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Genetics for sheep breeders

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Genetics is the science of how different features of an animal or plant are inherited by its offspring. It is a comparatively new science, the basic principles having been laid down little more than a century ago. The widespread application of genetics that we take for granted today has mostly developed since the Second World War.

The traits that determine the value of an animal can be divided into two types:

- Those controlled by a major gene. These are 'yes or no' characteristics that are either present or absent in an animal. Examples include the poll gene, black colour in sheep, or the Booroola F gene which increases lamb litter size. The manner in which these traits are inherited is fairly straightforward.
- Quantitative (or measurable) traits that are controlled by the combined action of a large number of genes, each of which has a small effect. These include most economically important traits (including fleece weight, live weight and fibre diameter) which vary continuously over a wide range rather than occurring in a 'yes or no' manner.

The exact way in which multiple genes control individual quantitative traits is seldom clear, but the way that these traits are inherited can be described and predicted statistically. Such statistical procedures form the basis of quantitative genetics. Information about an animal's performance and the performance of its relatives can be used to predict how its progeny will compare to the rest of the flock. Quantitative genetics forms the basis of modern animal breeding techniques.

Because the particular combination of genes that any lamb inherits from its parents will be random, modern animal breeding is more useful in predicting the characteristics of groups of animals than of individuals. Its methods will help to steadily improve your whole flock.

Setting your direction

The first step in establishing a breeding program is to decide what kind of changes need to be made to the existing flock. There is no use in making rapid change if it is in the wrong direction. It has been argued that the most successful breeders are those who do the best job of defining their aims most effectively.The breeders vision of the changes that should occur in the flock is the breeding objective (Farmnote 51/93).

The breeding objective is most usefully stated in terms of the traits that the breeder desires to change or maintain.The direction and size of the desired changes will be determined by the breeder's assessment of their economic importance.The breeding objective may include both measured and visually assessed traits.

A useful question to ask is: "What product do I plan to be selling in 5 to 10 years time?"

An example of a breeding objective could be:

"To increase greasy fleece weight by half a kilogram and reduce fibre diameter by one micron over a 10-year period while maintaining wool style and body comformation."

Other breeders might include increasing staple strength, reducing the range of fibre diameter in the flock (CVD) or other factors.

Selecting the right animals

Variation

(Farmnote 50/93)

Most traits of interest to sheep breeders have a 'normal' distribution. A familiar example is the histogram provided by fleece testing labs to show fibre diameter distribution. Many fibres have a diameter that is fairly close to the average. The number of fibres in each micron category drops rapidly moving further from the average. Only a few fibres of the finest or broadest microns are present in any sample.

Similarly, there will be many sheep in an unselected flock whose fleece weight is fairly close to the average. In a typical flock almost 70 per cent of sheep will have a clean fleece weight within 0.5 kg (one standard deviation) of the average. Only 2 per cent of sheep will be 1 kg (two standard deviations) above or below average for clean fleece weight.

The standard deviation (SD) is a measure of the degree of spread around the average value (mean). The coefficient of variation (CV) is the SD expressed as a percentage of the mean. Traits with a large CV vary widely around the average. Traits with a small CV show less variation. The variation seen in a flock is a combination of two things: differences between the genetic value of individual animals, and the environment.

Sheep with a larger number of favourable genes will have a higher genetic value. Even when lambs are run together they will be exposed to environmental differences which influence their hogget performance measurements (Farmnote 80/91, 100/2001).

Twins, for example, will be smaller and grow less wool than singles. Earlier born lambs will cut more wool than later lambs and the lambs of hogget ewes will be disadvantaged compared with lambs reared by older ewes (Farmnote 59/93). This means that a twin lamb born late in the drop to a hogget mother will have to be very good genetically to perform at the same level as a single lamb born early to a mature ewe.

Each animal is therefore the product of its genetic value combined with a certain amount of luck. Bad luck can make an animal with good genes look average or a genetically average animal look poor. Good luck can make an animal with average genes look a better breeding prospect than it really is.

This combination of genes and luck is what controls heritibly (Farmnote: 52/93). In a highly heritable trait, luck and genes are of nearly/ equal value in determining an animal's ranking within the flock. The lower the heritability of the trait, the greater the importance of luck, and the harder it becomes to predict progeny performance accurately.

Selection

The most important decision faced by breeders and their advisers is which animals should be kept as parents for the next generation. Rapid genetic progress (Farmnote 55/93) is only possible if the very best rams are selected as reserve sires. These are the only animals certain to possess superior genes as well as having had a favourable environment. The only way to be sure of selecting genetically superior animals is to focus on the outstanding animals in the top 5 to 10 per cent of the drop. You can increase your chances of picking the right animals by identifying environmental factors (such as litter size or birth date) and adjusting for them.

Selection criteria

Once the breeding objective (Farmnote 51/93) has been defined, the breeder must decide which traits will be used to select rams and ewes to be used for breeding. If the program incorporates indirect selection, these selection criteria may not be the same as the traits specified in the breeding objective. An example would be the use of selection based on reducing CV of fibre diameter to increase staple strength (Farmnote 46/98), or the use of faecal worm egg counts to increase resistance to internal parasites, (Farmnote: 52/02).

Breeding objectives including more than one measured trait, or using indirect selection, can be most efficiently achieved with the aid of a selection index (Farmnote 57/93). Achieving each breeder's different objective will require the development of an individual index.

Index selection

It is simple to rank rams using performance information on one trait. However, very few breeding objectives or selection programs are based on a single measured trait. Most Merino breeding objectives include both fleece weight and fibre diameter. Many breeders add other factors such as live weight, reproductive rate, staple strength, faecal worm egg count or fibre diameter distribution.

The selection index (Farmnote 57/93) is one of the most useful genetic tools available to help decide which rams have the most valuable combination of traits. It combines information from all measured traits to give each animal an overall score. Selection indices usually aim to identify a set of animals which carry the combination of genes that is most likely to achieve the objective across the whole flock. In doing so, the following factors are considered:

- The economic importance of each trait. As a rule of thumb, fleece weight will be most important, followed by fibre diameter, with other traits receiving less emphasis. The actual values used are defined by individual breeders in terms of their own enterprises and breeding objectives.
- Heritability of each trait (Farmnote 52/93). Traits which are more heritable are easier to change. They will therefore receive greater emphasis than less heritable traits. The heritabilities used are based on research results.
- Variability of each trait (Farmnote 50/93). Traits which show wide variation are easier to change than traits with a similar heritability which do not vary much. Larger differences between animals for the same trait make the best animals easier to find.
- How traits influence each other (Farmnote 56/93). Some genes which control one trait often influence other traits as well. An index takes account of such relationships between different traits. This means that index selection can be used to either prevent unfavourable changes in one trait as the result of changing another (e.g. increasing fleece weight without producing an increase in fibre diameter) or using one trait to improve another trait which is not measured (e.g. improving staple strength by selecting for reduced CVD).

An index will take account of these factors to provide:

- A system which can be used to rank animals for overall economic merit.
- Prediction of the changes that selection based on the index will cause in the flock over time (Farmnote 55/93). If a breeder is not happy with the predicted changes, the economic emphasis placed upon the traits in the objective may be changed to provide a different outcome.

Combining visual and objective selection

Most ram breeders want to incorporate some kind of visual assessment of sheep into their breeding programs. This may aid selection for traits such as wool style, conformation or fleece rot resistance. A common criticism of modern animal breeding techniques is that they pursue change in measured traits to the detriment of visually assessed characteristics. This need not happen.

Visually assessed traits can be incorporated into a measurement-based breeding program in several ways. Some examples are:

- Set independent culling levels for visual traits. Animals which do not meet these standards are not considered for selection.
- Set a minimum standard of objective performance and pick the most visually correct animals within the group.
- Use an integrated system for visual and measured selection such as the 'Ram Classing Lattice' proposed by Dolling, Anderson and Castle.

Each approach will have different results and produce different types of genetic change. The most appropriate method is likely to depend upon whether your breeding objective places more emphasis on measured or visual traits.

A simple approach is to identify the best available rams using performance records. Use the rams' index values to pick twice as many rams as you need for your breeding program. Half of this selected group can then be culled on visual characteristics.

Monitoring genetic progress

The genetic changes which occur in any breeding flock from year to year are small compared with the effect of seasonal differences or changes in management such as increased stocking rate. Simple observation or measurement of animal performance over the short term is a very poor indicator of genetic progress.

The best available measure of genetic progress in a flock where sire pedigrees are available is Best Linear Unbiased Prediction (BLUP). BLUP is a statistical technique which uses differences between the progeny of the same animals in different environments to distinguish between genetic and environmental effects on performance.

BLUP-estimated breeding values (EBVs) are an accurate selection tool (Farmnote 53/93). Changes in the average EBV of each year's hoggets can be used to measure genetic change.

Progress of flocks which do not have sire pedigrees available can be measured in other ways. One of the best is to use a reference sire in an on-farm progeny test (Farmnote 58/93).

The reference sire's progeny are compared to the breeding flock's progeny in an initial test and a few years later. The average performance of the reference sire's progeny will be the same for both tests. Any change in the relative performance of the two sets of progeny will be due to genetic change in the tested flock.

Long term production trends in the breeding flock can also be useful, but are the least accurate of the methods discussed. They only provide useful information after several years application of the same breeding objective. Wether trials (Farmnote 75/2002) also provide very useful information.

Genetic terms explained

(Farmnote 61/93)

BLUP (Best Linear Unbiased Prediction): A statistical tool which combines information on an animal's performance, the performance of its relatives and any known environmental differences to produce an

Estimated Breeding Value: Can be used to separate the genetic and environmental factors influencing animal performance.

EBV (Estimated Breeding Value) (Farmnote 53/93): Describes the estimated genetic difference between an animal and the average of a group. An EBV is equivalent to an animal's measured superiority after adjustment for heritability.

EPV (Expected Progeny Value): The amount by which an animal's progeny are expected to be superior to the progeny of the whole group. This is generally half the value of the animal's EBV for the same trait.

Environment: Any non-genetic influence on an animal's phenotype. Examples include nutrition, disease, age or climate. Even animals born and reared in the same flock under the same management will encounter many small environmental differences during their lives.

Genetic correlation: (Farmnote: 56/93) Describes the relationship between one trait measured in a group of animals and another trait measured in their progeny. For example, the negative genetic correlation between CVD and staple strength means that a group of parents with below average CVD is likely to produce progeny with above average staple strength. Genetic correlations reflect the extent to which genes that determine one trait also influence other traits.

Genotype: The particular combination of genes inherited by an individual. We cannot detect the important genes for most production traits, so we must rely on phenotype to estimate genotype.

Heritability: (Farmnote: 52/93) The proportion of an animal's superiority which can be expected to pass to its offspring. The amount by which an animal differs from the average will be influenced both by its genes and environmental conditions. Heritability represents the proportion of this difference which is due to genetic factors and will be transmitted to the animal's progeny. The heritability of fibre diameter for example is about 50 per cent. This means that if you mated a group of ewes and rams whose fibre diameter was a micron finer than the flock average, you would expect their progeny to be only half a micron finer than the rest of the drop.

Phenotype: An animal's measured or observed physical characteristics. Phenotype is determined by a combination of the genes which an animal inherits from its parents (genotype) and its environment.

Phenotypic correlation: (Farmnote: 56/93) This describes the relationship between two different traits measured in the same group of animals. An example is the higher staple strength seen in a group of animals with above average fleece weight.

Progeny test: (Farmnote: 58/95) A comparison between lambs born to a group of rams which were mated to randomly selected ewes at the same time. Pregnant ewes and progeny for all sire groups are run under identical conditions for the period of the test.

Repeatability: (Farmnote: 60/93) Describes the likelihood that animals will have the same ranking for a particular trait if measured more than once. It describes the proportion of an animal's superiority which is controlled by genes and permanent environmental effects (such as being born a twin). Repeatability is always higher than heritability for the same trait. This means that traits with traits with low repeatability are heavily influenced by temporary environmental effects.

Further reading

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