Building Capacity for Small Exporters to Exploit ‘new breeding technologies’

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Building Capacity for Small Exporters to Exploit ‘new breeding technologies’
Australia is a food exporting nation
The Project

• Department of Agriculture, Water and the Environment (DAWE)
  - Package Assisting Small Exporters (PASE)
• Project: ‘Building Capacity for Small Exporters to Exploit ‘New Breeding Technologies’
• Forward looking project with the primary aim of enabling Australian grains and horticultural industries to be first-movers in applying new breeding technologies to crop improvement
• Provide information on new science/technologies, and on the policies and regulations that relate to them both in Australia and with our trading partners
• Additional aim: to help promote international harmonisation of regulations and reduce barriers to trade
PASE supporting partners

Package Assisting Small Exporters (PASE)
Australian Seed Federation
CBH Group
RAYI Corporation
Murdoch University, Perth
Edstar Genetics Pty Ltd
Council for Grain Grower Organisations Ltd
The Department of Primary Industries and Regional Development, Government of Western Australia
Green Blueprint Pty Ltd
CropLife Australia
### Australian Wheat Exports (average 2016-2020)

Top 10 countries, 70-80% of exports

<table>
<thead>
<tr>
<th>Country</th>
<th>Amount (mmt)</th>
<th>Value (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>2.5</td>
<td>739</td>
</tr>
<tr>
<td>Philippines</td>
<td>1.5</td>
<td>465</td>
</tr>
<tr>
<td>Vietnam</td>
<td>1.3</td>
<td>404</td>
</tr>
<tr>
<td>Korea</td>
<td>1.1</td>
<td>361</td>
</tr>
<tr>
<td>China</td>
<td>1.1</td>
<td>346</td>
</tr>
<tr>
<td>Japan</td>
<td>0.9</td>
<td>335</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.7</td>
<td>225</td>
</tr>
<tr>
<td>India</td>
<td>0.7</td>
<td>346</td>
</tr>
<tr>
<td>Yemen</td>
<td>0.6</td>
<td>200</td>
</tr>
<tr>
<td>New Zealand</td>
<td>0.5</td>
<td>158</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>14.4</strong></td>
<td><strong>4,600</strong></td>
</tr>
<tr>
<td>(Domestic use)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: AEGIC
## Australian barley exports (average 2016-2020)

(Latest data not available)

<table>
<thead>
<tr>
<th>Country</th>
<th>Amount (mt)</th>
<th>Value (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>3,900</td>
<td>1,100,00</td>
</tr>
<tr>
<td>Japan</td>
<td>817</td>
<td>241</td>
</tr>
<tr>
<td>Thailand</td>
<td>250</td>
<td>78</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>215</td>
<td>49</td>
</tr>
<tr>
<td>UAE</td>
<td>122</td>
<td>32</td>
</tr>
<tr>
<td>Vietnam</td>
<td>120</td>
<td>41</td>
</tr>
<tr>
<td>Kuwait</td>
<td>103</td>
<td>24</td>
</tr>
<tr>
<td>Qatar</td>
<td>44</td>
<td>14</td>
</tr>
<tr>
<td>Taiwan</td>
<td>38</td>
<td>11</td>
</tr>
<tr>
<td>Korea</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,700</strong></td>
<td><strong>1,600</strong></td>
</tr>
<tr>
<td>Domestic use</td>
<td>3,200</td>
<td></td>
</tr>
</tbody>
</table>
Canola exports

Includes GM canola

Major export markets for

Australian canola

Total exports  $1.56 billion  2.7 million tonnes

Sources: Export data: ABS (average 2016-18)
Domestic use data: ABARES (average 2016-18)
$ = AUD
Australian fruit and vegetable exports

Asia 77%

(Source Hort Innovation 2019-2020)
But, Australia is an ancient and weathered continent.

Challenges to crop production:
- Often water limited
- Soils often nutrient poor
- Drought and heat stress
- Prevention of incursions of new pests and diseases

Need to apply the best science and technology to improve yields and quality, including gene-editing.
CONVENTIONAL AND NEW BREEDING TECHNOLOGIES

Conventional breeding
- Current cultivar
- Wild relative
- Beneficial gene
- Unwanted genes
- X
- F1 Generation
- Current cultivar
- X
- F2 Generation
- Many Backcrosses
- New cultivar

Transgenesis
- Gene from unrelated organism
- Beneficial gene
- Unwanted genes
- Transfer into plasmid in Agrobacterium
- Genes required for transfer
- New cultivar

Cisgenesis
- Gene from related species
- Beneficial gene
- Unwanted genes
- Transfer into plasmid in Agrobacterium
- Genes required for transfer
- New cultivar

Intragenesis
- Gene/component of gene from same species
- Beneficial gene
- Unwanted genes
- Transfer into plasmid in Agrobacterium
- Genes required for transfer
- New cultivar

Gene-editing (SDN-1)
- Current cultivar
- CRISPR/Cas9
- New cultivar

Genetically modified (GM) or Biotech Crops
Gene-edited (GE) crops
A comparison of breeding technologies

Gao, Genome engineering for crop improvement and future agriculture, Cell (2021), https://doi.org/10.1016/j.cell.2021.01.005
Gene-editing technologies

- Zinc finger nucleases (ZFNs)
- Transcription activator-like effector nucleases (TALENs)
- Clustered regularly interspaced short palindromic repeat (CRISPR/Cas9)

These systems are based on the production and repair of double stranded breaks (DSBs) via
- non homologous end joining (NHEJ)
- homology-directed repair (HDR)
CRISPR-Cas9

CRISPR-Cas9 targeted double-strand DNA break

**SDN-1** – non-homologous end joining (NHEJ) - natural repair mechanism, small nucleotide deletions, additions or substitutions

**SDN-2** – in the presence of an oligonucleotide template with ends homologous to each side of the double-stranded break, homologous end joining (HEJ or HDR) can occur, such that one or more bases can be included in the repaired sequence

**SDN-3** – as for SDN-2, but with a longer DNA insert, for example up to a full gene expression cassette

Other types of gene editing

- Sequence deletion/insertion (SDN-1) or replacement
- DNA free editing – Cas9 plus guide RNA (RNPs)
- Base substitution
- Prime editing
- Gene segment deletion
- Gene expression changes
- Epigenetic changes
The power SDN-1 gene editing for crop improvement


Left – pre-harvest sprouting, Right – edited to prevent pre-harvest sprouting (heads equally treated with water). Pre-harvest sprouting reduces grain quality and value.
Gene-edited potatoes without external DNA to improve the dietary quality – Sadia Iqbal

- GE targeting starch branching enzymes
- Amylose–resistant starch increased from 20% to 43% in RNP edited lines
- Slower glucose release helps reduce Type II diabetes, improves bowel health
Living organisms vs food products (Australia)

• **GM Living organisms** (GMOs or LMOs) - regulated in Australia by the *Gene Technology Act 2000* and administered by the Office of the Gene Technology Regulator (OGTR) – **SDN-1 de-regulated in Australia**

• **Food Products** are regulated in Australia - governed by *the Australia New Zealand Food Standards Code* and administered by Food Standards Australia New Zealand (FSANZ)
  - Food derived using new breeding techniques under review, public comment mid 2021
  - FSANZ will consider applications for commercial GE food products
Current status of regulation of GE crops

- GE SDN-1 crops deregulated
- Ongoing discussion with recommendation to deregulate GE SDN-1 crops (progressing)
- GE crops regulated
GE regulations – Argentina, a case study

• Five years experience
• GE products: much faster development from bench to market than GMOs

Developer profiles: GM vs GE products

GMO products deregulated (20 years)

- Foreign multinational: 8%
- Foreign SMEs: 2%
- Local companies & Public Research: 90%

Gene-edited products deregulated (5 years)

- Foreign multinational: 9%
- Foreign SMEs: 32%
- Local companies & Public Research: 59%

- Mainly public institutions, public research and SMEs
- More diversified traits and plant species

Path-to-market, SDN-1 products (Australia, SE Asia)

SDN-1 RNP products

SDN-1 products from transgenic selected lines captured by GM trigger

Treat as ‘conventionally’ bred products

Null segregants of SDN-1 products
The future

• FSANZ to accept SDN-1 gene-edited food (no external DNA) as non-GM
• No additional tier of regulations for gene-edited crops/products
  i.e. same treatment for SDN-1 crops/food as conventional breeding
• Public acceptance of GE crops/foods
• Use the term ‘gene-editing’ rather than ‘genome-editing’
• Counter EU influence on GE legislation
• Provide industry and government with updates and quality briefings
• Promote harmonisation of international regulations for GE crops/produce
• ‘Paradoxically, the main challenge facing genome editing is not scientific, but political’

• ‘It defies logic why introducing one single mutation in a specific genomic locus with extreme precision using Cas effectors is subject to strict regulations in some countries, while introducing thousands of simultaneous mutations in a completely uncontrolled manner by chemical/physical random mutagenesis methods is not regulated’

Jose Botella UQ, Brisbane, Australia (Zhan et al 2021, Genome editing for plant research and crop improvement, J Integrative Plant Biol https://doi.org/10.1111/jipb.13063)
Quote from a recent ISAAA webinar

• ‘Feeding the world is not a scientific problem – it’s a regulatory problem’

• Professor Jim Whelan, LaTrobe University, Melbourne, Australia
Acknowledgements: ISAAA; Department of Agriculture, Water and the Environment (DAWE), Package Assisting Small Exporters (PASE)