Successful varietal (clonal) forestry with radiata pine in New Zealand

Mike and Sue Carson
Varietal forestry with pines is being successfully implemented
An Example from Corn (Maize) Breeding
Varietal forestry is a new technology that is enabling radiata pine growers to:

- Reduce the rotation age by 2-3 years (or more)
- Plant at least 20% fewer trees, while still achieving a good final crop
- Reduce growth losses to foliar disease
- Create additional product options through matching genotypic and site attributes, and

This can all be achieved for less than $200 per hectare.
Genetics is the most important and most sustainable management input.

Estimates provided by Kaingaroa Timberlands-a large NZ plantation grower
Cryopreservation of embryogenic tissue is the key to cloning of pines
Somatic embryogenesis begins the multiplication process.

1. Embryo inside seed
2. Multiplied cells in tissue culture
3. New embryos develop
4. Germinating seedlings
5. Nursery plants
6. Cuttings from stoolbeds
   - Forest trials & plantations

Long-term frozen storage
improved clonal varieties are deployed as rooted cuttings
1st-generation selection is complete, and genetic diversity is being increased in the next generation

<table>
<thead>
<tr>
<th>Population</th>
<th>Number parents</th>
<th>Status Number</th>
<th>No. field-tested clones</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st generation</td>
<td>27</td>
<td>12.3</td>
<td>1,000</td>
</tr>
<tr>
<td>2nd-generation</td>
<td>91</td>
<td>30.1</td>
<td>2,000</td>
</tr>
</tbody>
</table>
We manage the gain vs diversity tradeoff when we deploy treestocks.
G X E is a benefit:cost tradeoff

- Burdon (1977) suggested “evaluating the expected genetic gain from the various options”
- Matheson and Raymond (1984) “The loss of potential gain should be used to assess the practical importance of G X E”
- Sue Carson (1999) “The small increase in predicted gain probably does not outweigh the cost of regionalisation.”
G X E in the FG Deployment Population is being managed through:

1. Broad-scale field testing
2. Selection of ‘across-the-board’ good performers
3. Validation with trials and inventory data
Clone/site/trait matching (G + E) an opportunity.
Wood density example

Clone 47

Clone 48
Wood density varies across sites—but shows little G X E. Clonal varieties can add 60kg/m³ wood density on any site.
We employ testing, validation and feedback to selection of varieties in a repeating cycle

<table>
<thead>
<tr>
<th>Population</th>
<th>Selection trials</th>
<th>Validation trials</th>
<th>Compartment stands</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZ 1\textsuperscript{st} generation</td>
<td>26 1999-2005</td>
<td>122 2001-2016</td>
<td>8+ 2007-2016</td>
</tr>
<tr>
<td>Australia 1\textsuperscript{st} generation</td>
<td>20 2003-2008</td>
<td>18 2008-2016</td>
<td>-</td>
</tr>
<tr>
<td>NZ 2\textsuperscript{nd}-generation (proposed)</td>
<td>25 2015-23</td>
<td>&gt;100 2021-30</td>
<td>&gt;100 2021-onwards</td>
</tr>
</tbody>
</table>
We use state of the art information management

• Purpose built for Trial and Production data since 2002
• Aim: all trial, pedigree, and production info at our fingertips
  – Easy and flexible calculation of genetic summaries
  – Subset and reformat data ready for analysis
  – Always up to date production inventories

Together, this accelerates the capture of genetic gain

• [www.gemnetics.com](http://www.gemnetics.com)
Genetic Testing, Selection & Validation

Row Plot Validation Trials

Single-tree plot Selection Trials

Operational plots for quantification of gain
Selection for growth rate in STP trials (Clone 17)

N.Z trials

Australian trials

Overall BLUP
Disease resistance gain validation-Rowplot trials

**Mean Dothistroma Resistance at 54 Months**

- Chart Area

<table>
<thead>
<tr>
<th>Genetic Entity</th>
<th>Resistance (%) not infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF19</td>
<td>40</td>
</tr>
<tr>
<td>CPMix</td>
<td>50</td>
</tr>
<tr>
<td>6293</td>
<td>60</td>
</tr>
<tr>
<td>7339</td>
<td>70</td>
</tr>
<tr>
<td>6365</td>
<td>80</td>
</tr>
<tr>
<td>6535</td>
<td>90</td>
</tr>
<tr>
<td>6693</td>
<td>100</td>
</tr>
<tr>
<td>6857</td>
<td>100</td>
</tr>
<tr>
<td>7193</td>
<td>100</td>
</tr>
<tr>
<td>6779</td>
<td>100</td>
</tr>
<tr>
<td>6000</td>
<td>100</td>
</tr>
<tr>
<td>6432</td>
<td>100</td>
</tr>
</tbody>
</table>
New tools will enable yield more cost-effective and representative inventories based on 100% samples. LIDAR results - heights of 7-year-old trees.
Progress is being achieved in multiple traits
Kaingaroa Forest -- 10 FG varieties

<table>
<thead>
<tr>
<th>Seedlot</th>
<th>Volume m³/tree % gain</th>
<th>% Acceptable for final crop</th>
<th>Stiffness Gpa Age 5</th>
<th>Dothistroma Resistance % Age 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP seed orchard controls –GF19</td>
<td>0.180</td>
<td>9</td>
<td>3.6</td>
<td>40</td>
</tr>
<tr>
<td>CP seed orchard controls –GF24</td>
<td>+6%</td>
<td>6</td>
<td>3.8</td>
<td>44</td>
</tr>
<tr>
<td>All 10 FG varieties</td>
<td>+28%</td>
<td>33</td>
<td>5.8</td>
<td>58</td>
</tr>
<tr>
<td>Best FG variety</td>
<td>+44%</td>
<td>44</td>
<td>7.2</td>
<td>75</td>
</tr>
</tbody>
</table>
Progress is being achieved in multiple traits
Kaingaroa Forest -- 3 FG varieties

<table>
<thead>
<tr>
<th>Seedlot</th>
<th>Volume m³/tree (% gain) Age 9</th>
<th>Stiffness Gpa Age 5</th>
<th>Density kg/m³ Age 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP seed orchard controls –GF19</td>
<td>0.218</td>
<td>5.7</td>
<td>324</td>
</tr>
<tr>
<td>CP seed orchard controls –GF24-30</td>
<td>-0.9%</td>
<td>5.9</td>
<td>318</td>
</tr>
<tr>
<td>Clone A</td>
<td>+15%</td>
<td>7.9</td>
<td>373</td>
</tr>
<tr>
<td>Clone B</td>
<td>+38%</td>
<td>8.1</td>
<td>345</td>
</tr>
<tr>
<td>Clone C</td>
<td>+17%</td>
<td>8.1</td>
<td>368</td>
</tr>
</tbody>
</table>
Gain prediction (BLUP) by year of deployment

HT BV - Top Production Clones

Year: 2007 to 2019

BV (std dev from the mean):
- Top 5
- Top 10
- GF19 controls
- GF25+ controls
- Ave 2nd Gen Parents
Carbon offsets represent an additional breeding goal.

Growth + Wood Density = Carbon

Plant and leave regime in a Bay of Plenty plantation.
Applications of both GM and GS will be best delivered through clonal varieties

• GM applications will likely;
  – be additive to gains achieved from clonal selection
  – include different traits e.g. sterility
  – require clones as a deployment platform

• GS applications will need to be;
  – effective with multiple traits
  – cheap enough for screening large numbers
  – very convincing!
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