MULTIBREED EVALUATION: THEORY AND APPLICATION

M. A. Elzo
University of Florida

Multibreed Population
Population composed of purebred and crossbred animals that interbreed

Complete	Incomplete

Numbers of Sires

<table>
<thead>
<tr>
<th>BGS</th>
<th>A</th>
<th>.75A</th>
<th>.50A</th>
<th>.25A</th>
<th>B</th>
<th>Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>.75A</td>
<td>13</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>.50A</td>
<td>16</td>
<td>11</td>
<td>9</td>
<td>11</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>.25A</td>
<td>11</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>13</td>
<td>11</td>
<td>9</td>
<td>11</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Br</td>
<td>10</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>16</td>
</tr>
</tbody>
</table>

Numbers of Dams

<table>
<thead>
<tr>
<th>BGS</th>
<th>A</th>
<th>.75A</th>
<th>.50A</th>
<th>.25A</th>
<th>B</th>
<th>Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>69</td>
<td>24</td>
<td>22</td>
<td>28</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>.75A</td>
<td>13</td>
<td>20</td>
<td>23</td>
<td>22</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>.50A</td>
<td>50</td>
<td>36</td>
<td>38</td>
<td>47</td>
<td>54</td>
<td>50</td>
</tr>
<tr>
<td>.25A</td>
<td>21</td>
<td>16</td>
<td>23</td>
<td>16</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>B</td>
<td>45</td>
<td>40</td>
<td>36</td>
<td>43</td>
<td>107</td>
<td>44</td>
</tr>
<tr>
<td>Br</td>
<td>21</td>
<td>15</td>
<td>19</td>
<td>23</td>
<td>23</td>
<td>66</td>
</tr>
</tbody>
</table>

Numbers of Calves

<table>
<thead>
<tr>
<th>BGS</th>
<th>A</th>
<th>.75A</th>
<th>.50A</th>
<th>.25A</th>
<th>B</th>
<th>Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>117</td>
<td>25</td>
<td>22</td>
<td>28</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>.75A</td>
<td>29</td>
<td>21</td>
<td>25</td>
<td>24</td>
<td>27</td>
<td>32</td>
</tr>
<tr>
<td>.50A</td>
<td>62</td>
<td>41</td>
<td>46</td>
<td>57</td>
<td>65</td>
<td>66</td>
</tr>
<tr>
<td>.25A</td>
<td>24</td>
<td>20</td>
<td>24</td>
<td>19</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>B</td>
<td>53</td>
<td>44</td>
<td>39</td>
<td>49</td>
<td>195</td>
<td>50</td>
</tr>
<tr>
<td>Br</td>
<td>23</td>
<td>16</td>
<td>19</td>
<td>26</td>
<td>25</td>
<td>106</td>
</tr>
</tbody>
</table>
### Number of Sires

<table>
<thead>
<tr>
<th></th>
<th>BGS</th>
<th>BGD</th>
<th>Sanmar</th>
<th>½S½B</th>
<th>Brahman</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
</tbody>
</table>

### Number of Dams

<table>
<thead>
<tr>
<th></th>
<th>BGS</th>
<th>BGD</th>
<th>Sanmar</th>
<th>½S½B</th>
<th>Brahman</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
</tbody>
</table>

### Number of Calves

<table>
<thead>
<tr>
<th></th>
<th>BGS</th>
<th>BGD</th>
<th>Sanmar</th>
<th>½S½B</th>
<th>Brahman</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BGD</td>
<td>Sanmar</td>
<td>½S½B</td>
<td>Brahman</td>
<td></td>
</tr>
</tbody>
</table>

### Genetic and Environmental Effects

- **Additive**
- **Nonadditive**
- **Direct**
- **Maternal**
- **Intrabreed**
- **Interbreed**

### Chart of Genetic Effects

- **Additive**
- **Nonadditive**
- **Direct**
- **Maternal**
- **Intrabreed**
- **Interbreed**
Chart of Environmental Effects

- **Additive (Direct + Maternal)**
  - Intrabreed
  - Interbreed

- **Nonadditive (Direct + Maternal)**
  - Intrabreed
  - Interbreed

Modeling Strategies Considered

- All Subclass Effects
- All Regression Effects
- A Combination of Subclass and Regression Effects

Actual Modeling Strategy

<table>
<thead>
<tr>
<th>Effects</th>
<th>Prediction</th>
<th>Covariance Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additive</td>
<td>Subclass</td>
<td>Regression</td>
</tr>
<tr>
<td>Nonadditive</td>
<td>Regression</td>
<td>Regression</td>
</tr>
<tr>
<td>Environmental</td>
<td>Subclass</td>
<td>Regression</td>
</tr>
</tbody>
</table>

Additive Regression Effects

- Intra and interbreed additive effects from all parental breeds
- 2 Breeds
- Intrabreed (A)
- Intrabreed (B)
- Interbreed (m_A-m_B)

Nonadditive Regression Effects

- Intra and interbreed interaction effects between alleles of all parental breeds
- 2 Breeds
- Intrabreed A/A
- Intrabreed B/B
- Interbreed A/B, B/A

Multibreed Model

- Record
- Multibreed Contemporary Group
- Age Dam-Sex Calf-Dam Group
- Sire Group and Mgs Group
  - (A, N, D, M)
- Sire and Mgs
  - (A, N, D, M)
- Residual
Multibreed Contemporary Groups

- Sex
- ≈ Age
- ≈ Environment

Connectedness

<table>
<thead>
<tr>
<th>Contemp Group</th>
<th>Group</th>
<th>Group</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Age of Dam

Age of Dam x Sex of Calf x Breed Group of Dam Subclass

Regression of Age of Dam (within Sex of Calf) on their fraction of Breed A

Additive Genetic Groups

- Group of Sire (Direct, Maternal)
  - Intrabreed A
  - Intrabreed B
  - Interbreed (mA-mB)

Subclass Groups (Accumulated)
Regression Groups (Deviated from A)

Nonadditive Genetic Groups

- Group of Sire x Group of Dam (Direct, Maternal)
  - Interbreed A/B, B/A

Regression Groups (Deviated from A/A and B/B)

Additive Genetic Deviations

- Sire (Direct, Maternal)
  - Intrabreed A
  - Intrabreed B
  - Interbreed (mA-mB)

Multibreed Additive Genetic Covariances
Nonadditive Genetic Deviations

- Sire x Breed Group of Dam (Direct, Maternal)
- Interbreed A/B, B/A
- Interbreed Nonadditive Genetic Covariances

Multibreed Genetic Predictions

- MEPD
- Additive (A)
  - Direct (D)
  - Maternal (M)
- Nonadditive (N)
  - Direct (D)
  - Maternal (M)
- Total (T=A+N)
  - Direct (D)
  - Maternal (M)

Covariance Estimation Procedure

- Multibreed REML, GEM Algorithm (MREM/LEM)
- Sire-Mgs Model
- Cholesky Elements of Base Cov Matrices
- Multibreed Cov Matrices
- Base Cov Matrices
- Variance Ratios & Correlations

Multibreed Herds

  - Growth Traits (Preweaning)
  - Carcass Traits
  - Growth Traits (Pre & Postweaning)
- Sanmartinero-Brahman - La Libertad (1999)
  - Growth Traits (Pre & Postweaning)

Traits

- Birth Weight
- Weaning Weight
- Postweaning Gain
- Carcass Weight
- Longis. Muscle Area
- Fat over LMA
- KPH Fat
- Marbling
- W-B Shear Force

Objectives

- Estimation of Genetic Parameters
- Prediction of Genetic Values
Model
- Record

Contemporary Group and Age of Dam
- Sire Group and Mgs Group
  (A, N, D, M)

Sire and Mgs
(A, N, D, M)
- Residual

Base Covariances
(2 Breeds & 2 Traits)

Additive Genetic
- 10 Intrabreed Angus (D,M)
- 10 Intrabreed Brahman (D,M)
- 10 Interbreed AB (D,M)

Nonadditive Genetic
- 10 Interbreed AB (D,M)

Environmental
- 3 Intrabreed Angus (D&M)
- 3 Intrabreed Brahman (D&M)
- 3 Interbreed AB (D&M)

Genetic Ratios
- heritability = Additive Var/Phenotypic Var
- interactibility = Nonadditive Var/Phenotypic Var

Estimates of Genetic Ratios

Growth Traits

<table>
<thead>
<tr>
<th></th>
<th>Heritab A</th>
<th>Heritab B</th>
<th>Interact A/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWD</td>
<td>.22</td>
<td>.23</td>
<td>.15</td>
</tr>
<tr>
<td>WWD</td>
<td>.25</td>
<td>.29</td>
<td>.18</td>
</tr>
<tr>
<td>BWM</td>
<td>.17</td>
<td>.18</td>
<td>.16</td>
</tr>
<tr>
<td>WWM</td>
<td>.18</td>
<td>.21</td>
<td>.20</td>
</tr>
</tbody>
</table>

Carcass Traits

<table>
<thead>
<tr>
<th></th>
<th>Heritab A</th>
<th>Heritab B</th>
<th>Interact A/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>.46</td>
<td>.39</td>
<td>.27</td>
</tr>
<tr>
<td>LMA</td>
<td>.42</td>
<td>.53</td>
<td>.28</td>
</tr>
<tr>
<td>FAT</td>
<td>.14</td>
<td>.24</td>
<td>.02</td>
</tr>
<tr>
<td>KPH</td>
<td>.03</td>
<td>.14</td>
<td>.05</td>
</tr>
<tr>
<td>MB</td>
<td>.16</td>
<td>.16</td>
<td>.12</td>
</tr>
<tr>
<td>WBS</td>
<td>.58</td>
<td>.17</td>
<td>.07</td>
</tr>
</tbody>
</table>

Straightbred and Crossbred Heritabilities

<table>
<thead>
<tr>
<th></th>
<th>BWD</th>
<th>BWM</th>
<th>WWD</th>
<th>WWM</th>
</tr>
</thead>
<tbody>
<tr>
<td>A x A</td>
<td>.22</td>
<td>.17</td>
<td>.25</td>
<td>.05</td>
</tr>
<tr>
<td>B x B</td>
<td>.23</td>
<td>.18</td>
<td>.29</td>
<td>.09</td>
</tr>
<tr>
<td>A x B</td>
<td>.19</td>
<td>.15</td>
<td>.22</td>
<td>.07</td>
</tr>
<tr>
<td>.5A.5B x A</td>
<td>.16</td>
<td>.32</td>
<td>.18</td>
<td>.44</td>
</tr>
</tbody>
</table>
**Straightbred and Crossbred Heritabilities**

<table>
<thead>
<tr>
<th></th>
<th>CW</th>
<th>RA</th>
<th>FR</th>
<th>KP</th>
<th>MB</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>A x A</td>
<td>.46</td>
<td>.42</td>
<td>.14</td>
<td>.03</td>
<td>.16</td>
<td>.58</td>
</tr>
<tr>
<td>B x B</td>
<td>.39</td>
<td>.53</td>
<td>.24</td>
<td>.14</td>
<td>.16</td>
<td>.17</td>
</tr>
<tr>
<td>A x B</td>
<td>.30</td>
<td>.34</td>
<td>.18</td>
<td>.07</td>
<td>.13</td>
<td>.25</td>
</tr>
<tr>
<td>.5A.5B x A</td>
<td>.37</td>
<td>.33</td>
<td>.03</td>
<td>.02</td>
<td>.19</td>
<td>.43</td>
</tr>
</tbody>
</table>

**Correlation Estimates**

- \( r_{(BWD,WWD)} \): .24 A and .22 B
- \( r_{(WWD,WWM)} \): -.28 A and -.22 B
- \( r_{(BWD,WWD)} \): .18 A/B
- \( r_{(BWM,WWM)} \): .12 A/B
- \( r_{(CWD,LMAD)} \): .45 A and .40 B

**Multibreed Predictions**

Comparison of sires of any fraction of parental breeds

Graphs assumed sires to be mated to \( \frac{1}{2} \)A \( \frac{1}{2} \)B cows

**Multibreed Genetic Bases**

- **Additive Genetic Base**
  \( = \) Mean of Brahman Alleles from Purebred and Crossbred Animals
- **Nonadditive Genetic Base**
  \( = \) Mean of A/A and B/B Intralocus Interactions from Purebred and Crossbred Animals

**MEPD Graphs - Growth Traits**

- **Direct**
  - WW
  - AN T
- **Maternal**
  - WW
  - AN T

Angus-Brahman
Sanmartinero-Brahman

**MEPD Graphs - Carcass Traits**

- **Direct**
  - AN T
  - CW
  - LMA
  - MB
  - WBS

Angus-Brahman
MEPD Graphs - Carcass Traits

- CW
- LMA
- MB
- WBS

Angus-Brahman

Carcass Weight
Additive Direct MEPD

Carcass Weight
Nonadditive Direct MEPD

Carcass Weight
Total Direct MEPD

Longissimus Muscle Area
Additive Direct MEPD

Longissimus Muscle Area
Nonadditive Direct MEPD
Correlation between MEPD
Growth Traits

<table>
<thead>
<tr>
<th></th>
<th>(A, N)</th>
<th>(A, T)</th>
<th>(N, T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWD</td>
<td>.25</td>
<td>.98</td>
<td>.42</td>
</tr>
<tr>
<td>WWD</td>
<td>.20</td>
<td>.94</td>
<td>.53</td>
</tr>
<tr>
<td>BWM</td>
<td>.40</td>
<td>.96</td>
<td>.65</td>
</tr>
<tr>
<td>WWM</td>
<td>.32</td>
<td>.98</td>
<td>.52</td>
</tr>
</tbody>
</table>

Correlation between MEPD
Carcass Traits

<table>
<thead>
<tr>
<th></th>
<th>(A, N)</th>
<th>(A, T)</th>
<th>(N, T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>.41</td>
<td>.93</td>
<td>.72</td>
</tr>
<tr>
<td>RA</td>
<td>.29</td>
<td>.94</td>
<td>.59</td>
</tr>
<tr>
<td>FR</td>
<td>.04</td>
<td>1.00</td>
<td>.06</td>
</tr>
<tr>
<td>KP</td>
<td>.16</td>
<td>1.00</td>
<td>.24</td>
</tr>
<tr>
<td>MB</td>
<td>.22</td>
<td>.99</td>
<td>.33</td>
</tr>
<tr>
<td>SF</td>
<td>.33</td>
<td>1.00</td>
<td>.39</td>
</tr>
</tbody>
</table>

Implications - Variability

Additive and Nonadditive Genetic Effects were important sources of variation for growth related traits
Feasible to Select for Additive and Nonadditive MEPD in Bos Taurus-Brahman Multibreed Populations

Implications - Predictions

No straightbred or crossbred sire group was completely superior to another group (Ranges Overlapped)
Conservative Selection Rule
First select Sires for Additive MEPD, and then for Total MEPD

National Multibreed Populations

A Single Multibreed Population
All breeds in the USA
Several Overlapping Multibreed Populations
Angus-Brangus-Brahman
Simmental (USA-Canada)-Simbrah-Brahman
Several Extended Breeds
(Straightbred Sires; Straightbred and Crossbred Dams)
Multibreed Genetic Bases

- Single Multibreed Population
  - Single Base (Add, Nonadd)

- Overlapping Multibreed Populations
  - Single Reference Base (Add, Nonadd)
  - Connected Reference Bases (Add, Nonadd)

- Extended Breeds
  - Weak Connections (Mgs, Mgd ?)

Multibreed Genetic Evaluations

- Single Multibreed Population
  - Additive, Nonadditive, Total

- Overlapping Multibreed Populations
  - Additive, Nonadditive, Total

- Extended Breeds
  - Additive, Nonadditive, Total (Within Ex Br)

Publication of MEPD

- Paper Multibreed Sire Summaries
  - Additive (Feasible)
  - Nonadditive, Total (Unfeasible)

- Electronic Multibreed Sire Summaries
  - Additive, Nonadditive, Total

  - Better Alternative
  - Mating Program Service

Final Remarks

- Definition of USA Multibreed Populations

- Methodological Research and Development

- Publication of Genetic Predictions

- Additional Services