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Sheep Breeding

Heritability, EBVs, EPDs and the NSIP

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Genetic improvement in a flock depends on the producer's ability to select breeding sheep that are genetically superior for traits of economic importance. This is complicated by the fact that an animal's own performance is not always a true indicator of its genetic potential as a parent.

How Much of an Animal's Performance Is Heritable?

An animal's performance (phenotype, P) for a trait is the result of its genes (genotype, G) and the effect of the environment (E) in which it is raised (for example, nutrition, health program, housing, weather and parasite exposure). Thus, the phenotype of an animal can be expressed as:

$$P = G + E$$

An animal's genotype is the set of genes that affects a particular trait. Those genes that act independently, or additively, make up the animal's breeding value (BV). This is the portion of the animal's phenotype that can be passed on to its offspring. As a result, we express the phenotype as:

$$P = BV + E$$

This is an oversimplification, but it will work for this discussion.

An animal's phenotype is observed or measured, but the animal's breeding value is what is of interest to the sheep breeder. Unfortunately, it is not possible to know the true genetic merit of an animal for a particular trait. Therefore, in order to make selection decisions, its breeding value must be estimated. The animal's own performance is one indicator of its breeding value. The usefulness of individual information depends on the proportion of the differences in performance between animals that is due to differences in breeding values. This difference is called the heritability of the trait:

$$h^2 = \frac{\text{BV Variation}}{\text{Phenotypic Variation}}$$

Heritability measures the relative importance of genetics and environment in developing an animal's phenotype for a trait.

Traits are not equally heritable; that is, traits are not equally affected by an animal's genetics. Theoretically, heritability can range from 0 to 100 percent. A heritability of zero indicates that all phenotypic differences between animals are due to environmental effects. A heritability of 100 percent indicates that all phenotypic differences between animals are due to differences in breeding values. Heritabilities for most economically important traits in sheep range from 5 to 55 percent (Table 1). Thus, most of the phenotypic differences observed between sheep are due to nongenetic, or environmental, effects. For highly heritable traits (30% or higher), the animal's own performance is a good indicator of its breeding value. For lowly heritable traits (below 20%), the animal's phenotype is much less useful. In these cases, having performance information on the animal's relatives will be important in estimating its breeding value.

Table 1. Heritabilities for different types of traits in sheep

Type of Trait	Level of Heritability
Reproductive	Low (5 to 20%)
Growth	Low to Moderate (10 to 40%)
Carcass	High (30 to 45%)
Fleece	Moderate to High (25 to 55%)
Dairy	High (30 to 45%)

What are EBVs?

An animal receives one-half of its genetic make-up from each parent, so its breeding value is expected to be the average of the breeding values of its parents:

Expected BV = ½(Sire's BV) + ½(Dam's BV)

This is only an expectation. An animal's true breeding value for a trait is never known. It must be estimated using the animal's own performance and/or performance of its relatives. This factor is called the estimated breeding value (EBV); it is the predicted value of an animal as a parent compared with other potential parents. Because selection is about choosing the parents of the next generation, this measurement is important to a sheep breeding program.

The simplest form of EBV is based on an animal's individual performance:

EBV = h^2 x Selection Differential

The selection differential is the difference between the individual's performance and the average performance of its contemporaries. For example, suppose a ram has a 60-day weaning weight of 40 kg (or 88 lb) and his contemporary group (other rams of the same breed and approximate age raised under the same conditions) has an average 60-day weaning weight of 28 kg (or 62 lb). His selection differential for weaning weight is 40 - 28 = 12 kg. Assuming a heritability of 10%, his EBV is 0.10 x 12 kg = +1.2 kg (or +2.6 lb).

What are EPDs?

A parent (sire or dam) passes on a random half of its independent gene effects to its offspring. Thus, a parent transmits, on the average, half its breeding value to its offspring. Half of the parent's breeding value for a trait is the expectation of what is inherited from the parent and is called the progeny difference (PD).

PD = ½BV

Recall the previous equation:

Expected BV = ½(Sire's BV) + ½(Dam's BV)

This equation can be rewritten as:

Expected BV = Sire's PD + Dam's PD

In other words, the expected merit of progeny from a particular mating is equal to the average of the parents' breeding values or the sum of their progeny differences.

Progeny difference is a very practical concept. It is the expected difference between the average performance of an individual's progeny and the average performance of all progeny (assuming randomly chosen mates). For example, if a particular ram has a PD = +0.5 kg for weaning weight, and he is mated to an average set of ewes, the weaning weights of his lambs are expected to be 0.5 kg heavier than average lambs.

Like breeding values, progeny differences are not directly measurable but can be predicted from performance data. Such predictions are called expected progeny differences (EPDs) and are commonly used to make genetic comparisons among animals. Just as the predicted difference is equal to half the breeding value, an EPD = ½ EBV.

What is the NSIP?

Producers of purebred flocks can have EBVs computed on their sheep by enrolling their flocks in the U.S. National Sheep Improvement Program (NSIP, **www.NSIP.org**). Producers submit on-farm performance data and NSIP returns genetic evaluations. Currently, genetic evaluations are limited to purebred sheep. However, commercial producers can use EBVs to improve traits in their flocks by selecting purebred rams with strong EBVs for traits that are economically important to them.

NSIP was established in 1986. Initially, it was limited to within-flock evaluations. As the program grew and more flocks with linkages (common genetics) joined, across-flock (within pure breed) evaluations were generated and NSIP became a breed-centered program.

Predictions of genetic merit were originally reported as EPDs. Through 2009, Virginia Tech conducted yearly genetic evaluations under the direction of Dr. Dave Notter. In 2010, NSIP finalized a partnership with Meat and Livestock Australia that transferred data processing from Virginia Tech to LambPlan, the national sheep performance program of Australia. This partnership allows the U.S. sheep industry to generate genetic evaluations, now reported as EBVs, every two weeks.

Currently, the following 20 breeds participate in NSIP:

Black Welsh Mountain	Meat Merino
Border Leicester	Oxford
Clun Forest	Polypay
Columbia	Rambouillet
Dorper/White Dorper	Romney
Dorset	Shropshire
Finnsheep	Suffolk
Hampshire	Targhee
Icelandic	Texel
Katahdin	White Suffolk

Specific traits for which EBVs are reported vary among breeds. EBVs for some of the more economically important traits are described in Tables 2, 3, 4 and 5.

An EBV is reported, in the normal units of a trait, as a deviation (+ or -) from the average population value, which is considered to be zero. Therefore, EBVs always have a positive (+) or negative (-) sign in front of them. The positive and negative symbols don't always mean better or worse; it depends on the trait. For example a WWT EBV of + 0.5 kg is good (i.e., heavier lambs at weaning) but a FD EBV of -0.3 microns is also good (i.e., smaller diameter fiber).

Table 2. EBVs for weight traits; reported for all breeds*

Trait	Description
Birth Weight (BWT)	Estimates direct genetic effects on weight at birth. Positive selection on BWT EBV is expected to increase birth weight; negative selection is expected to decrease birth weight.
Weaning Weight (WWT)	Provides an estimate of preweaning growth potential. Selection for high WW EBV is expected to increase weaning weight.
Maternal Weaning Weight (MWWT)	Estimates genetic merit for mothering ability. MWWT EBV reflects genetic differences in ewe milk production as realized by her lambs. It is derived by evaluating whether individual ewes produce lambs that are heavier or lighter than expected based on EBVs of the parents. Ewes whose lambs grow faster than expected are assumed to be better milk producers. Ewes whose lambs grow slower than expected are assumed to produce less milk. Selection for high MWWT EBV is expected to improve milk production.
Total Maternal Weaning Weight	Combines information on weaning weight and maternal milk. Previously, this was provided by NSIP as the Milk plus Growth EBV. Total Maternal Weaning Weight EBVs are not directly provided by LambPlan, but can be calculated from maternal weaning weight and weaning weight EBVs as: MWWT EBV + ½ WWT EBV Total Maternal Weaning Weight EBV recognizes that the genetic contribution of a ewe to the weaning weight of her lambs is the combined effect of her milk production (measured by MWWT EBV) and a random one-half of her genes for preweaning growth potential (measured by WWT EBV).

* Expressed in kg: 1 kg = 2.2 lb
Source: Dave Notter, *NSIP EBV Notebook,* Sept. 1, 2011.

Table 3. EBVs for wool traits; reported for western range and maternal wool breeds.

Trait	Description
Fleece Weight (GFW)	Estimates genetic potential for wool production; expressed as a percentage (%). GFW EBV is based on grease fleece weight.
Fiber Diameter (FD)	Estimates genetic merit for fleece quality; expressed in microns. Animals with finer, more desirable fleeces have negative FD EBV, so negative EBVs are favored for this trait.
Staple Length (SL)	Estimates genetic potential for length of the wool fiber. SL EBV is expressed in millimeters.

Source: Dave Notter, *NSIP EBV Notebook,* Sept. 1, 2011.

Table 4. EBVs for reproductive traits; reported for all breeds.

Trait	Description
Number of Lambs Born (NLB)	Evaluates genetic potential for prolificacy; expressed as a percentage For example, ewes with NLB EBVs of +10.0 are expected to have an average of 0.10 more lambs at each lambing than average ewes. Their daughters are expected to have an average of 0.05 more lambs at each lambing compared to daughters of average ewes. Selection on NLB EBV is expected to increase prolificacy in the flock.
Number of Lambs Weaned (NLW)	Evaluates combined ewe effects on prolificacy and lamb survival to weaning; expressed as a percentage. For example, ewes with NLW EBVs of +10.0 are expected to wean an average of 0.10 more lambs at each lambing than average ewes. Their daughters are expected to wean an average of 0.05 more lambs at each lambing compared to daughters of average ewes. Selection on NLW EBV is expected to increase weaning rate in the flock.

Source: Dave Notter, *NSIP EBV Notebook,* Sept. 1, 2011.

Table 5. EBVs for parasite resistance; reported for hair breeds.

Trait	Description
Worm Egg Count (WEC)	Evaluates genetic merit for parasite resistance based on worm egg counts recorded at weaning or at early or late postweaning ages; expressed as a percentage. Animals with low WEC EBVs are expected to have greater parasite resistance

Source: Dave Notter, *NSIP EBV Notebook,* Sept. 1, 2011.

How Can Sheep Breeders Use EBVs?

Consider the NSIP genetic evaluation for a sample set of five rams presented in Table 6. These data can be used to rank rams based on their expected contribution as sires and to choose sires for different flock situations.

Table 6. EBVs for growth, maternal and reproductive traits for five rams

			EBV			
ID	Sex	Birth Year	Weaning Weight (WWT,kg)	Maternal Weaning Weight (MWWT, kg)	Total Maternal Weaning Weight (kg)	Number of Lambs Born (NLB, %)
1	Ram	2010	-1.2	0.1	-0.5	10.1
2	Ram	2010	0.3	-0.6	-0.5	2.8
3	Ram	2011	2.2	0.7	3.3	-4.4
4	Ram	2012	0.4	0.2	0.4	17.2
5	Ram	2012	2.4	1	2.2	0.8

Ranking Rams

Consider weaning weight. Ram 5 ranks highest for this trait. He has a WWT EBV of +2.4 kg. Ram 5 is estimated to have genes that result in lambs that are 2.4 kg heavier at weaning than a ram of average genetic value from the same population (in other words, a ram with a WWT EBV of 0.0). Ram 5's WWT EPD is 1.2 kg (EPD = ½ EBV). If ram 5 is mated to a group of ewes of average genetic merit (WWT EBV = WWT EPD = 0.0), his progeny are expected to weigh 1.2 kg more at weaning than lambs sired by a ram of average value.

Ram 1 is on the other end of the rankings for weaning weight. He ranks last with a WWT EBV of -1.2 kg and, therefore, a WWT EPD of -0.6. If ram 5 and ram 1 are both mated to a group of ewes of average genetic merit, ram 5's progeny are expected to weigh 1.8 kg more at weaning than ram 1's progeny (see the equation below).

Expected difference in performance of progeny of ram 5 and ram 1	=	ram 5's WWT EPD – ram 1's WWT EPD	=	1.2 – (–0.6) kg	=	1.8 kg

Selecting Sires for Specific Flocks

Consider the flock situations presented below. Given the breeding objectives of the respective producers, which of the five rams (Table 6) would be the best choice (Table 7)?

Remember, EBVs (and EPDs) do not predict absolute performance. EBVs (and EPDs) are used for comparison and ranking.

What Does It All Mean?

Estimated breeding values are the best available estimates of genetic merit. They allow animals to be fairly and directly compared with other animals from the same breed. They do not necessarily reflect the animal's observed performance (phenotype), which is a combination of both genetic and environmental influences. Rather, they are an estimate of the genetic component of that performance. Estimated breeding values are tools to create and manage genetic change.

Table 7. Breeding objectives for three hypothetical flock situations

Situation 1	Producer is satisfied with lambing percentage (already 220%) but wants to improve milk production and growth rate. Choose ram 5 for high EBV for weaning weight, maternal weaning and total maternal weaning weight. Ram 5 is expected to sire fast-gaining lambs that grow well to weaning, relative to the breed average, and also to sire daughters that will produce above average weaning weights for their lambs.
Situation 2	Producer is satisfied with lamb weaning weight and growth rate but wants to improve lambing percentage. Ram 4 is the choice for this flock because he ranks highest for number of lambs born. His EBV for weaning weight, maternal weaning weight and total maternal weaning weight are all positive, so no progress should be lost for those traits. Ram 4 is expected to sire daughters that will have an average of 0.086 [(½)(0.172)] more lambs at each lambing compared to daughters of average rams.
Situation 3	Producer knows the flock has serious production problems and needs an improvement in total productivity. This situation is different from the other two. The producer is not satisfied with overall production in the flock and wants to improve performance in both growth and maternal traits. The goal here is to select a ram with high EBVs for all traits. Most of the time, rams will not rank high in all traits, so trade-offs are often required. In this example, it is a hard decision. Ram 5 is positive for all traits but ranks next to last for number of lambs born. Ram 4 ranks highest for number of lambs born but ranks in the middle for the other traits. Ram 3 ranks higher for weaning traits but has a negative EBV for number of lambs born. Neither ram 1 nor ram 2 is considered because of their overall rankings for the traits shown. Thus, it boils down to either ram 4 or ram 5. Either way, the producer has to make a trade-off. Because the primary determinant of profit in a flock is number of lambs sold, the producer may choose to give up a little with regard to weaning performance in order to make a big improvement in number of lambs born. In that case, ram 4 is the choice.

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