RESEARCH IN FOREST GENETICS AND TREE BREEDING AT THE UNIVERSITY OF WISCONSIN

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The genetics and breeding group in the Department of Forestry now has two faculty members and five graduate students. We are now a part of the Plant Breeding and Plant Genetics Group which includes six departments and twenty-six faculty members in an interdepartmental program of graduate teaching and research. Close cooperators are the Department of Plant Pathology at the University of Wisconsin, the Department of Natural Resources, and the U.S. Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics, Rhinelander, Wisconsin. Our research materials include four coniferous genera and one hardwood genus. Current research is summarized below for each genus.

Abies

Geographic Variation in Balsam Fir

Provenance and one-parent progeny studies were initiated with seed collections in 1960-62. Three-year-old seedlings were distributed for nursery transplanting in Michigan, Minnesota, and Wisconsin, and were measured after two seasons in nursery transplant beds at three locations.2 For the provenance material the range of mean total height was moderate (13.1 to 23.8 cm.). Effects of nursery location and seed source were statistically significant (99 percent probability) . The geographic pattern of variation was not clear, except for the concentration of eastern provenances as the five tallest. The shortest provenances were from the western portion of the range yet variable performance of collections from Manitoba and western Ontario precluded an interpretation of an east-west axis of variation.

Analysis of variation in frequency of frost damage was made possible by an early May frost in the central Wisconsin transplant beds during the fifth growing season. No other station reported frost damage. Fortunately, the seedlings in central Wisconsin were planted in three replicates. The range of variation expressed as the percentage of undamaged seedlings was large (12 to 98 percent) . Replicate and seed source effects were statistically significant (99 percent probability) . The pattern of variation for frost damage was markedly different than the pattern for height growth. The five least damaged provenances were from Wisconsin and Michigan. The five most damaged were from Manitoba and western Ontario. Simple linear regressions of frequency of frost damage on latitude and frost-free period of the seed origin were not statistically significant.

1 Research reported is funded by Federal Hatch Act and McIntire-Stennis appropriations, the Wisconsin Department of Natural Resources, the University of Wisconsin Graduate School, and the University of Wisconsin School of Natural Resources.

2 Mr. Richard Jeffers, Dr. Scott Pauley, and Dr. J. W. Wright assisted with height measurements.

Seed source height growth potential, as measured by total height of seedlings whose terminal shoot was undamaged, showed no association with frequency of frost damage within the population. This suggests that increased height growth may not necessarily involve increased danger of frost damage. For example, among the three tallest seed sources one ranked eighth (out of 59) in frequency of undamaged seedlings (58 percent); another ranked 48th (13 percent) .

Variation in total height and frost damage was clarified somewhat by periodic measurements on elongating shoots during the fifth growing season. The least frost-damaged provenance (Lower Peninsula of Michigan) was shown to have escaped frost by flushing about 10 days later than other measured provenances. Whether late flushing is common to other Lake States provenances is unknown. The value of late flushing as a frost-escape mechanism is uncertain because observations were limited to one growing season. Spring frosts are not uncommon in late May for central and northern Wisconsin, so that the results noted here may be largely incidental. The patterns of shoot elongation in one season suggested that rate rather than duration may be the principal determinant of differences in total height.

A nested sampling of maternal progenies within six Wisconsin and Michigan stands showed unexpectedly high variation. The range of variation was similar to the range-wide provenance variation. Progeny effects were greater than provenance effects for total height, whereas provenance effects were greater for frost damage as the result of one extensively frost-damaged provenance from the eastern Upper Peninsula.

The transplants in central Wisconsin were field planted at three Wisconsin locations in 1969. The transplants in Minnesota were field planted at one location and the material in Michigan is scheduled for field planting in 1970. Survival has been excellent in all field plantings to date.

Larix

Interspecific Hybridization with Japanese Larch

Interspecific hybrids of Japanese larch with western larch, tamarack, Siberian larch, and Dahurian larch have been produced to identify species combinations with high growth potential. Crosses between Japanese larch and tamarack seem especially promising in terms of growth rate. Hybrid seedlings will be grown one more season in the seedbed before field planting. The seedlings will provide material for studies on techniques for hybrid identification with emphasis on terpenes and other biochemical constituents.

Picea

Mutation Breeding in White and Norway Spruce

The effects of pollen irradiation on genetic variation are being studied in controlled crosses and selfings made with irradiated and nonirradiated pollen. The seedlings are completing their first season of growth. A first evaluation of radiation effects will be made in the nursery next year and subsequent evaluations will be made on field plantings.

Enzyme Analysis of White Spruce

Electrophoretic techniques for enzyme analysis are being used on leaf extractions to isolate enzyme systems suitable for genetic study and for demonstration of Mendelian segregation for isoenzymes. The objective of this approach is to provide techniques for population analysis of heterozygosity. The work is being done in cooperation with Dr. James King and Mr. Richard Jeffers of the USDA Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics.

Soil Ecotypes of White Spruce

The natural occurence of white spruce in southeastern Ontario on soils of widely differing calcium content has prompted a study of potential ecotypic differentiation based on soil differences. Seeds from trees growing on five calcareous and five noncalcareous soils were provided by Mr. Mark Holst, Canadian Department of Fisheries and Forestry. The seedlings are being grown in hydroponic culture at three different levels of calcium concentration and two levels of acidity.

Response to cultural conditions will be measured by dimensional characters and by chemical analysis of foliage.

Pinus

Seedling Seed Orchards of Red Pine

A combined research and seed-orchard development project for the Wisconsin Department of Natural Resources was initiated with seed collections in 1963-65 from 310 trees throughout Wisconsin.[3] The sampling was designed to allow the estimation of how much variation in growth of red pine is attributable to maternal progenies within stands, to stands within climatic provinces, and to climatic provinces.

The seeds were sown in 1967 in a manner designed to minimize nursery site heterogeneity. A row of 5 seed spots was sown with 10 to 12 seeds in each of 35 randomized complete blocks. Border rows were also sown. The intent was to thin, by hand, each seed spot to one seedling soon after germination. Excellent germination was achieved but damping-off fungi assisted in the thinning despite seedbed fumigation and fungicide applications. Mechanical thinning was postponed until the end of the first growing season to minimize the amount of transplanting required. Plot mortality was then alleviated by transplanting seedlings from multiple seedling spots to empty ones. The overall result was adequate representation of seed lots in about 90 percent of the plots but seedling variability within plots was greater than intended.

Measurements of total height are currently in progress. The seedlings will be tagged by plot, lifted by replicate, and field planted at three locations in 1970. Field measurements will be made at plantation ages 8 and 15. Then the slowest growing 225 progenies will be rogued, as will all but the largest tree in each plot of each remaining progeny. The result will be about 800 trees per plantation to be used as sources of seed for the Wisconsin state nurseries.

The biological basis for an expected improvement of up to 5 percent in wood yield comes from progeny tests established in Wisconsin several years ago (Lester and Barr 1965). Whether significant improvement is achieved will depend on the variation pattern revealed and the success of relatively early selection. The latter will be resolved by juvenile-mature correlation studies (Lester and Barr 1966) before converting the progeny test to a seed orchard.

Interspecific Hybridization With Pitch Pine

Controlled pollinations have been made on pitch pine using pollen of sand pine and spruce pine. The objective of this study is to identify species combinations with a high growth potential for low quality sites. Seeds will be available for testing in 1970.

Genetics and Biochemistry of Variation in Needle Tip Burn of Eastern White Pine

Ninety trees from throughout southern Wisconsin have been phenotypically classed as resistant or susceptible to needle tip burn. Several grafts from each selection have been made and are being used in studies of response to ozone fumigation. Repeatability analysis of reaction to ozone fumigation will be used to estimate the extent of genetic control. A survey of possible biochemical differences between susceptible and resistant types will be made.

Ulmus

In 1957 Dr. Eugene Smalley, Department of Plant Pathology, began a program of screening world-wide seed collections of elms for resistance to the Dutch elm disease. About 400 collections have been screened and more than 1,000 resistant individuals representing 8 species and several putative natural hybrids are now growing in an elm arboretum near Madison. Many of these trees have begun flowering in the past few years and a program of genetics and breeding has been developed jointly between the Departments of Forestry and Plant Pathology to determine patterns of inheritance for disease resistance and for ornamental traits. At present our interest is concentrated on four species, American elm, Japanese elm, slippery elm, and Siberian elm.

Genetics of American Elm

Three crossing studies have been made with American elm. The first was an attempt to reduce

[3] *D. T. Lester. Proposal for genetic improvement of red pine in Wisconsin. 16 p. (Unpublished.)*

the chromosome number (56) to the same level as other species in the genus (28) so that transfer of disease resistance might be possible through interspecific hybridization. Pollinations with highly irradiated pollen and with pollen of species which rarely, if ever, cross with American elms resulted in production of a few seeds but all seedlings had the chromosome number of American elm. Self-fertility is the most likely cause of these results.[4]

The frequent assumption that elms are self-sterile as a consequence of early development of the stigma (protogyny) has been examined in selfing studies over a three-year period. Forty-seven out of 57 selfed trees have produced seed in one or more years. Unfortunately, several of the 10 trees which failed to produce seed after one selfing have been sacrificed to highway improvement. At present, I have no individual of American elm in which self-incompatibility is certain. These results raise doubts about reports of interspecific hybridization with American elm (Britwum 1961, Johnson 1946, Smucker 1944). The existence of one authentic hybrid between American and Siberian elm indicates that crossing can occur but self-fertility seems to be common.[5]

Our most recent crosses in American elm have the objective of determining general and specific combining ability for resistance to Dutch elm disease. The resistant trees are survivors of artificial inoculations on 10,000 seedlings contributed by private nurserymen. Six of the 36 survivors flowered in 1969 and were used in the crossing scheme shown in table 1. Excluding the selfed combinations, an adequate number of seedlings was obtained for all but two crosses. Analysis of variation in growth and morphology will be made after one growing season and disease resistance will be tested by artificial inoculation in the second growing season.

Genetics and Breeding of Diploid Elms

From our collections of resistant diploid individuals 15 trees have been selected as potentially useful ornamentals. These trees are being propagated by root-sprout cuttings for evaluation in landscape settings. Included among these selections are individuals of Japanese elm, Siberian X Japanese elm hybrids, Siberian X slippery elm hybrids, and multispecies hybrids of European origin.

In our diploid crosses we are presently concentrating on Japanese, slippery, and Siberian elms. Some Japanese elms have the desirable features of red autumn leaf color, open branching, and moderately large leaves. Disease resistance seems to be high but we have not tested large numbers of Japanese elms. Slippery elm has open branching, a large leaf, and is known to produce vigorous hybrids with Siberian elm. Disease resistance is thought to be low, but has not been adequately tested. Siberian elm has high disease resistance and drought tolerance. These species and some hybrids have been crossed using single tree pollens and pollen mixes (table 2). Hybrids, authenticated by morphological comparison of progenies from intra- and interspecific crosses are now one or two years old. Each tree will be artificially inoculated and scored for reaction to inoculation within the next 2 years. Survivors will be tested again and then selected for ornamental traits.

Dutch plant breeders have been highly successful in developing genetic resistance to Dutch elm disease, and we have evidence from open-pollinated progenies of our Siberian elm X Japanese elm hybrid family that resistance to the Dutch elm disease can be maintained through breeding. This result coupled with the apparent ease of crossing among the three diploid species of current interest suggests that a high degree-of resistance to the Dutch elm disease can be maintained while a broad range of variation in ornamental traits is being developed.

[4] *Lester, D. T. Unpublished data.*

[5] *Personal correspondence with F. S. Santamour, Oct. 14, 1968.*

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Table 1.—Crossing scheme for disease-resistant and susceptible American elms (R = resistant, S= susceptible)

	R1	R2	S1	S2	R3	R4	S3	S4	R5	R6	S5	S6
R1	X	X	X	X								
R2	X	X	X	X								
S1	X	X	X	X								
S2	X	X	X	X								
R3					X	X	X	X				
R4					X	X	X	X				
S3					X	X	X	X				
S4					X	X	X	X				
R5									X	X	X	X
R6									X	X	X	X
S5									X	X	X	X
S6									X	X	X	X

Table 2.—Summary of elm families from crosses 1968-69

	U. japonica	*U. pumila*	*U. rubra*	*U. pumila* X *japonica*	*U. rubra* X *pumila*
U. japonica	X			X	
U. pumila	X	X	X	X	X
U. rubra	X	X	X	X	X
U. pumila X *japonica*	X	X	X	X	X
U. rubra X *pumila*		X	X	X	X