Moshannon, 3.8 and 4.4 at Shade Gap, and 2.2 and 3.2 at Towanda for the Penn Orchard and Westvaco tests, respectively.

Penn Orchard Test.–The mean 7-yr height for the Penn Orchard test, across all sites, was 5.4 m. Analyses of variance, by site, revealed that only at Black Moshannon were there significant differences among seedlots. However, at Black Moshannon, the first 26 of the 28 seedlots could not be statistically distinguished. Both of the hybrid lots were ranked near the bottom, justifying further analyses by seedlot group (Penn Orchard, production, and hybrid).

Analyses of variance performed on seedlot groups, by site, showed that group differences were only apparent at Black Moshannon. At Black Moshannon mean heights (m) were statistically similar at 7.0 and 6.8 for Penn Orchard and production groups, respectively, but the hybrid seedlot group was significantly shorter than both at 6.1 m ($P < 0.05$).

Westvaco Test.—Height averaged 5.0 m across all sites for the Westvaco test. Analyses of variance, by site, showed significant seedlot effects at the Shade Gap and Black Moshannon sites. Height mean separations revealed that at Shade Gap 19 of 20 seedlots and at Black Moshannon 18 of 20 seedlots did not significantly differ from each other. At Black Moshannon, all of the hybrids seedlots ranked in the bottom one-third and the bulk lot representing Penn "A" Orchard ranked 18th. At the Shade Gap site, hybrid seedlots were variably ranked from 1st to 17th and the Penn "A" Orchard bulk lot ranked 3rd.

Analyses of variance performed on seedlot groups (seed orchard, plantation, hybrid, and provenance), by site, revealed significant group effects present only at Black Moshannon where progeny of seed orchards were tallest (6.0 m); they were significantly taller ($P < 0.05$) than only the hybrids (5.4 m) (Table 3).

Table 2. Absolute differences in percentage survival, 7 yr after outplanting, of hybrid larch seedlots vs. Japanese larch, by site and test (positive values indicate hybrid superiority).

Site	Penn Orchard	Westvaco
	(%)	
Black Moshannon	0 (ns)	-2 (ns)
Shade Gap	0 (ns)	+24 (**)
Towanda	+32 (**)	+5 (ns)

(ns) = not significant at $P = 0.05$
(**) = significant at $P = 0..001$

Discussion

The relatively poor survival at Towanda and Shade Gap was most likely due to poor edaphic conditions, perhaps compounded by incomplete control of competing vegetation at these sites. Japanese larch is an upland species that will not tolerate poor drainage (Carter and Selin 1987, Aird and Stone 1955, McComb 1955) and grows best on well- or moderately well-drained soils. A soil-site relationship study in Pennsylvania by Parsonage (1989) found that texture, drainage, and depth of soil were the most important factors correlated to the growth of Japanese larch. In our study, high mortality at Towanda and Shade Gap appeared to be caused by both too much and too little water. Until 1988, 4 yr after outplanting, survival was 57% at Towanda and 77% at Shade Gap averaged over both experiments. Initial mortality at Towanda was evidently caused by the poorly drained and seasonally saturated soil at that site; mortality was highest in the wettest portions of the site. However, in June and July of 1988, a severe drought occurred across Pennsylvania with precipita-

Table 3. Mean height of seedlot groups, after 7 growing seasons, in the Westvaco test at Black Moshannon (means with the same letter are not significantly different).

Seedlot grouping	Height (m)	LSD grouping
Seed orchards	6.0	a
Plantations	5.9	a b
Provenance	5.5	a b
Hybrids	5.4	b

tion levels only about one-third of normal (Penn. Agric. Stat. Serv. 1988). During that growing season, survival was reduced by another 23% at the poorly drained (Towanda) site and even more so, 30%, at the well-drained (Shade Gap) site. The additional mortality was surprising since the plantations had been in the ground for over 4 yr and apparently were well established. We attribute the mortality to drought, because both soils are characterized by low available soil moisture in summer months (Towanda because of a fragipan). There was only 2% additional mortality at Black Moshannon during the same period.

The hybrid has been shown to survive better than either parent species on dry sites (Reck 1977). In our study, the hybrid seedlots had a survival advantage under the extreme moisture conditions at Towanda and Shade Gap, but they did not have an advantage at Black Moshannon. For the Penn Orchard test at the poorly drained and seasonally wet Towanda site, the 32% survival advantage of the hybrids was in place by 1988 and did not change after the 1988 drought. At the other extreme, in the Westvaco test, at Shade Gap, there was only an 8% survival advantage for the hybrids by 1988, but it increased to 24% after the drought. The difference in performance of Penn Orchard vs. Westvaco hybrid lots at Towanda vs. Shade Gap remains unexplained. However, it should be pointed out that there were only two Penn Orchard hybrid lots, and these represented only differing collection years from the same orchard, while hybrids in the Westvaco test were of more diverse origins.

In the Penn Orchard test, seedlots differed significantly in growth only at Black Moshannon. In the Westvaco test, significant differences in height were found at all sites. However, in both tests these differences were primarily between Japanese and hybrid lots as categories and not among Japanese seedlots. Hybrids were significantly shorter than the Japanese seedlots. In other plantings, in more severe climates such as interior Maine and Wisconsin, or in frost pockets, hybrids have outperformed Japanese larch (Carter and Selin 1987, Riemenschneider and Nienstaedt 1983).

Growth of the Penn Orchard test at Black Moshannon was excellent, with a mean of 6.9 m after 7 yr, and even the Westvaco test (planted with younger and smaller stock) averaged 5.8 m. These rates are comparable with those reported by Zavitkovski et al. (1983) (7.5 m in 9 yr) for intensively cultured larch. On such an excellent site, where growth potential is nearly maximized, one might expect maximum expression of growth differences among seedlots. However, considering Japanese larch alone, only 1 of the 26 and none of the 15 seedlots differed significantly for the Penn Orchard and the Westvaco tests, respectively. Further examination revealed that the tallest 19 seedlots in the Penn Orchard test were plus-tree seedlots from the Penn "A" seed orchard. However, seedlots from the Penn "A" seed orchard as a group, though tallest (7.0 m), were not significantly taller than production lots (6.8 m).

In the Westvaco test, averaged over all sites, the Penn "A" orchard bulk seedlot was 14% smaller than the best seedlot and ranked 14th of the 20 seedlots tested. At the best site, Black Moshannon, the Penn "A" orchard seedlot performed poorly, ranking 18th of 20 and 19% shorter than the best seedlot (5.3 vs. 6.5 m). Group analysis did show that seed orchard lots were tallest, on average, but they were not significantly taller than other Japanese larch groups (plantation or provenance collections).

A definitive test of the efficacy of plus-tree selection should include progenies of unselected trees from the same stand as selected trees. However, in practice, seed from plus-tree selections is commonly sold as "selected seed" with the implication that it is indeed genetically superior to other commercial lots. Thus, a test of the practical value of "selected seed" is whether it is superior to alternative, unselected lots on a random sample of sites where it is likely to be used Plus-tree selection failed this test in our study.

Conclusions and Recommendations

Results emphasize the greater importance of site selection relative to seed source with Japanese larch. Soils should be well drained but not droughty. Black Moshannon met those criteria in this study, and trees of the Penn Orchard and Westvaco tests had excellent survival and growth, the former approaching 1 m/yr and resulting in canopy closure by the seventh year at the spacing we used. On poorly drained or seasonally droughty sites, hybrid seedlots exhibited better survival than Japanese larch seedlots, but we believe that planting these larch on such sites should be avoided.

Seedlots differed significantly at all three sites in the Westvaco test but only at Black Moshannon in the Penn Orchard test. However, even when seedlots differed significantly, we found that most Japanese larch seedlots, even though from widely different origins, could not be statistically distinguished from one another. Japanese larch open-pollinated progenies from plus-trees in the Penn Orchard test were not significantly taller than control lots, nor were progenies from seed orchards (including Penn "A" Orchard) in the Westvaco test compared to progenies from plantations or natural stands. Therefore, there is no evidence from this study that plus-tree selection was effective in genetically improving the survival and growth of Japanese larch in Pennsylvania.

On good sites in Pennsylvania, Japanese larch outperformed Japanese-European hybrids but exhibited little variability among seedlots in height and survival. Based on these results, seed source, though important, is much less so than choosing the proper site to achieve excellent survival and growth of Japanese larch in Pennsylvania.

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SYMPOSIUM

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