Genetic improvement of productivity and health in Honeybees
– scope and developments in Australia

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Key Points:

1. What is genetic improvement, and why is it important?
2. What is needed to achieve it?
3. What’s in place?
4. Scope for genomics
5. Challenges
Genetic improvement makes a difference – Lamb in Australia:

**Real Gross Value of Production ($m)**

Lamb Industry Real On-Farm Income shows 3 phases:
- a) pre-1991 - real income declining by $17m per year
- b) 1990’s - real income growing by $19m per year
- c) 2000’s - real income growing by $220m per year

Genetic improvement makes a difference – Lamb in Australia:

**Industry Gross Value of Production v Sire Team Genetic Merit**

Vertical scale:
- GVP of Industry, & genetic merit of sires working in industry

Introduction of LAMBPLAN
What is genetic improvement, and why is it important?

- Genetic differences among queens generate differences in hive performance:
  - In honey production
  - In health and hygiene traits
  - In temperament
- Using the queens with the best genes each generation means better and better genes over time
- Without genetic improvement
  - Completely dependent on rising price of honey to be viable
  - Completely exposed to disease risk
Which Queen has the best genes?

- Kg Honey: 45 kg
- Health & Hygiene: 49 kg
- Over-wintering: 40 kg
- 52 kg
Which Queen has the best genes?

Daughter average = 47 kg

Daughter average = 46 kg
What is needed:

- Defined breeding goal:
  - What traits are important?
  - How important is each one?
- Recording:
  - Need data (consistently recorded) for each important trait
  - Need pedigree information (can be via genotype)
- Genetic (genomic) evaluation
  - Analysis to estimate genetic merit for recorded traits
- Selection:
  - Can use tools to jointly manage selection and inbreeding
- Size of population
  - Number of parents in recorded population is ideally 500-1,000 or more
  - This implies total recorded needs to be 5,000 or more (in bees, that means 5,000 recorded and pedigreed queens/hives per year)

R&D (AgriFutures-funded):

- Stage 1:
  - Outline principles
  - Analyse available data (Horners’, Queen Bee assessment program) – BLUP method
  - Benefit-cost estimation
- Stage 2:
  - Extend analysis to larger data set(s)
  - Genotype queens if available
  - Include genotypes in the BLUP evaluation
  - Develop recommendations for industry-wide application
R&D Progress 1:

- Dataset provided by the Horner family (Mudgee):
  - Only very small dataset for first analysis

- 4 categorical traits (ie scored 1-5) over 6 years – 3 cycles of breeding and production
  - CB: chalk brood, no variation observed
  - W: general rating of the “value” or work of the hive
  - Be: bee size
  - Br: brood viability

- Approximately 200 hives recorded within 1 family line for each trait

Results: genetic parameters

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability</th>
</tr>
</thead>
<tbody>
<tr>
<td>W – hive work rating</td>
<td>20%</td>
</tr>
<tr>
<td>Be – bee size</td>
<td>38%</td>
</tr>
<tr>
<td>Br – brood viability</td>
<td>40%</td>
</tr>
</tbody>
</table>

For all 3 traits, these values mean that the Horner’s could use their scores as a basis of selection, to improve the merit of their bees for these traits.

Estimates of genetic merit can be calculated using the heritability – and these estimates of genetic merit (EBVs) will make selection more effective.
Results: Example EBVs

<table>
<thead>
<tr>
<th>queen</th>
<th>EBV for W</th>
<th>EBV for Be</th>
<th>EBV for Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.01</td>
<td>0.19</td>
<td>-0.37</td>
</tr>
<tr>
<td>C1a</td>
<td>0.27</td>
<td>1.46</td>
<td>1.20</td>
</tr>
<tr>
<td>C1b</td>
<td>0.33</td>
<td>-0.05</td>
<td>-0.06</td>
</tr>
<tr>
<td>C2c</td>
<td>0.41</td>
<td>0.41</td>
<td>0.44</td>
</tr>
</tbody>
</table>

C1 is genetically below average for Brood Viability (Br)
C1a is genetically above average for Bee size (Be) and Brood Viability
C2c is genetically above average for Work Rating (W)

R&D Progress 2:

• Dataset provided by the Lindsay Bourke
  • Australian Queen Breeding Program

• A number of lines providing queens in each of several years

• Data analysed so far – weight of honey per season per hive (kg), from 134 recorded hives across 3 production seasons
R&D Progress 3:

- New data from Horners:
  - complete production season including individual hive weight of honey
  - Data on approx. 600 hives, including pedigree

- Genotyping program planned

- Evaluating genomics
  - Ability to select earlier
  - Turn over generations faster
  - BUT very data dependent ie LOTS of recording

Data from “Hygienic Behaviour in the AQBBP, June 2015 Update”
Beescientifics
Correlation between rph score and honey production ~ 0
Challenges and opportunities:

• Traits:
  • Honey production, hygiene traits, pollination traits, temperament
  • All heritable – can be improved simultaneously

• Opportunities:
  • Selection to improve all important traits
  • Value in industry-research continuous partnership
  • Value in wide-scale phenotyping in large breeding programs
  • International collaboration – data sharing (phenotypes and genotypes)

• Challenges:
  • Number of recorded queens
  • Number of viable (size) breeding programs
  • Recording of Varroa (and other diseases) incidence

New R&D collaborating with industry:

Partner co-investment from Australia - would enable
a) Increased scale of core (more queens, wider sample of Oz gene pool)
b) Satellite site recording
c) Additional traits recorded

Domestic R&D Collaboration:
a) Understanding the genetic basis of traits
b) Additional health traits
c) Assistance with genotyping?

Core:
• Recorded breeding program c 200 queens at Tocal, including genomic methods

Outreach (community engagement):
a) Teaching and training
b) Recording in smaller programs
c) Flow of genetic material if scale is large enough

International R&D collaboration:
a) Knowledge sharing (traits and recording methods, funding/partnership models)
b) Data sharing – genotypes enabling estimation of genetic relationships between populations
c) Potential exchange of genetic material for recording

Core:
Expected outcomes:

- Increased scale of recording ie number of pedigreed hives recorded per year
- Potentially more traits recorded, including for honey production, pollination traits and health
- Wider engagement with industry (pollinators, honey) would increase resilience via human capacity, and potentially increase even further the recorded population (this is the absolute core goal)
- Subject to quarantine, ability to test Australian material overseas, and overseas material here, even if only via exchange of genotypes, would be advantageous:
  - Would include scoping methods to select for Varroa resistance using both domestic and exotic genetics
  - Would include drawing on elite genetic material from overseas, for potential infusion into Australian genetic improvement program

Challenges:

- Size of program:
  - At least 500-1,000 recorded hives per year needed

- Time-scale:
  - Think of this as 5+5, +5, ...
  - Genetics is a continuous improvement, not a once-off

- Coordination:
  - Sectors working together is essential to ensure right focus of selection, and address market failure (returns re-invested in genetic improvement)
Vision:

• Continuous genetic improvement is:
  • Practical
  • Valuable – extra $250m each year is possible
  • Relatively straightforward if resources are allocated and coordinated
  • Essential to meet cost-price squeeze
  • Essential to ensure resilience to shocks

• Home-grown solution infusing best knowledge world-wide

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