Optimizing Breeding Program Design

Marker Assisted Selection

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Effect of new technologies

DNA technologies

» Parentage testing

» Marker Assisted Selection

» Marker Assisted Introgression
Selection for Quantitative Traits
polygenes and major genes

True situation

Genome: A -2 +4 +2 +1 +10
B +2 0 -2 +1 +3
C -2 0 -2 -1 -4

Effects
Genetic Environment Phenotype
+16 -10 +6
+5 +9 +14
-10 +20 +10

Observed situation

Phenotype
+6
+14
+10
How many genes?

- Maybe 5-10 large QTL explain the majority of the genetic variance.
- Mapping experiments should be able to detect these large QTL.

Many small genes with small effect, few with large effect.
Marker Assisted Selection

How it works

• Indirect markers

• Direct markers
Indirect genetic markers

A Ram:

His semen:
Indirect genetic markers

Can select among offspring ...

‘recombinants’
Indirect genetic markers

Phase can be opposite
We like to find the actual mutations!

A - always circle, always good

B - always triangle, always bad
Selecting for QTL genotypes

• Increase desired allele frequency at QTL

• Introgressing them into lines

• In addition to polygenic selection
Normal Genetic Evaluation

- Performance information
- Pedigree information

BLUP-EBV
average effect
Genetic Evaluation with QTL

- Performance information
- Pedigree information
- Marker information

BLUP-EBV
average effect

QTL genotype
- probability
- effect

Overall EBV
Effect of MAS on rate of genetic gain

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Meuwissen and Goddard, 1996
# Effect of MAS on rate of genetic gain

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Conditions that are good for Marker Assisted Selection

• Where heritability is low
  – e.g. fertility, nr. of lambs

• Where the trait is sex limited.
  – e.g. maternal effects, fertility, nr. of lambs

• Trait not measurable before first selection
  – e.g. longevity, micron blowout, fertility.
  – Most traits when using juvenile selection.

• Trait is difficult to measure.
  – e.g. disease resistance, recessive conditions, feed efficiency pigmented fibres, carcass traits
Discussion on simulation studies

• They assume response in one trait
  – Need whole breeding objective context
  – More a matter of *shifting response between traits* rather than increasing overall response
Discussion on simulation studies

• They assume response in one trait
  – Need whole breeding objective context
  – More a matter of *shifting response between traits* rather than increasing overall response

• 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
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
    - Carcass Traits, Feed Efficiency, Disease
  - When reproductive technologies are used
Juvenile sheep MOET/JIVET

More offspring of top ewe *before* testing it

Select based on parent average
No own information (performance or genotype):
Selection based on parent average
More between-family selection - more inbreeding
Genetic gain versus genetic diversity

• 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
The balance between increased merit and inbreeding
Between versus within family selection

Own information (performance or genotype):
More variation within families
More within-family selection – less inbreeding
MAS combined with reproductive technologies

- Genotype testing provides within family information

- Exploiting this variation allows early selection and genetic gain without jeopardizing inbreeding
Modelling Genotype Information in Beef Cattle Selection for RFI

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Australian Beef Breeding Objectives

• Growth
• Reproduction
• Feed Efficiency - RFI
• Carcass quality characteristics
  • MARBLE SCORE
  • TENDERNESS/PALATABILITY
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Residual Feed Intake (RFI)

Aim:
To model the change in response due to RFI QTL and model different selection strategies

• Residual feed intake – measure of the efficiency of an animal
• Heritable (0.39)
• Expensive to measure
  – 71 day feeding trial
Current Genetic Evaluation

Pedigree

Phenotypes

Progeny

Phenotypes

Evaluation

EBV

Accurate Evaluation of Genetic Merit
Genotype Notification

Pedigree

Phenotypes

Progeny

Evaluation

EBV

Genotype

Accurate Evaluation of Genetic Merit

Phenotypes

Phenotypes

Phenotypes
Method: Pseudo-BLUP Selection Index

- Own Phenotype
- Sire Information
- Dam Information
- Half-sib Information
- Progeny Information

Multi-trait Selection Index

Predict BLUP Selection Response
Method: Pseudo-BLUP
Selection Index

- Own Phenotype
- Sire Information
- Half-sib Information
- Progeny Information
- Dam Information

Multi-trait Selection Index

- Weight traits: BW, 200d, 400d and 600d weight
- Fertility traits: Days calving, calving difficulty and SS
- Scan traits: FD 12th/13th rib, P8, EMA and IMF%

Predict BLUP Selection Response
Method: Pseudo-BLUP

Selection Index

- Own Phenotype
- Sire Information
- Half-sib Information
- Progeny Information
- Dam Information

Multi-trait Selection Index

QTL

Predict BLUP Selection Response with QTL
Population Structure – Selection from 2 years

Age Structure (%) vs. Age Classes (Yrs)

- Non-MAS
- MAS

Progeny Carcass Info
Change in Gene Frequency

Male and Female Genotyping

Available for selection from 1 Year of Age

Male Only Genotyping
Increase in Annual Selection Response – Large QTL

Increase in Selection Response (%)

Year

- Males and Females (Year 1)
- Males Only (Year 1)
- Males and Females (Year 2)
- Males Only (Year 2)
Take home message

• Genotyping benefits depend on:
  – Gene inheritance
  – Genotype costs
  – Size of the gene effect

• As RFI is moderately heritable QTL the value of marker is decreased considerably if early selection not used.

• Optimisation of age structure is important