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GENETIC EVALUATION IN EUCALYPT BREEDING PROGRAMS

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INTRODUCTION

The Southern Tree Breeding Association (STBA) runs national tree improvement programs for *Eucalyptus globulus* and *Pinus radiata* in Australia. The cooperative breeding program for *E. globulus* has now been running for ten years following the amalgamation in 1994 of genetic material and data from eight selection and breeding programs that were previously managed by individual companies. This consolidation of the genetic resource for *E. globulus* resulted in broadly based genetic material for selection and breeding and also the availability of large amounts of performance data suitable for genetic evaluation. The TREEPLAN® genetic evaluation system, which was developed for the purpose of analysing this performance data, is being used to routinely update genetic values in *E. globulus*, *P. radiata* and *E. nitens* on a national basis. The systematic approach that has been adopted by STBA in genetic evaluation makes much more effective use of all pedigree and performance data, but also has led to other operational efficiencies in the programs.

TREEPLAN® GENETIC EVALUATION

The TREEPLAN® system is designed to apply best practise analytical technologies to commercial tree improvement programs. The optimal and preferred statistical method for breeding value prediction is best linear unbiased prediction (BLUP). BLUP is not new technology, but its industry wide application in trees has been limited in the past by a lack of computer power and software capability. Single-generation, single-site and single-trait analyses were often the norm in tree breeding, as software could only handle small and highly structured data sets. As a result, genetic evaluation was done inefficiently and breeding values were often biased, leading to an over or underestimate of the genetic worth of individual genotypes.

The STBA adopted the individual tree additive genetic model BLUP in its tree improvement programs during the 1990s (Jarvis *et al*. 1995). However, its application was limited to relatively small and uncomplicated data sets until the development of the TREEPLAN® system (Kerr *et al*. 2001, 2002; McRae *et al.* 2003). The STBA with assistance from the livestock industry (Animal Genetics and Breeding Unit) developed the TREEPLAN® genetic evaluation software with the capability to process performance data on a national and/or international scale. Subject to sufficient genetic linkage, TREEPLAN® allows STBA to rank the performance of genetic material on a species wide basis. It is relatively easy to incorporate data for new traits and weight information to target particular production environments and products. Prediction of genetic values is now a more dynamic process, such that TREEPLAN® breeding values are updated regularly as traits are measured, data compiled and validated.

TREEPLAN® is fully integrated with a web based data management system. The data management system acts as a dynamic repository for data and pedigree information and has the capability to handle multiple species. The system not only facilitates efficient storage and retrieval of data for genetic evaluation, but also the delivery of genetic values and other information to STBA Members and clients through the Internet. As new trials and traits are assessed, the data is entered into a database, analyses are done on a single site basis to allow for differences in productivity and heritability between sites, TREEPLAN® is run, and breeding values for all trees in the specified population are updated.

TREEPLAN® software is currently being enhanced by STBA, AGBU and the Forest and Wood Products Research and Development Corporation (FWPRDC). Enhancements will include the capability to incorporate DNA information (markers and candidate genes). Currently, it seems there is no efficient method for using results from genomic studies together with data for other performance traits, such as growth, form and wood quality. TREEPLAN® will be enhanced to fit complex spatial models of environmental heterogeneity within trials, and simultaneously predict breeding and clonal genetic values. Studies on genotype by environment interaction (GxE) will also allow STBA to target genotypes more strategically to different production environments.

Case study for *Eucalyptus globulus*

Genetic values for 152,170 genotypes in the national *E. globulus* database were updated using TREEPLAN® in 2004. This analysis included genetic values for native provenances (sub-races), native stand (founder) trees, first-generation and second-generation progeny. Data was included from 90 trials, including 16 second-generation progeny trials, with trees of different ages spread across Tasmania, Victoria, South Australia and Western Australia. In a multi-generation, multi-site, multi-trait and multi-age analysis, breeding values for growth traits were predicted in four production regions by three age classes (0-4 yrs, 5-8 yrs and 9-12 years). Basic density, by two age classes, and pilodyn penetration comprise wood quality traits. Data for pest and disease resistances (defoliation), kraft pulp yield, NIRA pulp and cellulose content, collapse, shrinkage and tree form traits is also being incorporated. Trees in the CSIRO collections (Gardner and Crawford 1987, 1988) are used to establish a baseline for monitoring genetic improvement in the population over time.

The primary breeding objective for the national *E. globulus* tree improvement program is to maximise the net present value per hectare ($NPV) from forests grown for kraft pulp production (Dutkowski *et al.* 2000). The breeding objective traits are harvest volume, wood basic density and kraft pulp yield. STBA expresses its genetic values in terms of these breeding objective traits. STBA members and *seedEnergy* Pty Ltd use the resultant TREEPLAN® genetic values to establish and cull orchards, and to select seed lots for deployment. Although the primary objective of most STBA Members is to produce wood chips for pulp markets, there is an increasing interest in sawlog regimes and other alternative products. The STBA, University of Tasmania and CRC-SPF are currently researching alternative breeding objective functions for other products and markets. It is likely that different traits and economic weights will be used in customised breeding objectives functions for the different markets. Depending on the outcomes of this research, it should be relatively straightforward to include data for new traits in genetic evaluation using TREEPLAN®.

CONCLUSIONS

Productivity and profitability in plantation forestry will be maximised only by using the best genetics and silviculture in combination. Decisions on genetic quality for a particular species should be based on objective performance data made available in tree improvement programs. The TREEPLAN® genetic evaluation system, which uses best practise analytical technologies, allows us to rank genetic material on a national basis for a given species. TREEPLAN® makes it is easy to target particular production environments and end products, and incorporate data for new traits. The adoption of the TREEPLAN® technology will lead to a faster rate of genetic improvement for plantation species like *E. globulus*, *E. nitens* and *P. radiata*.

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