Marker assisted Selection and Conservation

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Outline

- Marker Assisted Selection
- Reproductive technologies
- Their joint effect on breeding programs
- Application in developing countries

Using gene testing in livestock

- Parentage testing
- Marker Assisted Selection
- Marker Assisted Introgression
- Marker Assisted Conservation
- Development of transgenics

Selection for Quantitative Traits
polygenes and major genes

<table>
<thead>
<tr>
<th>Genome</th>
<th>Genetic</th>
<th>Environment</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+16</td>
<td>-10</td>
<td>+6</td>
</tr>
<tr>
<td>B</td>
<td>+5</td>
<td>+9</td>
<td>+14</td>
</tr>
<tr>
<td>C</td>
<td>-10</td>
<td>+20</td>
<td>+10</td>
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polygenic QTL
The distribution of QTL effects

- Maybe 5-10 large QTL explain the majority of the genetic variance.
- Mapping experiments should be able to detect QTL as small as 0.2 \( \sigma \)?

Many small QTL, few of large effect

Indirect genetic markers

Can select among offspring ...

How important is the marker information?

depends on:

Size of QTL effect
Frequency of QTL alleles
Probability that an M-animal has indeed a Q-allele

Marker assisted selection

How important is the marker information?

depends on:

Size of QTL effect
Frequency of QTL alleles
Probability that an M-animal has indeed a Q-allele

Direct Markers

- No need for performance recording
- No extensive family testing
- Not very many examples (except the 'obvious')
- Not always guaranteed

Linked Markers

- Need for performance recording within family
- Need for genotyping (2 generations)
- Linkage phase differs between families
- Need heterozygous parent (sire)
  - for marker genotype
  - for QTL genotype
‘Direct Markers’ in Livestock

• Genestar Marbling commercialized
• Genestar Tenderness commercialized
• Booroola Gene
• Inverdale Gene
• Callypyge Gene
• Double Muscling Gene
• DGAT Milk Fat%

Normal Genetic Evaluation

• Performance information
• Pedigree information

Genetic Evaluation with QTL

• Performance information
• Pedigree information
• Marker information

Effect of MAS on rate of genetic gain

<table>
<thead>
<tr>
<th>Selection after recording</th>
<th>Selection before recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen 1</td>
<td>Gen 5</td>
</tr>
<tr>
<td>Gen 1</td>
<td>Gen 5</td>
</tr>
<tr>
<td>h² = 0.11, V_QTL = 0.33</td>
<td>+21% +6% +45% +23%</td>
</tr>
<tr>
<td>h² = 0.27, V_QTL = 0.33</td>
<td>+9% +2.3% +38% +15%</td>
</tr>
<tr>
<td>h² = 0.27, V_QTL = 0.11</td>
<td>+1.3% +1.3% +8% +6%</td>
</tr>
</tbody>
</table>

Meuwissen and Goddard, 1996

Conditions that are good for MAS

• Where heritability is low
  – e.g. fecundity
• Where the trait is sex limited.
  – e.g. milk production, fecundity
• Trait not measurable before first selection
  – e.g. milk production, longevity.
  – Most traits when using juvenile selection.
• Trait is difficult to measure.
  – e.g. disease resistance, recessive conditions, pigmented fibres, carcass traits

Short and long term effects of Marker Assisted Selection

- Short-term benefits 2% to 60%
Discussion on simulation studies

- They assume response in one trait
  - Need whole breeding objective context
- They assume abundant recording of pedigree and gene testing
  - Will we have cheap DNA testing available?
  - We can apply strategies to save on genotyping.
  - Some degree of phase-testing is needed
- They assume gene effects are known
  - Need monitoring by measurement
  - Effect of background genes, environment, gene action?

Conclusion on MAS

- Effect on extra gain in breeding programs maybe limited to cases where
  - There are special genes with large effect
    - Disease resistance, Booroola, etc.
  - Breeding objective traits are difficult to measure
    - Some 'retrospective measurement is needed'
  - When reproductive technologies are used

Marker Assisted Conservation

Keep genetic variation (within/between breeds)

Possibly keep some ‘merit’

Can optimize these

Measuring genetic variation

‘neutral’ genetic variation based on genetic markers, randomly scattered across the genome
determine allele frequencies

<table>
<thead>
<tr>
<th>Marker</th>
<th>Breed A</th>
<th>Breed B</th>
<th>Breed C</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.9</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>M2</td>
<td>0.85</td>
<td>0.56</td>
<td>0.56</td>
</tr>
<tr>
<td>M3</td>
<td>0.1</td>
<td>0.63</td>
<td>0.63</td>
</tr>
<tr>
<td>M4</td>
<td>0.02</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>Var</td>
<td>0.164</td>
<td>0.425</td>
<td></td>
</tr>
</tbody>
</table>

Reproductive technologies

- Reproductive boosting
  - Artificial insemination: **AI**
  - Multiple Ovulation and Embryo Transfer: **MOET**
  - Oocyte Pickup
  - Juvenile In Vitro Embryo Transfer, **JIVET**
- Sexing of semen and embryos
- Cloning
- Whizzy Genetics - breeding in a test-tube

Reproductive technologies

- Increases selection intensities
- Increases accuracy of EBVs
- Decreases generation intervals
- Increases inbreeding
Artificial Insemination

- More intensive use of best sires
- Use of bulls from other regions/populations
- Establish links between herds
- Progeny testing
- More rapid dissemination of superior genes

Multiple Ovulation & Embryo Transfer - MOET

- More intensive use of best cows
  - "turns a cow into a sow"
- Use of cows across regions

Adult dairy MOET scheme

- More offspring of top cow after testing it

Juvenile dairy MOET scheme

- More offspring of top cow before testing it
  - Select based on parent average

Oocyte pickup and In Vitro Fertilization

- Obtain oocytes before sexual maturity
- Selection based on parent average
- Less accuracy but much lower generation interval

Australia 1999: 32 lambs born from a 6 mo old ewe

Juvenile beef MOET/JIVET

- Generation interval 15 months
- Generation interval 15 months
Even more juvenile beef MOET/JIVET

Between versus within family selection

Genetic gain versus genetic diversity

The balance between increased merit and inbreeding

Between versus within family selection

MAS combined with reproductive technologies

- Sustainable breeding programs require optimal selection balancing genetic gain and genetic diversity
- Potential short term benefits from reproductive technologies are inhibited by the need to maintain diversity

- Genotype testing provides within family information
- Exploiting this variation allows genetic gain without jeopardizing inbreeding
MAS combined with reproductive technologies

Additional response of MAS over non-MAS under optimal selection

<table>
<thead>
<tr>
<th>Select.Round</th>
<th>Adult Schemes</th>
<th>Juvenile Schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AI</td>
<td>MOET</td>
</tr>
<tr>
<td>1</td>
<td>7.8</td>
<td>7.1</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>-3.6</td>
</tr>
<tr>
<td>10</td>
<td>-3.3</td>
<td>-8.7</td>
</tr>
</tbody>
</table>

Adult Schemes: Own performance is known at selection
Juvenile Schemes: Own performance is not known at selection

**Conclusion:** MAS mostly beneficial in juvenile selection schemes

### Sexing semen or embryos

- Ability to sex semen makes little difference to rates of genetic gain:
  - Usually less than 5% extra genetic gains
  - About 10% in dairy (sex limited, progeny testing)

- However, effect on commercial production efficiency can be dramatic:
  - e.g. Using “male semen” from terminal sires
  - Gene testing can help target outcomes

### Cloning in animals

- Impact on rate of genetic improvement is minimal!
- Effects dissemination of good genetics

Today’s elite clones are expected to be as good as normal animals born in just over 10 years’ time.

Gene testing helps in clone testing and in targeting outcomes
### Future technologies

- MAS in the test tube?
- There will be a continued need for phenotypic testing
- May go toward the plant breeding practices
- IP implications?

### Conclusions

- Marker assisted selection can have some benefit in quantitative trait selection
  - But genetic improvement should be driven by trait and pedigree recording
- Reproductive rates & gene technology are synergistic
- Main application of gene technologies for ‘special cases’
  - Large and special gene effects, disease resistance
- Gene testing most useful in selection across breeds
  - Introgression / genetic diversity