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Genetic Base Populations, Gene Pools and Breeding Populations for Eucalyptus in Brazil

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Abstract

Eucalyptus is a major exotic species in Brazil. To be successful in use of this exotic, care must be taken to make maximum gains in both the short term and long term. To do this successfully requires a dual tree improvement program; an operational — (or use) phase for immediate gains and a developmental (research) phase for long-term, advanced-generation gains.

To make the desired type gains for either the short or long term, a proper gene base is needed. This is generally lacking for the eucalypts in Brazil, and some very inferior sources like the "Brazil source" originating at Rio Claro have been and still are being extensively used. This paper outlines some general approaches necessary to obtain, improve and maintain genetic base populations of *Eucalyptus* in Brazil. Several options are available but it is urgent to obtain action for all.

Methods are described in the paper; they consist of developing land races from current plantations, use improved sources from other areas and developing sources from the original populations in their native habitat. The few very best genotypes are used for the current operational phases for maximum genetic gain while a much larger number are held in clone banks and used in ongoing breeding programs for advanced generations.

The huge advantage of the eucalypts with quick and large gains was mentioned. Especially fortunate is the potential for narrowing the genetic base for desired economically important characters while at the same time broadening the base for adaptability and pest resistance. This is possible because the two groups of characteristics are usually genetically independent.

Key words: adaptation, base population, Brazil source, *Eucalyptus*, exotic species, gene base, land race, seed source, vegetative propagation.

Zusammenfassung

Eucalyptus ist die am meisten angebaute exotische Baumart in Brasilien. Um bei *Eucalyptus* durch züchterische Maßnahmen einen maximalen genetischen Gewinn zu erreichen, sind Lang- und Kurzzeitprogramme notwendig. Für beide Programme ist geeignetes züchterisches Ausgangsmaterial erforderlich. Bisher wurden in Brasillien in der Hauptsache weniger wertvolle Bestände, wie der bei Rio Claro, zur Vermehrung benutzt. In dieser Arbeit werden Methoden beschrieben, die auf die Entwicklung von für Brasilien am besten geeigneten Populationen abzielen. Die besten Bäume aus bereits bestehenden Beständen sollen selektiert, vegetativ vermehrt und ein Teil davon in Samenplantagen genutzt werden. Der Rest soll in Klonbanken erhalten werden, um für Züchtungsprogramme in späteren Generationen verfügbar zu sein. Zusätzlich soll Saatgut aus wertvollen natürlichen und Sekundär-Beständen importiert werden. So kann eine Ausgangsbasis mit erwünschten, ökonomisch wichtigen Merkmalen,wie z. B. Anpassungsfähigkeit und Krankheitsresistenz, geschaffen werden, die genetische Gewinne in späteren Generationen ermöglicht und zu einer gesunden Forstwirtschaft in Brasilien beiträgt.

Introduction

The introduction of eucalypts when grown as an exotic generally follows the pattern of (1) introduction and testing of several species and provenances, (2) selection followed by improvement of the best provenance, (3) establishment of seed production areas for early seed availability, (4) production of seed orchards from the very best trees of the best provenances. Such programs are primarily geared for early and maximum seed production for large-scale operational programs. Too often there has been little or no concern about the long-range aspects and the best methods to produce continually improved planting material over a number of generations. This has been made worse in *Eucalyptus* because the initial gains have been so large and many persons have become quite satisfied with the initially improved stock. For example, gains as large as 20% have been obtained from a simple seed production area; with more intensive programs, especially those including vegetative propagation, gains of 100% over the stock originally planted are not uncommon.

In Brazil a common pattern in the past has consisted of getting the original seed from Rio Claro and development of seed production areas and even seed orchards from this source material. Derivative stands from the original Rio Claro source have many problems stemming from hybridization and resultant "hybrid breakdown" and from related matings, since the original stands contained a limited number of parents. Although many organizations initially used this "degenerate" source of eucalypts for operational planting, they have generally switched to newer introductions from Australia or in the case of *E. grandis* from the Republic of South Africa or from Zimbabwe.

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Selection for Improvement and the Genetic Base

No matter what the initial seed source, selection programs of various intensities have usually been applied. The result of selection is to reduce the genetic variability; if done very intensively on an initially small base it can erode the genetic variability to such an extent that it will jeopardize the ongoing, long-term improvement in future generations (KLEINSCHMIT, 1979). Care must therefore be taken, whether seed or vegetative propagation is used, to keep a broad and flexible base in the breeding program from which outstanding trees or vegetative lines can be used in operational planting programs.

Any program based on genetic selection must have a suitable broad base of genetic variability from which the selections can be made. The genetic base and variability will be diminished in relation to the intensity of selection (LIBBY, 1973; YEATMAN, 1972). A reduction in the variability is needed if gain is to be achieved but it is also necessary to keep variability. These two objectives can be achieved by a two-phase program; in fact, any tree improvement program that does not include both is doomed to failure.

1. The first phase of a tree improvement program is the short-term operational (utilization) phase. It consists of mass-producing seed or vegetative propagules for operational planting. The genetic base need not be extremely broad, just enough to avoid a monoculture situation.
2. The second phase is more long-term and deals with development (research) usually maintained as a clone bank. Its objective is to retain as broad a genetic base as possible to serve as a pool for advanced-generation breeding. From this base, later selections will be made to be used in operational phases.

Too many programs, especially with the eucalypts, emphasize the operational phase with little concern for the longer-term and, in the long run, the more important developmental phase. This becomes especially true when hybrids are used or when vegetative propagation is employed. For both of these the developmental phase is just as important as it is in a standard seed orchard operation. The developmental phase should look forward to possible problems or changes; for example, if there is a danger of phosphate shortage in the future, strains could be developed that will be most suitable to grow with low levels of phosphorus. As forestry expands, planting will be desired on what are currently marginal sites; strains of trees to grow under unusually wet or dry conditions will be needed. The only way breeding for such special problems can be done is to have a very large gene pool in the clone bank from which the breeder can draw.

The need for developing special strains is always large when exotic species such as those of *Eucalyptus* are planted. Some type of insect or disease will always adapt to the new species (ZOBEL, 1979). The exotic is usually only partially well adapted to its new environment, so development of better adapted strains is needed. If a very narrow genetic base is used, danger of pest damage is greater and chances of developing better adapted material are small (YEATMAN, 1972; FRANKEL, 1977). The kinds of dangers mentioned become magnified in a narrowly defined program whose objective is immediate gain with little concern for future generations.

As tree improvement programs become more widespread and intensive, the forest tree species being worked with change from essentially wild populations to domesticated species (LIBBY, 1973). This change in essence makes the trees become dependent upon man for the proper genetic base. Before the very broad gene pool of natural stands is lost, action is needed to preserve it in clone banks for future breeding.

For exotic trees such as *Eucalyptus* in Brazil, broad-based wild stands are not available unless one goes back to Australia and Indonesia. This is difficult but necessary; it is not feasible, however, to rely on these wild stands for a supply of seed for operational planting (TURNBULL, 1977). This need has been fulfilled to some extent by use of seed from good plantations in South Africa or Zimbabwe. Although often very good, this in itself represents a restricted gene pool.

The tree breeder has a most fortunate set of circumstances in that there is usually only slight to no genetic relationship (or correlation) between economically important characteristics such as bole straightness or wood density and adaptive characteristics such as disease or insect resistance or adaptability to adverse environments such as heat or cold. This happy situation makes it possible with care and knowledge to breed trees with almost any combination of use and adaptability characters. The common lay attitude that scrawny, crooked, deformed trees somehow magically carry genes for pest resistance or adaptability simply is not true. Thus it is possible to develop trees with highly desired use characteristics by narrowing the genetic base while at the same time have trees resistant to pests or to adverse environments (ZOBEL, 1978).

The Brazil Situation

In summary of Brazil's Eucalyptus resource:

1. Brazil does not have natural eucalypt forests. Therefore, the basic gene pool is restricted, severely so in some instances because of the nature of the imported seed.
2. The Brazil eucalypts represent only a small fraction of the possible useful gene pool and variability of the eucalypts being used; this must be broadened.
3. Seed from outside sources used for operational planting in Brazil are usually from a very restricted gene base. Often the seed sent are from the best adapted land race from the country of origin which probably differs from the ideal in Brazil.
4. Huge acreages have been planted or are still being planted, using the degenerate material some persons refer to as the "Brazil source". It's performance is sub-par because of hybridization with poor species, hybrid-breakdown which results in bush type plants and related matings producing trees with inferior growth rate and form. Growth of eucalypts in Brazil can be increased from 30 to 100% by using proper seed sources and abandoning use of the "Brazil source".
5. Brazil urgently needs a large and reliable supply of *Eucalyptus* seed that are well adapted to the greatly differing environments and to the desired products in the country. No one source of any species is satisfactory for everything. We feel that one of the most disturbing trends in growing *Eucalyptus* in Brazil is the too often expressed opinion that there is some super source that will be good everywhere and for everything. As planting progresses and programs intensify, the best method is to use intensive selection to develop land races. If these are pure species, they can be utilized by seed or vegetative propagules. If hybrids are involved, the best ap-

proach is to use vegetative propagules. In either instance it is essential to keep a broad genetic base in the land race for breeding purposes, although the operational program can use a reduced base from intensive selection to achieve maximum gain.

6. Because of the widely differing environments under which the eucalypts are growing in Brazil and because of the wide product uses including charcoal, pulp, lumber, fuelwood and posts (sometimes all from the same species, especially *E. grandis)* it is essential that Brazil have a very active program aimed at increasing the variability and genetic base within the eucalypts.
7. In Brazil there is a tendency to overuse one or two species (primarily *E. grandis* and *E. urophylla)* instead of more accurately matching species to site and product.

Genetic Base Populations and Sources of Eucalypts

Fast genetic gains can be obtained while still maintaining the needed base (BRUNE, 1979), if:

1. Plantations from which selections will be made consist of a broad set of material, partially achievable by mixing plants from origins within a species.
2. Improved populations (F_1 and F_2) be planted in varied environments and subjected to intensive natural selection. Then man will select the best trees of the best families producing improved land races.
3. Use the best-adapted and best-performing trees and families in seed orchards or as vegetative propagules for operational, large-scale plantings but preserve a large number more in clone banks for advanced generations.
4. Incorporate into the gene pool more sources from outside or from other segments of the available populations.

Eucalypts are ideal for development of land races because of their early flowering, overlapping flowering time, and short rotations. Generation turnover is rapid, resulting in large gains. In addition, despite often restricted initial seed sources, *Eucalyptus* generally shows wide variability, enabling a fine opportunity for selection and gene recombination.

If intensive selection is applied to initially small populations, genetic variability will soon be eroded. Conversely, if sources are combined for wider variability, characteristics of specific ecotypes can be lost that will have special value for specific conditions. The ideal is to combine-test sources in mixture but at the same time maintain samples of the original populations for later use or recombination. In all situations in Brazil, a balanced breeding program will include the testing of new genotypes from the original range of the species. In some instances, obtaining and testing such sources is urgent becauses they are either being destroyed or their "purity" changed by mixture with genotypes brought into the area. Those that prove to have special value will then be combined with the original populations that were available. No matter what strategy of introduction or recombination is practiced, the most important gains will be derived from selections from the material grown in the new environment to form land races.

It can be stated in summary, and clearly, that the best approach for obtaining well-adapted, good-growing, high-quality, pest-resistant trees is to work through land races rather than to find an outside source that might be well adapted.

How to Proceed-Eucalyptus in Brazil

In the preceding sections, several steps were mentioned as ways to obtain and ensure a suitable genetic base for both short-and long-term gain in *Eucalyptus* in Brazil. They include bringing in new genotypes, recombining genetic material, subject them to both natural and man's selection and reproducing the desired material on a mass, operational basis. Our suggestions for action to develop the most effective Eucalyptus program in Brazil are enumerated below in a short and summary form:

1. Select the best trees from already-established plantations to develop land races. From these, make seed orchards from the very best or use them for vegetative propagation and put the rest in clone banks for gene preservation and breeding for advanced generations.
2. Bring in seed from proven good material of the desired species such as *E. grandis* from South Africa, Australia or Zimbabwe. From these plantations select the best trees for additional land race candidates.
3. Bring seed from different sources or species with the best potential areas from the native range of the species, grow in operational forest conditions and, from the best performers, select land race candidates. New sources can be handled in one of two methods:
   a. Mix seeds of several sources, plant from the mixed sources and select the best land race candidates. A new seed source will result but the identity of the original sources will be lost. Hold the extra trees in clone banks.
   b. Test each source separately, select the best land race cadidates and combine the best trees for the operational seed orchards or for vegetative cuttings. Put the rest in clone banks. We prefer this method over "a" above but it is more complex, a little more time-consuming and requires better record-keeping and control. It does enable one to later combine sources in desired combinations.
4. In all of the above situations, a most useful and viable option is to thin the plantations, leaving the best trees to form a seed production area. Another possibility is to collect seed from only the best trees prior to logging. Both methods will give considerable gain in form and pest resistance, only very modest gains in volume, but real good gains in adaptability to the new climate.
5. In the seed orchards and clone banks, make crosses, outplant these in tests in varied environments and select the best trees from the best families for advanced-generation programs. Follow-up breeding and methods of testing for use at this level is complex; this paper is not the place to go into details.
6. Do not place hybrids in a seed orchard for commercial seed production. When hybrids are crossed, such as $F_1 \times F_1$, segregation will occur with resultant trees varying from both parental species through all degrees of hybrids. This is not true for a program when vegetative propagation is used; here the outstanding individuals will be directly used.

If the above plans are generally followed, Brazil will very rapidly become free of outside seed sources for operational planting. Even of greater importance, a gene base will be preserved that will enable continuous gains through advanced generations. For the latter to be successful, the genetic base populations in the form of clone banks must be carefully maintained, crossed and tested, using suitable designs and methods.

Not all organizations can or should have complete breeding populations. The larger organizations and the government must be responsible for establishment and maintenance of genetic base populations. Free exchange of material is mandatory. Organizations, both large and small, will be dependent upon these breeding populations for continued gains; in fact, for a healthy eucalypt forest industry in Brazil. Too often activities concentrate on short-term gain for operational planting but the really important job for the long term welfare of Brazilian forestry is to have good gene conservation measures combined with the development, maintenance and testing of genetic base populations of eucalypts.

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Compatibility and Crossability Studies in Ulmus

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Summary

Eleven *Ulmus* species at the Arnold Arboretum were tested for compatibility and crossability. All these species, *Ulmus americana, carpinifolia, glabra, japonica, laciniata, laevis, procera, pumila, rubra, thomasii* and *wilsoniana*, are self-fertile. The successful intersectional crosses and the unsuccessful intrasectional crosses demonstrated, suggest that the current infregeneric classification of *Ulmus* is artificial. The form of dichogamy (protandry or protogyny) seems to be correlated with the compatibility between different species. The condition of dichogamy deserves consideration in sectional delimitations of the genus.

Key words: Ulmus species,self-compatible, interspecific crossings, protandry, protogyny.

Zusammenfassung

Im Arnold Arboretum wurden elf Ulmenarten auf Verträglichkeit und Kreuzbarkeit untersucht. Alle Arten, *Ulmus americana, carpinifolia, glabra, japonica, laciniata, laevis, procera, pumila, rubra, thomasii* und *wilsoniana*, waren selbstfertil. Die erfolgreichen inter- und die erfolglosen intrasektionalen Kreuzungen zeigten, daß die derzeitige systematische Einordnung der Gattungen von *Ulmus* künstlich ist.

Die Form der Dichogamie (Protandrie oder Protogynie) scheint mit der Kompatibilität zwischen verschiedenen Arten korreliert zu sein. Bei der Einteilung der Gattung in Sektionen verdient die Dichogamie besondere Beachtung.

Introduction

The elms are ornamental and timber trees. The principal and practical objective of controlled pollinations in the past has been to combine resistance to Dutch elm disease with desirable ornamental and growth traits. As a consequence of prevailing dichogamy in this anemophilous genus, previous workers (Britwum, 1960; Collins, 1967; Heybroek, 1968; Santamour, 1972) assumed elms to be self-sterile in the controlled hybridization experiments and no emasculation attempts were made. Successful crosses between species belonging to different sections of the genus *Ulmus* L. were reported. Considerable variation and taxonomic complexity exists, presumably as a result of natural hybridization among species (Melville, 1975, 1978; Richens and Jeffers, 1975, 1978; Richens, 1980).

The American elm has been the subject of research on floral biology and breeding systems. Lester (1968) indicated that protogyny in this species does not make it fully self-sterile (see also Johnson, 1946). To avoid any confusion in the results, Lester (1971) made use of previously known self-sterile and self-fertile individuals in the self-compatibility studies of American elm.

To test whether or not other species of *Ulmus* are self-fertile and interbreeding, studies were conducted at the Arnold Arboretum of Harvard University during the spring of 1980. This paper deals with the compatibility and crossability patterns of eleven species of *Ulmus*.

Materials and Methods

Intra- and interspecific crosses involving eleven species (*Ulmus americana* L., *U. carpinifolia* Gled., *U. glabra* Hudson, *U. japonica* (Rehder) Sarg., *U. laciniata* (Trautv.) Mayr, *U. laevis* Pallas, *U. procera* Salisb., *U. pumila* L., *U.*

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