THE RELEVANCE OF CURRENT HARDWOOD FOREST GENETICS RESEARCH TO URBAN ENVIRONMENTS

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Abstract.--Provenance testing, breeding, and clonal propagation are providing information relevant to urban hardwood forestry problems. Research on maples, oaks, walnut, elms and other species is already helpful in selection for air pollution tolerance, salt and metal tolerance, iron chlorosis, drought resistance, cold hardiness, growth rate, pest resistance, tree form characteristics, foliage color, and seasonal growth pattern. Examples are cited.

Additional key words: pollution tolerance, salt tolerance, drought resistance, cold hardiness, height growth, disease resistance, foliage color, flushing date.

INTRODUCTION

Forest geneticists working with hardwoods have made significant advances in the last 25 or 30 years. Some very important biological information has been provided for a number of key species. This information is very relevant to the needs of those concerned with trees in the urban environment.

In my opinion, the leadership of Pauley, Wright and others in assigning top priority to the analysis of genetic variation in forest trees by geographic provenance testing was fortunate for all users of the results of tree improvement research. It is logical that genetic selection and breeding should be preceded by (1) assembly of the widest possible diversity of material, and (2) evaluation of differences in numerous traits under a uniform environment. This provides a means of identifying and quantifying genetic differences. The selection base is broad and inclusive, especially if the test is replicated in a diversity of environments.

Forest geneticists have also been having some success with breeding. In hardwood tree improvement, species hybridization is now beginning to produce new genotypes of interest to urban users, and will play a much larger role as time goes by.

Most forest geneticists are continuously evaluating in their genetic material traits of the utmost importance to urban forestry. It is not always realized that there is a substantial common interest among foresters, nurserymen and arborists, especially with respect to hardwood tree species. In fact, hardwood tree improvement is getting to the point where the supply of improved trees is going begging as far as forest planting is concerned. The problems in hardwood forest planting are not so much the lack of suitable genetic material as the ability to get it in the ground and to take care of it after it has

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been planted. Thus geneticists concerned with hardwood tree improvement are currently giving their greatest attention to urban forestry, and will continue to do so until field foresters and timber producers are ready to use the products of their research.

Up to this point, few genetically improved selections of hardwoods have been released. The testing period is long in many species. Some of the needs of arborists and nurserymen as indicated by a recent survey (Kielbaso and Ottman 1978) can, however, be met by immediate use of geographic seed source information, especially when climatic adaptability is a problem. Other types of information are, by good fortune, concerned with highly heritable traits which can be detected at an early age, in some cases even in seedlings in growth chambers. This does not mean that research is providing all the answers to user problems. Certain specifically urban problems such as tolerance of confined root space, ease of maintenance and even resistance to vandalism require specially-designed experiments which have only recently begun to receive attention. However, I think our long-term hardwood selection and breeding programs are now a source of a lot of good information for urban user groups.

The discussion which follows will take up one problem at a time as related to tree selection, and review some of the research under way with important hardwoods. The review is brief and by no means all-inclusive.

GENETIC APPROACHES TO HARDWOOD USER PROBLEMS

Air pollution tolerance

Trees vary widely in their capacity to tolerate ozone and sulfur dioxide in the atmosphere. The high heritability of tolerance facilitates selection. Since pollutant levels, especially levels of ozone, vary widely from one area to another, natural selection could be expected to lead to the development of seed source variation in tolerance. There could also be natural geographic variation in the frequency of tolerant genes in local populations which predates air pollution.

In red maple, there is seed-source related variation in tolerance to ozone. In a fumigation study of trees from four sources, trees from Alabama were least affected and those from western Pennsylvania the most affected. Trees from Maine and Minnesota were intermediate in tolerance (Townsend and Dochinger 1974). Green and white ash have been found to have significant variation in ozone response among families of the same and different species. There is no correlation between symptom responses and either latitude or longitude. Total foliar ozone injury was a complex of independent symptom responses with some families tolerant of one type of injury but not of another (Steiner and Davis 1979).

Karnosky (1981) rated 32 urban tree cultivars of 11 species for tolerance to ozone (03) and sulfur dioxide (SO2), alone and in combination. The results are particularly meaningful because they are based on 3 years of replicated field testing (03) as well as on chamber experiments. All Norway maple cultivars tested were tolerant of all three pollutant exposures, as were 2 of 4 red maple cultivars, 2 of 3 sugar maple cultivars, one of 2 cultivars of green ash, the single beech cultivar, and all Ginkgo cultivars. The single white ash and sycamore cultivars were sensitive to all 3 pollutant exposures. Cultivars of some of these species and of honey locust were sensitive to one pollutant and not to another.

Hardwoods may be effective in removing gaseous pollutants from the atmosphere, provided that sensitivity and uptake rate are not highly correlated. Apparently they are not. White birch and white oak are ozone-sensitive and have a high capacity for removing ozone from polluted air. Sweetgum and white ash are also ozone-sensitive, and have a relatively low rate of ozone sorption. Because of tree injury, these species are, therefore, not suitable for pollution absorption. However, sugar maple seems to be a species which is relatively tolerant of ozone and can also effectively lower the concentration of ozone in heavily polluted areas (Townsend 1974). It seems probable that there are other tolerant species, not yet tested, which will also be good ozone-removers.

<u>Salt and metal tolerance, iron chlorosis</u>

Highway and street de-icing salts can be very injurious to hardwoods. Experiments have shown that dogwood and sycamore are much more susceptible to injury from sodium chloride than is Japanese pagoda tree. Pin oak is intermediate. In red maple, it appears possible to select for combined tolerance to ozone and de-icing salts (Townsend 1980).

Species of hardwoods also differ widely in tolerance of high levels of aluminum. Tests using a hydroponic system showed that hybrid poplars can be sensitive to very low concentrations of aluminum, whereas species of oak and birch can tolerate much higher levels. Autumn-olive is intermediate between these species (McCormick and Steiner 1978). There is also significant variation within species. In a test of paper birch, provenances (but not families within provenances) differed significantly in both rate of root elongation and apparent response to aluminum (Steiner et al. 1980).

Deficiency of a metal can also be a problem in urban trees. A well-known example is the iron chlorosis of pin oak growing in neutral to alkaline soils. Experiments with population samples from various parts of the natural range have indicated that trees native to the north-central and northwestern parts of the range are more resistant to iron chlorosis than are those from other regions. It is possible that the drier soil conditions of this region and consequent reduced availability of iron could have contributed to the evolution of chlorosis resistance. Further investigation of the northern Illinois population, which was consistently highly resistant in experiments, seems desirable for within-population selection (Berrang and Steiner 1980).

<u>Drought resistance</u>

Genetic improvement in drought resistance can often be achieved by raising trees from seed collected in drier parts of the natural distribution of the species.

In sugar maple, the best seed-tree candidates for a combination of drought resistance, good form and high vigor are the trees found in mixed sugar maple, red oak and white oak stands in central Illinois, as illustrated by trees from McLean County. These trees have an extensive, deeply-penetrating root system, acceptable stem form and fast growth. Similar phenotypes native to the limestone hills of western Ohio also offer good selection possibilities (Kriebel 1963, Kriebel and Gabriel 1969).

In black walnut, seedlings from Illinois, Indiana and Kentucky wilted earlier in greenhouse watering experiments than did trees from Kansas and Missouri, but results of field tests were not correlated with those from the greenhouse (Bey 1974). At present, specific recommendations are not available for drought resistance selection in walnut.

Red maple seedlings from different seed sources representing wet or dry sites differ markedly in their response to experimentally-induced water stress. This variation can serve as a basis for a selection and breeding program to create more drought-resistant cultivars of this species (Townsend and Roberts 1973).

Red oaks of Kansas and Missouri origin had significantly higher survival rates than other selections in a Kansas seed source experiment, where summer drought conditions are prevalent (Deneke 1975). They were also above average in growth rate in nearly all field tests at age 13 (Kriebel *et al*. 1976).

Cold hardiness

At middle latitudes (39° - 41°) in the central states, hardwood trees grown from seed collected more than 300 kilometers to the south often have severe winter injury, whereas trees of northern Lake States, Canadian and northern New England origin are least affected. This is typical of red maple, red oak and black walnut (Townsend 1977, Kriebel *et al*. 1976, Bey 1979). In sugar maple, seed collection can be made 500 km to the south of this region, but trees of the most northern seed sources break bud early at middle latitudes (Ohio). Nursery stock of these northern sources is sometimes injured by late spring frosts (Kriebel 1957).

A special cold-hardiness problem can occur in northern areas with the use of container-grown seedlings, because of the unusually-severe root exposure conditions resulting from above-ground winter storage. Santamour (1979) has recommended seed selection from the coldest origins for seedlings to be grown in containers, or grafting on cold-hardy rootstocks when one raises cultivars of unknown geographic origin. Selection of extreme northern genotypes may, however, introduce an undesirable level of growth retardation. Protection of containerized stock by mulching would seem to be a better alternative, unless slow growth is acceptable.

Cold-hardiness recommendations vary for each hardwood species and should be checked before selection of a seed source.

Growth rate

Growth rate of hardwoods is usually extremely sensitive to the local environment, including soil and moisture conditions as well as climate. Thus in some species, e.g. sugar maple, the relative performance of trees of different seed sources cannot be determined accurately until the trees are 15 to 20 years old. In sugar maple, Ohio experiments indicate that the local seed source is the best for growth rate improvement (Kriebel 1975). On the other hand, some improvement in vigor could be obtained in black walnut plantations in Illinois, Indiana and Michigan by using seed collected up to 300 kilometers south of the planting site (Bey 1979).

In red oak, there is no advantage in geographic source selection for vigor. Seed for stock to be planted in the 38° to 43° latitudinal belt of the North Central region may be selected anywhere west of the Appalachians, with Tennessee and Missouri as southern limits and the southern Lake States as northern limits (Kriebel et al. 1976). An intensive stand selection program under way in Ohio will provide specific recommendations for growth rate selection.

Early results of red maple experiments provide a preliminary guide for nurserymen collecting seed. The fastest-growing seedlings came from north central and east-central sources, whereas trees from northern and southern areas grew more slowly (Townsend et al. 1979).

In elms, disease resistance is a more important trait than vigor, but hybrid vigor has been obtained from some species crosses with improved disease resistance (Townsend 1980).

Disease and insect resistance

Most of the elm selections made at the Delaware, Ohio USDA laboratory combine disease resistance of the Asiatic species with the horticultural desirability of European species. A mixture of "aggressive" and "non-aggressive" forms of the fungus is used in testing for resistance to Dutch elm disease. One selection, the 'Urban' elm, has been released and is in commercial production. Several other superior hybrid and American elm clones are being tested for possible future release. A new program of advanced generation crossing will provide a pool of material for future selection (notes from A. M. Townsend) Several disease-resistant elm selections by the U.S. National Arboretum are under nation-wide evaluation and observation. These include hybrids of Chinese elm and one pure Chinese elm with desirable form and autumn leaf color (Santamour 1977).

Seed source variation in resistance to *Verticillium* wilt has been identified in red maple. Arkansas and Illinois families showed significantly less foliar symptom development than those of four other seed sources. Prospects seem favorable for development of *Verticillium*-resistant clones (Townsend and Hock 1973). *Verticillium* wilt resistance is also being evaluated in open-pollinated Norway maple families from Syracuse and Rochester selections. The possibility of developing resistant lines through breeding appears promising (Manion 1981).

Anthracnose-resistant first-generation hybrids of American sycamore and the Turkish plane tree (*Platanus orientalis* L.) have been produced by the

National Arboretum and are currently being evaluated in the field. The commonly-planted hybrid, the so-called 'London Plane', is actually an advanced-generation segregate or backcross to the American sycamore. Most London planes are susceptible to sycamore anthracnose (Santamour 1977).

Results of experiments on hybrid poplars suggest that the capacity of a tree to internally "wall-off" wound tissue is under genetic control. Some clones appear to compartmentalize discolored wood more effectively than others. If the results apply to other species, it may be possible to select trees that develop small columns of wound-induced internal defect, thereby improving chances for tree survival in the urban environment, where wounding is one of the most serious tree problems (Shigo et al. 1977).

I cannot provide a specific illustration of a successful ongoing program of genetic improvement in insect resistance of an important deciduous tree. It has not been possible, for example, to select for and transmit-to progenies the apparent resistance of the 'Moraine' honeylocust to the mimosa webworm (Santamour 1977). Selection and breeding are often complicated by flexibility or absence of host specificity, as in the cases of the gypsy moth and the Japanese beetle. Knowledge of species preferences of an insect is, a help but only allows replacement of one species with another. Selection for avoidance of insect injury may be possible where there is wide phenological variation in a tree species (see later discussion under "seasonal growth pattern").

Tree form characteristics

Genetic selection of deciduous trees for desirable crown and stem form does not need to be confined to single-tree selection and clonal propagation. Improvement can often be obtained from geographic source selection alone. In red and sugar maple, trees of northern origin have straighter stems than those from the southern states. In part this is due to winter dieback of growing tips, but in sugar maple there is also an inherent tendency toward a diffuse or forking branch habit in trees from the Ohio valley southward (Townsend et al. 1979, Kriebel 1957). In sugar maple, our southern Illinois seed source produces trees with moderate branchiness, moderate growth rate and extreme summer- and winter-hardiness. The combination of traits makes a good medium-size ornamental or shade tree for northern and southern Ohio (Kriebel 1975). It should be tested in other parts of the Midwest.

Greening for form, especially the "vase" shape of the American elm, is an integral part of elm breeding programs (Townsend and Schreiber 1975).

Foliage color

in red maple, trees of the most northern sources develop the most intense autumn color, as judged by the amount of red pigment in the leaves. The best autumn color can be obtained by collecting seed from trees native to the, northern Lake States, Canada, and northern New England. These trees are not, however, as fast-growing as trees from more southern origins (Townsend et al. 1979).

Among the superior elm clones currently being tested is a red fall-colored, vase-shaped Chinese elm (*U. parviflora* 76).

Seasonal growth pattern

In every tested species of deciduous tree with a wide geographic distribution, there is source-related variation in the time of leaf flushing in the spring and of the onset of dormancy, leaf coloration and leaf drop in the autumn. Geographic patterns are often very systematic, as in the north to south trend in fall coloration in sugar maple. For this reason, it is possible to select an early- or late-flushing seed source, to avoid, for example, coincidence of the development of new leaves with the destructive stage of an insect's life cycle. Late-flushing might also be desirable in low-lying, frost-prone locations if a species is frost-sensitive. Time of leaf-drop is under strong genetic influence. It should be possible, for example, to select trees for leaf drop at times more suitable for municipal collection than may be the case if leaf fall is distributed over a period of several months. Nurserymen may also prefer early leaf drop for earlier autumn lifting and transplanting.

CONCLUSIONS

A number of the problems confronting nurserymen and arborists in raising, planting and maintaining hardwood trees in the urban environment are under current investigation in research on some of the most important species.

A substantial amount of information useful for genetic selection is already available from the geographic seed source tests scattered throughout the North Central region, and much more will become available in the next few years. Some of these tests include enough within-population samples to make it possible to select for vigor as well as adaptability.

Controlled breeding, species hybridization and clonal selection are useful for specific requirements, such as disease resistance and form, which cannot easily be met by provenance selection. The elm breeding program is a notable example.

LITERATURE CITED

Berrang, P. and K. C. Steiner. 1980. Resistance of pin oak (*Quercus palustris*) progenies to iron chlorosis. J. Am. Hortic. Sci. 105: 519-522.

Bey, C. F. 1974. Drought hardiness in black walnut. Proc. 9th Cent. States For. Tree Impr. Conf.: 138-144.

__________. 1979. Geographic variation in *Juglans nigra* in the mid-western United States. Silvae Genetica 28: 132-135.

Deneke, F. J. 1975. A red oak provenance trial in Kansas. Trans. Kansas Acad. Sci. 77: 195-199.

Karnosky, D. F. 1981. Chamber and field evaluations of air pollution tolerances of urban trees. J. Arboric. 7: 99-105.

Kielbaso, J. J. and K. A. Ottman. 1978. Public tree care programs. Proc. Nat. Urban Forestry Conf. 2: 437-447.

Kriebel, H. B. 1957. Patterns of genetic variation in sugar maple. Ohio Agr. Exp. Sta. Res. Bull. 791. 56 p.

______________. 1963. Selection for drought resistance in sugar maple. Proc. 2nd World Consult. For. Genet. and Tree Impr., Stockholm. FAO/FORGEN 63 - 3/9: ii+5.

______________.1975. Twenth-year survival and growth of sugar maple in Ohio seed source tests. Ohio Agr. Res. and Devel. Center Res. Circ. 206, 9 p.

Kriebel, H. B. and W. J. Gabriel. 1969. Genetics of sugar maple. USDA Forest Serv., Res. Pap. WO-7, 17 p.

Kriebel, H. B., W. T. Bagley, F. J. Deneke, R. W. Funsch, P. Roth, J.J. Jokela, C. Merritt, J. W. Wright and R. D. Williams. 1976. Geographic variation in Quercus rubra in north central United States plantations. Silvae Genetica 25: 118-122.

Manion, P. D. 1981. Norway maple decline. J. Arboric. 7: 38-42.

McCormick, L. H. and K. C. Steiner. 1978. Variation in aluminum toxicity among six genera of trees. For. Sci. 24: 565--68.

Santamour, F. S., Jr. 1977. The selection and breeding of pest-resistant landscape trees. J. Arboric. 3: 146-152.

Santamour, F. S., Jr. 1979. Root hardiness of green ash seedlings from different provenances. J. Arboric. 5: 276-279.

Shigo, A. L., W. C. Shortle and P. W. Garrett. 1977. Genetic control suggested in compartmentalization of discolored wood associated with tree wounds. For. Sci. 23: 179-182.

Steiner, K. C. and D. D. Davis. 1979. Variation among Fraxinus families in foliar response to ozone. Can. J. For. Res. 9: 106-109.

Steiner, K. C., L. H. McCormick and D. S. Canavera. 1980. Differential response of paper birch provenances to aluminum in solution culture. Can. J. For. Res. 10: 25-29.

Townsend, A. M. 1974. Sorption of ozone by nine shade tree species. J. Am. Hortic. Soc. 99: 206-208.

____________. 1977. Characteristics of red maple progenies from different geographic areas. J. Amer. Soc. Hort. Sci. 102: 461-466.

______________.1980. Increasing the suitability of nursery-grown trees for urban sites. In: New Horizons from the Hortic. Res. Institute, 1979: 3-5.

Townsend, A. M., and L. S. Dochinger. 1974. Relationship of seed source and developmental stage to the ozone tolerance of Acer rubrum seedlings. Atmos. Envir. 8: 957-964.

Townsend, A. M., and W. K. Hock. 1973. Tolerance of half-sib families of red maple to Verticillium wilt. Phytopathology 63: 673-676.

Townsend, A. M., and B. R. Roberts. 1973. Effect of moisture stress on red maple seedlings from different seed sources. Can. J. Bot. 51: 1989-1995.

Townsend, A. M., and L. R. Schreiber. 1975. Recent progress in the breeding and selection of elms. Proc. 9th Cent. States For. Tree Impr. Conf: 1-6.

Townsend, A. M., J. W. Wright, W. F. Kwolek, W. F. Beineke, D. T. Lester, C. A. Mohn and A. F. Dodge. 1979. Geographic variation in young red maple grown in north central United States. Silvae Genetica 28: 33-36.