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Genetic evaluation – the breeders' perspective

Thomas McRae[1], Peter Buxton[1], David Pilbeam[1], Richard Kerr[2], Gregory Dutkowski[2]
[1]The Southern Tree Breeding Association Inc., Australia; [2]PlantPlan Genetic, Australia

Tree improvement programs aim to breed, select and deploy genetic material with improved biological characteristics for traits of commercial importance. Advanced generation breeding programs are complex: data is generated for numerous traits measured on many trees at different times, at different locat ions, and for different reasons. The purpose of data analysis and genetic evaluation is to summarise all performance data amassed in many trials over time, and use the results to make predictions about the potential of different genotypes for use in breeding and deployment.

The tree breeder has many decisions to make. Does the economic model differ among companies? Does the potential of different genotypes vary according to site type and production system? What genotypes to select and graft into breeding arboreta and seed orchards? What genotypes to use as parents and in what combinations throughout the breeding season? What progeny to put in trials, how many sibs in each trial, and what trial designs to use? When to assess trees in trials? Which traits are measured on which genotypes? Where and how is the data and information stored and analysed? Who can access the data and results? Are predictions meeting expectations? Are gains over time monitored? Can genetic material from different sources be compared, in biological and economic terms? How is relatedness managed in populations over time? How do we incorporate new theories and the latest research findings?

Decision making is dynamic as information available to the breeder is continually changing on a daily, monthly and yearly basis with rolling front programs. The breeder needs ready access to flexible tools and systems that can assist with various tasks if optimal decisions are to be made. Progress will be discussed in the context of cooperative tree improvement programs in Australia.

Genetic evaluation - the breeders' perspective

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Southern Tree Breeding Association Inc.
Australia

Australian tree improvement programs

A few species dominate (85%) plantation forestry

	P. radiata	*E. globulus*	*E. nitens*	Southern pines
Production zone	Temperate - medium rainfall	Temperate - medium to high rainfall	Temperate - medium to high rainfall	Tropics and sub-tropics high rainfall
Regions	NSW, Victoria, SA, WA and Tasmania	WA, SA, Victoria and Tasmania	Tasmania and Victoria	Queensland (+ N NSW)
Production area	765,000 ha	615,000 ha decreasing	190,000 ha	153,000 ha
Target market for forest products	Structural sawn timber for building, joinery, plywood, posts, poles, residues for pulp, particle and panel board	Export chip for pulp and paper (developing interest in solid wood and veneers)	Export chip for pulp and paper, solid wood and veneers	Structural sawn timber for building, joinery, plywood, posts, poles, residues for pulp, particle and panel board
Breeding began	1950s	late 1980s	1970s	1950s

What do we mean by genetic evaluation?

We should be clear by now!

The prediction of the genetic component of individuals' phenotypes. Further, we aim to separate out the additive part of the genetic component that can be transferred to future progeny (the breeding value), from the non-additive part. The non-additive part is important for understanding the individual's deployment value (Kerr)

Assignment of values of genetic worth for a variety of measured and derived traits of entities in genetic improvement programs based on data, pedigree and trial designs (Dutkowski)

Our tree breeders are largely in agreement

Distills down large amounts of data to a usable format

What are some of the important considerations when it comes to genetic evaluation?

We need a genetic resource and an understanding of its genetic architecture

We need knowledge about the pedigree

We need relevant data and information on traits of interest

We need to understand the characteristics of the test and target environments

We need to consider all the data and information simultaneously with ideally one solution for any particular situation

We want flexibility to change the models and assumptions as necessary

We want flexibility to add new traits

We want transparency (and not be too reliant on any individual)

We want a record of previous evaluations and to be able to build on these

We want a measure of reliability (quantify the degree of risk)

We want to be able to independently validate the results

We want to benchmark against a common baseline and monitor gain over time

We need to understand the consequences of selection for future generations

We want the ability to easily incorporate data, results and findings of research projects

We want ready (but authorised) access to the results for use in breeding and deployment

Member specific evaluations may be needed

Understand resources are finite (generate efficiencies)

Appreciate expertise is finite (use common platforms)

Genetic evaluation is part of operations – not a research task

Evaluation systems need to be user friendly (despite complexity)

Timeliness – decision making

What are some of the important technical considerations when it comes to genetic evaluation?

Use best practise science (apply the theory)

Use appropriate models (individual tree model BLUP)

"a more complete model is expected to be more accurate" (Wiggans)

Highly unbalanced data is the norm and increasingly so

Multivariate evaluation is essential

Evaluations need to be computationally feasible

We want reliable measures of reliability (accuracy)

Pedigree can be complex (individuals, families, aggregates and groups)

Heterogeneous variances are the norm

Data measurement protocols can change over time

Models must account for varying quantities and quality of data (use BLUP)

Models should be trial and trait specific (heritability varies)

GxE can be important and must be accommodated

Measured traits in forestry are not usually the objective traits

Australian tree improvement programs

	P. radiata	*E. globulus*	*E. nitens*	Southern pines
Number of active breeding programs	1 Cooperative	1 (+1) Cooperative	3 ~ independent	1 Company
Original programs	8 + infusions	10 + infusions	9 + infusions	1 + infusions
TREEPLAN evaluations	annual (2002+)	annual (2002+)	2-3 yrs (2005+)	annual (2014+)
Geographic range	Industry wide	Industry wide (plus local)	Industry wide (but local)	Industry wide (regional)
Economic objectives breeding	National + risk traits	National + risk traits	Company specific	1 company
Economic objectives deployment	Regional + company specific	Regional + company specific	Company specific	Company specific
Strategy	annual rolling front 2000	annual rolling front 1995	transition to rolling fronts?	adopted rolling font 2010

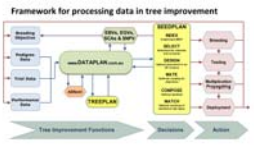
Universal tools

Economic models

DATAPLAN database

TREEPLAN genetic evaluation

SEEDPLAN suite of tools



Tools and systems are fully integrated

Tools are flexible

Users share costs of maintenance and development across species and programs

Examples of genetic evaluations for Australian tree improvement programs using TREEPLAN

	P. radiata	*E. globulus*	*E. nitens*	Southern pine hybrids
Trials	183 (388)	149 (184)	132 (163)	60 (20 + 300)
Multi-site (GxE)	7 regions (change to 3+)	4 regions (to change)	4 (Cold, Dry, High, Normal)	single
Multi-age	age classes for growth (4), wood quality (2)	growth (3)	growth (4), wood quality (3), form (3),	6 age classes growth, wood quality, form
Multi-trait	growth (19), form (5), wood quality (4), diseases (4), pests (1)	growth (12), form (1), wood quality (3), diseases (1)	growth (27), wood properties (20), form (7)	growth (12), wood quality (24), form (18)
Site and trait specific models	yes	yes	yes	yes
Generations (cycles)	4	3	3	3 (4)
Pedigree	Pure species Complex (OP, CP, groups, clones, aggregates)	Pure species Complex (+partial selfing)	Pure species Complex	Hybrids and pure species Complex (clones, OP, CP, pollen mixes)

Examples of genetic evaluations for Australian tree improvement programs using TREEPLAN

	P. radiata	*E. globulus*	*E. nitens*	Southern pine hybrids
Trials (included)	183+	149+	132	60+
SC traits (predicted)	33	17	54	29+
BOT (derived)	12	7	25	6
Genotypes	366,826+	272,601+	198,705	142,529+
Families (with SCAs)	9836	5996	4124	1752+
Genetic groups	28	32	11	31
Genetic values	many EBV and EGV for all SC and BOT traits	many EBV and EGV for all SC and BOT traits	many EBV and EGV for all SC and BOT traits	many EBV and EGV for all SC and BOT traits
Economic indices	many	many	many	fewer
Accuracies (+SE)	yes for all SC BOT traits and IDX	yes	yes	yes

Australian tree improvement programs

Tools were developed to facilitate genetic evaluation and use of outputs

	P. radiata	*E. globulus*	*E. nitens*	Southern pines
DATAPLAN	2001 expanding	2001 expanding	2005 mainly new data	2012 populating
SEEDPLAN deployment tools				
INDEX	yes	yes	yes	?
SELECT	yes (2010+)	yes (2010+)	yes	yes (2014)
MATE	yes (2008+)	yes (2008+)		2015?
DESIGN	yes (2012+)	yes (2012+)	yes (2012)	yes (2014)
MATCH	yes	yes	?	?

Results of genetic evaluations are used for decision making?

Breeding

Selection of parents (pollen and scions) for breeding

Breeding values (EBVs) are used

Maximise gain for objective(s) while managing relatedness (rate of change in group coancestry)

Rolling front breeding scheme – the parental group is constantly changing each year

Timeliness (biology dictates)

Breeders use the SELECT and MATE allocation tools

Results of genetic evaluations are used for decision making?

Deployment

Selection of parents for seed orchards

Optimise gain for objective(s) while managing relatedness (status number) in the immediate generation

Deployment systems differ

Customer demands differ

Seed producers use the SELECT and DESIGN tools

Economic objective(s)

Genetic values are only part of the equation

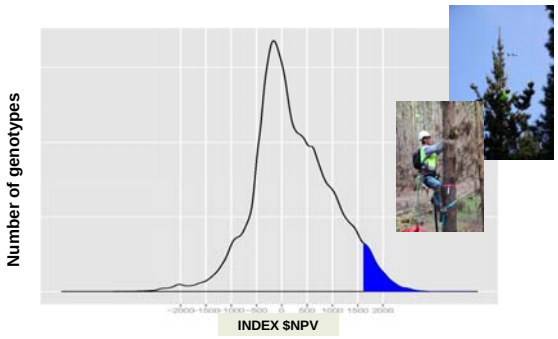
Economic indices ($NPV) are used for selection in breeding and deployment

Economic weights vary with production environments and processing systems

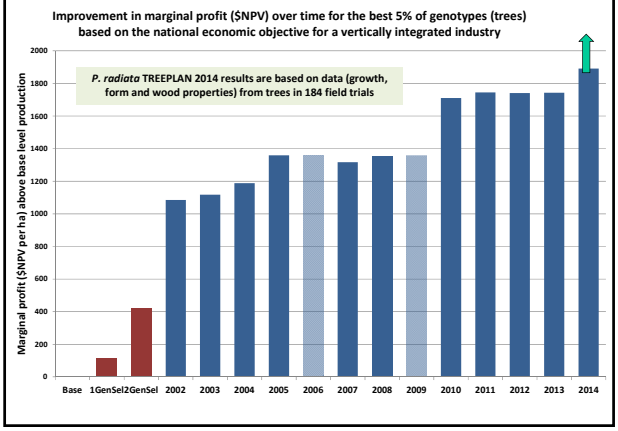
Genetic values also vary (mean and scale) with different target environments

Measures of genetic merit and economic worth must be customised

Radiata pine – Economic worth $NPV



NPV$ = w_1GROWTH - w_2BRANCH - w_3SWEEP + w_4STIFFNESS



Summary of survey responses by our breeders

How important is tree improvement to your company?

A: most said critical

How important is genetic evaluation to your tree improvement program(s)?

A: most said critical

Summary of survey responses by our breeders

Do you use the results of evaluations?

A: yes (or would like to)

Do you have confidence in the results generated?

A: confident++

What other things would you like done?

A: Harness some of the potential of genomic technologies

CONCLUSIONS

Integrated TREEPLAN evaluation system is working well for our breeders

Predictions are largely meeting expectations - Breeding programs are making gain

Forestry companies have increasing confidence in predictions for deployment

CONCLUSIONS

Genetic evaluation is considered part of operations – it's not a research project

Increased transparency with integrated systems has reduced risk

Rolling front programs are more efficient – but a good evaluation system is essential

More phenotypes!