Genetic Improvement of Dairy Cattle
Some Generalities and the Development in Germany

Leo Dempfle

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1 Some Generalities about Genetic Improvement

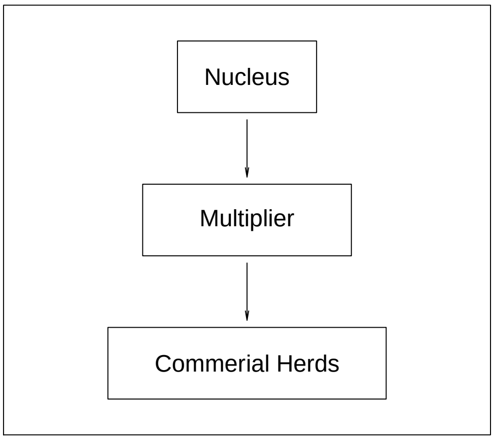
For any genetic improvement scheme we have (in theory):
- the Target Population
- the Nucleus
- the Multiplier

The Target population is the commercial population which we want to make more efficient and thus more profitable. This target population can comprise anything from several thousand cows up to several million cows (N_T).

The Nucleus is a subpopulation of the Target population of size N_N. In the Nucleus comprehensive pedigree and performance recording is going on and selection and culling is executed in order to achieve genetic improvement and thus **genetic progress** (ΔG).

In order to transmit the genetic progress (achieved in the Nucleus) to the Target population (commercial population) the multiplier is needed. If artificial insemination (AI) can be used the AI station functions as the Multiplier. If fertilisation is done by natural service then we need quite a large Multiplier of size (N_M). There the males used in the Multiplier are provided by the Nucleus and the males produced in the Multiplier are handed on to the commercial population.

Schematic Picture of Nucleus − Multiplier − Commercial Herds



Depending on the used technology there must be a fixed relationship between the size of the Multiplier and that of the Commercial population ($k \times N_M = N_T$).
The size of the Nucleus is only restricted downwards. It must be big enough so that it can provide all the males for the multiplier. Also there is a minimum size required in order that inbreeding is not unduly increasing. On the other hand the greater the Nucleus the higher is the genetic progress but also the cost. Whereas the cost of the nucleus is approximately linearly increasing with size, we have a diminishing return with respect to the genetic progress. It is therefore important that the size of the nucleus is chosen with respect to genetic but also economic considerations.

The major field for the geneticists is the nucleus. In the nucleus we should know all relationships (complete pedigree) and we must report all relevant performance traits which have a reasonable impact on profitability. That concerns the major economic traits measuring output (milk yield and milk contents like protein content and fat content) as well as functional traits (milkability, fertility, stayability) and health traits (mastitis, feet and leg problems, physiological disorders). That recording has to be done in a systematic way, so that with the help of statistical analysis the animals can be compared with each other in a fair way.

The selection (and culling) is based on these comparisons. What kind of genetic improvement scheme is utilised depends very much on the local circumstances (classical progeny testing scheme, young sire scheme or young sire scheme with genomically enhanced breeding values). The goal must be clear; One must know in what direction the population is genetically to be moved and the improvement has to be done in such a way that the genetic progress in that direction is as great as possible per time unit. Just to identify a few outstanding bulls is not sufficient, since in a good genetic improvement scheme the outstanding bull of today is mediocre in a few years and thus outdated very quickly. That means also that the breeding scheme must have a very long time horizon. There is also the task for the geneticist that not only the genetic progress per year is very high but that this genetic progress is sustainable over a long time (large effective population size)!

2 Overview of Dairy Production in Germany

2.1 Geography and Population of Germany

Germany is located in the west-centre of Europe between latitudes 47° and 55° N and between longitudes 5° and 16° E. The area is approximately 360 000 km^2. Climate is temperate and marine to continental. Temperature im summer can go up to 30° C and higher and in winter down to -25° C and lower.

Of the 360 000 km^2 land there are about 110 000 km^2 forest and 187 000 agricultural land (118 000 km^2 arable land and 47 000 km^2 grassland). The main crops are wheat, rye, barley, oats, maize (mainly for silage), potato and sugar and fodder beets.

For Germany the gross domestic product (GDP) per capita is 41 513 US$ (39 028 US$ after correction for buying power - about 10 times the figure for India). Agriculture and Forestry contribute only 1 % to the GDP.

Germany is a federal state with 16 'Länder' and it belongs to the European Union (EU).

Germany has about 81 million inhabitants. Only a small fraction of them depend on a-griculture.

In comparison India is about 9 times the size of Germany and it has about 15 times the human population of Germany.

2.2 Trends in dairy cattle population and production

In 2012 Germany had 82 900 dairy farms keeping 4.2 million dairy cows and it is thus the country within the EU with the most dairy cows (followed by France with 3.6 million). The annual average production of milk is estimated as 7250 kg/cow.

The number of dairy cows is steadily going down, the number of dairy farms are even going down much faster, the herd size is increasing and the yields are also increasing. Due to the German History (Unification in 1989) long time trends are difficulty to get and to interpret. Therefore the relevant trend for the federal state of Bavaria are shown. This trend is typically for the 'old federal states' (Bavaria has more than 30 % of all German dairy cows):

Year	# Dairy farms '000	# Dairy cows '000	Milk kg
2012	38	1219	7349
2008	45	1257	6946
2004	54	1297	6611
2000	62	1429	6192
1996	81	1559	5659
1992	100	1640	5437
1988	132	1890	4977
1984	155	2028	

3 Institutions in Genetic Improvement

3.1 Animal Identification

Animal Identification is regulated by the EU. In Germany the Ministry of Food, Agriculture and Consumer Protection is responsible for proper execution of the rules and it commissioned the organisation for recording to execute the directive. The whole system was established in April 1997, in response to the BSE crisis. There the Council of the European Union implemented a system of permanent identification of individual bovine animals enabling reliable traceability from birth to death. The main goal was the localisation and tracing of animals for veterinary purposes, which is of crucial importance for the control of infectious diseases.
The system for the identification and registration of individual bovine animals includes the following elements:
double eartags for each animal with an individual number; maintaining a register on each holding (farm, market etc.); cattle-passports; a computerised database at national level.
The ear tag for any cow contains a country code (DE for Germany), a two digit code for the federal state, and a unique 8 digit number for the individual.

This identification system is now also used by the pedigree and performance recording organisations.

3.2 AI Organisations

In Germany the artificial insemination (AI) of cattle gained momentum about 1950. In the aftermath of the war sexually transmitted diseases were quite a big problem. With proper (hygienic) work of the AI organisation these diseases can be reduced. The introduction of AI was in strong opposition to the breed societies. It took quite a while until the two kinds of organisations cooperated. Originally there were many small AI organisations; most of them were farmers' cooperatives but some were also private companies. Over the years many AI station merged. In 1953 there existed 113 AI stations whereas nowadays there are only 21 stations left. The bigger stations serve about half a million dairy cows each. Most stations use frozen semen, but a few progressive ones also use fresh semen.
Some of the stations are now integral part of breed societies also offering embryo transfer and ovum pick-up. The work of the AI organisations is closely regulated by the animal breeding law.

3.3 Performance Recording Organisation

In nearly each federal state in Germany there is an **independent** performance recording organisation, which is usually a farmers' cooperative. All these organisations work according to ICAR standards. In some European countries (eg Switzerland) the function of the recording organisations is taken on by the breed societies. Originally the task of the recording organisations was the measuring of milk yield and the reporting of mating, calving and exits. Very early also the measuring of the fat content was included and around 1980 also protein content was measured. Nowadays also somatic cell counts and urea content of milk is included. Trials are underway to include also health data.
Presently there are 3.6 million dairy cows under recording, that is about 86 % of all German dairy cows.

3.4 Data Management

Since pedigree and performance recording produces a lot of data each recoding organisation used to have its own data processing unit. With the development of more and more sophisticated methods for estimating breeding values two centres evolved which specialised and took on that task. One centre (VIT in Verden) is located in North-Germany and is responsible for Holstein-Friesian (black and red), Jersey and Angler in Germany and in Luxembourg, whereas 'Grub' is responsible for Fleckvieh (Simmental), Brown Swiss and a few other minor breed in Germany, Austria and Czech. These two centres have developed a lot of expertise and are closely working with Interbull.

3.5 Breed Organisations

In Germany breed societies were founded around 1890, thus they have a history of 120 years. For quite a long time the selection was heavily based not on performance but on the looking of the animal (so-called exterior of the animal). At the beginning you could be member of a breed society without having performance recording. Breed Societies were heavily supported by the governments of the German states by:
- taking over about 80 % of the cost of milk recording
- providing the executive manager of the breed society free of cost
- forcing all cattle owners by the animal breeding laws to use a licensed bull; only breed societies could provide such a bull.

Breed societies were unrivalled until the AI organisations come up in the middle of last century. Since then some of them developed into very strong marketing organisations and some developed into very comprehensive genetic improvement and marketing organisations.

3.6 Evolution of Genetic Improvement in Germany

As already mentioned organised genetic improvement started in Germany (like in other central European countries) about 120 years ago. At the beginning formal traits ('type' and 'form') were very important. As the most important performance trait in dairy and dual purpose cattle milk yield was measured. Over time also the fat content become part of the routine recording. Even at that time a class of elite breeders evolved. Those elite breeders had a lot of prestige and usually they were very good with respect to husbandry and nutrition. This situation prevailed in Germany until about 1950. Then widespread artificial insemination (AI) was established. At the beginning AI was not much used for genetic improvement but mainly for combatting sexually transmitted diseases and as a convenient method of getting the cows pregnant. In Great Britain that development was somewhat earlier and having AI large number of daughters of an AI bull were then available and some statistics could be done on it. The findings indicated that bulls of the famous top breeders were not much better than any randomly taken bull! For Germany there are no analysis available but most likely the results would have come out similarly. In all these years up to 1950 neither Mendelian genetics nor population genetics or quantitative genetics had much influence on animal breeding of livestock (apart from colour genetics and a few other traits like polledness). Through the work of Lush (1945 and earlier) quantitative genetics had an impact on Livestock improvement and with the advent of AI and computers large data sets could be analysed. At similar time (1954) Henderson proposed the herdmate method and Alan Robertson the contemporary comparison method for sire evaluation in AI. These methods were implemented in Germany around 1965 (varying between the federal states). From that point on there was a friendly cooperation between the breed societies and the AI organisations. In my judgment that can be regarded as the start of systematic evidence based animal breeding in Germany. The further development in Germany was very similar as in the other countries in Europe.

Also in the middle of the sixties the replacement of the black spotted cattle (Schwarzbunte) by the North-American Holstein Friesian (Holsteinisation) and of Braunvieh by the Brown Swiss took place mainly by using imported semen. The reason for the exchange of breeds was mainly caused by the change of the general economic conditions (eg lower prices of concentrates) which favoured single purpose animals compared to dual purpose animals. Around 1975 the BLUP (Best Linear Unbiased Prediction) for sire evaluation and the technique of embryo transfer were introduced. In 1980 the recording of protein content of milk was countrywide introduced, but had still a low weight in the aggregated breeding value. At around the same time the use of Open Nucleus Breeding Scheme (ONBS) was heavily discussed but did not lead to large changes. In the last couple of years use of sexed semen was introduced (but not much used). Dramatic changes came about in the estimation of breeding values. There were two important developments:

- Huge expansion of the cattle population under recording. There was a dramatic structural change in herd size. The average size of the herds belonging to the breed societies was 6.6, 19.5, 58.9 cows in the years 1960, 1985, 2010 respectively. With a herd size of less than 7 cows the livestock keeper needs no sophisticated recording in order to manage his herd. If you have, however, more than 60 cows it is very necessary to have some kind of recording in order to know when the cow has calved, should be mated, or dried off, etc. So in small herds the cost of the recording has to be carried by the breeding scheme whereas in a big herd the farmer needs the recording and the cost for the breed society is very small. This argument is strengthened by the fact that nowadays 20% of the herds in our recording scheme do not belong to a breed society. They just do it to strengthen the management. This is the reason why 1950 only 25% of all dairy cows were in the recording scheme whereas nowadays the percentage is 86%. Thus the nucleus (recorded population) is a huge fraction of the commercial population.

- Advances in Genetics. The sequencing of the human genom was very costly, but lead to many innovations, so that nowadays the sequencing of an individual is quite affordable.

The exploitation of the Single Nucleotide Polymorphism (SNP) lead to the development of the genome enhanced breeding value estimation. There it is necessary to correlate the SNP variation with the phenotypic measurements. The North American breeders implemented such a scheme and each single country in Europe was not big enough to do it on its own. So, France, Netherland, Germany and the Scandinavian countries joint forces and carried out the estimation procedure. Thus they were able to use more than 25 000 progeny tested bulls (being based on about 3 million progenies). Now a young bull with known parents can be estimated with sufficiently high reliability so that young bulls are already heavily used and people no longer wait until the progeny yields are available. Quite likely that classical progeny testing will be phased out completely in the future. This development will shorten generation interval and will speed up genetic progress per year.

3.7 Current Status of Genetic Improvement Programmes in Germany

The organisations involved in genetic improvement are in a state of fast transition, but they are changing unequally fast.
The pedigree and performance recording organisations will be least affected. However, that organisation should become even more flexible and should be responsible for all recording (not only milk related traits), like collecting health traits and type scores obtained by linear description.

The other organisations involved will either merge or cooperate very closely. Already there is one organisation in the Holstein breed which carries out the genetic improvement programme (selection of bull dams, genotyping and selection of all potential young bulls) and is offering AI (serving about 600 000 cows), sexed semen, embryo transfer including ova pick-up, sexed embryos and genotyping service for selection of bull dams and for within herd selection. In addition it is very strong in marketing the products (semen and breeding stock) of the genetic improvement programme.

The estimation of breeding values is nowadays extremely demanding with respect to expertise and computing power. There Germany has two units which are carrying out this task. One is doing it for all single purpose breeds (and for horses and other species), the other for dual purpose breeds (Fleckvieh, Brown Swiss). The latter cooperates closely with Austria and Czech.

3.8 Final Remarks

There are two main aspects one has to consider:
Recording: Fundamental for any breeding scheme is the availability of good pedigree and performance records. That statement is still very true when you include genetic information like SNP. In that respect people have coined the phrase 'Phenotype is King!'.
Appropriateness: Situations are very different from country to country. One can not assume that the procedures of one country are optimal for another country where there are very different conditions (infra-structure, market requirements, etc.). Thus one has to analyse for each genetic improvement scheme very carefully how it has to be designed to serve the country best. Just copying the procedures from another countries, which might have quite different conditions, is not a good solution.