Tree improvement in plantation forestry in Australia

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Forestry is a major industry in Australia with 2 million ha of softwood and hardwood plantations. The logs are used for building, construction, furniture, paper, and paperboard products.

The main plantation species are radiata pine, blue gum, shining gum and southern pines. These are supported by advanced generation tree improvement programs. Pine programs started in the 1950s as separate state and privately funded programs, while eucalypt programs began in the 1970s and were largely privately funded. Privatisation, consolidation of ownership, some advances in technology and a willingness to collaborate has seen individual programs consolidated into species and industry wide cooperatives, or better collaboration among programs. This has led to efficiencies and increased genetic gain.

Tree Breeding Australia is a consortium of forest owners, seed and plant propagators, and research agencies. It manages national cooperative tree improvement programs for radiata pine and blue gum and supports breeding programs of other companies by providing access to its online systems for data management and genetic evaluation.

The breeding programs are guided largely by economic objectives. Rolling front strategies with overlapping generations of breeding and testing have generated efficiencies and increased gains. Data is consolidated in national and species wide databases for joint multivariate analysis using TREEPLAN software. Genetic material is tested in trials well connected across a range of site types typical of the plantation estate to account for genotype by environment interactions. Genotypes are cloned in some species programs and tested alongside seedlings. A current focus is pre-emptively testing material across a range of environments likely to reflect future climates and industry expansion. Genomic information is integrated into evaluations by augmenting pedigree information with genomic relationship matrices. This has improved accuracies and selection prior to phenotypic information becoming available. Relatedness and potential build up in group coancestry in breeding populations is better managed with new tools. Gains from breeding have been demonstrated in all species and new designs have allowed integration of progeny testing with large plot trials.

The programs are well supported by collaborating scientists in various research agencies. This encourages innovation and ensures research outputs are rapidly adopted by industry.

Measuring and improving wood quality in Australian softwood plantations

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Abstract

Wood quality will decline in plantations as productivity increases if insufficient attention is paid to measuring and improving wood properties. Two wood quality assessment tools and methods (IML PD400 RESI resistograph and Fibre-gen's ST300 acoustic wave velocity) were tested in genetic trials across temperate and sub-tropical softwood plantations. In radiata pine large-scale data of 41,597 wood density and 15,964 acoustic velocity measurements were collected in eleven field trials. In southern pine, 8,032 density and 8,914 acoustic velocity assessments were collected in five field trials. In radiata pine, the heritability of wood density measured by RESI PD400 and acoustic wave velocity measured by ST300 instruments ranged from moderate to high, averaging h^2=0.52±0.07 and h^2=0.45±0.07, respectively. In the slash × Caribbean pine hybrid, the heritability of ST300 acoustic wave velocity based on a total of 11 current and historic trials was on average h^2=0.44±0.11.

In radiata pine, genetic correlations of diameter over bark were more adverse with RESI predicted density (r_a=-0.36) than with ST300 acoustic velocity (r_a=-0.04). Correlations were also more adverse between predicted density and form trait stem straightness (average r_a=-0.11) than for acoustic velocity (r_a=0.22). In slash × Caribbean pine hybrid trials, the average genetic correlation of ST300 acoustic velocity with tree diameter over bark was r_a=-0.16, and with tree height it was r_a=0.14, indicating that negative genetic correlations between wood properties and diameter may be overcome by placing greater selection emphasis on tree height.

As a large amount of wood quality data is added to genetic evaluations, the selection response in wood stiffness is high relative to other traits in breeding objective and is heavily influencing the response in the multi-trait selection index. That indicates that breeding programs may require a revision of economic weights, genetic variances and correlations between selection and breeding objective traits.

Keywords: Pinus radiata, slash × Caribbean pine hybrid, wood quality, tree breeding

Innovative applied breeding of superior eucalypt hybrid clones in China

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Stora Enso Guangxi manages 80,000 ha of plantations in southern China to supply pulpwood and veneer logs. A tree improvement program commenced in 2003, in collaboration with local forest research institutes, to develop superior *Eucalyptus* hybrid clones. The program used discrete generation reciprocal recurrent selection among the genotypes from five *Eucalyptus* species for hybrid generation and followed by multiple-stage clonal selections. Therefore, a large number of trials are separated by species and selection stage.

Revision of the strategy in 2017 lead to the development of a single synthetic population (incorporating multiple species) with a rolling front program using shortened generation intervals. New field trial designs now test all pure species, their hybrids and multiple stages of clonal selections together in large ‘integrated’ trials. Such tests markedly reduced the number of trials established per year, but the testing scale increased to around 7,500 trees each and selection accuracy increased.

To facilitate selection, all historical field trial data were entered into a single database, along with all new data as collected. To date, up to 8 million measurements from 350,000 trees representing 160,000 genotypes have been entered. Full pedigrees have been constructed for the entire breeding population. This enables use of all data and kinship information in computation of more accurate Breeding Values (BVs) and Genetic Values (GVs), through the TREEPLAN® big data multivariate analyses tool to select parents for the next generation of breeding and clones for further testing and commercial deployment.

Clones selected for pre-commercial testing are first included in trials with small unreplicated plots spread across 12 sites and then, after reselection, in independent 10 ha pilot-scale plantations at each of 4 sites. The key output expected from breeding is developing at least 1 new operational clone every 2 years, which is substantially faster than that achieved historically.

Maintaining the competitive edge for Australian tea tree oil production

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Tea tree oil (TTO) is an iconic Australian natural product marketed globally in healthcare, cosmetic, pharmaceutical and veterinary products. TTO is produced in specialised foliar oil glands, rich in terpenoid compounds that provide its antiseptic and antifungal properties. The entire shoot of the plant is harvested and steam distilled to produce a purified essential oil. Australian TTO production occurs in north-eastern NSW and far North Queensland. The 2020 crop generated about 1,100 tons of oil (GVP ~AU$50M), with ~90% of production sold overseas.

Domestication of tea tree began in the early 1980's as the industry transitioned from a reliance on natural stands for harvesting to purpose-grown plantations. A tea tree breeding program commenced in 1993 and was led until 2017 by NSW DPI with the CSIRO contributing until 2009. It underpinned the stabilisation and growth of the industry by developing a reliable source of seed cultivars with high oil quality that progressively increased in oil yields over the initial three generations of domestication.

Moving forward the challenge for tea tree breeding is a continued supply of improved germplasm for the Australian industry to maintain its global competitiveness against increasing overseas TTO production in China, South Africa and Kenya. Southern Cross University is now leading the Australian tea tree breeding effort as it moves into its fourth cycle of breeding. While focus remains on increasing oil yield, it will progressively broaden into emerging cost-of-production issues, including stress tolerances and new oil quality characteristics. Breeding methodologies need to be sophisticated to continue to make gains in oil yields, as the opportunities to make large advances, which were available in the early stages of domestication due to large inter-provenance and within-provenance effects, will diminish. Some of the approaches taken to address this challenge and other methodologies to improve breeding efficiencies will be discussed.

Keywords: Tea tree oil, tree breeding, Melaleuca alternifolia, cost of production, stress tolerance