A REVIEW OF THE WORLDWIDE ACTIVITIES IN TREE IMPROVEMENT FOR *Eucalyptus grandis, Eucalyptus urophylla* AND THE HYBRID UROGRANDIS

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Abstract:--The most commonly utilized hardwood plantation species for pulp and paper production are *Eucalyptus grandis*, *Eucalyptus urophylla* and their hybrid, urograndis. These species have been developed in a large number of countries due to their rapid growth in areas that receive more than 700 mm of rainfall and that have little or no frost. In addition, the species produce seed in a number of locations when planted as exotics and can be cloned using rooted cuttings. Their adequate wood properties mainly for pulp and paper but also for lumber have made them highly desirable and relatively well researched compared to the many hundreds of other eucalypt species. This paper is a review of the worldwide activities in tree improvement with *Eucalyptus grandis*, *Eucalyptus urophylla* and their hybrid, urograndis.

Keywords: tree improvement strategy, cloning, seed production, plantation development, gene conservation

INTRODUCTION

The native range of *Eucalyptus grandis* includes the states of Queensland and New South Wales in Australia with a range of south latitude from 18 to 33 degrees, a range of altitude from sea level to 1100 m, and a range of annual precipitation from 690 to 2480 (Eldridge et al., 1993). In the native range *E. grandis* receives very few frosts and this affects the areas where the species can be planted.

For *E. urophylla* the native range includes a number of islands in Indonesia of which the most important are Wetar, Timor, Flores, Adonara, Pantar, Alor and Lomblen. The altitudinal range of the species is the largest of any eucalypt species and is from 70 to 2690 meters. Annual rainfall varies from 600 to 2500 mm while the range of south latitude varies from 7.5 to 10 degrees (Eldridge et al., 1993).

FAO (1993) gives 10.06 million hectares of eucalypt plantations outside Australia as of 1990. The species *E. grandis* and *E. urophylla* are amongst the most frequently planted eucalypts for industrial processing in the pulp and paper industry though recent large scale planting in China may alter this. The hybrid urograndis occurs in fewer countries given the cost of making control cross seed, the need to have both of the pure species to make the cross and the lack of control cross technology. The author could only find reports of urograndis plantations in the following countries: South Africa, Brazil, Congo, China, Mexico, Colombia and Venezuela.

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BRIEF HISTORY OF UTILIZATION OF THE SPECIES

Both *E. grandis* and *E. urophylla* have had taxonomic histories that led to confusion in early years. Much of what was called saligna in South Africa and Zimbabwe was *E. grandis* and confusion still exists over saligna seed from southern Africa appearing on the seed label when the trees are actually *E. grandis.* In the case of *E. urophylla* there is still an effort to separate this taxa into different species. In addition the seed originally imported into Brazil was collected from two trees in the Bogor Botanical Garden with the label *E. alba* though the trees were probably pure *E. urophylla.*

Commercial planting with *E. grandis* began in the late 19th century in South Africa (Poynton, 1979) with the intention to be used as mining timber due to shortages of wood from native forests. Plantations were later developed in Europe, the America's, Asia and the less arid areas of Africa. Exact records of introductions are usually not available but much of the seed was obtained from Coifs Harbour, Queensland, Australia.

The commercial planting with *E. urophylla* from collections made in Indonesia began less than thirty years ago though the Dutch colonizers in Indonesia did use the species for ornamental purposes in Jakarta and the Bogor Botanic Garden both on the island of Java where the species is not indigenous. Seed was collected from the trees in the Bogor Botanic Garden and planted in Rio Claro, Brazil. Following adequate flowering and seed production, seed from arboretum trees at Rio Claro, Brazil were used for plantation establishment for many years (Eldridge et al., 1993). This seed would have been hybrid in many cases since many of the eucalypts in the Rio Claro arboretum flower during the entire year. More recently large commercial seed collections have taken place on the islands of Flores and Timor.

Pioneering work in Brazil in the early part of the 20th century by Edmundo Navarro de Andrade led to the publication in 1939 of his book *0 Eucalipto.* The first eucalypt plantations in Brazil were for fuelwood and were established by railroad companies. These plantations were from a genetic base of two trees in the Rio Claro arboretum pollinated by surrounding eucalypts. Seed was then collected from selected trees in these plantations for establishing new plantations. After several cycles there was a decline in productivity with almost 15% of the trees having stunted development and the cause was related matings along with inbreeding depression. Given the tax incentive program for plantation establishment which began in Brazil in the 1960's and the poor quality of local seed, large eucalypt seed importations were undertaken from Zimbabwe and South Africa. Seed was also imported from the natural range in Australia but this seed was not available in large quantities and produced trees with considerable disease problems. In the 1970's Champion Papel e Cellulose began mother tree collections of *E. grandis* in Australia and Aracruz undertook collections of *E. urophylla* in Indonesia. At the same time there were collections being made by CTFT of *E. urophylla* in Indonesia for trial establishment in the Congo.

Both species have been included in species trials in many countries. Provenance and progeny trials have been undertaken on a large scale in a substantially smaller number of countries. It is presumed that only those countries where the species have been planted on a semi-commercial scale can the expense be justified to acquire seed from the native range for trial establishment. One of the reasons why *E. urophylla* has not been planted more widely is the continuing difficulty to obtain seed both from the native range and/or from existing tree improvement programs.

Two of the reasons that *E. grandis* and *E. urophylla* have been used commercially are their propensity to produce seed in a diversity of climate and soil conditions worldwide as well as the relative ease with which these species can be propagated in forest seedling nurseries. It is no accident that the tree species commercially planted all produce seed and can be produced in non-capital intensive nursery conditions.

TREE IMPROVEMENT STRATEGIES

It appears from the literature (Poynton, 1979) that the first formal tree improvement activity with *E. grandis* began in South Africa in the late 1950's while activity in tree improvement with *E. urophylla* began in the late 1960's in the Congo (Eldridge et al., 1993) and in the 1970's in Brazil. The first report in the literature for urograndis was from Brazil. For both species it can be generally stated that initial tree improvement efforts were undertaken by government agencies whereas today private industry accounts for the majority of activity.

Differences in eucalypt tree improvement strategies result from the need to produce wood of short fiber species, existing genetic base, experience of staff and funding. Presently, organizations are involved with tree improvement with these species from those in the stage of initial seed introductions to others with biotechnology including operational use of tissue culture and trials with transformed plants. These strategies can be placed in five categories:

1. Initial Introductions
2. Improved Seed
3. Cloning and Beyond
4. Tree Improvement
5. Species and Provenance Diversification

<u>Initial Introductions.</u> To match climate and soil conditions of the establishment site(s) to the genetic material available in the market is much easier today than in the previous years. This is due to written reports in journals and proceedings as well as more frequent visits by many to existing programs with plantations. The large assumption here is the experience level of the individuals making decisions of where to source seed for trials and plantations. Initial and subsequent germplasm introductions by seed, rooted cuttings, pollen or micropropagated plants must also consider the technical guidelines published by FAO (Ciesla et al., 1996).

The strategy of initial introductions should be to attain as wide a genetic base as possible. This base from the native range and established programs can be maintained in trials and pilot plantations for subsequent tree improvement and deployment strategies. However, initial operational plantations should use improved seed from the best source possible, matched to the soil and climate conditions of the area being planted. Use of seed from the native range for operational plantations will result in less volume production compared to plantations established with improved seed from selected sources.

Those organizations relying on purchased seed from identified sources would not technically be considered to have a tree improvement strategy. Only if their staff begin local collections to establish a land race will plantations be improved over the long term.

Improved Seed. Given that in the majority of sites for *E. grandis* and *E. urophylla* do produce seed it is not difficult to produce improved seed of these species. In many cases the seed is produced in thinned commercial stands or trials. It is also common to observe clonal seed orchards established with those individual trees that root from cuttings. Not many organizations, however, have established trials of seedlings to rogue orchards. Those organizations with more advanced programs tend to test clones for the roguing of seed orchards. Seedling progeny trials also allow the best families to be deployed.

Seed production in *E. grandis* and *E. urophylla* can quickly satisfy internal demand by an organization. This leads to the possibility to sell or make an interchange of seed with other areas. This ease of seed production has allowed much international movement of seed, some of good quality and some of poor quality. Also, many researchers or commercial forest managers do not place sufficient attention on the soils and climate of the site of origin of this seed before acquiring large quantities for planting. Significant losses in stand productivity result from using the wrong seed source.

Control pollination is used in some countries. The objectives are to produce new material for selection and to allow seedlings to be planted in trials to rogue seed orchards. However, many organizations do not have the technical skills to make successful control cross pollinations. Open pollination is a very well established method of tree improvement in eucalypts. However, the insect pollinated eucalypts do permit an accumulation of deleterious genes as was the case in the early years of eucalypt plantations in Brazil. Lack of pedigree control will limit future genetic improvement in programs relying on open pollination unless biotechnology techniques such as DNA fingerprinting can be utilized.

Cloning and Beyond. Following the stages of seed introductions and improved seed production those organizations seeking higher yields and more uniform wood will go to clones. Clones require more technical skill in nursery employees, silviculture and management. To be successful in clones requires a sustained financial commitment due to the costs of selection and testing. The most costly item in clones is the absolute requirement to test clones on multiple sites. With experience, clones matched to site will maximize yield.

Numerous systems have been developed for clonal production. Clones will have three to five times the cost of seedlings. The larger cost of clones will be due to the production and collection of coppice material from which to select cuttings for rooting. Early testing, tissue culture and other techniques can be used to reduce the time from selection of a superior individual from seedling origin to operational clonal plantations (Wright, 1995). It must be remembered that cloning is not tree improvement but rather the multiplication of superior phenotypes.

1.Testing numerous seed sources i.e. species, provenances, families
2.Use of appropriate silviculture
3.Desirable wood for processing
4.Ability to produce seed at an early age
5.Coppice and rooted cutting for cloning
6.Ability to tissue culture or micro-propagate
7.Knowledge of disease and insect pests

CONCLUSIONS

There is considerable effort worldwide to improve *E. grandis, E. urophylla* and urograndis. Some of the difficulties in the years ahead will be a decreased genetic base in these species' native range due to logging, conversion to agriculture or other uses such as housing estates. One aspect that must be considered is access to genetic material in the native range by those organizations willing to participate in *ex-situ* gene conservation efforts especially when led by organizations such as CAMCORE. One lesson from agriculture is that permanent access to genetic material from the native range is essential for long term success in any plant genetic improvement program.

Numerous opportunities exist to obtain more genetic gain from these species. Improvements in the rooted cutting process (Wright, 1995) and in more sophisticated tree improvement strategies (Osorio et al., 1995) will continue. The use of biotechnology and marker aided selection hold much promise though how this technique can resolve genotype environment interactions is not clear. Infusion of genetic material be it seed, clones or strands of DNA will assist many organizations. Finally use of novel methods for incorporation of pulp and paper properties in a selection index will result in large economic gains.

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