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SPECIES HYBRIDIZATION IN THE GENUS *PINUS*

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Abstract

Results of a breeding program in which a large number of pine species were tested indicate that a number of species and hybrids may be useful in the northeastern United States. Austrian black pine x Japanese black pine and hybrids containing Japanese red pine all had good growth rates. While none of the soft pines grew faster than eastern white pine, a number of hybrids grew equally fast and the nonnative component in the crosses may provide pest resistance, which is the number one problem in the Northeast.

INTRODUCTION

IN 1947, the genetics project, located at the Morris Arboretum near Philadelphia, Pennsylvania, began an extensive hybridization program with a number of genera of trees. Reports of species crossability have been published by J. W. Wright (1948, 1953, 1958, 1959).

This paper reports on the performance of the pine hybrids at two locations: Washington Crossing State Nursery in west-central New Jersey (lat. 40°15′ N., long. 74°45′ W.) and Williamstown, Massachusetts (lat. 42°45′ N., long. 73°15′ W.).

MATERIALS AND METHODS

With few exceptions, the trees used as parents were planted specimens of unknown seed origin and were located in the Morris Arboretum and the surrounding area. Seedlots with numbers preceeded by the letter "N" were supplied by a cooperator and in most instances were not of hybrid origin. The exceptions were two lots of (*Pinus nigra* × *Pinus densiflora*) × open-pollinated seed supplied by Cold Harbor Laboratory, Long Island, New York.

A 6 × 6 foot spacing was used in all plantings at each location. A completely randomized, single-tree plot design was used in some plantations while others contained rows from a single source or a combination of the two.

All seedlings for the New Jersey planting were grown in the Washington Crossing State Nursery. Seedlings were moved to a field location adjacent to the nursery when they were 3 years old (May 1955).

Trees were measured in March, 1967, after 12 field seasons (15 years from seed), and the following information was recorded: survival, height, diameter, straightness of main stem, number of branches, multiple stems, forking of main stem or lack of apical dominance, and presence of cones.

Seedlings for the Massachusetts plantings were also grown in the New Jersey nursery and field planted in May, 1955, and May, 1956, as 2-year-old seedlings. The trees were measured in October, 1968, after either 13 or 14 field seasons (15 or 16 years from seed), and survival, height, diameter, and form were recorded for each tree. Additional information such as the presence of weevil injury, heavy fruiting, or unusual branching habits was noted for individual trees or seedlots.

RESULTS

Washington Crossing, New Jersey

Summaries of data for seedlots of section *Pinus*, subsections *Sylvestres* and *Contortae* are presented in Table 1. Seedlots with similar parentages have been combined. Individual seedlot summaries are included in Table 2.

Summaries for section *Strobus*, subsection *Cembrae, Strobi,* and *Cembroides* are presented in Table 3. Individual seedlot information is presented in Table 4.

The soft pines generally had good survival with the possible exception of *P. griffithii*. When *P. griffithii* was used as the female parent, survival was lower than that obtained using other species; also reduced growth was apparent. Growth of *P. strobus* × *P. griffithii* hybrids was as good as any other combination, but there was a definite reduction in growth for the reciprocal cross—*P. griffithii* × *P. strobus*. Survival and growth of selfed lots of *P. strobus* were poorer than those of outcrossed hybrids.

Survival of the hard pines was fair to good with as much variability between seedlots as between species combinations. There was reduction in survival and growth of selfed lots (*P. densiflora, P. thunbergiana*).

Williamstown, Massachusetts

Summaries of data for each planting at Williamstown are presented in Table 5. All species in these plantings are in section *Pinus*, subsection *Sylvestres* and *Controtae*.

The reliability of the survival figures is again dependent on the number of seedlings planted.

Seedlots with *P. sylvestris* or *P. banksiana* as the female parent generally had good survival while seedlots with *P. nigra, P. thunbergiana*, or *P. contorta* as the female parent had lower survival. Survival of seedlots containing *P. densiflora* was intermediate regardless of the pollen parent. The only exception to the above is that survival from *P. thunbergiana* is improved when *P. tabulaeformis* is the pollen parent—an increase of nearly 50 percent.

Seedlots with *P. nigra* and *P. thunbergiana* female parents were shorter than other combinations except for the *P. thunbergiana* × *P. tabulaeformis* combination, which produced good height growth. *P. sylvestris* and *P. densiflora* produced good height growth at this location and *P. banksiana* had excellent growth.

In the following list, seedling information is from 3- or 4-year nursery measurements previously published by Wright (1958, 1959). The "tree" information was collected in 1967 after the seedlings had been outplanted 12 seasons (15 years from seed).

P. thunbergiana × *self*. Seedlings were 10 to 50 percent shorter than crossed *P. thunbergiana*. Trees were still 20 percent smaller and survival was reduced 12 percent.

P. thunbergiana × *P. thunbergiana*. No seedling information was available. Trees were slightly smaller than most other hybrids in the New Jersey planting.

P. thunbergiana × *P. densiflora*. This cross had good seed set and seedlings were 50 percent taller than *P. thunbergiana*. This height advantage had shrunk to less than 15 percent by 1967.

P. thunbergiana × (*P. densiflora* × *P. thunbergiana*). Trees in New Jersey were 14 percent taller than *P. thunbergiana* or about the same height as *P. thunbergiana* × *P. densiflora*. Trees in Massachusetts were 19 percent taller and 13 percent larger in diameter than *P. thunbergiana*. Survival was about the same.

P. thunbergiana × *P. tabulaeformis*. Seedlings were 10 to 30 percent smaller than *P. thunbergiana*. Trees in New Jersey were 20 percent larger, and in Massachusetts trees were over 100 percent larger. Survival was also improved by 50 percent.

P. thunbergiana × *P. yunnanensis*. Seedlings were about 15 percent larger than *P. thunbergiana*, and trees in New Jersey maintained this advantage.

P. thunbergiana × *P. taiwanensis*. Seedlings were 20 percent larger than *P. thunbergiana*. This advantage had decreased to only a 12 percent difference by 1967.

P. thunbergiana × *P. massoniana*. Seedlings were 30 to 60 percent taller than *P. thunbergiana*, but the trees were less than 10 percent taller by 1967.

P. thunbergiana × *P. nigra*. Seedlings were only slightly bigger than those of *P. thunber-*

giana but the trees were 32 percent taller, 51 percent larger in diameter, and had a 36 percent survival advantage.

P. thunbergiana × *(P. thunbergiana* × *P. densiflora).* Seedlings were slightly bigger than *P. thunbergiana,* but none was outplanted.

P. thunbergiana × *(P. nigra* × *P. densiflora).* No information is available on seedling performance. Trees were about the same size as *P. thunbergiana.*

P. densiflora × *self.* Seedlings were 10 to 20 percent smaller than crossed *P. densiflora.* By 1967 these trees were 47 percent shorter, 60 percent smaller in diameter, and had 30 percent less survival than *P. densiflora.*

P. densiflora × *P. thunbergiana.* Seedlings were slightly larger than *P. densiflora* but trees were 33 percent shorter and 37 percent smaller in diameter.

P. densiflora × *P. sylvestris.* Seedlings were taller than *P. densiflora.* Trees were slightly smaller but survival was equally good.

P. densiflora × *(P. densiflora* × *P. sylvestris).* No information is available on seedling growth. In New Jersey the trees were 10 to 15 percent smaller than *P. densiflora,* and in Massachusetts they were comparable.

P. densiflora × *P. nigra.* Seedlings were shorter than *P. densiflora,* but trees at both locations were about the same size as *P. densiflora.*

P. densiflora × *P. massoniana.* Seedlings were taller than *P. densiflora.* The one surviving tree was about the same size as *P. densiflora.*

P. densiflora × *(P. densiflora* × *P. thunbergiana).* No seedling growth information is available, but trees in Massachusetts were about the same size as *P. densiflora.* In New Jersey the trees were 17 percent shorter and 34 percent smaller in diameter. Survival was about the same.

(P. densiflora × *P. thunbergiana)* × *P. thunbergiana.* Trees in New Jersey were 18 percent shorter and 50 percent smaller in diameter than *P. densiflora.* Survival percentages were similar.

(P. densiflora × *P. thunbergiana)* × *(P. densiflora* × *P. thunbergiana).* Trees were 17 percent shorter than *P. densiflora,* but diameters were about the same. Survival was reduced by 40 percent.

P. tabulaeformis × *P. sinensis.* A comparison with *P. tabulaeformis* was not possible, but this hybrid was as good as many others in the New Jersey planting.

P. nigra × *P. thunbergiana.* Seedlings were slightly larger than *P. nigra* and trees were 10 to 15 percent larger. Survival was 40 percent better.

P. nigra × *P. densiflora.* Based on seedling performance, this is one of the best hybrids; however, trees in New Jersey were only 10 percent larger than *P. nigra.* Survival was improved by 60 percent.

P. nigra × *(P. densiflora* × *P. thunbergiana).* No seedling information is available on this hybrid, but *P. nigra* × *(P. thunbergiana* × *P. densiflora)* seedlings were larger than *P. nigra.* Trees of these two hybrids were about the same size, and survival of *P. nigra* × *(P. densiflora* × *P. thunbergiana)* was 65 percent better than *P. nigra.*

P. nigra × *P. tabulaeformis.* Seedlings were taller than *P. nigra,* but none was outplanted.

P. sylvestris × *P. sylvestris.* No seedling information. Trees in New Jersey and Massachusetts were about the same size as other *P. sylvestris* hybrids.

P. sylvestris × *P. massoniana.* Trees were 14 percent taller and 22 percent larger in diameter than *P. sylvestris.*

P. sylvestris × *P. nigra.* Seedlings were 25 percent shorter than *P. sylvestris,* but trees in New Jersey were 10 percent taller than *P. sylvestris.*

P. sylvestris × *(P. densiflora* × *P. sylvestris).* Seedlings were taller than *P. sylvestris.* Trees at both locations were approximately the same as *P. sylvestris.*

P. sylvestris × *(P. densiflora* × *P. thunbergiana).* No seedling information is available, but the trees in Massachusetts were the same size as *P. sylvestris.*

P. banksiana × *P. banksiana, P. banksiana* × *P. contorta, P. banksiana* × *(P. contorta* × *P. banksiana).* No seedling information is available. Trees in Massachusetts were very similar in height and all very good compared

to other hard pine hybrids. Survival was excellent. *P. banksiana* × OP (of questionable parentage) was 20 percent shorter and 30 percent smaller in diameter than trees of these three hybrids.

Information on soft pines was obtained only from the New Jersey planting.

P. strobus × *self.* No seedling information is available. Trees were more than 25 percent shorter and 50 percent smaller in diameter than crossed *P. strobus.* Survival was very poor compared to other crosses containing *P. strobus.*

P. strobus × *P. strobus.* Trees were as good as any hybrid in the planting.

P. strobus × *P. griffithii.* Seedlings were taller and had a larger diameter than *P. strobus.* This difference was not apparent in trees, and both the hybrid and *P. strobus* were the same size.

P. strobus × *P. flexilis.* Poor seedling growth was attributed to a poor pollen parent. Trees were still slightly shorter (13 percent) but this hybrid is not slow growing compared to others in the planting.

P. strobus × *P. koraiensis.* The hybridity of this group is questionable. The trees are as large as *P. strobus,* and it is possible that this, in fact, is the true parentage of these trees.

P. strobus × *P. ayacahuite.* Seedlings were taller than *P. strobus,* but trees were approximately the same size.

P. strobus × *P. parviflora.* Seedlings were shorter than *P. strobus.* Trees were 39 percent shorter and 49 percent smaller in diameter.

P. griffithii × *self.* None of the crosses containing *P. griffithii* female parents produced fast-growing trees. Selfing reduced height by 25 percent and diameter by 50 percent.

P. griffithii × *P. griffithii.* This is a small tree in comparison to *P. strobus.* It may be useful in pest resistance work, but it is not suitable for wood production in the New Jersey region.

P. griffithii × *P. parviflora.* The seedlings of this combination were not large and none was planted.

P. griffithii × *P. strobus.* Seedlings were taller than either *P. strobus* or *P. griffithii* and this hybrid was recommended for further evaluation. The trees were 13 percent taller than *P. griffithii,* but 30 percent shorter than *P. strobus* and the reciprocal cross *P. strobus* × *P. griffithii.*

P. ayacahuite × *P. strobus.* Seedlings were taller than *P. strobus* and about the same size as *P. strobus* × *P. ayacahuite.* There was no *P. ayacahuite* for comparison but trees of this hybrid combination were 21 percent shorter and 24 percent smaller in diameter than *P. strobus.* The reciprocal, *P. strobus* × *P. ayacahuite,* was 13 percent taller and 28 percent larger in diameter than *P. ayacahuite* × *P. strobus.*

P. ayacahuite × *P. griffithii.* Seedlings were similar in size to *P. ayacahuite* × *P. strobus* and taller than *P. strobus.* Trees were 20 percent smaller than *P. strobus* and slightly smaller than *P. ayacahuite* × *P. strobus.* Survival was the poorest of all *P. ayacahuite* hybrids.

P. ayacahuite × *P. flexilis.* Seedlings were 50 percent smaller than *P. ayacahuite* × *P. strobus.* Trees were 35 percent shorter and 23 percent smaller in diameter. Poor growth may be partially attributed to a poor *P. flexilis* pollen parent.

P. flexilis × *P. griffithii.* Seedlings were taller than either *P. flexilis* or *P. griffithii.* No trees of this combination were found in the New Jersey planting; however, the one *P. flexilis* tree is as large as any other hybrid, including those of *P. strobus.*

P. peuce × *P. strobus.* Seedlings were smaller than *P. strobus.* There were no trees in the planting; however, *P. peuce* × OP is a small tree, about one-half the size of *P. strobus.*

SUMMARY

These comments refer only to the species and hybrids included in the central New Jersey and northwestern Massachusetts plantings; seed from other sources, species, and hybrid combination could possibly outperform or underperform this entire group of plants. *Pinus resinosa* (red pine), *P. rigida* (pitch pine), and *P. echinata* (shortleaf pine) are examples of native species that might have been included for comparison purposes, and

many nonnative species were omitted.

Hybrids containing the designation "OP" are of questionable parentage, in some instances because the pollen could have come from several sources including selfing, trees of the same species, or trees of a compatible species. Comments in the Results are, therefore, limited to hybrids of known parentage, but all combinations are listed in Tables 2, 4, and 5.

This group of trees was not produced with the intent to study growth rate; in most cases they were the products of studies to determine species crossability. The parent trees were specimens available at the Morris Arboretum and in the surrounding area. They could have come from the best or the worst stands and/or parents.

In spite of these problems, a considerable amount of information on a large number of species and hybrids has been gathered. The data from these two locations should provide tree breeders with valuable information on adaptability of these species and hybrids.

A few of the hybrids and species in these plantings warrant further investigation. The use of "select" rather than "available" parents should result in even better progenies than those represented in this study.

Pinus nigra × *P. thunbergii* and the reciprocal cross looks promising and, because the natural range of both species extends above 45° N latitude, there is reason to think the hybrid would do well in many parts of the Northeast. *P. thunbergii* is a maritime species, but it has performed relatively well as a pure species at our two test sites and has done very well in hybrid combination with several other species.

Pinus densiflora extends slightly above 42° N latitude in its native range and in combination with both *P. nigra* and *P. sylvestris* as either the male or female parent, it looks very promising. Both *P. nigra* and *P. sylvestris* are found at least as far north at 50° N latitude. The variation in growth rate and stem form of *P. sylvestris* suggests that the selection of good parents in this species would yield substantial dividends in any hybrid progeny.

Pinus thunbergii × *P. tabulaeformis* and × *P. sinensis*, which is probably a form of *P. yunnanensis*, did very well in our planting and should do well in most of the region. Southern sources of *P. tabulaeformis* apparently grow faster and straighter than northern sources and if this species is as diverse as reported, parental selection would be worth the effort. *P. yunnanensis*, which is a southern species—below 30° N latitude—on mainland China, apparently does not adversely affect the growth of hybrid combinations at more northerly latitudes.

We have not yet found a soft pine that will grow as fast as the native white pine, *Pinus strobus*, in the Northeast. It appears that the greatest value of introducing new species or using them in hybrid combinations with *P. strobus* would be to increase resistance to the white pine weevil (*Pissodes strobi*) or blister rust (*Cronartium ribicola*).

The hybrid *P. strobus* × *P. griffithii* (syn *P. wallichiana* A. B. Jacks) looks as good as pure *P. strobus in our tests.* In its native range, which is restricted to higher elevations in the Himalayan Mountains (below 36° N latitude), *P. griffithii* stands are composed of tall, straight trees obviously unaffected by any major pests. Progeny tests are currently underway in New Jersey and Maine to see if this species has any resistance to the white pine weevil. If resistance is observed, hybrids or backcrosses may provide a useful solution to the major deterrent to growing soft pine in the Northeast. It is already known that *P. griffithii* has some resistance to blister rust and could be used in the North Central region with *P. strobus*, and perhaps in the West with *P. monticola.*

The other species of soft pine that responded well in these trials was *Pinus ayacahuite.* While it did not outgrow *P. strobus*, this species and hybrids containing *P. ayacahuite* grew very well in the region. Considering that the range of this species does not extend above 20° N latitude in Mexico, we were surprised by its apparent adaptation to planting sites above 40° N latitude. More information is definitely needed about variation within the species and its possible pest resistance.

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Table 1.—Washington Crossing, New Jersey—data on trees of section *Pinus* after combining seedlots of similar parentage from Table 2

Parentage ♀ ♂	Number planted	Survival (%)	Height (ft)	Diameter (in)	Tallest tree (ft)
nigra × nigra	9	22	16.5	3.5	20.0
nigra × OP	99	69	15.1	3.3	25.0
nigra × thunb	23	65	18.9	3.8	25.0
nigra × (thunb × OP)	5	80	22.7	4.5	27.0
nigra × densi	5	80	18.3	4.4	24.0
nigra × (densi × thunb)	9	89	18.4	3.5	25.0
nigra × sin	3	100	18.7	3.6	24.0
densi × self	12	67	10.5	1.4	17.0
densi × densi	24	96	19.9	3.5	28.0
densi × OP	104	75	15.6	2.7	22.0
densi × syl	12	100	18.0	3.2	26.0
densi × syl + OP	11	73	17.9	3.2	23.0
densi × (densi × syl)	38	71	15.3	2.4	23.0
densi × nigra	17	71	18.2	4.1	25.0
densi × mass	1	100	19.0	4.3	19.0
densi × thunb	13	77	13.4	2.2	18.0
densi × thunb + OP	1	100	19.0	3.0	19.0
densi × (densi × thunb)	19	79	16.6	2.3	18.0
(densi × thunb) × thunb	6	83	16.2	1.8	20.0
(densi × thunb) × OP	8	75	17.2	3.0	19.0
(densi × thunb) × (densi × thunb)	18	56	16.5	3.2	18.0
tab × OP	28	86	16.2	3.2	22.0
tab × sin	3	67	20.0	4.2	21.0
syl × syl	29	79	17.3	3.6	21.0
syl × OP	15	80	16.4	3.2	18.0
syl × mass	5	100	20.0	4.6	23.0
syl × nigra	6	86	18.8	3.8	22.0
syl × densi + OP	6	67	18.0	3.9	20.0
syl × (densi × syl)	38	95	17.4	3.4	23.0
bank × OP	40	87	19.1	4.4	23.0
bank × (cont × bank)	20	80	17.1	4.0	22.0
bank × (cont × bank) + OP	20	75	18.1	4.3	21.0
thunb × self	23	52	12.7	2.1	17.0
thunb × thunb	122	64	16.0	2.6	22.0
thunb × thunb + OP	13	69	14.3	2.2	20.0
thunb × OP	134	61	15.6	2.7	24.0
thunb × densi	80	66	18.3	3.3	26.0
thunb × (densi × thunb)	162	65	18.5	3.2	26.0
thunb × tab	114	70	20.4	3.9	28.0
thunb × tab + OP	89	88	20.9	3.9	28.0
thunb × sin	116	74	18.8	3.6	30.0
thunb × tai	3	67	18.0	3.7	23.0
thunb × mass	56	41	17.5	2.9	23.0
thunb × nigra	11	100	23.4	5.3	27.0
thunb × (nigra × densi)	1	100	18.0	4.3	18.0

Table 2.—Washington Crossing, New Jersey—performance of individual seedlots in section *Pinus*

Seedlot number	Parentage ♀	Parentage ♂	Survival (%)	Height (ft)	Diameter (in)	Form[a]	Branches[b]	Fruit[b]	Tallest tree (ft)
841	nigra	nigra	22	16.5	3.5	3.0	3.0	2.0	20.0
452	nigra	OP	83	13.4	2.8	1.8	2.4	1.0	20.0
454	nigra	OP	100	14.3	2.3	2.0	2.0	1.0	20.0
569	nigra	OP	71	17.4	3.6	1.6	2.4	1.4	22.0
754	nigra	OP	77	17.4	3.6	2.3	2.9	2.0	25.0
757	nigra	OP	75	13.0	2.0	3.0	2.0	1.0	18.0
758	nigra	OP	73	11.6	2.1	2.0	2.5	1.0	16.0
840	nigra	OP	43	15.0	2.7	3.0	2.7	2.0	17.0
846	nigra	OP	20	16.0	4.5	2.0	3.0	4.0	16.0
987	nigra	OP	60	16.3	3.9	2.0	2.7	1.0	20.0
1127	nigra	OP	75	5.7	1.7	3.0	3.0	1.0	9.0
1450	nigra	OP	33	18.0	3.2	3.0	3.0	3.0	18.0
537	nigra	thunb	75	20.7	4.6	2.0	3.0	2.0	21.0
539	nigra	thunb	100	17.7	3.1	2.7	2.3	1.3	25.0
751	nigra	thunb	100	19.1	3.5	2.3	2.6	2.0	24.0
839	nigra	thunb	40	17.5	5.0	2.5	3.0	3.0	18.0
625	nigra	(thunb × OP)	80	22.7	4.5	2.0	2.7	2.0	27.0
1135	nigra	densi	75	16.3	3.5	2.0	2.7	3.0	17.0
1141	nigra	densi	100	24.0	7.1	4.0	4.0	1.0	24.0
752	nigra	(densi × thunb)	89	18.4	3.5	2.9	3.0	2.0	25.0
755	nigra	sinensis	100	18.7	3.6	3.0	3.3	1.0	24.0
742	densi	self	33	12.0	1.1	3.0	2.0	1.0	12.0
745	densi	self	78	10.3	1.5	3.2	2.2	2.0	17.0
497	densi	densi	96	19.9	3.5	2.7	2.9	3.3	28.0
423	densi	OP	88	17.3	2.6	2.7	2.9	3.1	22.0
432	densi	OP	67	16.5	2.8	3.1	2.5	2.6	20.0
611	densi	OP	78	18.4	4.1	3.1	3.3	3.0	21.0
618	densi	OP	50	16.5	3.5	3.0	3.0	2.5	20.0
736	densi	OP	68	16.5	2.3	2.8	2.7	3.0	22.0
741	densi	OP	100	16.0	3.5	4.0	3.0	2.0	16.0
748	densi	OP	80	11.4	1.5	3.3	2.7	2.0	17.0
Neg 976	densi	OP	100	21.0	3.5	2.0	2.0	3.0	21.0
Neg 978	densi	OP	78	17.6	3.4	2.6	2.4	2.0	22.0
Neg 980	densi	OP	75	15.8	3.1	3.4	3.1	2.5	21.0
2483-48	densi	OP	100	12.0	1.7	2.0	2.0	1.0	12.0

426	densi × syl	100	19.0	3.5	3.0	3.0	4.0	19.0
495	densi × syl	100	19.6	3.9	3.0	2.6	2.4	26.0
740	densi × syl	100	16.5	2.6	3.3	3.0	3.0	24.0
434	densi × syl + OP	100	12.0	1.2	4.0	2.0	1.0	12.0
496	densi × syl + OP	83	18.4	3.6	2.8	2.8	2.2	23.0
502	densi × syl + OP	50	19.5	3.2	2.5	2.0	2.5	20.0
746	densi × (densi × syl)	75	15.5	2.6	3.1	3.0	3.0	21.0
747	densi × (densi × syl)	67	14.9	2.2	2.8	2.6	3.0	23.0
617	densi × nigra	71	18.3	4.1	3.0	3.4	2.3	25.0
743	densi × massoniana	100	19.0	1.3	3.0	2.0	1.0	19.0
1527-51	densi × thunb	77	13.4	2.2	3.1	2.7	2.0	18.0
616	densi × thunb + OP	100	19.0	3.0	4.0	2.0	4.0	19.0
610	densi × (densi × thunb)	79	16.6	2.3	3.6	2.6	3.2	18.0
614	(densi × thunb) × thunb	67	19.5	2.2	2.0	2.0	3.0	20.0
738	(densi × thunb) × thunb	100	14.0	1.6	2.7	2.0	2.0	16.0
615	(densi × thunb) × OP	75	17.2	3.0	2.8	2.7	3.3	19.0
737	(densi × thunb) × (densi × thunb)	56	16.5	3.2	3.2	2.7	3.0	18.0
733	tab × OP	95	15.9	3.1	3.0	2.7	2.0	22.0
734	tab × OP	75	17.3	4.0	2.7	3.3	1.5	20.0
834	tab × OP	100	18.0	4.8	3.0	3.0	1.0	18.0
732	tab × sin	100	20.0	4.2	2.5	3.0	2.0	21.0
619	syl × syl	60	16.7	3.7	2.5	3.5	1.3	21.0
693	syl × syl	89	17.6	3.6	2.5	3.3	2.0	21.0
694	syl × OP	88	17.3	3.4	2.7	2.7	2.0	18.0
Neg 1029	syl × OP	100	14.0	2.7	2.0	3.0	2.0	16.0
Neg 1128	syl × OP	60	16.0	2.9	3.3	3.3	2.0	17.0
697	syl × mass	100	20.0	4.6	2.8	3.4	2.0	23.0
696	syl × nigra	86	18.8	3.8	3.0	3.2	1.0	22.0
516	syl × densi + OP	67	18.0	3.9	2.7	3.5	2.0	20.0
695	syl × (densi × syl)	89	17.5	3.6	3.3	3.1	3.0	23.0
698	syl × (densi × syl)	100	17.3	3.2	2.8	3.2	2.0	23.0
568	bank × OP	84	19.0	4.5	3.2	4.0	2.8	23.0
Neg 877	bank × OP	90	19.1	4.4	3.2	3.8	3.2	21.0
762	bank × (cont × bank)	80	17.1	4.0	3.1	3.9	3.0	22.0
566	bank × (cont × bank) + OP	75	18.1	4.3	3.5	3.9	3.1	21.0

Continued

Seedlot number	Parentage ♀	♂	Survival (%)	Height (ft)	Diameter (in)	Form[a]	Branches[b]	Fruit[b]	Tallest tree (ft)
635	thunb × self		45	12.6	2.0	3.6	2.6	1.0	17.0
802	thunb × self		33	11.0	1.8	3.0	3.0	2.0	11.0
810	thunb × self		100	12.3	2.3	2.5	2.3	2.0	16.0
821	thunb × self		50	16.0	2.5	3.0	2.0	2.0	16.0
1163	thunb × self		100	13.0	2.0	3.0	2.0	1.0	13.0
545	thunb × thunb		100	15.5	2.5	2.5	2.3	2.0	20.0
630	thunb × thunb		73	16.6	3.0	3.3	2.3	2.0	21.0
636	thunb × thunb		60	13.0	2.0	3.0	2.7	2.0	15.0
705	thunb × thunb		59	17.1	2.5	2.9	2.1	2.0	22.0
715	thunb × thunb		40	15.6	2.4	2.8	2.4	2.0	19.0
717	thunb × thunb		60	16.6	2.6	2.5	2.1	2.0	21.0
726	thunb × thunb		79	15.3	2.8	3.2	2.7	2.0	21.0
727	thunb × thunb		71	15.8	2.5	2.8	2.5	2.0	20.0
544	thunb × thunb + OP		67	17.0	2.8	3.0	2.2	2.0	20.0
546	thunb × thunb + OP		71	12.2	1.7	3.0	2.4	1.4	15.0
540	thunb × OP		100	20.3	3.9	2.5	2.5	2.0	24.0
631	thunb × OP		55	17.0	2.7	3.3	2.5	2.0	24.0
634	thunb × OP		78	16.4	2.7	2.7	2.4	2.0	20.0
728	thunb × OP		68	14.7	2.1	2.9	2.2	2.0	19.0
789	thunb × OP		100	16.7	3.2	3.0	2.3	2.0	17.0
792	thunb × OP		50	9.0	1.0	2.0	2.0	1.0	9.0
796	thunb × OP		50	13.5	2.5	3.0	2.0	1.0	16.0
798	thunb × OP		33	16.5	2.7	3.0	3.0	2.0	19.0
799	thunb × OP		100	9.0	1.3	3.0	2.0	1.0	9.0
801	thunb × OP		50	12.3	2.2	3.0	2.3	2.0	15.0
813	thunb × OP		50	18.0	3.3	3.0	2.0	2.0	18.0
N979	thunb × OP		60	17.0	3.3	2.7	2.3	2.0	19.0
N1261	thunb × OP		78	15.5	2.8	2.9	2.4	1.6	20.0
N1262	thunb × OP		31	14.8	2.8	3.2	2.3	1.0	21.0
2167-51	thunb × OP		40	17.5	2.3	3.0	2.5	2.0	18.0
627	thunb × densi		75	16.9	2.9	2.7	2.4	2.8	24.0
628	thunb × densi		60	16.3	3.5	3.3	3.3	3.3	17.0
629	thunb × densi		55	16.3	2.8	2.8	2.5	2.0	19.0
632	thunb × densi		85	21.1	4.0	2.9	2.7	3.0	26.0
639	thunb × densi		71	22.6	4.5	3.0	2.8	3.0	26.0

791	thunb × densi	100	22.0	3.2	3.0	2.0	3.0	22.0
805	thunb × densi	50	11.0	1.5	4.0	3.2	3.0	11.0
808	thunb × densi	100	17.0	2.5	3.0	3.0	3.0	17.0
816	thunb × densi	33	19.0	4.5	4.0	4.0	4.0	19.0
822	thunb × densi	80	18.7	2.7	3.0	2.0	3.0	23.0
830	thunb × densi	50	15.5	2.2	3.0	1.5	3.0	16.0
702	thunb × (densi × thunb)	52	19.6	3.0	3.0	2.5	2.0	24.0
713	thunb × (densi × thunb)	63	17.8	2.9	3.0	2.4	2.0	24.0
723	thunb × (densi × thunb)	83	21.1	4.0	3.0	2.8	2.0	26.0
730	thunb × (densi × thunb)	85	18.3	3.7	2.9	2.6	2.0	23.0
797	thunb × (densi × thunb)	50	17.0	2.7	3.0	2.0	1.0	17.0
817	thunb × (densi × thunb)	100	20.0	4.0	3.0	2.0	1.0	20.0
633	thunb × tab	100	18.7	4.1	3.0	2.5	2.0	23.0
638	thunb × tab	63	16.9	2.7	3.0	2.2	2.0	20.0
703	thunb × tab	83	21.2	3.9	2.4	2.6	3.0	28.0
704	thunb × tab	79	21.9	4.4	2.7	3.3	2.0	27.0
714	thunb × tab	71	22.5	4.3	2.7	2.9	3.0	27.0
716	thunb × tab	53	20.5	4.1	2.5	3.1	3.0	25.0
790	thunb × tab	50	17.0	3.1	3.0	3.0	3.0	17.0
794	thunb × tab	50	21.0	3.6	2.5	2.0	2.0	24.0
803	thunb × tab	80	14.0	3.1	3.7	2.7	2.0	18.0
706	thunb × tab + OP	88	20.8	3.9	2.8	2.8	3.0	28.0
718	thunb × tab + OP	86	21.2	3.8	2.7	2.7	2.0	27.0
700	thunb × sin	30	14.9	2.5	2.9	2.6	1.0	25.0
701	thunb × sin	81	20.6	4.3	2.8	3.2	2.0	28.0
711	thunb × sin	18	14.7	2.6	3.5	2.5	1.0	19.0
712	thunb × sin	89	22.2	4.4	3.1	3.2	2.0	30.0
828	thunb × sin	100	7.0	0.6	2.0	2.0	2.0	7.0
806	thunb × tai	50	13.0	2.9	4.0	4.0	3.0	13.0
826	thunb × tai	100	23.0	4.6	3.0	2.0	1.0	23.0
710	thunb × mass	26	18.6	3.0	3.2	2.4	1.0	23.0
721	thunb × mass	44	17.6	3.1	3.2	2.7	2.0	23.0
731	thunb × mass	53	16.9	2.7	3.0	2.6	1.0	23.0
629	thunb × nigra	100	26.0	5.2	2.0	2.0	3.0	26.0
637	thunb × nigra	100	21.3	5.2	2.0	3.0	2.0	22.0
699	thunb × nigra	100	23.9	5.4	2.4	2.9	2.0	27.0
818	thunb × (nigra × densi)	100	18.0	4.3	3.0	2.0	2.0	18.0

[a]1—best; 4—poorest.
[b]1—few; 4—many.

Table 3.—Washington Crossing, New Jersey—data on trees of section *Strobus* after combining seedlots of similar parentage from Table 4

Parentage ♀ ♂	Number planted	Survival (%)	Height (ft)	Diameter (in)	Tallest tree (ft)
strobus × self	3	33	15.0	2.1	15.0
strobus × strobus	22	87	21.4	4.1	29.0
strobus × strobus + OP	4	100	20.7	3.8	25.0
strobus × OP	71	80	19.1	3.8	28.0
strobus × griffithii	44	93	21.5	4.6	29.0
strobus × griffithii + OP	46	72	17.2	3.7	26.0
strobus × flexilis	3	100	18.7	4.5	23.0
strobus × koraiensis	8	87	22.1	4.4	28.0
strobus × ayacahuite	21	81	19.6	4.3	30.0
strobus × ayacahuite + OP	4	75	22.0	4.2	26.0
strobus × parviflora	4	75	13.0	2.1	17.0
griffithii × self	3	33	10.0	1.3	10.0
griffithii × griffithii	15	53	13.5	2.6	23.0
griffithii × griffithii + OP	94	33	12.0	2.0	24.0
griffithii × OP	102	26	11.4	2.1	21.0
griffithii × strobus	3	67	15.5	2.7	17.0
griffithii × strobus + OP	51	20	12.4	2.1	17.0
griffithii × koraiensis + OP	10	10	6.0	0.4	6.0
ayacahuite × OP	23	78	17.3	3.2	24.0
ayacahuite × strobus	20	65	17.0	3.1	24.0
ayacahuite × strobus + OP	19	79	18.8	3.9	26.0
ayacahuite × griffithii	21	43	15.2	3.6	22.0
ayacahuite × flexilis	3	67	11.0	2.4	16.0
flexilis × flexilis	1	100	21.0	4.1	21.0
flexilis × OP	8	50	13.7	2.5	23.0
peuce × OP	2	100	10.5	1.4	11.0
parviflora × cembra + OP	2	100	11.5	1.4	13.0

Table 4.—Washington Crossing, New Jersey—performance of individual seedlots in section *Strobus*

Seedlot number	Parentage ♀	Parentage ♂	Survival (%)	Height (ft)	Diameter (in)	Form[a]	Branches[b]	Fruit[b]	Tallest tree (ft)
376	strobus	self	33	15.0	2.1	2.0	1.0	1.0	15.0
365	strobus	strobus	100	23.5	4.5	1.7	2.7	1.5	29.0
366	strobus	strobus	100	21.3	4.5	2.3	2.7	1.5	25.0
389	strobus	strobus	67	21.3	3.8	2.2	2.5	2.0	27.0
390	strobus	strobus	75	17.7	2.7	2.0	2.3	2.0	21.0
370	strobus	strobus + OP	100	21.7	4.1	1.7	2.0	2.0	25.0
607	strobus	strobus + OP	100	18.0	2.8	2.0	2.0	1.0	18.0
381	strobus	OP	100	17.0	2.6	2.0	3.0	1.0	20.0
386	strobus	OP	100	24.8	4.9	2.0	2.6	2.0	28.0
392	strobus	OP	100	23.5	4.6	1.7	2.3	1.0	27.0
396	strobus	OP	100	24.0	4.6	2.0	2.0	1.0	24.0
606	strobus	OP	67	16.0	3.1	2.5	3.0	1.0	16.0
N1146	strobus	OP	63	14.4	3.0	2.3	3.1	1.5	24.0
N1156	strobus	OP	76	13.8	2.8	2.4	2.9	1.0	21.0
1957-49	strobus	OP	100	24.4	4.9	1.8	2.9	1.3	28.0
1958-49	strobus	OP	100	24.0	5.0	2.0	3.0	1.0	24.0
2146-49	strobus	OP	100	22.0	5.4	2.0	3.0	3.0	24.0
367	strobus	griffithii	94	22.7	5.2	2.1	2.9	2.0	29.0
371	strobus	griffithii	100	20.3	3.7	2.0	2.0	1.5	27.0
376	strobus	griffithii	86	16.8	3.1	2.2	2.4	1.0	24.0
382	strobus	griffithii	86	25.0	5.3	2.2	2.7	1.5	28.0
384	strobus	griffithii	100	25.3	5.0	2.0	3.0	1.0	29.0
387	strobus	griffithii	100	16.2	3.8	2.7	3.0	1.0	22.0
394	strobus	griffithii	100	24.0	5.8	2.0	2.0	2.0	27.0
596	strobus	griffithii	100	19.0	4.5	3.0	4.0	1.0	19.0
397	strobus	griffithii + OP	100	17.8	2.6	2.6	2.6	1.5	26.0
603	strobus	griffithii + OP	25	13.0	2.0	3.0	3.0	2.0	13.0
604	strobus	griffithii + OP	67	18.1	4.5	2.4	3.4	1.5	26.0
605	strobus	griffithii + OP	83	15.5	3.3	2.7	3.1	1.5	25.0
608	strobus	griffithii + OP	100	18.0	3.5	2.0	3.0	1.0	18.0
284	strobus	flexilis	100	22.0	5.8	2.0	3.0	1.0	23.0
380	strobus	flexilis	100	12.0	2.0	2.0	3.0	1.0	12.0
362	strobus	koraiensis	100	25.0	4.9	2.0	3.0	2.0	25.0
388	strobus	koraiensis	80	25.7	5.4	2.5	2.3	2.0	28.0
391	strobus	koraiensis	100	13.5	2.1	1.5	1.5	1.0	17.0
363	strobus	ayacahuite	64	16.7	3.7	2.9	3.6	1.0	19.0
369	strobus	ayacahuite	100	21.7	4.8	2.3	2.3	1.0	24.0
373	strobus	ayacahuite	100	9.5	1.3	2.0	2.0	1.0	10.0
379	strobus	ayacahuite	100	23.5	5.3	2.2	2.7	2.0	30.0

Continued

Seedlot number	Parentage ♀	♂	Survival (%)	Height (ft)	Diameter (in)	Form[a]	Branches[b]	Fruit[b]	Tallest tree (ft)
398	strobus × ayacahuite + OP		75	22.0	4.2	2.3	3.0	2.0	26.0
395	strobus × parviflora		75	13.0	2.1	2.3	2.3	1.0	17.0
415	griffithii × self		33	10.0	1.3	2.0	1.0	1.0	10.0
416	griffithii × griffithii		100	19.0	3.8	2.5	2.0	1.0	23.0
583	griffithii × griffithii		56	11.4	2.1	3.2	2.6	1.0	15.0
584	griffithii × griffithii		25	13.0	2.3	2.0	3.0	1.0	13.0
489	griffithii × griffithii + OP		36	11.7	1.0	2.6	2.2	1.0	18.0
491	griffithii × griffithii + OP		20	14.3	3.1	3.5	3.2	1.0	24.0
459	griffithii × OP		50	16.0	3.7	2.0	2.0	1.0	16.0
410	griffithii × OP		100	16.0	2.0	2.0	1.0	1.0	16.0
486	griffithii × OP		50	11.4	2.0	3.5	3.2	1.0	15.0
494	griffithii × OP		26	10.8	1.5	3.6	2.8	1.0	14.0
585	griffithii × OP		5	11.0	2.4	3.0	3.0	1.0	11.0
595	griffithii × OP		30	10.0	2.6	3.0	3.0	1.0	16.0
N1005	griffithii × OP		20	13.2	2.5	2.7	3.2	1.5	21.0
414	griffithii × strobus		100	14.0	2.3	1.0	2.0	1.0	14.0
581	griffithii × strobus		50	17.0	3.2	2.0	3.0	1.0	17.0
484	griffithii × strobus + OP		46	13.0	1.9	2.5	3.0	1.0	17.0
490	griffithii × strobus + OP		20	13.0	2.3	3.2	2.7	1.0	17.0
479	griffithii × koraiensis + OP		10	6.0	0.4	3.0	2.0	1.0	6.0
578	ayacahuite × OP		74	17.5	3.2	2.0	2.8	1.0	24.0
1533-50	ayacahuite × OP		100	16.5	3.2	2.7	3.0	1.0	17.0
574	ayacahuite × strobus		65	17.0	3.1	2.2	2.5	1.0	24.0
575	ayacahuite × strobus + OP		79	18.8	3.9	2.3	2.8	1.0	26.0
576	ayacahuite × griffithii		43	15.2	3.6	2.9	2.4	1.0	22.0
577	ayacahuite × flexilis		67	11.0	2.4	3.0	3.0	1.0	16.0
250	flexilis × flexilis		100	21.0	4.1	2.0	2.0	3.0	21.0
574	flexilis × OP		100	7.0	0.7	2.0	1.0	1.0	7.0
1085-47	flexilis × OP		100	9.0	0.8	2.0	1.0	1.0	7.0
1532-51	flexilis × OP		33	19.5	4.3	3.0	3.5	1.5	23.0
892	peuce × OP		100	10.5	1.4	2.0	2.0	1.0	11.0
403	parviflora × cembra + OP		100	11.5	1.4	1.5	1.0	1.0	13.0

[a]1—best; 4—poorest.
[b]1—few; 4—many.

Table 5.—Williamstown, Massachusetts—performance of individual seedlots in section *Pinus* by planting

Seedlot number	Parentage ♀	♂	Survival (%)	Height (ft)	Diameter (in)	Form[a]	Tallest tree (ft)
	GP-02-55 (Blocks I & II)						
N1117	nigra	OP	43	11.0	1.8	3.0	14.0
N1211	nigra	OP	20	17.0	2.0	1.0	17.0
N1009	syl	OP	75	17.5	4.0	3.9	24.0
N1033	syl	OP	10	4.0	—	5.0	4.0
N1128	syl	OP	71	20.2	4.2	3.0	24.0
N1215	syl	OP	95	25.7	6.0	4.2	31.0
N976	densi	OP	62	21.6	3.9	4.4	28.0
N978	densi	OP	85	24.7	3.9	3.7	28.0
N980	densi	OP	30	—	—	5.0	—
617	densi	nigra	80	20.5	4.1	3.1	26.0
610	densi	thunb	67	20.6	3.2	4.8	24.0
N979	thunb	OP	39	19.1	3.6	3.9	24.0
638	thunb	OP	11	16.0	2.2	4.0	19.0
555	bank	bank	95	27.8	4.5	3.7	32.0
561	bank	bank	100	27.0	5.0	2.5	30.0
563	bank	bank	100	27.7	4.7	3.1	28.0
552	bank	cont	100	26.8	4.1	2.6	31.0
559	bank	cont	80	27.3	5.0	3.0	32.0
562	bank	cont	17	28.5	6.1	3.4	32.0
566	bank	cont	12	27.9	4.8	3.8	32.0
558	bank	(cont × bank)	90	26.1	3.8	2.6	31.0
565	bank	(cont × bank)	79	27.1	4.3	3.6	30.0
568	bank	(cont × bank)	95	26.3	4.0	3.5	31.0
849	cont	OP	17	24.0	3.9	3.0	24.0
850	cont	OP	25	8.0	1.8	5.0	8.0
	GP-2A-56						
693	syl	syl	85	23.1	6.0	3.9	27.0
694	syl	syl	80	22.8	5.7	3.7	27.0
698	syl	(densi × syl)	90	24.0	6.1	3.7	29.0
695	syl	(densi × thunb)	95	22.3	5.6	3.8	27.0
739	densi	OP	35	18.3	3.0	4.3	22.0
735	densi	(densi × syl)	80	18.7	3.5	4.7	25.0
747	densi	(densi × syl)	55	19.2	3.4	4.4	23.0
737	densi	(densi × thunb)	45	15.3	2.4	4.4	21.0
N1261	thunb	OP	20	8.0	0.8	5.0	9.0
705	thunb	thunb	35	11.7	1.5	5.0	15.0
715	thunb	thunb	10	9.0	1.0	5.0	9.0
717	thunb	thunb	25	10.8	1.6	4.8	13.0

Continued

Table 5.—Continued

Seedlot number	Parentage ♀	♂	Survival (%)	Height (ft)	Diameter (in)	Form[a]	Tallest tree (ft)
702	thunb × (densi × thunb)		15	14.7	1.7	4.3	19.0
707	thunb × (densi × thunb)		10	11.5	1.2	4.5	13.0
713	thunb × (densi × thunb)		40	13.7	2.1	4.9	21.0
730	thunb × (densi × thunb)		20	9.5	1.2	4.2	14.0
727	thunb × (densi × thunb)		20	18.2	2.3	4.2	21.0
719	thunb × (densi × thunb)		25	10.6	1.3	5.0	15.0
703	thunb × tab		70	20.6	3.6	3.8	24.0
706	thunb × tab		70	20.4	3.7	3.6	25.0
714	thunb × tab		90	22.3	3.8	3.7	30.0
718	thunb × tab		65	23.7	4.0	3.1	26.0
	GP-2C-56						
763	bank × OP		75	23.4	3.8	3.5	30.0
42-353-50	bank × OP		75	20.6	2.9	3.2	28.0
566	bank × (cont × bank)		75	26.2	4.8	3.1	30.0
762	bank × (cont × bank)		75	25.6	4.2	2.8	31.0
764	bank × (cont × bank)		90	23.7	4.1	3.6	29.0
	GP-2B-56						
754	nigra × OP		25	—	2.9	3.5	3.7[b]
N987	nigra × OP		25	—	2.1	3.2	3.0[b]
N978	densi × OP		60	—	3.6	3.4	4.4[b]
N980	densi × OP		55	—	3.3	4.6	5.0[b]
N1009	syl × OP		80	—	3.6	3.6	4.7[b]
N1010	syl × OP		95	—	5.0	3.7	6.0[b]
N1128	syl × OP		100	—	4.3	3.5	5.5[b]
N1200	syl × OP		100	—	4.7	4.0	6.5[b]

[a]1—best; 5—poorest.
[b]Largest diameter.

APPENDIX

List of scientific and common names of species included in this report[1]

Section *Strobus*	
Subsection *Cembrae*	
P. cembra L.	Swiss stone pine
P. koraiensis Sieb. & Zucc.	Korean pine
Subsection *Strobi*	
P. ayacahuite Ehrenberb	Mexican white pine
P. flexilis James	Limber pine
P. griffithii McClelland	Himalayan white pine
P. parviflora Sieb. & Zucc.	Japanese white pine
P. peuce Grisebach.	Balkan pine
P. strobus L.	Eastern white pine
Section *Pinus*	
Subsection *Pinus*	
P. densiflora Sieb. & Zucc.	Japanese red pine
P. massoniana Lamb.	Masson pine
P. nigra Arn.	Austrian pine
P. resinosa Ait.	Norway pine
P. sinensis[2]	
P. sylvestris L.	Scots pine
P. tabulaeformis Carr.	Chinese pine
P. taiwanensis Hayata	Formosa pine
P. thunbergiana Franco.	Japanese black pine
P. yunnanensis Franchet.	Yunnan pine
Subsection *Australes*	
P. echinata Mill.	Shortleaf pine
P. rigida Mill.	Pitch pine
Subsection *Contortae*	
P. banksiana Lamb.	Jack pine
P. contorta Dougl.	Lodgepole pine

[1]Critchfield and Little 1966.
[2]Variety of *P. yunnanensis*.

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