Breeder's Perspective on Genomic Selection for the South African Dairy Cattle Industry

Poena van Niekerk, Japie van der Westhuizen and Esté van Marle-Köster

Introduction

Currently the Dairy Cattle industry is by far a net importer of semen to be used on the national herd. This is not uncommon for a country with a dairy cattle population the size of South Africa. The main reason for this is that big global players have invested in systems that are supportive of applying modern research and development tools in identifying superior genetic animals. Prior to the new Genomic Selection revolution the most successful breeding organisations and countries have made use of the following very important aids:

- Well designed and laid out milk recording systems with the following properties:
    - Innovative means of attracting a large proportion of dairy farmers to take part.
    - Integrated processes from recording at source (farm and laboratory), data handling, quality steps, management reporting, genetic evaluation and application by farmers and other role players.
    - Industry insight, ownership and participation in decision making and application of new techniques and processes.
- Mixture of government and industry support in research and development as well as sharing ownership in newly founded techniques or platforms for commercialisation of research products.
- Adoption of all the important industry role players of the following important aspects that enhance genetic progress:
    - Scientifically based and trustworthy recording practices. An important non negotiable aspect is adherence to international guidelines and standards, especially of the International Committee for Animal Recording (ICAR).
    - Application of techniques and practices for breeding value prediction that be backed up scientifically.
    - Participation in global genetic evaluations via the Interbull Centre (of ICAR).
    - Free trade in semen (and embryos) across international borders.
    - Scientifically designed selection indices based on bio-economical simulation and other models ensuring the ranking of animals on the genetic merit for maximum profit (for the different types of markets).
    - Meticulous processes of identifying suitable parents and the application of well designed mating practices to reach the pre selected breeding goals.
- Well developed markets for semen and embryo trade and systems to ensure the genetic merit quality of these products.

Laying the foundation.

Given the background and willingness to adopt technology it came as no surprise that the major role players immediately put steps in place to use genomic selection in dairy cattle breeding. This, however did not happen overnight as many countries had the vision to lay the right foundation. A very good example of this is the United States of America where the industry and government took hands in establishing a proper bio bank where biological material (mostly semen) of all AI bulls had to be stored for later use in programs based on molecular genetics. The lack of decisive actions from government in South Africa in this regards is probably one of the main reasons for a proper base of material to be used as reference populations, especially for locally bred bulls.

In most cases governments has also shown a keen interest in investing in the establishment of reference populations for dairy cattle. In this regards private laboratories have also made part of the processes to assert skills and techniques to enable private enterprise to render a commercial service once the development has been completed. In some cases, like New Zealand and The Netherlands the development have mainly been driven by private concerns (LIC and CR-V).

One very important aspect that role players quickly realised is that money can be saved by exchanging genetic (SNP) profiles of globally influential animals (mainly AI bulls). This has lead to the formation of three important consortia, namely the North American Genomic Consortium, EuroGenomics and IgenoP. The first two are mostly exclusive while IgenoP allows for free exchange and data base sharing.

Other 'Genomic Breeding Values' services, not based on proper reference populations and validation with local breeding value prediction systems, have also been on offer to dairy farmers and AI companies on a commercial scale. This has lead to some confusion in the industry as the results can not be verified against the genetic merit of the animals.

How will Genomic Selection make a practical difference in genetic progress.

Since the inception of Genomic Selection in the major dairy countries, the uptake has been very fast. The major advantage of genome based breeding values is for young bulls without measured daughters. Most traits of economic importance in dairy cattle is either sex limited or can only be verified at a late age. Examples are: Milk production and Quality, Udder Health, Female Fertility and Productive herd life.

The key equation for genetic progress for a trait (per year) is:

$$\Delta G_j = (r_{AA'} * i * \sigma_a)/Gi$$

Where ΔG_j = genetic change per year.

r_{AA} = accuracy of selection, that is the correlation between the true and estimated breeding values.

i = selection intensity.

σ_a = additive standard deviation (standard deviation in breeding values).

Gi = average generation interval.

The introduction of BLUP breeding values has contributed towards faster genetic changes (ΔG_j) because these predictions have a marked influence on r_{AA} (more accurate prediction of the true breeding value) and to some degree Gi (early predictions by means of parent averages for sex limited traits, although not always reliable enough).

Applying molecular techniques resulting in GEBVs will have a marked influence on ΔG_j as:

- The correlation between the predicted and true breeding values (r_{AA}) will increase, especially for young animals.
- The generation interval (Gi) is shortened considerably as the early prediction of genetic merit for sex limited traits is much more reliable at a young age. This mainly negates the need for elaborate and expensive progeny testing systems.
- The selection intensity (i) will also increase as early filtering is applied by identifying parents of potential AI bulls earlier and with higher precision.
- The playing field for identification of suitable parents for AI sires widens it can also have an influence on σ_a simply because of the identification of superior animals in the population from herds that would traditionally not have contributed (mostly because of relative standing in the breed/population) to the pool of influential breeding animals.

In practice, in a system where young animals with potential are subjected to genomic testing (and the information correctly used to calculate GEBVs), the generation interval is shorter, the top animals in the breed are identified more easily and the prediction of the genetic merit reflects the true breeding value more accurately.

Figure 1 indicates how genomic information assists in predicting the genetic merit of animals in a population.

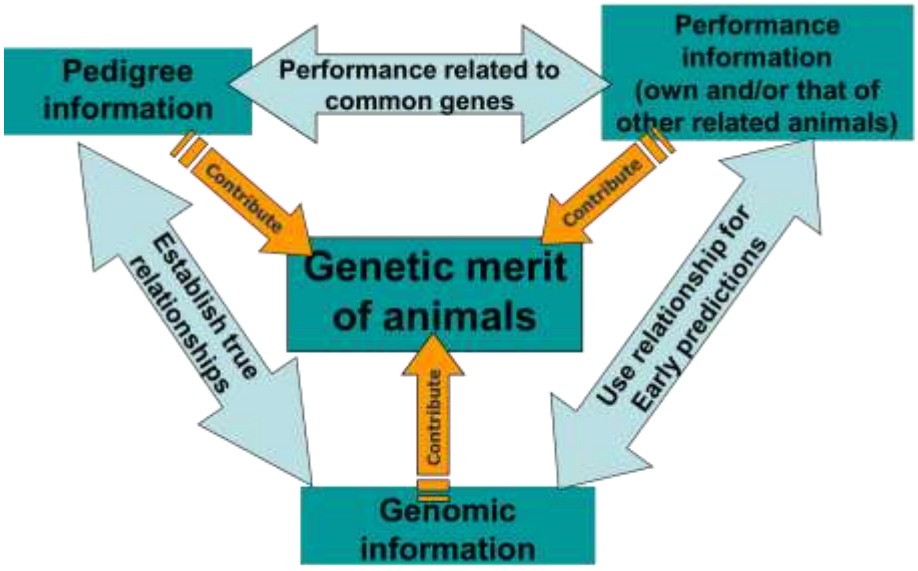

Figure 1. Interaction between and value of different sources of information in predicting the genetic merit of livestock in a population.

The real impact in dairy cattle breeding stems from the fact that dealing with sex limited traits, such as milk production (and related traits) has traditionally been the main contributor for the excessively long generation interval as the results of progeny tests need to assist in decisions to select bulls as AI sires.

Figure 2 illustrates the impact genomic selection has on the early prediction reliability of a trait like milk production in dairy cattle.

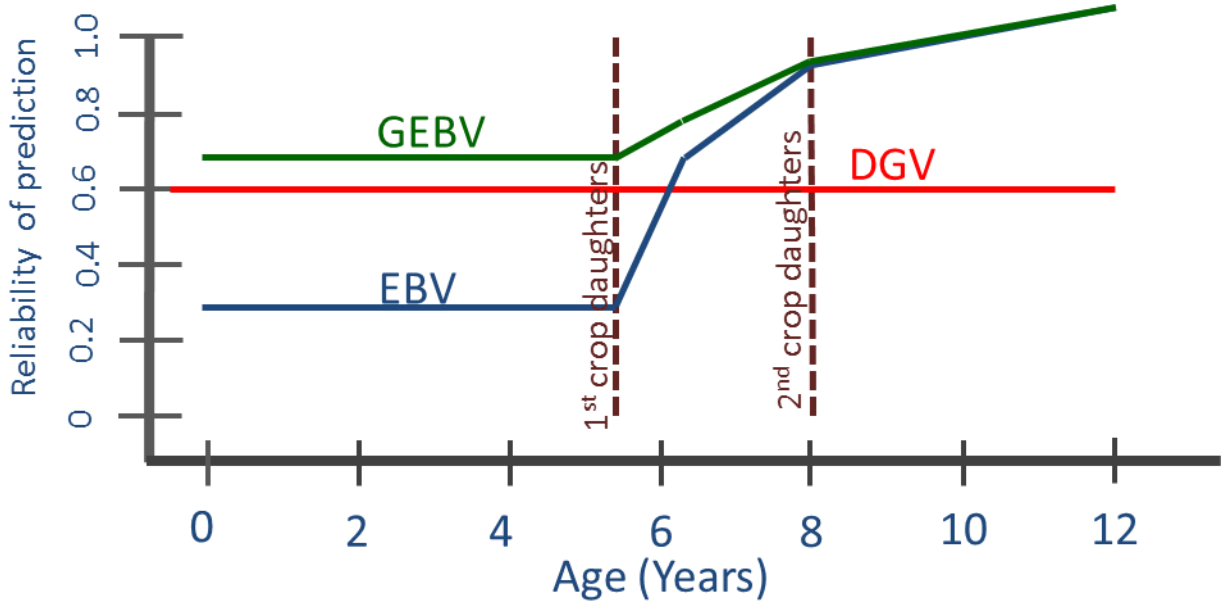

Figure 2. Change in reliability of genetic merit prediction for an AI sire for a sex limited trait like milk production

From Figure 2 it is clear what the genomic selection advantage of early prediction is. This advantage in prediction reliability is no longer valid once the performance of some daughters are known (the number depends on the heritability estimate for a specific trait but is usually in the order of 10 daughters for milk production or milk solids, more for fertility traits).

Choosing the right path.

The industry needs to realise that there are no short cuts and the right path needs to be followed.

1. The first realisation is that an initial input, in terms of financing and also effort, needs to be made.

   In this regards the establishment of a proper reference population, per breed, is needed. Two important sources of genotype data should be used, namely identifying locally bred bulls with a large impact on the specific breed and also international bulls (bred elsewhere) that impacted on the South African population.

   Locally bred bulls that only impacted locally need to form part of a locally financed program to obtain their genomic profiles.

Joining or making use of an international body for the exchange of genome information of international bulls is the very first step to obtain such information. This will avoid duplication. Free exchange of genotypes is, for example, possible via IgenoP. Further opportunities should also be explored via contacts with breeders' societies elsewhere and by striking deals with international AI companies.

Parallel to these efforts is the adaptation of local genetic evaluation units to accommodate the inclusion of genome information, once the relationship between EBVs and DGVs has been established.

2. The next important step is the setting up of a science based and reliable service to the (dairy) industry where biological samples and parent average EBVs serve as the sources op breeding value predictions (GEBVs) for young animals.
3. The system should be a continuous source in its own right of genome information being validated against the breeding value predictions (also by means of imputation from less dense SNP Chips).
4. This whole process should still be aimed at obtaining the maximum number of phenotypic records through active participation in recording. The notion that genomic selection negates the need for measurement and recording is totally false.
5. All genetic merit predictions should be incorporated in the bio-economically based selection indices that should be available for each animal in the breed.

Keeping perspective

All this will come to nothing if there is no perspective in the breeding of superior livestock. Figure 3 is an attempt to illustrate the balance needed between the three key components in animal breeding, namely:

- Breeding goals and selection criteria based on bio-economical models.
- Trustworthy, accurate and timely breeding value (genetic merit) predictions linked to identification of genetically superior animals fitting into the breeding goals.
- Employing proper mating plans to accelerate genetic progress towards the breeding goals.

Figure 3. Illustration of the inter relationship between pursuing breeding objectives, genetic merit prediction and plans to achieve goals in livestock breeding.

Ignorance more frequently begets confidence than does knowledge: it is those who know little, not those who know much, who so positively assert that this or that problem will never be solved by science.
Charles Darwin