SHEEP SIRE REFERENCING SCHEMES - NEW OPPORTUNITIES FOR PEDIGREE BREEDERS AND LAMB PRODUCERS[a]

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Summary

Sire referencing schemes are cooperative breeding schemes which, through the use of artificial insemination, allow comparisons of sheep across cooperating pedigree flocks. Sire referencing schemes have been established in the Suffolk, Charollais and Texel breeds and are likely to be established in other breeds soon. This note explains how these schemes work and what advantages they offer both pedigree breeders and crossbred lamb producers in selecting rams.

Current Performance Recording Schemes

The aim of any performance recording scheme for pedigree sheep is to assist breeders in identifying genetically superior animals for pure breeding, and to assist customers in selecting rams for crossing. Such schemes are needed because:

i. The performance of all animals is a function both of their genetic make up (termed 'breeding value') and a host of non-genetic factors such as feed quality and quantity, exposure to disease, physical climate, management and husbandry skills of the owner, etc. (loosely termed 'management' or 'environmental effects'). Recording schemes attempt to disentangle these two types of factors and attempt to identify those animals which are truly genetically superior.

ii. Selection 'by eye' can be misleading. Large differences in characteristics such as liveweight obviously can be detected by eye, but distinguishing between animals of more similar weight is very difficult. Simple objective measurement of performance takes the guesswork out of selection and extends the range of characteristics which can be improved by selection (for example, fat and muscle depths are difficult to assess by eye or hand, but can be estimated fairly simply by ultrasonic scanning).

In Britain, most pedigree sheep performance recording takes place under the auspices of the Meat and Livestock Commission (MLC). The MLC's Sheepbreeder recording scheme caters for breeds where the objective is to improve either (i) lamb growth and carcass composition, (ii) ewe mature size, (iii) litter size, (iv) maternal ability, or various combinations of these. Recorded flocks are most numerous amongst the terminal sire breeds. In these breeds, recording was initially based on adjusted 8 and 21 week liveweights. However, recently, many flocks in these breeds have started to use ultrasonic scanning to provide estimates of fat and muscle depths at around 20 weeks of age - in 1990 over 350 MLC recorded flocks used ultrasonic scanning. Adjusted measurements of liveweight, fat depth and muscle depth are provided for scanned animals, together with an overall 'lean growth index score' with

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scores ranging from around 20 points to 220 points within each flock. This index, which was developed at The Scottish Agricultural College (SAC), Edinburgh, aims to identify those animals with relatively high liveweights and muscle depths but relatively low fat depths.

The basis of all variants of the MLC Sheepbreeder Scheme is that records of performance are adjusted for known non-genetic influences, such as birth and rearing rank (single, twin, etc.) and dam age. In addition to presenting measurements adjusted for these effects, rams are rated in bands according to their superiority in the recorded trait within their own flock. Rams in the top 10 per cent in adjusted performance in a given flock are rated as A, those in the next 15 per cent as B and animals of average, or below average, performance as C and D, respectively. This enables breeders and lamb producers to readily identify outstanding animals in all recorded flocks.

Undoubtedly the use of top performance recorded stock can have major benefits on the physical and financial performance of pedigree and crossbred flocks. However, current recording schemes do have limitations. The greatest of these is that, currently, records of performance and ram ratings cannot be compared across flocks or across years. In other words, it is impossible to tell whether an A-rated ram in one flock is better or worse than an A-rated ram in a different flock. Similarly, we cannot tell whether an A-rated ram recorded in 1990 is better or worse than a ram of the same rating recorded in 1991 (whether in the same or in a different flock). One of the biggest influences on the rate of genetic progress that can be achieved, either in pedigree or crossbred flocks, is the number of rams available for selection whose estimated breeding values (EBVs) can be compared directly - it is easier to identify and select animals of outstanding genetic merit from a large group than from a small group. Hence, the inability to compare animals across flocks and years imposes a major constraint on genetic progress in British sheep flocks.

The reason that records of performance cannot be compared across flocks or years is that differences in average performance between pedigree flocks and between years arise both for non-genetic and genetic reasons and these are difficult to separate. For example, different pedigree flocks have different management and feeding policies, but they also use different rams. Likewise, variations in the weather from one year to the next affect animal performance (directly or indirectly through the quality and quantity of feed available) but so too does the introduction of new breeding stock from one year to the next. The only effective way to disentangle these genetic and non-genetic differences between flocks and years is to use the performance of related animals in different flocks and years as a benchmark. In dairy cattle populations worldwide, because of the widespread use of artificial insemination (A.I.), related animals occur in many different herds and in different years. The availability of these 'genetic links' across herds and years, together with the use of sophisticated methods of estimating breeding values which capitalize on these links, are major reasons for the well documented genetic progress which has been made in dairy cattle, particularly in North America.

The use of A.I. in most British sheep breeds is very low, and so genetic links between most pedigree flocks are weak. Sire referencing schemes (SRS) have been established in the Suffolk, Charollais and Texel breeds to deliberately create genetic links between pedigree flocks and hence enable comparisons of animals across cooperating flocks. (SAC is actively involved in research and development to improve A.I. techniques in sheep. Through its trading division, Edinburgh Genetics, SAC offers an A.I. service to sheep breeders to allow participation in SRS). Before describing how SRS operate, it would be helpful to consider approaches to estimating genetic merit in a bit more detail.

Approaches to Estimating Genetic Merit

Most sheep producers recognize that an animal's performance is a function of its genetic makeup (breeding value) and the way it is managed and fed, or happens to be exposed to disease

etc., as described above. In other words, an animal of low genetic merit for a particular aspect of performance may look better than it really is as a result of good feeding or management and, similarly, an animal of high genetic merit may look worse than it really is as a result of poor feeding and management. The major challenge facing pedigree breeders and lamb producers selecting rams is to disentangle these genetic and non-genetic effects on performance, and to identify those animals with the highest breeding values - that is, those which will leave progeny of the highest genetic merit. Traditionally, attempts to disentangle these effects have been made in two steps:

 i. correcting records of performance for non-genetic effects; and

 ii. estimating breeding values from corrected records of performance on one or more traits from the individual animal and/or its relatives.

Correcting records of performance for non-genetic effects

For some non-genetic effects, it is possible to measure the average effect on performance. For instance, with enough records of 21 week weight, or fat and muscle depths, it is possible to measure the average differences between lambs of different birth and rearing rank, or of lambs from ewes of different ages. Although we recognize that we can only measure the average difference between birth rank or dam age groups, it helps in comparing individual animals if we take account of these average differences. Selection by eye, or on unadjusted performance records, for example for liveweight, would tend to pick out early born single lambs from mature ewes. Although these animals would tend to be larger themselves, they would not necessarily leave progeny with the highest growth rates. Records of performance are often adjusted simply by subtracting or adding the average difference, say, between birth rank or dam age classes, so that lambs are compared as if they were all born on the same day, as twins, out of mature ewes. Another approach, the one currently used in the MLC Sheepbreeder Scheme, is to assume that, on average, lambs of different birth and rearing rank out of dams of different ages are of equal genetic merit. That is, animals are ranked within their own particular birth rank and dam age group (so called 'contemporary environmental groups'). This assumption of equal genetic merit is probably not valid in many cases, but this method of adjusting for non-genetic effects does have other advantages, particularly when flock sizes are small, as they are in most pedigree breeds in Britain, and where there are large differences in performance between flocks.

Although there are non-genetic effects, such as birth rank and dam age, which we can readily identify and attempt to correct for, there are others which we either do not recognize or which we recognize and can do little about. For example, we know that diseases affect animal performance, but it is extremely difficult to predict how an affected animal would have performed if it had not contracted the disease. The best that breeders can do to minimize the influence of these non-genetic effects is to treat animals which they wish to compare in the same way.

Using information from relatives and for several traits

The only way to measure the true breeding value of an animal with certainty is to measure the performance of very large numbers of its progeny. However, we can estimate breeding values with varying degrees of accuracy from the performance of (1) the animal itself, (2) its ancestors, (3) smaller numbers of progeny, (4) other relations, eg. brothers, sisters, etc., or (5) various combinations of 1 to 4 above (eg. the MLC Sheepbreeder Scheme for terminal sire breeds uses information on the individual animal's performance, together with that from full and half brothers and sisters, and other relatives in some cases).

The reason that we are able to estimate an animal's breeding value from the performance of its relatives is that relatives share genes from common ancestors - the closer the relationship, the more genes in common and the greater the resemblance between the relatives - either in appearance or performance.

The accuracy with which breeding values can be estimated from performance of relatives depends, not only on the closeness of the relationship, but also on the number of relatives with records of performance available.

The similarity between relatives depends not just on the closeness of the relationship, but also on the heritability of the characteristic concerned. In fact, one way of defining heritability is as the proportion of the superiority in performance of parents which is passed on to their offspring.

For traits with fairly high heritabilities, such as liveweight and fatness, an animal's own performance is a fairly good indicator of how its offspring will perform (its breeding value). For traits with lower heritabilities, such as number of lambs born, the animal's own performance is a less accurate indicator of its breeding value, and records from a large number of relatives are particularly useful.

In the simplest case, an animal's estimated breeding value (EBV) is its own superiority in performance (eg. advantage in 21 week weight compared to contemporary animals, say, 10 kg for a particular ram) multiplied by the heritability of the trait concerned (about 0.25 for 21 week weight, resulting in an EBV of 10 x 0.25 which equals + 2.5 kg for the ram concerned). In practice, the performance of relatives is often used to refine EBVs based on individual performance, essentially by adjusting these upwards or downwards, depending on the 'track record' of the relatives. For example, if we had to choose between 2 rams with identical adjusted 21 week weights, one from a family with high average weights and the other from a family with lower weights, we would have more faith in the ram from the fast growing family. Including information from relatives in the EBVs for these 2 rams would increase the EBV for the ram from the fast growing family, and decrease the EBV for the ram from the slower growing family.

In many cases, the economic performance of farm livestock depends on more than one characteristic. It has therefore become common to measure several characteristics of performance and to combine EBVs for individual traits into a single score for overall merit - such as the lean growth index described earlier. Index selection involves 'weighting' EBVs for individual traits according to their relative economic importance and their relationship to other traits of economic importance.

Improved Methods for Estimating Breeding Values

Several decades ago, new procedures, known by the acronym BLUP, were developed in the USA for evaluating the genetic merit of progeny tested dairy bulls. BLUP methods for estimating BV have now been adopted for dairy cattle evaluations in many countries, including the UK, and are being used increasingly in other species.

BLUP stands for Best Linear Unbiased Prediction which sounds complicated, but the important fact is that BLUP is the best method we have for estimating breeding values. That is, BLUP EBVs are closer to true breeding values, or more accurate, than EBVs produced by other methods.

BLUP differs markedly from traditional methods of estimating BV in one very important respect. It estimates the environmental effects and breeding values simultaneously rather than in two steps, which results in better estimation of both environmental effects and breeding values. In addition, it can make full use of records of performance from all related animals, whether in the same or different flocks, to give more accurate estimates of breeding value. As long as there are reasonable num-

bers of related animals in different flocks, or contemporary groups (flocks are 'linked' or 'connected') and in different years, then BLUP EBVs can be compared across flocks and years. The ability to compare animals across flocks with BLUP evaluations will allow much greater progress, both in pedigree and commercial flocks as rams (in particular) can be selected from a much wider pool than at present with only within-flock evaluations.

Because EBVs can be compared across years, the genetic progress in a breed or in a group of linked flocks can be charted year by year - a valuable check for breeders, and an important marketing tool to demonstrate to customers that the breed or group of flocks is improving.

Running BLUP evaluations requires large computing resources. However, developments in computer hardware and software now make BLUP evaluations feasible in many more animal breeding programs. This, together with improvements in A.I. techniques for sheep to produce links across flocks, provide the basis for Sire Referencing Schemes.

Sire Referencing Schemes

The diagram in Figure 1 illustrates how sire referencing schemes operate. The principle of these schemes is that each cooperating breeder agrees to use semen from several rams from a team of 'reference sires' on a proportion of the ewes in his or her own flock. Table 1 gives an example of how the progeny of reference sires can help in selecting ram lambs across flocks. Table 1 shows the 21 week weights of ram lambs in 2 flocks, A and B. The lambs are the progeny of several different rams, but one ram (Sire No. 1) has been used in both flock A and flock B. The performance of lambs in flock A is higher than that in flock B, resulting in a 10 kg higher flock average for flock A.

Table 1. Example Showing How Reference Sires Allow Comparisons Across Flocks.

Ram lamb no.	Sire ID	Adjusted 21 week wt. (kg)	Within-flock EBV for 21 week wt.		Across-flock BLUP EBV for 21 week wt.	
			EBV (kg)	Rank	EBV (kg)	Rank
Flock A						
1	1 (Ref)	84	+2.25	1	+0.75	4 tie
2	1 (Ref)	79	+1.00	4	-0.50	10 tie
3	1 (Ref)	81	+1.50	3	0.00	8
4	3	76	+0.25	5	-1.25	12
5	3	83	+2.00	2	+0.50	6
6	4	72	-0.75	7	-2.25	14
Flock A average		75				
Flock B						
51	1 (Ref)	60	-1.25	6	-0.25	9
52	1 (Ref)	62	-0.75	5	+0.25	7
53	1 (Ref)	59	-1.50	7	-0.50	10 tie
54	7	69	+1.00	3	+2.00	2
55	7	64	-0.25	4	+0.75	4 tie
56	8	72	+1.75	1	+2.75	1
57	8	67	+0.50	2	+1.50	3
Flock B average		65				

If neither flock had used the reference sire (Sire 1), then we would probably pick ram lamb number 5 in flock A which has the highest adjusted weight (83 kg) and the highest within-flock EBV for 21 week weight (+2 1 kg). However, the use of the reference sire shows that:

i.   in flock A, the progeny of the reference sire are generally better than the progeny of other rams;

ii. in flock B, the progeny of the reference sire are generally worse than the progeny of other rams.

If the ewes in the 2 flocks are of similar genetic merit, we expect the progeny of the same reference sire to be of similar genetic merit in the two flocks. The fact that the progeny of the reference sire are better than others in flock A indicates that the other sires used in flock A are of lower merit than the reference sire. On the other hand, the fact that the progeny of other sires in flock B are better than those from the reference sire indicates that the non-reference sires and their progeny are of higher genetic merit than the reference sire. This illustrates how the reference sires are used as a benchmark to identify animals of outstanding merit across flocks. The last 2 columns show how this would be reflected in the across-flock BLUP EBVs and the across-flock rankings. These show that the animals with the highest EBVs are lambs 56, 54 and 57, two of which (54 and 57) could have been overlooked if we had used only within-flock EBVs.

As well as making use of the comparative performance of the progeny of reference sires across flocks, BLUP EBVs will be more accurate as a result of more effective separation of genetic and environmental effects on performance, and using information from all relatives. This will result in differences between within-flock and across-flock rankings. At first sight this may cause concern, but even when these differences are less easy to reconcile than in the example shown here, it is important to remember that the across-flock EBVs are most accurate.

Some reference sires are used in successive years to create genetic links which allow EBVs to be compared across years. Other reference sires are replaced by superior rams, identified by their across-flock EBVs. Thus the reference sires have a dual role - creating genetic links across flocks and years and producing more rapid dissemination of genetic improvement. It is difficult to separate the benefits of using BLUP from the benefits of linking flocks but the use of BLUP EBVs probably allows around 20% extra annual genetic progress compared to that possible with traditional methods of estimating breeding value. Additionally, the linking of flocks in the manner described to create a larger pool of animals for selection probably allows around a further 30 to 60 per cent improvement in response to selection.

Sire Referencing Schemes have been used for several years in sheep or beef cattle in New Zealand, Australia, France and the USA. Sire Referencing Schemes were established in the Suffolk and Charollais breeds in the U.K. in 1989/90. The Suffolk Sire Referencing Scheme currently involves around 30 pedigree flocks, with a total of around 2000 ewes. Members of the Suffolk SRS use a minimum of two references sires on a minimum of 30 ewes in their own flock. Currently about 6 reference sires are offered to members annually. These are replaced periodically by high ranking rams, selected on their across flock EBVs, and subjected to additional screening on functional fitness, breed type and conformation.

The Charollais Sire Referencing Scheme involves around 20 flocks, with a total of around 1700 ewes. Currently two reference sires are available annually for use on a minimum of 10 ewes each in all participating flocks.

Advantages to Pedigree Breeders and Crossbred Lamb Producers

In brief, Sire Referencing Schemes offer advantages to participating breeders, to non-participating breeders who purchase rams from SRS, and to crossbred lamb producers purchasing rams from SRS because:

i. EBVs for sheep in SRS are more accurate because they are evaluated using BLUP. (Within-flock EBVs will differ from across flock EBVs as a result of (a) more effective separation of genetic and non-genetic effects, and (b) fuller use of information from relatives. Whenever within-flock and across-flock EBVs are available, breeders and lamb producers should always use across-flock EBVs as these are more accurate).

ii. BLUP EBVs can be compared across flocks participating in SRS - this vastly increases the pool of animals available for selection, allowing more intense selection of outstanding animals, and hence faster rates of genetic progress.

iii. BLUP EBVs from SRS can be compared across years. This enables breeders and commercial producers to ensure that the animals they select are better than those used in previous years.

Although participation in Sire Referencing Schemes is on a relatively small scale at the moment, involvement in existing schemes, and the extension of these schemes to other breeds, is highly likely in future. Although the techniques involved are new to sheep breeding in Britain, they have been widely applied and proven in other livestock species, and both pedigree sheep breeders and lamb producers can use the results with confidence.

Figure 1
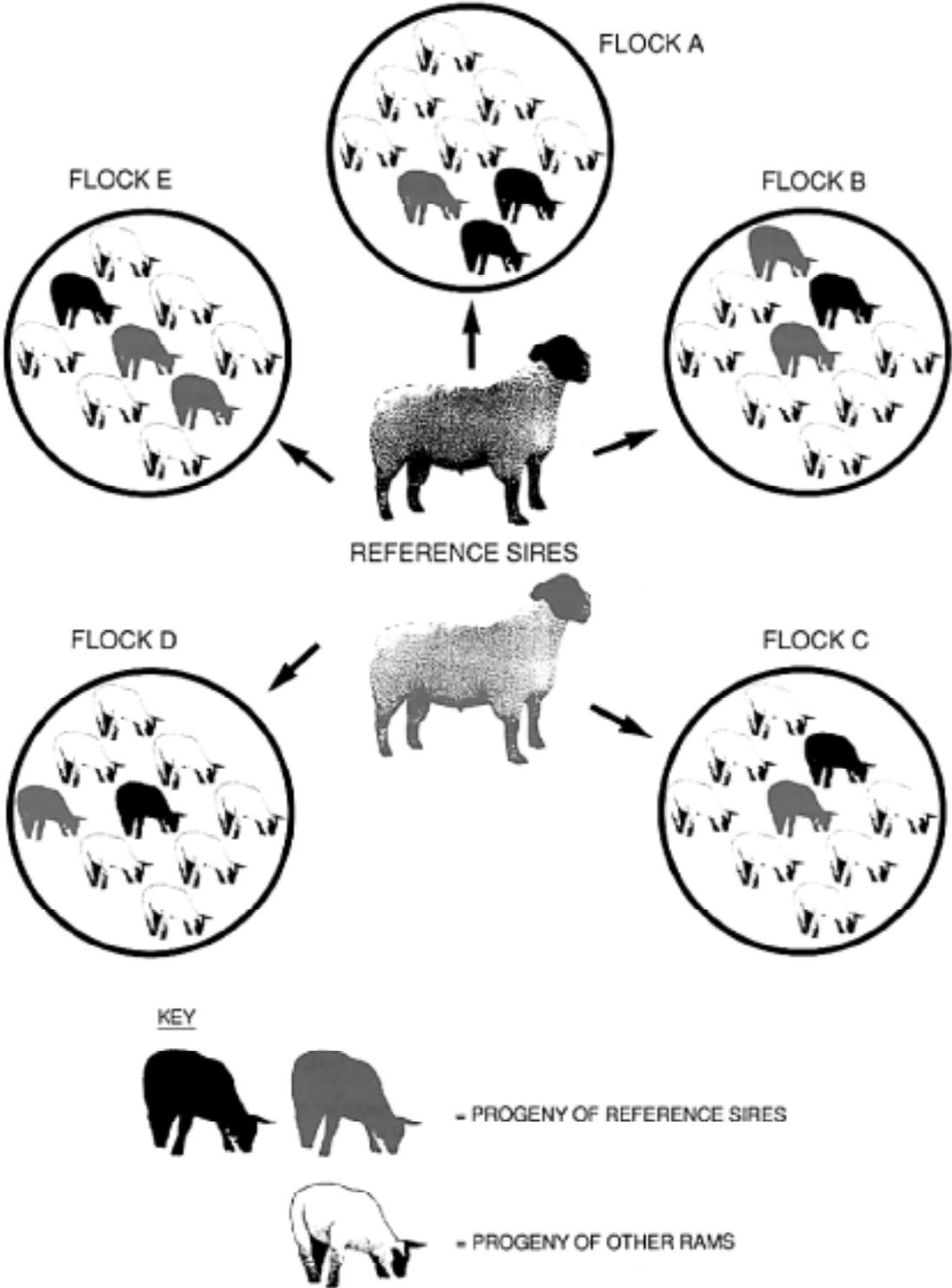
SCHEMATIC DIAGRAM OF A SIRE REFERENCING SCHEME