Discussion paper – Scenario analysis for the RPBC genomics programme

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1. Introduction

The brief for this work is to develop a model to analyse the costs and benefits of different scenarios for implementation of integrated genomic selection at RPBC. The term "integrated genomic selection" incorporates the understanding that future operational models for the RPBC will incorporate innovation in both genomics and traditional breeding, not one or the other. The model will allow the costs and benefits of the entire programme to be investigated and better understood. It will provide a framework to develop and understand scenarios of how the implementation of new technologies including genomic selection might proceed, and the implications of any decisions.

The following steps are proposed:

- Define the approach to scenario analysis
- Describe the process of implementation
- Define the scope of the model. Define the key parameters that will drive results, modelling assumptions.
- Produce a first cut model and present scenarios and discuss implications

2. The approach to scenario analysis

The approach that has been proposed and agreed is to define a base scenario which is the most likely. This scenario should be consistent with RPBC priorities for adoption of new technologies as they are evaluated and accepted under RPBCs research and business criteria.

The scenarios should also take account of time lags generated by

- the need to prove new technologies operationally
- the likely different rates of adoption of genomic selection by individual forest owners and
- practicalities of adoption in the deployment phase

This step will involve some duplication as the new technology is implemented alongside the existing, and the management and governance groups satisfy themselves that full adoption (and discarding of the old technology) can proceed.

The assumption for the base case is that the level of gain remains the same in both phenotypic and genomic selection, but the gain will be delivered sooner with the successful inclusion of genomic selection.

While the base case should be generally accepted as the 'most-likely' scenario, alternative scenarios will be developed to explore other likely options

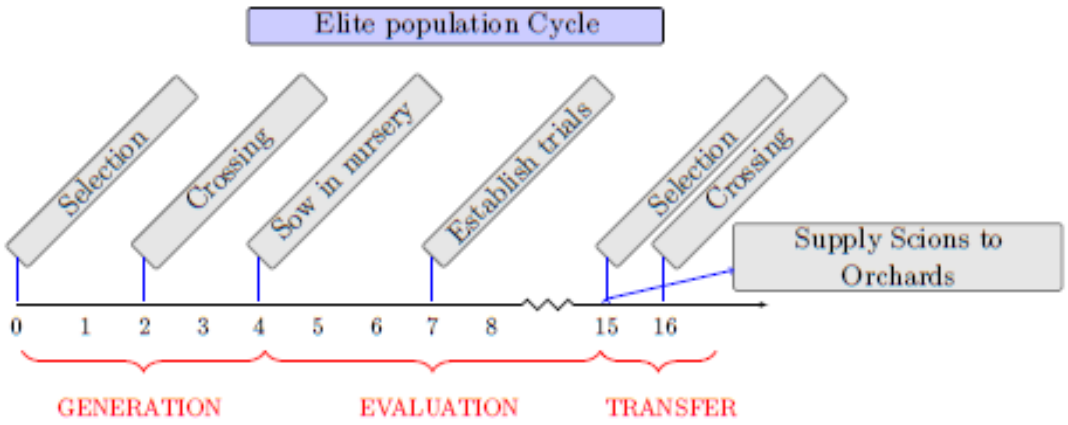
3. Describe the process of implementation

- What is the business as usual RPBC operation and process of improvement of Radiata pine.
- What are the key deliveries from the genomics programme (description and timing of delivery)
- How will they be integrated in to "business as usual" and at what time?
- What are the alternative scenarios for implementation?

a. Describe “business as usual”

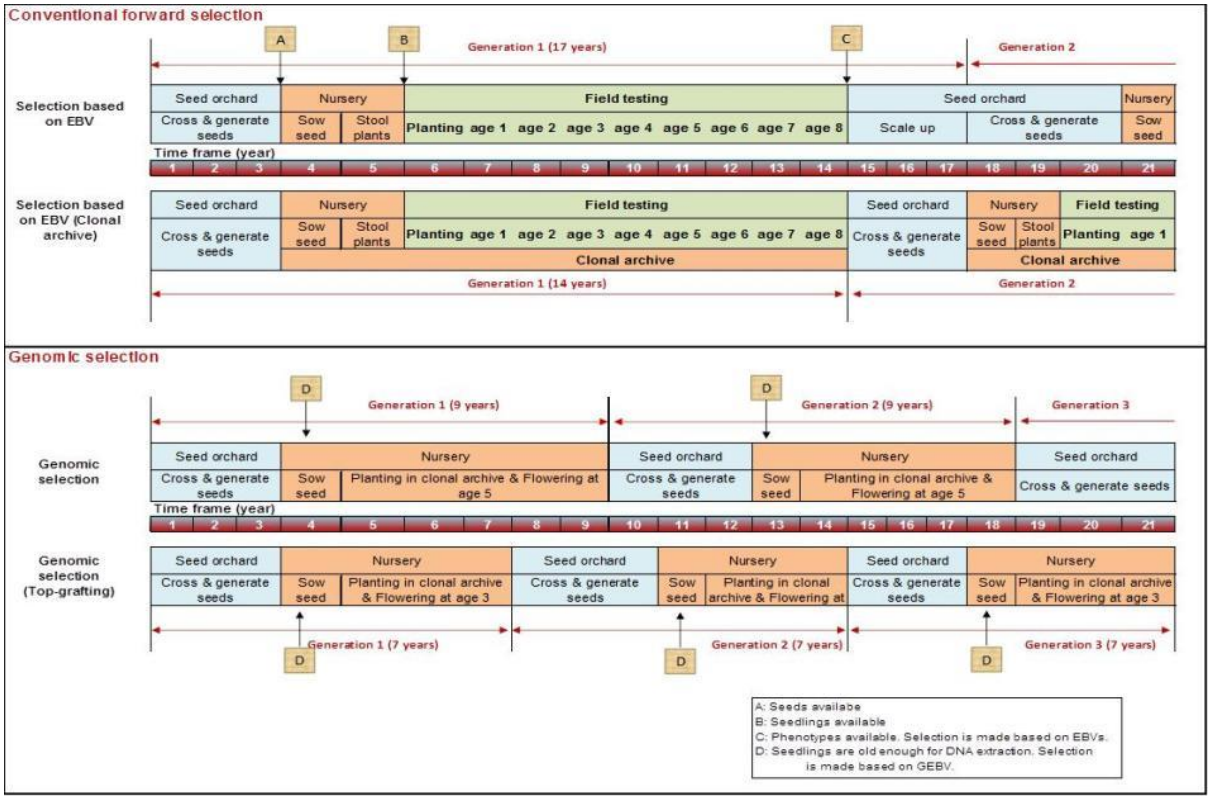
There is quite good agreement on the current process, described as “forward selection with clonal testing” in Jefferson and “selection based on EBV (clonal archive)” in Li and Dungey.

Figure 1: Current RPBC process



Source: Paul Jefferson, 2016 Breeding Management plan

Figure 2: Current and proposed process (using genomic selection)



Source: Li and Dungey (2015)

b. Describe the base case genomic selection scenario

It seems the most likely option is to reduce to the cycle to 9 years with flowering at age 5, or to 7 years if early flowering were possible (age 3). Since there is a difference of opinion on early flowering feasibility (Paul Jefferson pers. comm.) this should be handled as two scenarios. It has also been suggested (R. McConnochie pers. comm. that flowering will only save about 9 months

c. Alternative scenarios (to be determined)

4. Define the scope of the model

RPBC operations

The current RPBC practice is described (P Jefferson pers. comm.) as a process of forward selection with clonal testing. This process takes about 15 years. This is the development of the process from the previous backward selection process which includes progeny testing. While this is described as the current practice, it is clear it is some way from being "business as usual". For example, it is understood that the major seed orchard producers have not included any germplasm from this process yet into their seed orchards.

Main components of RPBC operations are:

- Placing material into archives, and maintaining archives. Producing crosses from the archive material. Using the archive as a source of grafting buds. Clonal trials are also used as an early source of a limited number of grafting buds
- Breeding selection trial establishment and measurement
- Calculation of breeding values (breeding values are re-calculated every year, as new information comes to hand)
- Demonstration trials (these are row plots/ genetic gain trials, which can also be used for mensurational purposes, e.g. quantifying genetic gain for yield tables)
- Provision of material to seed orchards and clonal producers (generally from the archive, but also from trials)
- Data management and analysis

RPBC operations consists of a large set of trials, the focus of which is the testing at age 8 and the search for better material to meet specific needs of industry.

The main RPBC programme (Paul Jefferson *pers. comm*.) is the 2003/04 trials which consists of 1700 individuals from 60 families (the so-called "elites"). There are 5 clones planted at each site, and there are 12 -14 sites in New Zealand and Australia

The last of these will be evaluated in 2020 to 2023 (includes the Australian trials).

Operational costs are documented below

	Actual		Forecast		
	F11	**F12**	**F13**	**F14**	**F15**
Main	210	245	238	270	315
Elite	35	135	70	65	65
Production		10	20	5	5
Breeding values	40	30	30	30	30
Evaluation of genetic gain	78	80	42	32	35
Breeding archives	61	35	30	30	30
Conservation archives	28	22	10	15	30
Germplasm transfer		5	5	5	5
Gene resource population	50	10	11	38	13
TOTAL	502	572	456	490	528

Sources: Breeding management plan May 2011

Area	Budget F16	Budget F17
Main population	$282,000	$215,000
Elite population	$116,000	$173,000
Production populations	$31,000	$15,000
Evaluation of genetic gain	$28,000	$50,000
Breeding archives	$100,000	$90,000
Conservation archives	$10,000	$10,000
Total	$567,000	$553,000

Source: Jefferson (2016)

We need to define which components of this budget are required to run the current forward selection with clonal testing process (which takes 15 years)

Need to determine what component of the operational cost would not be required if genomic selection were fully implemented.

Genomic selection

The key deliverable from the Genomics programme is the identification of a relationship between SNPs () and the traits that are measured at age 8. If there is a strong and reliable relationship, it is expected that the genomic selection can replace field testing over time.

One of the key outputs of the genomic selection programme is a SNP panel with data for all the key traits

It is expected this would reduce the breeding cycle from 15 to 9 years, with alternative scenarios providing earlier delivery.

The operational components of genomic selection are:

Operation	Cost
Collect tissue	?
DNA preparation	$4-$5
Genotyping	$50-$70 US
Calculating GEBVs	???

(Further information will be sought on this from Scion)

	2014	2015	2016	2017	2018	2019	TOTALS
Progeny test	$40,000	$20,000	$10,000	$5,000	$5,000	$120,000	$200,000
Establishment of an additional 400 clones over 3 sites	$200,000						$200,000
Assessment of an additional 1400 clones over 3 sites	$40,000	$15,000	$10,000	$5,000	$5,000	$100,000	$175,000
DNA extraction (X2)	$75,000	$100,000	$50,000	$50,000	$25,000	$25,000	$325,000
Establish 1000 clones of 2006 selected elite population							$0
Dothi assessment of clonal trials (3 or 4 sites)			$40,000	$40,000			$80,000
TOTALs	$355,000	$135,000	$110,000	$100,000	$35,000	$245,000	$980,000

Multiplication and Deployment

The multiplication cycle was not modelled in detail in previous work. The first cut of the model will also not model the deployment processes in detail but will focus on defining the constraints of process in terms of delivery of gain.

Note that deployment is currently based on the GF+ system. Seed producers currently monitor GF+ values for new germplasm, and will tend to wait until GF+ values stabilise. They regard the variance in GF+ values as too much to make an early decision on deployment. However it could be possible to provide seed producers with additional information (what is the probability that the mean value of new germplasm x is greater than a benchmark parent, for example). This could lead to earlier introduction of new material (Wei Young, pers. Comm)

It is suggested by the seed producers (Wei Young) that genomic selection is shortening the cycle of information only – not changing the biology.

1. Seed orchard production cycle

The model should also include the seed orchard production cycle. Critical issues are

Seed orchard management principles.

- How quickly can new genetic material be introduced into the seed orchard?
- What evidence is required for the introduction of new material
- What are the time lags for implementation
- What are the time lags to full production?

"…It takes about six years from when top clones are grafted in the seed orchard to when CP seeds are available to make seedlings. It takes another year in the nursery before the genetically improved treestocks can be planted in the field…." (Wei-Young Wang)

2. Clonal production cycle (embryogenesis with cuttings)

This will also be included in the model, as a significant source of planting stock for some forest owners.

3. Cuttings alone

Many nurseries using cuttings as a way of making expensive and scarce seed go further

Theoretical and actual gain

This is a major topic in its own right, and will not be traversed in more detail than is necessary to model scenarios. The particular driver of the difference of interest in this exercise is the inherent inertia in the deployment system which means the full theoretical gain may not be achieved.

- The mothers in the seed orchard are selected partly on the basis of cone production
- For embryogenesis, there is a filtering effect as some clones do not respond to cryo-preservation
- Also for all cuttings based systems, some individuals are poor at producing roots and therefore do not produce good cuttings
- Irrespective of the method, there is often a shortage of grafting buds when new material is first identified

Conclusion: irrespective of the means of bulking up and deployment of genetic gains, there is some dilution of the theoretical gains.

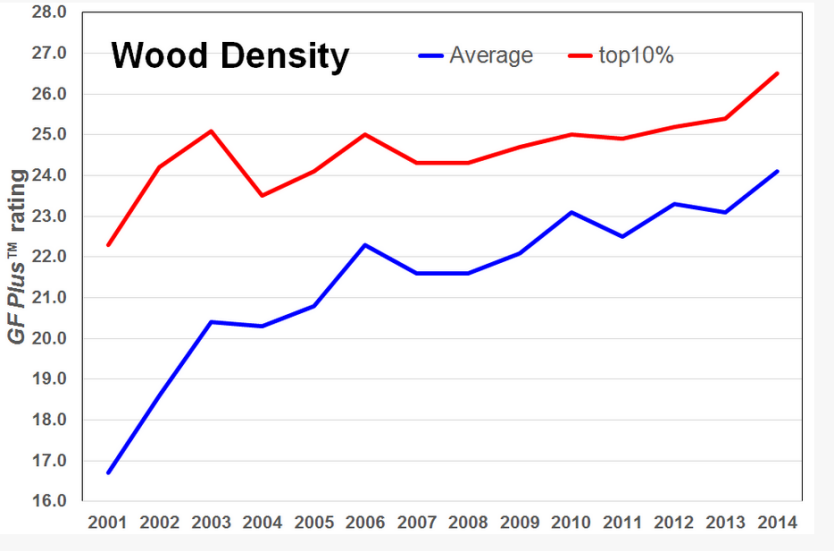
Estimation of gain

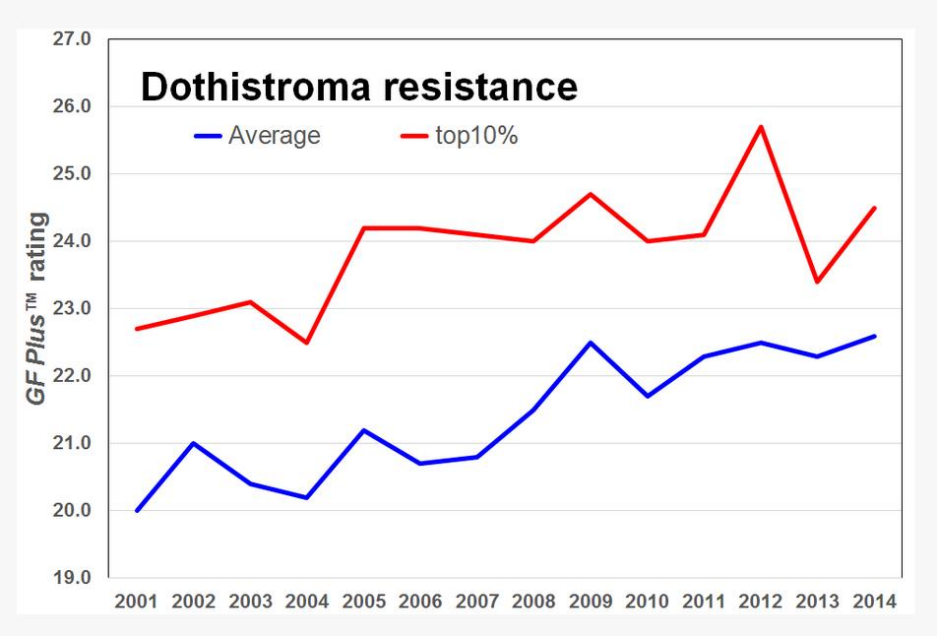
This will be modelled from breeding values, with information provided by Paul Jefferson. There has been quite a lot of previous work done on this, including work by Wei-Young using GF+ values to show how gain has progressed annually, for specific traits.

The application of "regional" breeding values will also need to be determined.

Key question: does genomics result in an improvement in breeding values? How is improvement measured?

Some examples of gain information are shown below

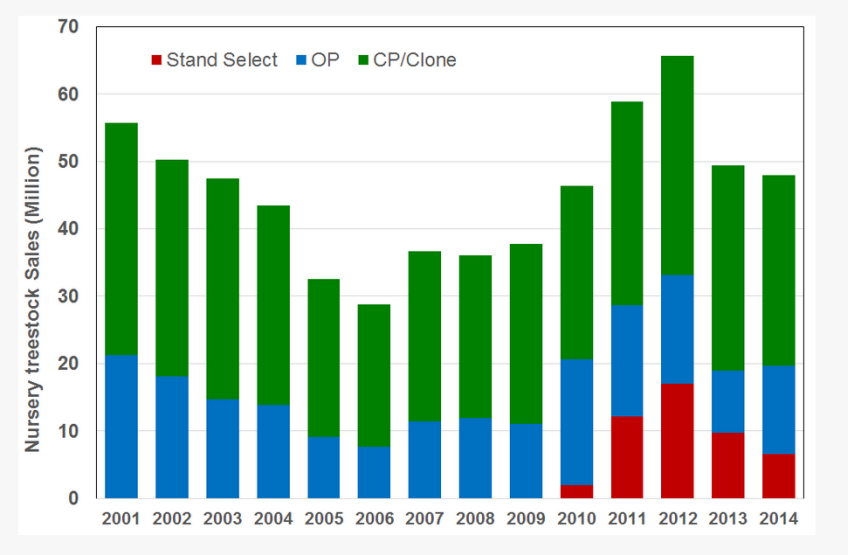




http://nz.pfolsen.com/market-info-news/wood-matters/2015/august/deployment-of-genetic-gain-in-radiata-pine-plantation

Adoption of new technology

The current members of the RPBC have different rates of adoption of new technology (this may be affected by ownership structure, level of vertical integration, and other reasons. The scenario analysis will probably not model different adoption rates for technology, but will make a specific assumption which will be agreed with RPBC.



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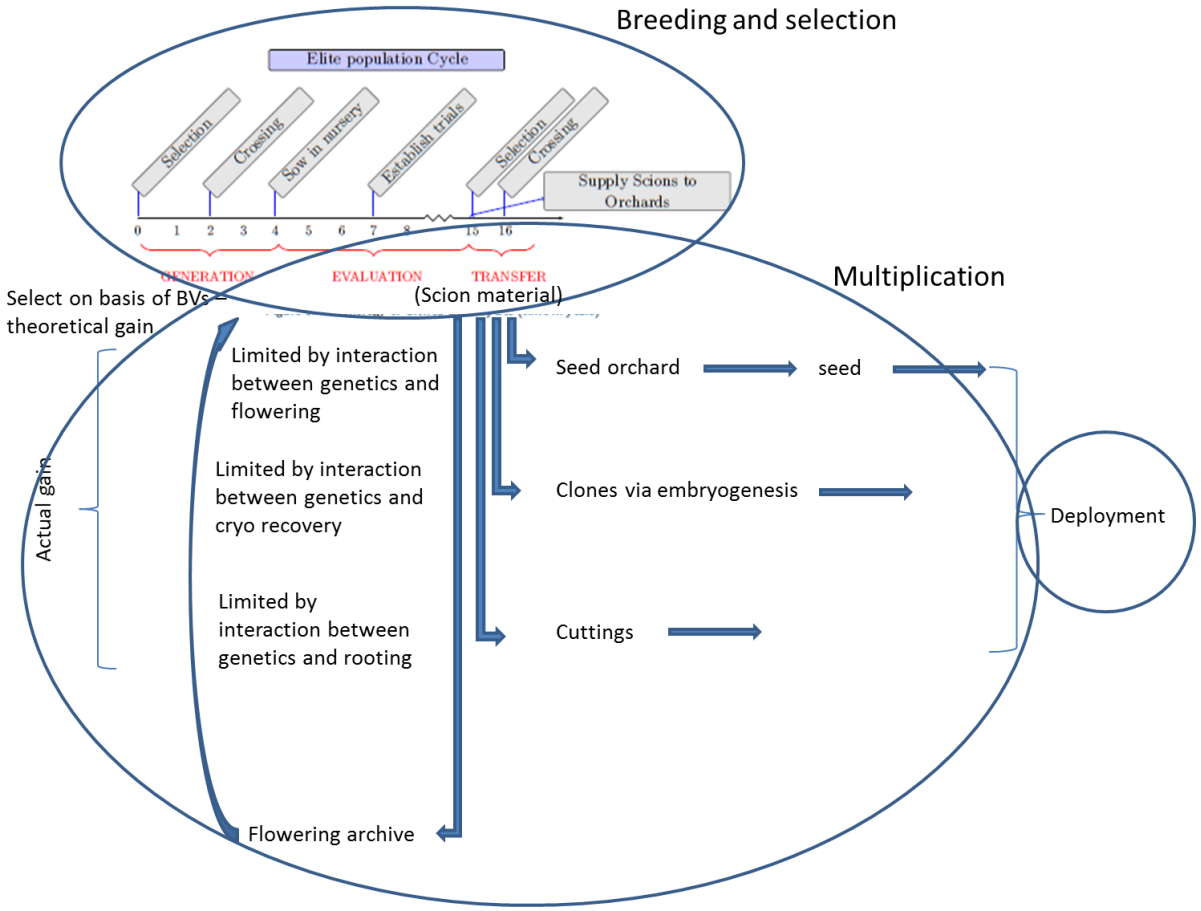
Other initiatives

- Top grafting and accelerated flowering
- Dothistroma work

5. Representation of breeding process, through to deployment



Next steps

- Clarify applications of scenario analysis and spreadsheet model
- Get an estimate of genetic gain from the latest breeding value estimates
- Information on costs, and other gaps
- Agree on alternative scenarios
- Spreadsheet model
- Present results

6. References

Jefferson, P. (2016). Proposed F17 Programme for RPBC Operations, April 2016.

Li Y. and H. Dungey (2015). Expected benefit of genomic selection over forward selection in radiata pine breeding and deployment RPBC Paper 37.

http://nz.pfolsen.com/market-info-news/wood-matters/2015/august/deployment-of-genetic-gain-in-radiata-pine-plantation

http://nz.pfolsen.com/market-info-news/wood-matters/2015/july/genetic-improvement-doesnt-happen-overnight-but-it-does-happen/