Chapter 19 – Crossbreeding Systems

Crossbreeding System – A mating system that uses crossbreeding to maintain an optimal level of hybrid vigor and(or) breed complementarity.

I. Evaluating Crossbreeding Systems
II. Terminal Sire Systems
III. Rotational Systems
IV. Composite Animals
V. Breeding for Uniformity
Chapter 19 – Crossbreeding Systems

• Learning Objective: To learn the basis for a well planned and sustainable crossbreeding program that utilizes breed complementation (judicious selection of sire and dam breeds) and capitalizes on hybrid vigor (heterosis).
Chapter 19 – Crossbreeding Systems

• I. Evaluating Crossbreeding Systems:
  – **Merit and Availability** of Component Breeds (wise choice of breeds)
  – Hybrid Vigor (exploit **GCV** for economic traits)
  – Breed Complementarity (utilize **BV** by combining breed strengths)
  – Consistency of Performance (a **uniform** product is the key)
  – **Replacement** Considerations (requires a plan)
  – **Simplicity** (must be practical)
  – **Accuracy** of Genetic Prediction (possibly use purebred sires with accurate EPD’s)
II. Terminal Sire Systems:

- Terminal Sire Crossbreeding System – “A crossbreeding system in which maternal-breed females (dams) are mated to paternal-breed males (sires) to efficiently produce progeny that are especially desirable from a market standpoint. Terminally-sired females are not kept as replacements, but are all sold and harvested as meat animals.”
Chapter 20 – Mating Systems

- Why are crossbreds more profitable?
  - Hybrid vigor (Heterosis)
    - Increase in performance of crossbreds compared to parental breeds, due to dominance.
  - Breed Complementation
    - Combining breed strengths by utilizing sire and dam breeds, due to breeding value.
Genetic and heterotic effects for Market weight (g) for Altex sire X New Zealand White dam crossbred rabbits

<table>
<thead>
<tr>
<th>Breed</th>
<th>BV&lt;sup&gt;I&lt;/sup&gt;</th>
<th>BV&lt;sup&gt;M&lt;/sup&gt;</th>
<th>Cross</th>
<th>h&lt;sup&gt;I&lt;/sup&gt;</th>
<th>h&lt;sup&gt;M&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZW</td>
<td>0</td>
<td>0</td>
<td></td>
<td>66</td>
<td>-</td>
</tr>
<tr>
<td>Altex (A)</td>
<td>304</td>
<td>-88</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean = \( \text{BV}_{A}^{I} + \text{BV}_{A}^{M} + \text{h}_{A}^{I} \times 0.5 \times (304) + 0 \times (-88) + 1 \times 66 \) = 2,051 grams

*Medellin and Lukefahr (2001)*
Two-Breed Terminal Cross

Charolais bulls  →  Angus cows

1/2 Charolais : 1/2 Angus
(both sexes sold as feeders)

Expected Weaning Performance = 498 lb

Olson, 1998
Genetic and heterotic effects for WW(lb)\(^a\)

<table>
<thead>
<tr>
<th>Breed</th>
<th>BV(^I)</th>
<th>BV(^M)</th>
<th>Cross</th>
<th>h(^I)</th>
<th>h(^M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus (A)</td>
<td>0</td>
<td>0</td>
<td>A X B</td>
<td>52</td>
<td>45</td>
</tr>
<tr>
<td>Brahman (B)</td>
<td>6</td>
<td>8</td>
<td>A X C</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Charolais (C)</td>
<td>80</td>
<td>9</td>
<td>B X C</td>
<td>42</td>
<td>35</td>
</tr>
</tbody>
</table>

\(^a\)Olson, 1998; Across-breed EPD's ([Link](#))
Predicted WW Performance for Charolais X Angus:

<table>
<thead>
<tr>
<th></th>
<th>$BV^I$</th>
<th>$BV^M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>.5(0)</td>
<td>1(0)</td>
</tr>
<tr>
<td>$C$</td>
<td>.5(80)</td>
<td>0(9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$h^I$</th>
<th>$h^M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$AXC$</td>
<td>1(8)</td>
<td>0(15)</td>
</tr>
</tbody>
</table>

Mean $BV^I_A$, $BV^I_C$, $BV^M_A$, $h^I_{AXC}$, $h^M_{AXC}$

$$= 450 + [.5(0) + .5(80) + 1(0) + 1(8) + 0(15)]$$

$$= 498 \text{ pounds}$$
Three-Breed Terminal Cross

- Brahman bulls
- Angus cows

1/2 Brahman : 1/2 Angus
- Expected Weaning Performance = 505 lb
  - heifers retained as replacements
  - steers sold as feeders
  - selected bulls sold for breeding

1/2 Charolais : 1/4 Angus : 1/4 Brahman
- (both sexes sold as feeders)
- Expected Weaning Performance = 565.5 lb

Olson, 1998
Predicted WW Performance from a Charolais bull X Brahman X Angus cow mating:

<table>
<thead>
<tr>
<th></th>
<th>BV\textsuperscript{I}</th>
<th>BV\textsuperscript{M}</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.25(0)</td>
<td>.5(0)</td>
</tr>
<tr>
<td>B</td>
<td>.25(6)</td>
<td>.5(8)</td>
</tr>
<tr>
<td>C</td>
<td>.5(80)</td>
<td>0(9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>h\textsuperscript{I}</th>
<th>h\textsuperscript{M}</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXB</td>
<td>0(52)</td>
<td>1(45)</td>
</tr>
<tr>
<td>AXC</td>
<td>.5(8)</td>
<td>0(15)</td>
</tr>
<tr>
<td>BXC</td>
<td>.5(42)</td>
<td>0(35)</td>
</tr>
</tbody>
</table>

Mean $= 450 + [.25(6) + .5(80) + .5(8) + .5(8) + .5(42) + 1(45)]$

$= 565.5$ pounds
Three-Breed Terminal Cross

Maternal Breed A

F₁ AB Female

Terminal sire boar

Maternal Breed B

Market all progeny

Source: University of Missouri - Extension
II. Terminal Sire Systems:

Advantages:
1) Full hybrid vigor (100%)
2) Breed complementation
3) Simple

Disadvantage:
1) System does not provide a source of female or male replacement breeding stock
III. Rotational Systems:

- Rotational Crossbreeding System – “A crossbreeding system in which generations of females are “rotated” among sire breeds in such a way that they are mated to sires whose breed composition is most different from their own (i.e., a spatial rotation involving purebred sires of different breeds).”
Table 19.1a Breed composition and percentage retained hybrid vigor (HV) for two-breed, rotationally-crossbred cows involving purebred sires by generation.

<table>
<thead>
<tr>
<th>Gen.(^a)</th>
<th>Breed of sire(^b)</th>
<th>A</th>
<th>B</th>
<th>(%F_1) HV(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>B</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>1/2</td>
<td>1/2</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>1/4</td>
<td>3/4</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>5/8</td>
<td>3/8</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>5/16</td>
<td>11/16</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>21/32</td>
<td>11/32</td>
<td>69</td>
</tr>
<tr>
<td>6</td>
<td>B</td>
<td>21/64</td>
<td>43/64</td>
<td>66</td>
</tr>
<tr>
<td>7</td>
<td>A</td>
<td>85/128</td>
<td>43/128</td>
<td>67</td>
</tr>
<tr>
<td>8</td>
<td>B</td>
<td>85/256</td>
<td>171/256</td>
<td>66</td>
</tr>
<tr>
<td>9</td>
<td>A</td>
<td>341/512</td>
<td>171/512</td>
<td>67</td>
</tr>
<tr>
<td>10</td>
<td>B</td>
<td>341/1024</td>
<td>683/1024</td>
<td>67</td>
</tr>
</tbody>
</table>

\(^a\) Gen. = Generation.

\(^b\) Breed: A = Angus; B = Brahman.

\(^c\) Heterosis (hybrid vigor) expression, relative to a fully-crossbred, \(F_1\) animal.
Table 19.1b Breed composition and percentage retained hybrid vigor (HV) for two-breed, rotationally-crossbred cows involving purebred sires by generation.

<table>
<thead>
<tr>
<th>Gen.</th>
<th>Breed of sire</th>
<th>Breed</th>
<th>A</th>
<th>B</th>
<th>%F₁ HV</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
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<td>A</td>
<td>B</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>A</td>
<td>25</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>B</td>
<td>63</td>
<td>37</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>A</td>
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<td>69</td>
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<td>5</td>
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</tr>
<tr>
<td>7</td>
<td>A</td>
<td>B</td>
<td>66</td>
<td>34</td>
<td>67</td>
</tr>
<tr>
<td>8</td>
<td>B</td>
<td>A</td>
<td>33</td>
<td>67</td>
<td>66</td>
</tr>
<tr>
<td>9</td>
<td>A</td>
<td>B</td>
<td>67</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>10</td>
<td>B</td>
<td>A</td>
<td>33</td>
<td>67</td>
<td>67</td>
</tr>
</tbody>
</table>

a Gen. = Generation.
b Breed: A = Angus; B = Brahman.
c Heterosis (hybrid vigor) expression, relative to a fully-crossbred, F₁ animal. Eventually, heterosis stabilizes (67%; Formula: \(\frac{2^n - 2}{2^n - 1}\)).
Breed A

Breed B

Bull B

A 50% B 50%

Bull A

A 25% B 75%

Bull B

A 62.5% B 37.5%

Bull A

A 31.2% B 68.8%

Bull B

A 65.6% B 34.4%

Bull A

A 32.8% B 67.2%
III. Rotational Systems:

- Rotational Crossbreeding System – A crossbreeding system in which generations of females are “rotated” among sire breeds in such a way that they are mated to sires whose breed composition is most different from their own (i.e., a spatial rotation involving purebred sires of different breeds).
Three-Breed Rotational Crossbreeding System

Tuli bull (Honey Bear) → Crossbred ♀

Red Angus bull (PCC Simon) → Crossbred ♀

Senepol bull (WC 950K)
Senepol cattle originated from the N’Dama breed from West Africa
The Senepol Breed
The Tuli Breed
The Tuli Breed
Matching Forage Supply and Cow Nutrient Requirements

Calve in May - Breed in late July-August - Wean in Oct.-Nov.
(Modified figure from Kit Pharo.)
Brush Control – Strategy is to stay on top (the business model is profit per acre)
Bull introduced on July 25, 2009, for 60 days (100% pregnancy; all cows calved within 21 days, except one.)
Management – Summer Breeding

Two, 2 year-old bulls that were fertility tested in Aug. 2010 and July 2011 that each had ≥95% live sperm cells score.
On July 25, 2011, this 4 year old bull bred four cows during the day (100 °F). Seven bull calves were receiving early training as well.
Calves are weaned in Oct.-Nov. after fall rains via fence-line weaning. Cows are all at dry-maintenance stage. Window of opportunity for cows to get fat before winter.
Is there an added advantage of lighter colors and slick coats to external parasite resistance?
Rotational Crossbreeding Program:

Red Angus-sired cow with her Senepol-sired AI calf

Senepol-sired calf as a cow with her Tuli-sired AI calf

Tuli-sired calf as a cow with her Red Angus-sired AI calf

Red Angus-sired calf as a cow with her Senepol-sired AI calf
Table 19.1c Breed composition and percentage retained hybrid vigor (HV) for three-breed, rotationally-crossbred cows involving purebred sires by cycle and generation.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Gen.</th>
<th>Breed of AI sire</th>
<th>RA</th>
<th>S</th>
<th>T</th>
<th>%F₁ HV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>RA</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>S</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>T</td>
<td>25</td>
<td>25</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>RA</td>
<td>63</td>
<td>13</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>S</td>
<td>31</td>
<td>56</td>
<td>13</td>
<td>88</td>
</tr>
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<td>6</td>
<td>6</td>
<td>T</td>
<td>16</td>
<td>28</td>
<td>56</td>
<td>88</td>
</tr>
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<td>3</td>
<td>7</td>
<td>RA</td>
<td>58</td>
<td>14</td>
<td>28</td>
<td>84</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>S</td>
<td>29</td>
<td>57</td>
<td>14</td>
<td>86</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>T</td>
<td>14</td>
<td>29</td>
<td>57</td>
<td>86</td>
</tr>
</tbody>
</table>

a Gen. = Generation.
b Al sire breed: RA = Red Angus; S = Senepol; T = Tuli.
c Heterosis (hybrid vigor) expression, relative to a fully-crossbred, F₁ animal. Eventually, heterosis stabilizes (86%).
III. Rotational Systems:

Advantage:
1) System provides a source of female replacement breeding stock

Disadvantages:
• No sire x dam breed complementarity (breeds used must be of similar or compatible biological types, usually as dam breeds)
• Less than full (100%) hybrid vigor

\[
\%\text{RHV} = \frac{2^n - 2}{2^n - 1} \quad (n = \text{number of breeds})
\]

<table>
<thead>
<tr>
<th>n</th>
<th>%RHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td>4</td>
<td>93</td>
</tr>
<tr>
<td>5</td>
<td>97</td>
</tr>
</tbody>
</table>
Heterosis Stabilization Trend in 2- and 3-Breed Rotational Crosses
Rota-Terminal Crossbreeding System

Expected Weaning Performance = 539.7 lb

Simbrah-sired heifers
(.42)S : (.37)B : (.21)A

Simbrah bulls

Brangus bulls

Expected Weaning Performance = 527.1 lb

Brangus-sired heifers
(.42)A : (.37)B : (.21)S

Expected Weaning Performance = 548.6 lb

Charolais bulls

Calves from Brangus-sired dams
(.50)C : (.20)A : (.19)B : (.10)S

Expected Weaning Performance = 558.4 lb

Calves from Simbrah-sired dams
(.50)C : (.20)S : (.19)B : (.10)A

(all Charolais-sired calves sold as feeders)

Olson, 1998
IV. Composite Animals:

- **Definition:**
  - A hybrid with at least two and typically more breeds in its background. Composites are expected to be bred to their own kind, retaining a level of hybrid vigor normally associated with traditional crossbreeding systems.
IV. Composite Animals:

- **Features:**
  - Intra-population matings
  - Retained heterosis
  - Utilize desirable proportions of breeds of genetic merit
  - High level of uniformity
  - Ideal option for small herds

Polypay breed (Dorset, Finnsheep, Rambouillete, Targhee)
IV. Composite Animals:

[Diagram showing the inheritance of traits from Simmental bulls, Hereford cows, Brahman bulls, and Angus cows, leading to the creation of Simmental × Hereford × Brahman × Angus bulls and cows with a specific phenotypic ratio of 1/4 S: 1/4 H: 1/4 B: 1/4 A.]
IV. Altex rabbits are a composite breed developed with a breed foundation of \( \frac{1}{2} \) Flemish Giant, \( \frac{1}{4} \) Californian, and \( \frac{1}{4} \) Champagne d’Argent. Calculate the level of retained heterosis:

![Diagram of breeding plan]

- **BREEDS**
  - Three Breeds:
    - Flemish Giant (FG) - Sire source
    - Californian (CAL) and Champagne d’Argent (CHA) - Dam sources

- **F₁ LINES**
  - Reciprocal crossing of F₁ lines

- **F₂ POPULATION**
  - (\( \frac{1}{2} \) FG, \( \frac{1}{4} \) CAL, \( \frac{1}{4} \) CHA breed composition)
  - Random differentiation into two closed lines: selected (S) and unselected (U)

- **GENERATION 0**
  - Initial parental generation without selection

- **SELECTION**
  - Five generations of intense selection for 70-day body weight in S line

- **NEW BREED DEVELOPMENT**
  - Line crossing of S and U to expand genetic base - final stage in development of the Altex breed

*Figure 1. Schematic representation of the breeding plan leading to the development of the Altex commercial sire breed.*
IV. Composite Animals:

**Modified formula:**

\[
%\text{RHV} = (1 - \sum p_i^2) \times 100
\]

\[
\text{If equal p:}
%\text{RHV} = \left(\frac{(n-1)}{n}\right) \times 100
\]

**Altex breed**

Altex: ¼ Californian, ¼ Champagne d'Argent, ½ Flemish Giant

<table>
<thead>
<tr>
<th>n</th>
<th>%RHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
</tr>
</tbody>
</table>

%RHV = (1 - (.25^2 + .25^2 + .5^2)) \times 100

= (1 - (.375)) \times 100

= 62.5%
IV. Composite Animals:

Modified formula:

\[
\%\text{RHV} = \left(1 - \sum p_i^2\right) \times 100
\]

If equal p:

\[
\%\text{RHV} = \left((n-1)/n\right) \times 100
\]

Santa Cruz: \(\frac{1}{4}\) Red Angus, \(\frac{1}{4}\) Gelbvieh, \(\frac{1}{2}\) Santa Gertrudis (3/16 Brahman and 5/16 Shorthorn)

\[
\%\text{RHV} = \left(1 - (.25^2 + .25^2 + .1875^2 + .3125^2)\right) \times 100
\]

\[
= (1 - (.2578)) \times 100
\]

\[
= 74.2\%
\]
IV. Composite Animals:

- **Attributes of Pure Composite System:**
  - **Hybrid vigor** – If influence is large, composites may be more uniform than purebreds for quantitative traits
  - **Breed complementarity** – May be little opportunity because distinct sire and dams breeds are not involved
  - **Consistency of performance** – Similar as for purebreds because there is no further increase in variation due to BV
  - **Replacement considerations** – male and female can be saved for breeding
  - **Simplicity** – An advantage over terminal and especially rotational crossbreeding
  - **Accuracy of genetic prediction** – Little information on composites
  - **Designed to fit certain environments** – “Custom made”