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Genetic Improvement of Trees Used in Wind Breaks

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The genetic quality of the nursery stock used in windbreaks has been a concern of many people responsible for windbreak planting for about as long as other people have been concerned about the genetic quality of loblolly pine (Pinus taeda L.). In 1923 Johnson (1923) cautioned tree planters in the Great Plains of North America to use only tree species proven to be hardy in their area. He also described within-species variation in Siberian elm (Ulmus pumila L.) noting that "strains" coming from different localities in China were quite variable in hardiness when grown in the northern Great Plains. Progress in improving trees and shrubs for windbreaks has not been as dramatic as the gains have been with timber species. The benefits of windbreaks are substantial, but they are often indirect and long-term. There has been little pressure on government and university research administrators to devote more of their resources to the genetic improvement of windbreak species. Private industry has not become involved in producing genetically-improved seed of windbreak species because of the limited market for such seed.

Despite the meager allocation of money, resources and people to the effort, the genetic improvement of windbreak species is continuing at a steady pace in many parts of the world.

1. The types of improvement being sought for windbreak species
2. The importance of improving these traits
3. Methods or programs being utilized to achieve these improvements
4. results of these improvement efforts
5. Improved cultivars currently available for windbreaks
6. Future needs.

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Traits of Importance to Windbreaks

Survival

Traits that affect tree survival are of greatest importance in windbreak establishment. Windbreaks are most commonly planted in regions of climatic and edaphic extremes where plant life is subjected to periodic stresses from limited water, poor soil, high winds, cold winter temperatures, and attack by insects, animals and diseases. Establishment of planting stock is often difficult, uncertain and expensive. Replanting for several years is often necessary to achieve satisfactory stocking rates. To be effective, a windbreak must maintain a minimum density to provide the benefits for which it was designed. Other improvements in a tree are meaningless if it does not survive. Significant differences among origins in rates of survival have been reported for most of the provenance tests that have been conducted on windbreak tree species.

Cold hardiness

Cold hardiness may take several forms: resistance to winter injury, frost tolerance or frost avoidance. Common forms of winter injury are branch-tip die-back, frost cracks, winter sunscald, cambial injury, root injury and needle burning of conifers. That resistance to low winter temperatures is especially important for trees and shrubs of the Canadian prairies. Selection of cold hardy genotypes is generally carried out after episodes of late spring frosts, early autumn freezes or unusually severe winter weather. The problem of relying on such episodes in the selection process is their sporadic, unpredictable nature and the difficulty of observing uniform conditions on a repeatable basis.

Drought hardiness

Drought hardiness or drought resistance describes the relative abilities of different plant species to survive extended periods of reduced precipitation. There are three major types: drought escaping, drought tolerating and drought avoiding. Drought-escaping plants complete their life cycles before severe water deficits occur. Drought-tolerating plants possess the ability, through the properties of their protoplasm, to survive desiccation. Drought-avoiding plants are able to postpone dehydration through structural features affecting water absorption and loss.

Genetic variation in drought resistance has been reported for several angiosperm windbreak tree species. Lack of research concerning drought resistance among coniferous species may be the result of fewer problems with this trait among these species

Pest resistance

The importance of breeding for pest resistance depends upon the availability, suitability and cost of other methods of pest control. If chemical or biological control methods are effective, environmentally safe and inexpensive, then it makes little sense to devote major resources and time to breeding for resistance to a particular pest. Unfortunately, there are few tree species used in windbreaks for which this is the case. Most often other control methods are too expensive, ineffective or not compatible with other farming operations that must be carried out at the same time control measures should be applied. In these situations, breeding for pest resistance may offer the only practical means of controlling pest damage.

Several cultivars of windbreak tree species with proven resistance to specific insects or diseases are available. Hybrid poplars (Populus sp.) resistant to leaf rusts (Melampsora and Marssonia species) and Austrian pine (Pinus nigra Arnold) resistant to Dothistroma pini Hulb. are the most widely planted examples of such cultivars.

Adaptability to poor soil

Many of the sites where windbreaks are needed have soils that make tree establishment and growth difficult. Alkaline soils, saline soils, sandy soils, blow sand and soils with high water tables have soil properties that may limit the choice of tree and shrub species. Very little information exists concerning within-species variation in adaptability to poor soils. As more provenance tests are established on a greater variety of sites, the information on adaptability **to poor soils will be increased.**

Growth rate

The height of a windbreak is a major determinant of its effectiveness. For maximum effect, it is best to choose trees that will grow as tall as the site will allow. Fast-growing trees that reach maximum height quickly will reduce the time required for the windbreak to produce its maximum benefits. After the species have been chosen, the next decision affecting growth rate is choice of seed source or cultivar. It is at this point that tree improvement activities can benefit the tree planter by providing planting stock capable of faster growth than common, nursery-run planting stock. Within-species variation in growth rate has been reported in most windbreak species for which provenance tests have been conducted.

Crown Form

Most windbreaks are planted to accomplish what their name implies; a reduction in wind velocity or a change in wind flow patterns. The distance protected and the effectiveness of wind reduction are governed by windbreak height, density and orientation to prevailing winds, (George, 1971). The capacity of a windbreak to furnish protection depends on its structure, i.e. the sum total of all tree and shrub foliage contributing to its effective height, density and continuity (Read, 1968). Windspeed reduction patterns are determined primarily by the porosity and distribution of pores in the barrier (Skidmore, 1976). The primary purpose for which a windbreak is established will determine its optimum permeability, e.g., windbreaks designed to distribute snow may be more porous than those designed to control wind erosion. Windbreak density can be controlled by adjusting the number of tree rows, spacing between trees in-the-row, spacing between rows and the choice of tree or shrub species used in each row.

On an individual tree basis, crown density is determined by component factors of branch angle, branch diameter, number of branches, live branch retention, and kind and amount of foliage (Dawson and Read, 1964). Crown density may be estimated and subjectively scored as very sparse, sparse, moderate, dense or very dense. Because wind protection is important during the entire year, the density of deciduous species is best judged when the trees are without foliage. In coniferous trees, foliage production, years of needle retention and relative needle length contribute to the overall density rating.

The heritability's of traits influencing crown density and form are largely unknown for most windbreak species. Only a few provenance studies of windbreak species have measured variation in crown characteristics

TREE IMPROVEMENT METHODS FOR WINDBREAK SPECIES

There are seven basic steps used for the genetic improvement of most tree species:

1. Assess the range of genetic variation in major traits among populations (species trials, provenance tests)
2. Select individual phenotypes superior for traits of interest
3. Intermate the selected trees to combine favored traits (wind pollination, controlled pollination, breeding)
4. Evaluate the progeny of these mattings on a variety of test sites (progeny testing)
5. Select among progeny for phenotypes exhibiting the best combination of traits
6. Propagate selected phenotypes by vegetative propagules (grafts, cuttings or tissue culture) or by seed
7. Release improved cultivars.

The first and most basic practice that should be instituted by all nurserymen and tree planters is labeling seed and planting stock as to seed source as well as species. To understand the geographic variability of the many species of trees and shrubs being planted in windbreaks, tree planters must keep track of the seed sources they are planting. If problems arise such as plantation failures, pest damage, die-back or lack of winter hardiness, they may be linked to the use of a poorly adapted seed source. On the positive side, such information may document the wide adaptability of particular seed sources over a variety of sites and climates.

The second low-cost practice that can produce immediate results is the use of local seed sources. If good information is not available on the potential performance of a particular seed source, e.g., one available from a commercial seed dealer, then avoid it and try to collect or purchase seed from a local source. A local seed source of a native species should be well adapted to the planting site. For an exotic species, try to collect seed from plantations or windbreaks that have survived and performed well for at least half their expected rotation-age. The use of planting stock grown from such seed should pose less risk of failure than planting stock grown from seed for which there is no past history. Determining whether a seed source can be considered 'local' may be facilitated by the use of seed zoning maps. Seed zones are subdivisions of land areas established to identify areas of relatively homogeneous soil types, climate and other factors that influence tree survival and growth (Cunningham,1975). Planting stock grown from seed collected from trees growing in one seed zone should perform well when planted in the same seed zone.

A third practice that can be instituted quickly and relatively inexpensively is the collection of seed from phenotypically superior trees or stands. Superior stands used for this purpose are called seed production areas. This practice can be beneficial even if the seed trees have not been proven superior by provenance or progeny tests. Even if such selections eventually prove to have been superior only because of favorable environmental conditions and are unable to pass that superiority on to their offspring, it is unlikely that they are genetically inferior to an unselected seed source of unknown performance potential. Trees that are larger, healthier and more vigorous than adjacent trees, for rea- sons that cannot be ascribed to site quality, are potentially genetically superior, and should be utilized as interim sources of improved seed. In North America, seed-production areas have been established for at least 49 species of trees and shrubs commonly planted in windbreaks. Many of these seed production-areas furnish seed used to grow seedlings of cultivars that have been "officially released" by state experiment stations or federal agencies such as the Soil Conservation Service and the Agricultural Research Service of the United States Department of Agriculture.

Release of named cultivars is an important method to promote the use of genetically improved trees and shrubs used in windbreaks. Plant breeders have used this procedure to identify and promote the use of improved varieties of wheat (Triticum aestivum L.), barley (Hordeum vulgarae L.), flax (Linum usitatissimum L.), corn (Zea mays L.) and many other crops. Varieties, also called cultivars, are the culmination of the breeder' s efforts to improve a particular crop. A cultivar represents the best plant material available at that time for a particular use. Cultivars of tree and shrub species are tested over a variety of sites for several years to ensure that they perform above the average for that

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species and are worthy of release. Table II lists the tree and shrub cultivars that have been released for use in windbreaks and other conservation-type plantings. Planting stock of these cultivars is generally available from nurseries operated by state agencies or associations of soil conservation districts.

The Future

Most of the future work in the genetic improvement of windbreak species will continue the traditional methods and techniques that are currently being used. Seed orchards will be established for many of the major windbreak tree species, such as ponderosa pine (Pinus ponderosa Dougl. ex-Laws.), Scotch pine, blue spruce, Black Hills spruce (Picea glauca), Rocky Mountain juniper (Juniperus scopulorum Sarg.), eastern redcedar (Juniperus virginiana L.), Austrian pine, Siberian elm, green ash, hackberry (Celtis occidentalis L.), silver maple (Acer saccharinum L.), honey locust (Gleditsia triacanthos L.) and possibly bur oak (Quercus macrocarpa)

Several tree species that are normally propagated by vegetative means will be genetically improved by "packaging" clonal mixtures. Hybrid poplars, native cottonwoods (Populus sp.) and perhaps even some of the willow species (Salix sp.) will benefit from this approach. Clones used in the mixtures will be selected on the basis of clonal tests on a variety of sites and will exhibit high levels of pest resistance, increased rate of growth, adaptability to adverse sites and compatibility with other clones in the mix. Composition of the clonal mixtures will be dynamic and substitution of clones based on new information will be a standard operating procedure. The introduction of genetic variability into field plantings by the use of clonal mixtures is a key ingredient for improving species such as the hybrid poplars. The impact of many of our disease and insect problems can be significantly reduced by the use of clonal mixtures. This approach brings with it special problems for the nurseryman because it requires extra effort and special care in lifting, sorting, labeling and packing the trees for distribution. Those researchers and tree improvement specialists responsible for determining the composition of the clonal mixture will have to test each clone rigorously, paying particular attention to competition between clones and choosing very carefully clones that are compatible and that will complement each other when planted together.

In the last few years, several new techniques have developed which tree breeders can use for tree improvement. These techniques include tissue culture, electrophoresis and genetic engineering. With tissue culture, trees can be vegetatively propagated, but more importantly, superior trees can be selected in a test tube. Tissue from trees can be grown in a test tube and screened for resistance to diseases and insects, tolerance to high pH or resistance to herbicides. Electrophoresis can be used by tree breeders to identify superior seed sources, detect pollen contamination in seed orchards or predict long-term seedling performance. Genetic engineering may allow tree breeders to transfer superior genes from one organism into another. For example, if genes for drought tolerance are isolated in a grass species, these genes might be incorporated into trees, allowing better survival after planting. Tree breeders will benefit from these new techniques more than any other group of plant breeders. Long generation intervals and prolonged field testing will no longer be the obstacle to tree improvement they once were.