Understanding Genetics

Wayne Upton

Variation in Performance

If we take measurements in animal populations invariably there is variation. The table below shows measurements taken on some two year old bulls that have been running together all their lives.

Weights vary from 644 kg to 982. This variation is the basis on which we can select superior animals. If weight is important then it might be said that the animal weighing 982 kg is superior to the others. What causes such an exceptional animal to be so much better than its contemporaries? There are two basic reasons:

- it has probably inherited better genes making it genetically superior
- it has been lucky and experienced a better environment.

Most likely the reason is a combination of both of these.

If we look at the distribution of any of the measurements shown in Table 1 we see that they roughly conform to what is known as a normal distribution (Figure 1 graphically displays the distribution of scrotal sizes for the bulls in Table 1). The normal distribution simply means that most of the animals have measurements around the average and only a few are found to have very high or very low values. For example, in Figure 1 most of the animals have scrotal size measurements between 38 and 42 cm but only one animal has a measurement that is greater than 43 cm.

Table 1: Measurements on young bulls

No	Wt	EMA	P8	Rib	SS	IMF
30	874	116	11	8	40.5	4.1
31	930	124	9	5	40.5	3.6
32	982	114	17	10	41	4.3
33	846	113	14	9	39.5	4.7
34	780	109	14	7	37	4.3
35	902	121	11	7	40	4.1
36	894	118	11	7	41	4.3
37	904	120	14	8	40.5	4.1
38	858	116	15	8	40.5	4.1
39	836	116	10	6	39.5	3.6
40	854	119	6	4	43.5	2.8
41	768	109	9	5	35.5	3.8
42	758	107	12	8	39	4.2
43	800	110	14	9	38	4.3
44	796	106	10	7	37.5	3.8
45	820	111	9	6	39.5	3.3
46	846	111	9	7	34	4
47	800	108	8	5	39.5	3.9
48	834	112	10	7	40.5	4.1
49	816	113	12	7	40.5	4.3
50	676	97	5	5	36	3.4
51	698	96	10	7	37.5	4
52	664	95	7	5	40	4.1
53	700	98	9	7	39.5	4.1
54	672	97	8	6	40	3.6
55	644	97	7	5	39	4
56	666	95	6	4	40	4
57	662	92	5	5	41.5	3.7
58	776	104	9	6	37.5	4.2
59	736	100	11	8	41	4.3
60	690	103	11	6	38.5	4.2
Average	789.7	108.0	10.1	6.6	39.3	4.0
Minimum	644	92	5	4	34	2.8
Maximum	982	124	17	10	43.5	4.7
Stan Dev	90.9	9.0	3.0	1.5	1.9	0.4

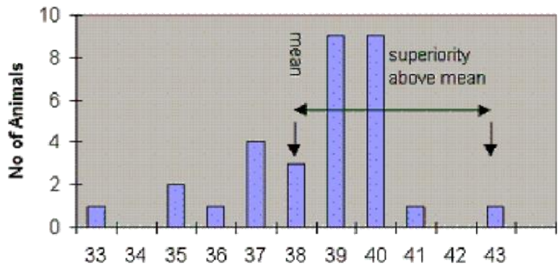

Figure 1: Distribution of Scrotal Size

Generally if you have larger numbers of animals the distribution will be smooth with most animals around average. Genetic improvement relies on selecting those animals that are superior. However we know that only part of the superiority is due to genetics, the rest being due to luck and environmental factors.

Heritability describes the amount of this superiority that is due to genetics. By test mating a number of bulls and measuring the superiority of the progeny compared to the superiority of the selected parents heritability can be estimated.

In seeking genetic change we are not really interested in how much environmental luck an animal has had, because that source of superiority cannot be transmitted to the next generation. We want to be able to choose the animals with better genes.

The Breeding Value (BV) of an animal is a description of the value of an animal's genes to its progeny.

We cannot see what genes an animal carries, so we can never fully **know** what an animal's BV is. However, we can estimate it. We can calculate an animal's Estimated Breeding Value (EBV) from various sources of information, including the following:

- its own performance or phenotype for the trait of interest
- its own performance for other traits
- the performance of its relatives for both the trait of interest and other traits.

How do we predict an animal's breeding value given its phenotype (measured performance) for a single trait most usefully expressed as a difference from the population mean? We must use our knowledge of the proportion of superiority that is generally due to genetics (heritability).

Performance is best measured as the difference between the individual and the group average. To take the example above the selected animal had a scrotal size of 43.5 and the average for the group was 39.3 cm. The selected animal had scrotal size 4.2 cm above the average.

We can calculate how much advantage the progeny of selected animals may have over their average mates by multiplying its measured performance (phenotypic superiority; P) by the heritability (h^2) of the trait. This is known as an EBV (Estimated Breeding Value).

$$\mathbf{EBV = h^2\ P}$$

But only half the genes come from the bull, so if only the bull is selected and the cows to which he is mated are herd average then only half of the genetic advantage of the sire will be realised in the progeny. To predict the progeny performance we need to multiply this EBV by half, and the term becomes EPD (Estimated Progeny Difference).

Scrotal size has a heritability of approximately 40%, ie. only 40% of the advantage is due to the animals genes the rest is due to good luck. This means that a group of young bulls by our selected animal should have an average scrotal size that is 0.85 cm (4.2 X 40% X 0.5) above the average of a group of bulls sired by average bulls.

In some countries, animal breeders use Estimated Progeny Differences (EPDs) rather than EBVs to describe the breeding merit of candidates for selection. Here is the difference:

- EBVs describe the value of an animal's genes to its progeny, and yet it only transmits half of its genes to any one progeny. So, given mates of average value, the predicted merit of an animal's progeny is half of its EBV. Alternatively, the predicted merit of the progeny of a mating pair is the average of their EBVs. This will be described in more detail later.

- EPDs have the half already built in. So, given mates of average value, the predicted merit of an animal's progeny is its full EPD. Alternatively, the predicted merit of the progeny of a mating pair is the sum of their EPDs.

Thus the relationship between EBVs and EPDs is quite simple:

EPD = EBV/2

Estimated Breeding Values (EBVs) and BREEDPLAN

The predictions of genetic merit provided by GROUP BREEDPLAN are called Estimated Breeding Values, or EBVs. These EBVs are the best estimates of an animal's genetic merit for each recorded trait.

EBVs are based on pedigree and performance records provided by individual breeders. The performance of individual animals within each herd, or contemporary group, is compared to the average performance of other animals of the same age group in that herd, run under the same conditions and treated equally. Comparisons between animals born and reared in different years, or in different herds or management groups, are made through the use pedigree links between these comparison groups.

With the extensive use of AI and the trading of performance recorded breeding stock amongst herds a network of pedigree links has been established which enables the adjustment for environmental differences between herds, years and management groups. This allows comparisons between animals from totally different environments, even between Australia and New Zealand.

EBVs are expressed in the units of measurement for each particular trait, and are shown as +ive or -ive differences from the breed base. For example, a bull with an EBV of +50 kg for 600-Day Wt is estimated to be genetically 50 kg heavier than the breed base of 0 kg. Since the zero breed base is set to a historical benchmark, the average EBVs of animals in each year drop has changed over time as a result of genetic change within the breed. Animals should be viewed as being "above breed average" for a particular trait only if their EBVs are better than the average EBVs of all animals born in their year drop. A useful "benchmark" for animals currently for sale is the average EBVs for calves born in 1998 (ie. "T" drop).

In using EBVs to assist in selection decisions it is important to achieve a balance between the different groups of traits and to place emphasis on the traits that are important to your herd, your markets, and your environment.

One of the advantages of having a comprehensive range of traits reported is that you can avoid extremes in one trait and select for animals with adequate performance in all traits of economic importance.

Accuracy (Acc)

The "accuracy" value of an EBV gives an indication of its reliability and the likely extent of its possible change as more information becomes available. EBVs are only "estimates" based on the available information at the time of the analysis. As additional information becomes available the more accurate will be the resultant EBVs, and the likelihood of them changing further is reduced.

For example, a bull at two years of age will have EBVs based on his own performance and those of his siblings, parents and other relatives. As the bull is used, and his progeny recorded, more information becomes available about his likely genetic merit. His EBVs will almost certainly change and because of more total information, the accuracy of the EBVs will increase.

The accuracy values for each EBV are influenced by the heritabilities of the traits. For lowly heritable traits more information is needed to give a similar accuracy to that of highly heritable traits.

Accuracies are expressed as percentages. The higher the percentage, the greater the confidence that the EBV is an accurate estimate of the individual's breeding value and the less likelihood of it changing as additional information becomes available.

Even though an EBV with a low accuracy may change as further information is recorded, it is still the best estimate of an animal's genetic merit for that trait at any given time. As more information becomes available, an EBV is just as likely to increase in value as it is to decrease in value.

What do the EBVs mean?

Estimated Breeding Values are expressed in actual units relative to a fixed historical base (base =0 a 600 day EBV of +50 is 50kg above the base). The absolute value of any EBV is not critical, but rather the differences in EBVs between potential candidates for selection.

Calving Traits

Calving Ease Traits

EBVs are provided for several traits related to calving ease, an important characteristic for cattle. Calving difficulty has an obvious negative impact on the profitability of a herd through increased calf and heifer mortality, slower re-breeding performance and considerable additional labour and veterinary expense. EBVs for traits related to calving ease are calculated from calving ease score, birth weight and gestation length data provided by breeders.

Calving Ease (DIR) EBVs

Calving Ease (DIR) EBVs are estimates of genetic differences between animals in the ability of their calves to be delivered from two-year-old heifers without assistance.

Calving Ease (DIR) EBVs are reported as differences in the percent (%) unassisted births. Higher and more positive (+ ive) EBVs indicate fewer assisted births.

Higher, more +ive, Calving Ease (DIR) EBVs are more favourable. The EBV is for calving ease so +ve is preferred. In a mythical average herd, a bull with +5 for calving ease will cause less calving difficulties (2.5%) in two year old heifers than a bull with an EBV of 0. As the herd average performance changes so will the effect of the difference in the EBV. In a herd with high levels of calving difficulty an EBV of +5 will give even more benefit compared to a bull with an EBV value of 0.

Calving Ease (DTRS) EBVs

Calving Ease (DTRS) EBVs are estimates of genetic differences between animals in the ability of their daughters to calve without assistance when they are two-year-old heifers.

Calving Ease (DTRS) EBVs are reported as differences in the percentage (%) of daughters with unassisted calvings. Higher and more positive (+ive) values indicate fewer assisted births.

Higher, more +ive, Calving Ease (DTRS) EBVs are more favourable. For example, a bull with an EBV of +3% would be expected to produce heifers that have less calving problems than the daughters of a bull with an EBV of -3%.

Gestation Length (GL) EBVs

GL EBVs are estimates of genetic differences between animals in the number of days from the date of conception to the calf birth date. GL EBVs are calculated from the joining date and birth date records for calves achieved by AI or Hand Mating.

A shorter GL is generally associated with lighter birth weight, improved calving ease and improved re-breeding performance among dams. In addition, calves born with a shorter GL are often heavier at weaning due to more days of growth. Consequently, more negative GL EBVs are considered to be more favourable.

Lower, or more -ive, GL EBVs are generally more favourable. For example, a bull with a GL EBV of -2 days would be expected to produce calves that are born earlier, and more easily, than a bull with a GL EBV of +2 days.

Birth Wt EBVs

Birth Wt EBVs are estimates of genetic differences between animals in kg of calf birth weight.

Calf birth weight is the biggest genetic contributing factor causing calving difficulty in heifers. In order to minimise the risk of calving difficulty it is recommended that you only use bulls over your heifers that have relatively lower birth weights.

Whilst low Birth Wt EBVs are favoured for calving ease they are also generally associated with lower overall growth potential. Consequently, birth weight and growth need to be carefully balanced. Excessive emphasis on low birthweight can lead to smaller (lower growth) heifers in the next generation ie. the calves from the low birthweight bulls. These smaller heifers may then have lower maternal calving ease because their frame size and pelvic opening are not large enough. Hence advantages from selecting low birthweight will be lost by the maternal component of calving ease.

Fortunately, animals can be found that have both moderate Birth Wt EBVs and above average EBVs for later growth.

Small, or moderate, Birth Wt EBVs are more favourable. For example, a bull with a Birth Wt EBV of +2 kg would be expected to produce lighter calves at birth than a bull with a Birth Wt EBV of +6 kg, with a lower risk of a difficult birth. It should be noted that over-emphasis on low birth weight will generally reduce your later weights and may leave heifers that themselves have more calving difficulty. The policy should be to select the highest possible birth weight that your heifers will handle.

Growth Traits

In general, with all other things being equal, higher growth rates will lead to higher profitability. In most economic analyses conducted positive emphasis on growth is warranted. However, one of the consequences of continued selection for increased growth EBVs is an associated increase in body size at all ages, together with increases in feed requirements per animal for maintenance, but not an increase in feed requirement per unit of beef produced. Selection for growth must always be balanced with concurrent selection for all other traits of economic importance.

The fear of many breeders is that their cattle get too big but if you place the right amount of emphasis on all traits of importance it will soon become obvious when an animal is too big. Too big is when cows won't re-breed in the environment in which you are running them, calving difficulties become too high or steers won't fatten on the nutritional regime on offer.

Growth EBVs are calculated from weight data submitted by breeders, adjusted to relevant age classes prior to analysis. In addition, birth weight data also contributes to growth EBVs due to its positive relationship with later weights.

200-Day Wt EBVs

200-Day Wt EBVs are estimates of the genetic differences between animals in kg of live weight at 200 days of age. This is a measure of an animal's early growth to weaning. It is an important trait for breeders turning off animals as vealers or weaners.

Larger, more +ive, 200-Day Wt EBVs are generally more favourable. For example, a bull with a 200 Day Wt EBV of +30 kg would be expected to produce heavier calves at 200 days of age (or weaning) compared to a bull with a 200-Day Wt EBV of +10 kg.

400-Day Wt EBVs

400-Day Wt EBVs are estimates of the genetic differences between animals in kg of live weight at 400 days of age. This is an important trait for breeders turning off animals as yearlings.

Larger, more +ive, 400-Day Wt EBVs are generally more favourable. For example, a bull with a 400-Day Wt EBV of +50 kg would be expected to produce heavier calves at 12 to 14 months of age compared to a bull with a 400-Day Wt EBV of +30 kg.

600-Day Wt EBVs

600-Day Wt EBVs are estimates of the genetic differences between animals in kg of live weight at 600 days of age. This is an important trait for breeders targeting the production of animals suited for heavy weight grass or grain fed markets.

Larger, more +ive, 600-Day Wt EBVs are generally more favourable. For example, a bull with a 600-Day Wt EBV of +70kg would be expected to produce heavier progeny at 18 to 20 months of age than a bull with a 600-Day Wt EBV of +40kg.

Mature Cow Weight (Mwt) EBVs

MWt EBVs are estimates of the genetic differences between cows in live weight (kg) at 5 years of age.

A cow with a Mwt EBV of +80 would be expected to have a higher mature weight than a cow with a Mwt EBV of +60. There is a correlation between Mwt EBV and the growth EBVs. It can be expected that a cow with a higher Mwt EBV may require more feed to maintain her than a cow with a lower Mwt EBV, she is also more likely to have a heavier calf at weaning.

A rough guide is that Mwt EBV should be less than the same animals 600-Day Wt EBV. For example a cow that has a larger Mwt EBV than its 600d EBV is able to pass on its growth to its progeny while maintaining a lower mature size.

Milk EBVs

Milk EBVs are estimates of the genetic differences between animals in milk production potential, expressed through variation in 200-Day Wt (kg) of calves.

A bull with a Milk EBV of +15 would be expected to sire daughters with higher milk production than a bull with Milk EBV of +5 kg. This higher milk production potential should be reflected through higher weaning weights among the daughter's calves. There is a considerable time lag before a bull obtains a reasonable accuracy for its Milk EBVs due to the interval before any growth performance data is available from his daughter's calves. If a bull is to be used as a terminal sire with no daughters kept as female replacements then his Milk EBVs can generally be disregarded.

The optimum level of milk production potential among beef cows is dependent upon the production system and environment in which the cows are run. Selection for increased milk production may be warranted when cows are run under good nutritional conditions and calves are sold as weaners. However, some environments may not support high milking cows.

Larger, more +ive, OR moderate, 200-Day Milk EBVs can be more favourable, depending on the environment.

Fertility Traits

Fertility is a critical component influencing the profitability of a breeding herd. EBVs are provided for two fertility traits - Days to Calving (DC) and Scrotal Size (SS). These traits both contribute important information to assist in making breeding decisions that maintain the high fertility of cattle. DC EBVs are calculated from the joining and calving date records provided by breeders. SS EBVs are based on measurements recorded on yearling bulls.

Scrotal Size (SS) EBVs

SS EBVs are estimates of the genetic differences between animals in scrotal circumference (cm) at 400 days of age.

Increased SS is associated with increased semen production in bulls, and earlier age at puberty of bull and heifer progeny. SS also has a favourable relationship with DC, such that bulls with larger SS tend to have daughters with shorter DC.

Larger, more +ive, SS EBVs are generally more favourable. For example, a bull with an SS EBV of +4 cm would be expected to produce sons with larger testicles at yearling age and daughters that reach puberty earlier than the progeny of a bull with an SS EBV of -4 cm.

Days to Calving (DC) EBVs

DC EBVs are estimates of genetic differences between animals in female fertility, expressed as the number of days from the start of the joining period (ie. when the female is introduced to a bull) until subsequent calving.

DC promotes those cows that calve earlier in the season compared to those that calve later, while penalising those cows that do not calve. Negative DC EBVs indicate a shorter interval from the start of joining season until calving.

Variation in DC is mainly due to differences in the time taken for females to conceive after the commencement of the joining period. Females with shorter DC EBVs tend to be those which also show early puberty as heifers, which return to oestrous earlier after calving and conceive early in the joining period. Only natural/paddock joinings are used to calculate DC EBVs, with data from AI and embryo transfer excluded.

DC EBVs for bulls are based on the reproductive performance of their daughters and other close female relatives.

Lower, or more -ive, DC EBVs are generally more favourable. For example, a bull with a DC EBV of -5 days would be expected to produce daughters that conceive earlier in the joining period than the daughters of a bull with a DC EBV of +5 days.

Carcase Traits

GROUP BREEDPLAN uses data obtained from ultrasonic real-time scanning of live animals plus chiller assessment to calculate EBVs for eye muscle area (EMA),subcutaneous fat cover at the 12/13th rib site and the P8 rump site, carcase weight, percentage retail beef yield and percent intra-muscular fat (Marbling). Retail beef yield may be collected from abattoirs who supply such data or it may be estimated from the known relationship between carcase weight, fatness and eye muscle area. Percent Intra-muscular fat may be estimated by scanning, taken from meat samples collected in the abattoir or marble score can be recorded.

Selection for increased carcase yield and carcase value should be an important objective for breeders of cattle. EBVs for carcase traits can be used to assist in targeting market requirements.

Carcase Weight (Cwt) EBVs

Cwt EBVs are estimates of the genetic difference in carcase weight adjusted to 650 days of age.

Larger, more +ive, Cwt EBVs are generally more favourable. For example an animal with a Cwt EBV of +40 would be expected to produce progeny with heavier slaughtered carcases at 650 days of age than an animal with a Cwt EBV of +30. Do not confuse this with yield, the Cwt EBV is an indication of the animals carcase weight and not an indication of the animals yield percentage.

Eye Muscle Area (EMA) EBVs

EMA EBVs are estimates of the genetic differences between animals in eye muscle area (cm2) at 12/13th rib site, in a 300kg carcase.

Larger, more +ive, EMA EBVs are generally more favourable. For example, a bull with a EMA EBV of +4 cm2 would be expected to produce steer progeny with a greater degree of muscle expression than a bull with an EMA EBV of +1 cm2.

Rib Fat EBVs

Rib Fat EBVs are estimates of the genetic differences between animals in fat depth (mm) at the 12/13th rib site, in a 300kg carcase.

The use of Rib Fat EBVs depends on your goals relating to the finishing ability of your animals. Breeders aiming to breed leaner cattle may select for lower fat values, whilst a breeder aiming to use a bull over dairy cross cows to produce vealers may need to choose a bull with higher fat EBVs to ensure meeting market demands.

Recent research results indicate that there is a negative (but in this case negative is favourable) genetic relationship between Rib Fat EBVs and DC EBVs. A bull with positive EBVs for fat will be likely to leave daughters with shorter days to calving (more fertile). Consequently, breeders should be cautious about applying intense selection for lower Fat EBVs in situations where female replacements are kept.

A bull with a Rib Fat EBV of -0.4 mm would be expected to produce leaner calves at 450 days of age than a bull with a Rib Fat EBV of +0.4 mm.

More positive (+ive), OR more negative (-ive), Rib Fat EBVs may be more favourable, depending on your breeding goals.

Rump Fat EBVs

Rump Fat EBVs are estimates of genetic differences between animals in fat depth at the P8 rump site, in a 300kg carcase.

Differences between Rib Fat EBVs and Rump Fat EBVs can indicate differences in fat distribution among animals. Relationships between fertility and rump fat are similar to those described for rib fat.

More positive (+ive), OR more negative (-ive), Rump Fat EBVs may be more favourable, depending on your breeding goals.

Retail Beef Yield percentage (RBY%) EBVs

RBY% EBVs are estimates of genetic differences between animals percentage (%) retail beef yield, in a 300kg carcase.

Larger, more +ive, RBY% EBVs are generally more favourable. For example an animal with a RBY% EBV of +0.9 would be expected to produce progeny that would yield higher percentages (%) of saleable beef in a 300 kg carcase, than an animal with a RBY% EBV of +0.1.

Intra-muscular Fat Percentage (IMF%) EBVs

IMF% EBVs are estimates of genetic differences between animals in percentage intramuscular fat (marbling) at the 12/13 rib site in a 300kg carcase.

Larger, more +ive, IMF% EBVs are generally more favourable. For example an animal with an IMF% EBV of +0.8 would be expected to produce progeny that would express more marbling in a 300kg carcase than an animal with an IMF% EBV of +0.1. Recent research would suggest that 1 marble score is equivalent to approximately 1.5% intra-muscular fat so the variation shown between sires is not that large. This relationship still needs more data to data to confirm the conversion from marble score to intra-muscular fat.

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A joint unit of NSW DPI and UNE