Sheep Breeding and Genetics

Genetics and the Environment

All characteristics (traits) of an animal that can be seen or measured are referred to as its phenotype. This includes height, weight, growth rate, wool colour, temperament, reproductive ability, disease resistance etc. An animal’s phenotype for each of its traits depends on both genetics and environment. At conception, genetic material from the sperm and the egg merge, and the resulting fetus will contain 50% of its genes from the dam and 50% from the sire. These genes contain information regarding how each of the animal’s traits will develop (genetic potential or genotype). The environment in which an animal develops will affect whether the full genetic potential will be achieved. For example, a lamb may have the genetic potential to achieve a maximum adult height of 90 cm. How tall the animal actually becomes depends on the environment in which it develops (i.e. food supply, protection from the elements, health care etc.). With optimum conditions the lambs will be 90 cm. Under natural circumstances, the lamb could never be taller than this as the genes it inherited from its parents have set the upper limit. If the lamb is raised under very poor conditions, with poor feed, heavy parasite load etc, its adult height will be much less, as growth will be limited by environment. However, even with the phenotypic adult height of 70 cm, it would still be able to pass the genetic potential for greater height to its offspring. The opposite is also true, and a favourable environment can mask poor genetics, just as good genetics may be masked by poor conditions. Sheep do not pass on their environment to their progeny - only their genes. Sheep that have been especially well fed and pampered may look exceptionally good at shows or sales. However, their genetics may not result in a similar phenotype if their offspring are raised under different conditions. Therefore, it may be worthwhile to purchase genetic stock proven to perform well under a management system similar to your own.

Selection and Heritability

Selection is the process of deciding which animals will be used as breeding stock, and which will not be used (castrated, sold, or slaughtered). Producers may base their selection decisions on various economically important traits of the stock, in the hope that the offspring will be profitable. Selecting and breeding rams and ewes that grew quickly as lambs, for example, should produce lambs with a genetic potential for fast growth. If the fastest growing lambs from the next generation are retained, the genetic potential for this trait should continue to increase.
Selection over long periods of time for particular characteristics has lead to the development of breeds with recognisable phenotypes.

Traits are not equally affected by the animal’s genetics. The heritability of a trait is a measure of the relative importance of genetics and environment in developing the phenotype. Table 1 list a few examples of traits and their heritability. The genetic contribution to the phenotype of a trait with a low heritability is only ~10%, whereas with highly heritable traits genetics may account for approximately half of the final phenotypic result. Since the heritability of all these traits is greater than zero, selection will result in genetic improvement for that trait. However, improvement will be much faster (occur in fewer generations) for traits with high heritabilities.

Table 1: Examples of heritability of specific traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability</th>
<th>Percent influenced by genetics (Heritability)</th>
<th>Percent influenced by environment</th>
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<tbody>
<tr>
<td>Reproductive (e.g. prolificacy)</td>
<td>Low</td>
<td>5-15%</td>
<td>95-85%</td>
</tr>
<tr>
<td>Growth (e.g. growth rate, carcass)</td>
<td>Moderate</td>
<td>25-45%</td>
<td>75-55%</td>
</tr>
<tr>
<td>Fleece traits and conformation</td>
<td>High</td>
<td>45-60%</td>
<td>55-40%</td>
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Sheep Breeds:

‘What breed should I choose?’ is one of the first questions asked by people interested in getting into sheep production. The answer to that question will be based on many factors including:

- Management system (e.g. producers interested in lambing on pasture will probably steer away from the higher maintenance prolific breeds; accelerated lambing programs will run much smoother with breeds that have long breeding seasons etc.)

- Marketing Strategy (e.g. producers who wish to sell into the heavy lamb market will probably select a breed that will not over-fatten by the time the market weight is reached (heavy mature weight). Conversely, producers who are selling the majority of their lambs at less than 80lbs may find that the heavier breeds do not adequately fatten at lighter weights.)

- Breeding Strategy (e.g. pure bred vs. commercial, see below)

Although individual breeds have unique characteristics, sheep can be grouped into several general classes (for further descriptions of individual breeds see the pamphlet ‘Canadian Sheep’):

1. Terminal or Sire Breeds: These breeds are generally characterized by rapid growth, musculature, and good carcass traits. Reproductive performance may be somewhat lower than in the maternal breeds. Some examples of terminal breeds are: Texel, Suffolk, and Charollais

2. Maternal Breeds: These breeds tend to have higher fertility, increased number of multiple births, higher milk production, increased longevity, and mothering ability. However, they tend not to be as large or well muscled as the terminal breeds. Some examples of maternal breeds are: Dorset, Outaouais Arcott, and Romanov

3. Dairy Breeds: These breeds have been specifically selected for high milk production. The milk from ewes is mainly used to produce cheeses, such as feta, ricotta, and Camembert. Examples of dairy breeds are: East Friesian and British Milk Sheep.

4. Wool Breeds: Different breeds have different types of wool. Although the production of various items requires the use of different types of wool, some breeds have become known as ‘wool breeds’ in light of the fact that their wool may be highly valued in specialty markets. Examples of these breeds are: Icelandic, Merino, and Shetland
In spite of the fact that these categories have been listed, please keep in mind that all breeds have lambs, will grow, have wool, produce milk, and have a carcass! There is considerable variation both within and between breeds and paying close attention to the breeders reputation for quality genetics, as well as the breed that they are selling, is an important part of making the correct decision when buying breeding stock.

**Breeding Strategies:**

*Pure breeding (Straight cross)*

This is the simplest type of breeding system, as all the sheep (rams and ewes) are the same breed. As noted above breeds have generally been selected for a specific aspect of their production (e.g. fast growth, strong maternal characteristics etc.). However, in a commercial lamb operation the number and quality of market lambs are important, so both terminal and maternal characteristics need to be incorporated into the breeding strategy. Therefore, purebred producers often supply ‘seed stock’ to commercial producers, who will use the purebreds as a foundation for a crossbreeding program.

**Crossbreeding Strategies:**

As the name suggests, crossbreeding is the mixing of two or more breeds together. There are two main benefits to crossbreeding.

- **Hybrid vigour or heterosis:** Hybrid vigour refers to the fact that crossbred offspring often out-perform the average of their parents. Hybrid vigour decreases as the heritability of a trait increases. Therefore, it is often used to improve performance for low heritability traits. For example, two maternal breeds may be crossed to further improve reproductive performance in their offspring. This greatly benefits fertility traits, which are of low heritability and do not respond well to selection. Crossbred ewes are generally more fertile, productive, and long-lived than purebred ewes. For example, if a prolific breed (produces 3 lambs on average) is crossed with a less prolific breed (1.6 lambs on average), the cross is expected to produce \((3+1.6)/2 = 2.3\) lambs on average. However, the crossbreed ewe might well produce 2.5 lambs on average. The extra production over the average of the parental breeds \((2.5 – 2.3 = 0.2\) lambs) is due to hybrid vigour or heterosis.

- **Breed Complementarity:** This refers to the crossing of two dissimilar breeds in order to combine the best traits of both breeds. An example of this would be crossing a well-muscled Texel ram with highly fertile Rideau Arcott ewes to produce a large crop of high quality lambs. Although the lambs may not be as heavily muscled as straight Texels, the lambing percentage will be much higher with the Arcott influence. This type of strategy is likely to produce better results than trying to select for highly fertile, heavily muscled animals within one breed.

**Types of Crossbreeding Strategies:**

*Two Way Cross*

In this case, rams of one breed are used to breed ewes of a second breed, resulting in crossbred lambs. This strategy takes advantage of hybrid vigour and/or breed complimentarity in the offspring. Breeding is relatively simple as you are only dealing with one breed of ewes and one breed of ram. However, since the offspring are crossbred, all replacements must be purchased.

*Three-Way Cross*

This strategy mates the two-way crossbred ewe lambs (‘F1’ lambs) to a ram of a third breed. The resulting progeny are a mix of three different breeds. This strategy takes advantage of hybrid vigour in the crossbred ewe as well as in the three-way crossed lambs. However, all replacement
ewes still need to be purchased. Some producers specialize in producing crossbred ewe lambs for this type of system.

**Three-Way Rotational Crosses**

Similar to the three-way cross, the three way rotational cross starts with mating a crossbred ewe to a ram of a third breed. The crossbred ewe lambs are kept as replacements rather than being sold. These three-way cross ewe lambs are then mated to one of the two breeds in the first cross, and the process continues in the same manner. The following table illustrates the system.

<table>
<thead>
<tr>
<th>Generation</th>
<th>Ram</th>
<th>Ewes</th>
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<tbody>
<tr>
<td>1</td>
<td>Suffolk</td>
<td>Rideau Arcott x Dorset</td>
</tr>
<tr>
<td>2</td>
<td>Rideau Arcott</td>
<td>1/2 Suffolk x 1/4 Rideau Arcott x 1/4 Dorset</td>
</tr>
<tr>
<td>3</td>
<td>Dorset</td>
<td>5/8 Rideau Arcott x 2/8 Suffolk x 1/8 Dorset</td>
</tr>
<tr>
<td>4</td>
<td>Suffolk</td>
<td>5/8 Dorset x 1/4 Rideau Arcott x 1/8 Suffolk</td>
</tr>
<tr>
<td>5</td>
<td>Rideau Arcott</td>
<td>5/8 Suffolk x 1/4 Dorset x 1/8 Rideau Arcott</td>
</tr>
</tbody>
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This method of breeding helps maintain hybrid vigour and eliminates the problem of having to buy in replacements. However, the breeding season can get complex since there is a need for three separate breeding flocks each year for the three different breeds of rams. Accurate record keeping and animal ID are critical with this system.

**Roto-Terminal Crossing**

This type of breeding program combines three-way crossing and the rotational crossing programs. In this system, a percentage of the Rideau Arcott x Dorset ewes from generation 1 (table above) would be bred in a two-breed rotational system using a Rideau Arcott or Dorset ram. All of the ewe lambs from this breeding would be kept as replacements. The remaining portion of the Rideau Arcott x Dorset ewes would be bred to a terminal sire, such as a Suffolk ram, and these lambs would be marketed.

This strategy produces replacements within the system and retains hybrid vigour in the ewe flock. However, three separate breeding groups are required each year to accommodate the three different breeds of ram, which requires reliable animal ID and record keeping systems.