

GENETIC EVALUATION OF CATTLE AND SHEEP

INTRODUCTION

M.E. GODDARD*

When choosing sires and dams with which to breed future generations, the genetic merit that they will pass on to their offspring (called their breeding value) is of great importance. If we wish to continue to improve a trait we must choose the animals with the highest breeding values for that trait. We cannot do this unless we can estimate the breeding values of the animals available for selection. In the past, various methods have been used to estimate breeding value including a critical study of the animal's appearance but, in recent years, new and more accurate methods have been introduced into the dairy, beef and wool industries. In this segment I describe the principles on which estimation of breeding values is based. The following contributions explain how these are applied to the dairy, beef and wool industries.

Allowing for environment effects

An animal's appearance and performance depends on both the genes that it inherits and the environment in which it grows and produces. However, it only passes its genes to its offspring. Some environmental factors affect the animal throughout its life, for instance, conditions in its mother's uterus before birth, while others have only a short term effect, for instance on one season's milk yield or wool growth.

The importance of these environmental factors means that an animal's appearance and performance is not an accurate guide to its breeding value. In estimating an animal's breeding value we try to allow for these environmental effects in two ways. First, there are environmental factors whose effect is repeatable and known. For instance, we know that mature cows wean heavier calves than young cows and so we can correct for this effect. Second, there are environmental effects whose magnitude we do not know. For instance, calves grazing in different paddocks experience different environments and this will affect their growth rates. We deal with this problem by comparing an animal with other animals that have been reared and run together and treated similarly.

Early genetic evaluation systems simply calculated the deviation of each animal from the mean of its management group and assumed that the average genetic merit of all management groups was the same. However, this assumption is not often justified because some groups are genetically superior to others. If there is some genetic link between the groups, such as both groups containing offspring from the same sire, then it is possible to estimate the genetic difference between the groups. A major advantage of the statistical method known as best linear unbiased prediction (BLUP) is that it estimates genetic and environmental differences simultaneously. However, if there are no known links between groups then we must estimate breeding values on a within-group basis and cannot compare the breeding values of animals in different groups. -This is necessary where bulls are, used in one herd only, or where pedigrees are not recorded.

* Department of Agriculture and Rural Affairs. E. Melbourne, Vic. 3 0 0 2 .

Using information from relatives

Because animals share some genes with their relatives, the performance of these relatives is useful in estimating an animal's breeding value. The most useful relatives, once their records become available, are progeny, because they provide a direct record of breeding value, although a large number of progeny is necessary to make the estimate highly accurate. However, other relatives such as parents and sibs are also useful. BLUP allows information on an animal's own performance and that of all its relatives to be correctly combined to estimate its breeding value.

Errors in estimating breeding value

Even among a group of animals reared and run together there are environmental factors which cause large differences between them. If the heritability of a trait is 25 %, then 75 % of the variation between animals is due to unknown environmental effects and non-additive genetic effects. Consequently, animals which perform better than the average of their group typically owe part of this superiority to unknown environmental factors and part to superior breeding value. Similarly, if a bull's first three daughters are excellent we should not expect that all future daughters will be as good. Unless an animal has a large number of progeny we cannot estimate its true breeding value very precisely. BLUP and selection index methods take account of the amount of information available on each animal when estimating breeding values. Consequently, among animals with an estimated breeding value for milkfat yield of +30 kg, half will have a true breeding value above +30 kg and half below +30 kg, but their average true breeding value will be +30 kg.

The likely error in estimated breeding values (EBV) can be assessed from the correlation between estimated and true breeding values (r) which is called the 'accuracy' of the EBV. In dairy cattle it is conventional to report r^2 which is known as the reliability. Although accuracy in estimating breeding values is desirable, it is necessary to reach a compromise between high accuracy and other desirable features of a breeding program such as low generation interval and low cost. The best breeding programs operate at intermediate levels of accuracy.

Interpretation of estimated breeding values

The expected breeding value of a calf or lamb is simply the average of the EBVs of its parents. For instance, the expected breeding value for milk yield of a calf whose sire is +1000L and dam is -200L is +400L. Heifer calves such as this will produce on average 400L more milk per lactation than calves with an expected breeding value of zero, although individual calves may be better or worse than expected.

'GENETIC EVALUATION IN THE MERINO SHEEP INDUSTRY'

R.P. LEWER*

Most selection of replacement sires and dams in the Merino sheep industry is still on the basis of subjective assessment. The classifier attempts to predict the genetic merit of animals by using visual indicators which he assumes are correlated with the traits he wishes to improve. Although relatively inefficient, this method has the advantage of being cheap to operate. However, some costs are hidden, including the cost of sub-optimal genetic progress towards the breeding objective. There is a strong movement toward a combination of subjective and

* Animal Breeding and Research Institute, Katanning, W.A. 5317.

objective assessment, particularly for ram selection.

Estimated breeding values (EBV) for objectively assessed traits are more accurate than for most subjectively assessed characteristics; that is they have higher heritabilities. Also these objectively assessed traits, such as fleece weight, are often directly related to commercial profitability.

The model

In a simple model, the performance of a particular animal for a given trait can be expressed as:

Phenotype = Group mean + Breeding value + Environmental effect
(Observed value)

This can be transformed to allow estimation of the breeding value as:

EBV = Phenotype - Group mean - Environmental effect

Two important points emerge from this equation.

- (i) The more that is known about the environmental factors which have affected an animal's performance, the more accurate will be the estimate of its breeding value
- (ii) Because EBVs are expressed as a deviation from group mean, they can only be used to compare animals in the same group. We cannot compare animals in different groups because we cannot tell if the differences in performance are genetic or environmental. Comparisons between animals in different groups require special assumptions or procedures.

Environmental effects

In Merino breeding, important environmental effects include the age of the dam of the individual, date of birth, whether it was born and reared as a single or multiple, its sex and management group. When comparisons are made within one of these factors, that effect can be ignored. This is usually the case with sex and management group effects.

Merino ram breeding enterprises are almost invariably large scale. Little or no recording is carried out at lambing and therefore no information is available on dam age, dam's identity, whether born and reared as a single or multiple or date of birth. Lambs born from young ewes, twins and those born later in the season are penalised relative to their contemporaries. Therefore EBVs are less accurate and genetic gain will be slower than might have been possible had more details been recorded.

Estimation of breeding values

There are invariably some unknown environmental effects which contribute to an animal's performance. The best that we can do to allow for these effects is to assume that some of an animal's superiority or inferiority is due to unknown environmental effects. Consequently we estimate its breeding value to be closer to the mean of the population than its phenotypic value.

This is achieved by:

$$EBV = h^2 (P - \bar{P} - E)$$

Where h^2 = heritability

P = individual's performance

\bar{P} = average group performance

E = known environmental effects

This is a direct EBV; for instance, measurements of fleece weight are used to predict breeding value for fleece weight. The accuracy of the EBV can sometimes be improved by utilising information on other traits. For example, measurement of hogget weight is useful in predicting breeding value for litter size because it is correlated with it and more heritable than litter size. A selection index combines several sources of information to estimate breeding value. In sheep breeding, the objective is almost always to improve more than one trait using more than one measurement (selection criteria). A selection index is therefore the appropriate method of evaluation.

Breeding values can be more accurately estimated if information on the performance of relatives is included. For example, dams' and half-sisters' lambing data could be included in a ram's EBV for reproduction rate.

Examples

(i) Woolplan Woolplan is a testing and recording service for sheep that have been fleece tested (Lewer et al. 1986). It is based on estimation of breeding values for traits of value in a commercial Merino breeding enterprise, namely, clean fleece weight, fibre diameter, number and weight of hoggets and mature live weight. EBVs take account of both direct and correlated measurements and provide for the use of combinations of clean fleece weight, fibre diameter, hogget live weight and dam's number-of-lambs-weaned as selection criteria; the first two are mandatory. The EBVs are combined into a selection index by weighting each by an appropriate relative economic value and summing overall.

The heritabilities and correlation estimates used in Woolplan are from research flocks where environmental effects are routinely recorded. In an industry where the same environmental effects are ignored these estimates will over-estimate breeding values because the appropriate heritabilities will be about 10 - 15 % lower than those assumed. However, if the relevant data are supplied, Woolplan has the facility to correct for dam age, birth/rearing rank and date of birth either by using standard correction factors, or by using the data itself to provide the necessary information.

Woolplan EBVs are based on individual performance test data for individual selection; Because, in the foreseeable future, there is unlikely to be a strong change towards pedigree recording in Merino flocks, the evolution of a system which includes relatives' information is likely to be slow.

Generally, Woolplan EBVs can be compared within management groups only. If rams are randomly assigned to management groups, then Woolplan can compare rams in different groups. Methods of dealing with non-random allocation are currently being considered.

(ii) Sire Referencing A sire referencing scheme (SRS) is a system of formal development of genetic links between flocks to enable comparisons to be made between sires used in different flocks. A pilot scheme is being operated from WA (Lewer 1987) and is now expanding interstate. Because the reference sires are used in other flocks, it is possible for each breeder to compare the offspring of his own rams with those of the reference sire and, hence, indirectly with the offspring of rams in other flocks. To obtain fair estimates of breeding value it is essential that ewes are randomly allocated to rams and that all progeny are run together and treated alike. Then the environmental factors which affect each animal's performance tend to average out over the group of offspring from each ram.

The data are adjusted for birth type (single or twin), average mating dates are recorded, and the EBV of each ram is calculated from the deviation of his progeny from those of the reference sire. The genetic links between flocks then enables EBVs to be compared across flocks.

Rams are assessed in the sire reference scheme by computing EBVs for clean fleece weight, fibre diameter and hogget live weight. Final choice of replacement reference sires is based on sheep classers' grades and comments within progeny groups and flocks. A method of comparing classer comments across flocks has yet to be devised.

GENETIC EVALUATION OF BEEF CATTLE

H.-U. GRASER* and B. TIER*

Our beef cattle breeding industry in Australia is characterized as an extensive industry with some 30 different breeds, some 40,000 breeding herds, a wide variety of environments and management practices and low usage of artificial insemination (AI). However, within this industry a small but growing group of registered and commercial breeders, about 400 in July, 1987, is undertaking a sometimes intensive performance recording program with their cattle using the National Beef Recording Scheme (NBRS).

To assist the development and uptake of performance recording and genetic evaluation procedures in the industry, the Australian Meat and Livestock Research and Development Corporation (AMLRDC) has assumed responsibility for the NBRS. The Agricultural Business Research Institute (ABRI) at the University of New England has been licenced to market the Scheme and process the data. AMLRDC is also funding the research and development of the genetic evaluation procedures in NBRS which are known as BREEDPLAN and GROUP BREEDPLAN.

In contrast to dairy cattle, most economically important traits in beef cattle are not sex limited and can be measured at an early age. This permits substantial genetic gains to be made with herds of adequate size. As the amount of genetic linkage across herds is small due to the small amount of AI used, genetic evaluation is being primarily directed at the individual herd under the name BREEDPLAN. However, across-herd evaluation system, GROUP BREEDPLAN, is also available to groups of herds or to breeds which have established strong genetic links between herds. Performance recording of beef cattle in Australia is voluntary and the responsibility of the producer; there is no external control, but assistance is available if requested. In the future, some performance information may be directly transferred from the abattoirs to the central NBRS computer for processing.

Genetic improvement in beef cattle profitability is a complex task:

*Animal Genetics. and Breeding Unit, a joint venture of the University. of New England and NSW Department of Agriculture, Armidale, N.S.W. 2351.

reproduction, production and product have to be considered. The genetic evaluation of these characteristics requires the intensive recording of many traits and a complex evaluation procedure. Furthermore, the breeding objective has to be defined and economic values obtained for the traits in that objective. Ideally, one single figure should be calculated and used to rank all animals available for selection at each stage. Currently, we have neither the sets of economic weights for the range of breeding objectives covering the array of production-marketing environments nor the comprehensive recording and evaluation systems. Progress is being made towards these ends and here we describe briefly the current genetic evaluation system.

Breedplan 1987

At the time of writing, (July 1987), genetic evaluation procedures are implemented only for the evaluation of growth traits and preweaning maternal performance. Two analytical procedures are used; one for birth weight as a single trait, and the other for weaning, yearling and final weights using a multi-trait model. Together, these comprise the basic BREEDPLAN system in NBRIS. As weights at different ages are correlated, a simultaneous analysis of the traits is necessary to avoid selection bias, e.g. castration of below average calves at weaning, or their sale as weaners, and the subsequent missing records at yearling age. As weaning weight is a product of the calf's potential to grow and the dam's ability to produce milk, weaning weight is treated as a combination of these two components: 200-day growth and 200-day milk. Genes for milk are of course transmitted from one generation to the next by both dam and sire even though they are only expressed in cows. Research has shown that the genetic correlation between the two traits, growth and milk, is very low positive to slightly negative and BREEDPLAN treats these traits as uncorrelated.

The so-called 'animal models' (Quaas and Pollak 1980), in which the breeding value of each animal is included, are used in BREEDPLAN, and the relationships between all the animals in the herd is also incorporated in the analyses. Such a model accounts for mating biases if the information, such as performance records of previous calves, on which mating decisions were made is included in the data. Hence, breeders can make selective matings, best sire to best cows, and still obtain valid EBVs for all animals in the herd.

The use of all pedigree information via the relationship matrix also allows for genetic comparison of animals across management groups and between years, provided these genetic groups and years are linked by common sires and dams. In addition, the relationship matrix accounts for genetic trends, permitting the direct comparison of animals generations apart. However, introduced animals that are unrelated to the herd cause problems in herds with many years of recording and genetic trends different from zero. The breeding values of these animals may then be over- or under-estimated until they have many progeny in the importing herd. To overcome this problem a procedure has been implemented in BREEDPLAN, which assumes the genetic value of these imported sires to be equivalent to their contemporary herd sires rather than to those animals used when the herd started performance recording.

Records are preadjusted for the differences in age of calf at weighing using multiplicative adjustment factors derived from breed- and age-specific intercepts (Raymond 1982). Age of dam at calving is also adjusted using breed-specific multiplicative adjustment factors. These adjustment factors will eventually be estimated on a breed within region or even herd basis to further improve the removal of these non-genetic biases and increase the accuracy of the estimated breeding value.

One of the most difficult problems is the correct definition of management groups, i.e. the group of contemporary records which are used in making the initial comparisons in the analyses. Breeder defined management groups are further divided by date of birth in 29-day intervals, to minimise age adjustment error and to better account for seasonal changes. However, it is now clear that this is insufficient, as animals with the same recorded management code and of similar age are often weighed on different days, so were probably raised in different management groups. Often single animals, particularly bulls, are weighed prior to sale. Do these have to be treated as a separate management group? A considerable extension effort is required to ensure that breeders correctly identify animals managed differently. Software can provide for checks, but will never be able to make the correct decision on all occasions.

Estimated Breeding Values are reported for all sires in the herd, for all reproductively active cows and for the last two calf-crops separated into heifer, steer and bull calves. The EBVs are expressed in kg for the traits birth weight, 200-day weight (split into calf growth and cow milk production components), yearling weight, final weight and a maternal value for 200-day weight. Further, for each trait, the average EBVs for cows calving in a particular year and for heifers, steers and bulls are calculated and printed for up to 16 years of recording, as monitors of realised genetic progress. The environmental trend for each trait is also shown to assist in management decisions. The first 200 recorded calves in each herd are used as a base, with their average EBV set to remain constant at zero. This avoids changes over time with the addition of new data. Because this base is different in each herd BREEDPLAN EBVs cannot be used to compare animals in different herds.

Errors are inevitable in the estimation of breeding values. These errors can be substantial if little information is available for an animal. Accuracies for BREEDPLAN EBVs are not calculated because this would substantially increase computing costs and complicate the output. However, the EBVs are the 'Best' estimates given the data and the model. They should be used to make selection decisions for those traits for which they were calculated and within the herd which provided the data set.

Group breedplan

To allow the combined analysis of several herds a multi-herd version of BREEDPLAN has been developed (Graser et al. 1987). On request, several herds are checked for sufficient genetic links and then analysed jointly. GROUP BREEDPLAN EBVs are published in a similar form to BREEDPLAN evaluations. However, other information, such as lists of sires and cows with the lowest EBVs for birth weight and the highest EBVs for other traits (trait leaders), is also provided. An additional charge is made for the extra computing and clerical work involved in the GROUP BREEDPLAN analysis.

Future developments

A major research program is underway to further improve the genetic evaluation system for the Australian beef cattle herd. Additional traits, such as serving capacity and scrotal circumference, and carcass characteristics will be included, and the flexibility of the system increased to accommodate all major industry needs. The correct treatment of records from embryo transfer calves will be included and research into a multi-breed genetic evaluation has started. In parallel to this work, research has commenced at the Animal Genetics and Breeding Unit and elsewhere to define breeding objectives for the range of marketing environments and derive the economic values for the traits. The beef industry will then have a comprehensive and flexible performance recording and genetic evaluation

DAIRY INDUSTRY

L.P. JONES*

The dairy industry has been fortunate in that many farmers have recorded production as part of their general farm management. Modern statistical procedures, such as BLUP, as well as the increased power of computers enable us to make better use of these records. Only records which have already been collected are required to compute breeding values for production. Interest in conformation or type, milking speed and temperament has led to these characters being recorded in some herds.

Details of the method for assessing breeding values is given by Jones (1985). Records are corrected for known environmental factors such as age and stage of lactation. A unique feature of the Australian scheme is that the milk yield of a cow on a particular test day is compared initially with that of all other cows tested on the same day. This enables us to use lactations in progress effectively. After correction of data for age and stage of lactation, the test day records are used to calculate a 'production index' for each lactation. Using BLUP, cows are compared with other cows calving in the same herd, year and season. All lactations for a cow are used and optimum use is made of pedigree information so that the ABVs for cows and bulls can be estimated at the same time. Because of practical limitations the relationship between a cow and her daughter is not used if they are in different herds. Widespread use of AI provides linkage between herds and allows the breeding values of bulls and cows in different herds to be compared.

Because of the importance of overseas bulls to some Australian breeds, note is taken of the estimated breeding value calculated in their own country. The method developed by Goddard and Smith (personal communication) assumes that our initial estimate of the genetic merit of an overseas bull is, its 'converted breeding value' (Goddard 1986) rather than the breed mean.

Australian Breeding Value (ABV)

This is the term used to compare the genetic merit of bulls and cows in the dairy industry. A heifer whose ABV is +30 kg is expected to produce 10 kg of butterfat per lactation more than a heifer with an ABV of +20 kg for example. However, for individual cows, the prediction of their performance is poor because environmental effects may cause their actual yield to be higher or lower than expected from their breeding value. ABVs are expressed relative to a base, this base being a set of bulls who had daughters on file in 1981-82. The base is such that less than 40 % of cows have a positive ABV. It is the difference between ABVs that is important, not their absolute values.

Characters . . .

At present ABVs are published for milk, fat and protein production, fat and protein percentage, as well as for 29 type characters. In future, ABVs will also be computed for temperament, ease of milking, ease of calving and longevity. In the longer term, there may be demand for ABVs for other traits or for overall profitability (Goddard 1987). A major limitation to computing an ABV for overall profitability with confidence is lack of information on individual feed intake, although a measure of size may allow a sufficiently accurate assessment-

Usina ABVs

The Australian Dairy Herd Improvement Scheme computes and publishes ABVs of bulls for type and production. It also sells lists of top cows for production ABVs to the industry, and ABVs of cows are supplied to the owner by state herd recording schemes. It is largely left to personnel in the industry to decide how to use this information.

The availability of ABVs has two main benefits to the industry. First, it increases the confidence with which farmers can select bulls. ABVs enable us to compare bulls from all Australian AB centres as well as from overseas. Farmers are prepared to pay a premium for semen from bulls with high ABVs for milk and fat.

Second, AB centres make use of the lists of top cows in planning their contract matings. This helps ensure that the new teams of young bulls are of the highest merit possible. This, in turn, guarantees that we will continue to make genetic progress and, at the same time, it enables farmers to use more semen from unproven bulls and enables us to get more accurate progeny tests.

Some centres have demonstrated their determination to breed bulls with high ABV by selecting from the unregistered population, increasing their selection differential. Some breed societies have opened up their herd books considerably in an attempt to co-operate with programs to improve the productivity of their breed;

The Future

Now that the Australian Dairy Herd Improvement Scheme is computing breeding values routinely, I see no reason why the program should not continue. Clearly, the program will need to adapt to changes in computing technology in order to minimize costs. Modifications to the programs will need to be made as we get better estimates of environmental factors. We may allow for factors such as time from calving to conception so that we do not penalize cows that conceive early.

ABVs for temperament, speed of milking and ease of calving will be available in the next two years. As records for other characters, such as mastitis resistance, become available, ABVs can be computed.

Modern physiological techniques, such as growth hormone injections and embryo transfer, create some problems for computing breeding values or may affect the improvement programs. Nicholas and Smith (1983) have suggested a program using multiple ovulations and embryotransfer. This drastically reduces the size of the population that needs to be recorded. If such programs become widely used the value to genetic improvement of herd recording would decline. Computation of ABVs would still be of value for comparing bulls from different schemes. A high proportion of farmers might continue herd recording for farm management purposes but this would not be necessary for the genetic improvement scheme:

Use of growth hormone can affect the accuracy of comparisons. The main problem arises if there is differential use of growth hormone within a herd. If farmers use growth hormones only on their best cows then measured differences will be increased. ABVs of treated cows will be overestimated. The problems arising from such treatment are no different from problems arising from differential feeding. If the cost is such that it is worthwhile to treat some cows but not others, the number of herds using differential treatment may be greater than for other treatments. Recording schemes may have to enable recording of treated cows. Of course, schemes cannot do much where farmers use growth hormone to cheat the system and produce high ABVs for some cows.

Australian Breeding Values (ABVs), by allowing all dairy bulls to be validly compared, have enabled dairy farmers and semen production centres to make more informed decisions in breeding replacements. This has provided a tremendous incentive to genetic improvement programs.

CONCLUSION

M.E. GODDARD

Livestock breeders wish to select stock that produce the most desirable offspring. Therefore it is logical that estimated breeding values become the 'currency' in which we discuss genetic merit. The introduction of similar schemes in the dairy, beef and wool industries should make it easier for all those involved with livestock breeding to understand the concepts involved.

After correcting data for known environmental effects, animals are compared within management or contemporary groups. In dairy and beef systems BLUP is used to simultaneously estimate environmental differences between management groups and genetic differences between animals. In the Woolplan data, there are no links between management groups so a within-management group comparison using a selection index is used. The dairy evaluation system, the sheep reference sire scheme and Group Breedplan use links between herds to compare animals in different herds, while Breedplan makes only within-herd comparisons. In beef and dairy evaluations an animal's own performance and that of its relatives are used to estimate its breeding value. Woolplan, Breedplan and Group Breedplan use multi-trait models. This allows information from all traits to be used when calculating each EBV.

I expect EBVs will improve further in the future. It is most important to maintain and improve the quality of input data, including correct identification of parentage and correct assignment to management groups. An increase in across herd evaluations will have great advantages for the wool and beef industries.

REFERENCES

- GODDARD, M.E. (1986). Livest. Prod. Sci. 13: 321.
 GODDARD, M.E. (1987). Proc. Aust. Assoc. Anim. Breed. Genet. 6: 192.
 GRASER, H.-U., TIER, B., NICOL, D.C., SCARTH, R.D., HAMMOND, K. and ALLEN, J. (1987). Proc. Aust. Assoc. Anim. Breed. Genet. 6: 124.
 JONES, L.P. (1985). Proc. Aust. Assoc. Anim. Breed. Genet. 5: 242.
 LEWER, R.P., PONZONI, R.W., MORGAN, P.D. and VANRENAN, D.S. (1986). Proc. 3rd World Congr. On Genetics. Appl. to Livestock Prod. 9: 645.
 LEWER, R.P. (1987). Proc. Aust. Assoc. Anim. Breed. Genet. 6: 139.
 NICHOLAS, F.W. and SMITH, C (1987). Anim. Prod. 36: 341.
 QUAAAS, R.L. and POLLAK, E.J. (1980). J. Anim. Sci. 51: 1277.
 RAYMOND, C.A. (1982). M.Sc. Thesis, University of New England.