

Putting Genomics into Practice

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Introduction

Genomic Selection uses the DNA profile of an animal in conjunction with their ancestry and performance information to give a better estimate of the genetic merit of an animal at a younger age. It has completely revolutionised the way dairy cattle breeding programmes operate throughout the world. The process allows the initial screening of thousands of selection candidates with the selection of only a small percentage of these. In addition bulls get used more at a younger age, thereby achieving high reliability at a much younger age. This will decrease the time taken to find high EBI proven bulls by about 5 years. Genomic selection of young bulls was launched in Ireland in 2009. The increase in reliability of a genomic proof over and above the parent average is between 10 and 25% - equivalent to around 14 daughters in milk production.

The Next Generation Herd is a new concept that has very close links to genomics. Genomic selection has the potential to increase genetic gain by 50%, however we must ensure that by selecting on EBI we are not having a detrimental effect on other traits that are currently not under consideration. The next generation herd will be used to ensure the integrity of the genomic evaluations, but also to collect information on traits that are difficult to measure on a commercial scale.

The objective of this document is to outline the implementation and the uptake of genomic selection in Ireland since Spring 2009, and outline the objectives of the Next Generation Herd.

Uptake of Genomically Selected Bulls

Genomically selected (GS) bulls were first available to farmers in Spring 2009. Table one contains details of the amount of semen from GS bulls compared to daughter proven bulls over the last 3 years. These figures are based on ~500k inseminations/year collected via AI technician handhelds. Trends would be expected to be similar for DIY inseminations. Semen usage has increased from 34% in 2009 to 47% in 2011. Compared to daughter proven bulls with Irish daughters (DP-IRL) and daughter proven bulls with daughters in foreign countries

(DP-INT), the GS bulls had a higher EBI but a lower reliability in each of the 3 years. With higher risk associated with lower reliability bulls, farmers were encouraged to use a team of GS bulls (minimum of 4). These recommendations appear to have been followed as the average number of GS bulls used per herd was 5 in 2011, up from 4 in 2009 and 2010. This compares to about 3 for both of the daughter proven bulls categories.

Table 1. Percent inseminations, average number of bulls used, average EBI and reliability for daughter proven bulls in Ireland (DP-IRL), foreign imported bulls (DP-INT), and genomic selected bulls (GS).

Proof	2009			2010			2011		
	% Use	Bulls/hrd	EBI (Rel)	% Use	Bulls/hrd	EBI (Rel)	% Use	Bulls/hrd	EBI (Rel)
DP-IRL	37	2.7	120 (86)	25	3	146 (76)	29	2.8	143 (75)
DP-INT	29	3	133 (56)	34	3	155 (47)	24	3.3	155 (47)
GS	34	4	179 (55)	40	4	218 (56)	47	5.1	218 (57)

The very positive uptake of GS bulls can be attributed to the difference in genetic merit between these bulls and the daughter proven bulls. The weighted average EBI of the GS bulls in 2011 was €75, more than one standard deviation (€62), ahead of the DP-IRL bulls. The lack of semen from some of the very high EBI bulls was also a factor in the initial uptake of GS bulls.

Results

With the introduction of any new technology it is important to validate the evaluations of genomic bulls once they subsequently become proven. Over the last number of years approximately 1 bulls that were marketed with a GS proof now have a proof based on daughters. It is important to note that the GS proof is a prediction of where a bull will be when he is *highly proven* (>95% EBI reliability) therefore these comparisons are incomplete as it will take at least second crop daughters for bulls to reach this level of reliability. However, it should nevertheless give a good indication as to how the proofs are working. There are three values predicted for young animals. The parent average which is half the sire and half the dam, the DNA value which exclude the parental information, and the official genomic value (combination of parent average and genomic only). On average the official genomic value has a weighting of 70:30, parent average to genomic, however it can be as low as 5% genomic or as high as 50% genomic depending on the amount of an animal's back

pedigree that has been genotyped. Table 2 shows the correlations between the daughter proof and each of the 3 other indexes. In terms of the average values of each trait, the DNA value is closest to the daughter proven in terms of production. There is an overestimation of 50kg milk, 1.7kg fat and 1.9kg of protein between the official genomic value and the daughter proof. As a result the official genomic evaluation will have these values subtracted from the milk production traits. The DNA values are currently closer to the daughter proven proofs in terms of the average but the official genomic evaluation does a better job of ranking the bulls as the correlation is higher. It is important to note that the parent average proof was also over predicting how good an animal was ultimately going to be. Currently, there appears to be little bias between the official genomic evaluation and the daughter proven proof for fertility traits, so no adjustment is needed at this time. This is something that will be constantly monitored and updated accordingly. Results to date in Ireland are in-line with results from other countries who have implemented genomic selection.

Table 2. Correlations and mean difference between daughter proofs and GEBV, DGV, and parent average for GS bulls (n=144) selected when in lay-off but now with greater than 70% reliability for production traits based on daughters milking.

	Correlation			Mean Difference		
	GEBV	DGV	PA	GEBV	DGV	PA
Milk (kg)	0.77	0.73	0.73	50	27	60
Fat (kg)	0.63	0.62	0.55	1.7	0.3	2.0
Prot (kg)	0.73	0.64	0.71	1.9	-0.8	2.1
CI (days)	0.64	0.58	0.66	-0.1	-0.6	-0.8
SU (%)	0.50	0.41	0.37	-0.1	-0.45	-0.35

Genotyping young animals

An increasing number of farmers are choosing to genotype young animals, be it males that might be of interest to AI companies, or females when deciding on which animals to use as replacements or which animals to sell. The expected spread in EBI from parent average that can be expected once a genotype is available on an animals of the order of $\pm\text{€}100$ at the extremes, with the average EBI about the same for both parent average and genomic EBI. The majority of animals fall between $\pm\text{€}40$. The increase in reliability is of the order 20%. A new genomic service has been launched by ICBF primarily aimed at genotyping female animals. A subsidized rate of $\text{€}30$ (compared to $\text{€}50$ normally) is being offered for the first 10,000 females genotyped. The criteria for participation being that a complete cohort of females (i.e., all heifers born in the same year) are done to ensure against selection bias.

These females will go on to be used in the reference population once they start to gain performance information. Another benefit to the new service is that it is now being done on 7000 markers compared to 3000 in the past; thereby allowing more animals to be done as the need to have a sire genotyped is reduced and it will also give higher reliabilities.

Elite animals identified will also be of interest to AI companies, looking for suitable cows from which to purchase males calves, and to the next generation herd looking to bring in suitable replacements.

Genomics for other dairy breeds

At the moment genomics is only possible for Holstein and Friesian animals. This is because the reference population consists only of these breeds. Currently there are over 4500 AI sire in the reference population. The use of other dairy breeds has been limited in Ireland until recent years therefore the number of bulls for the reference population measures in the tens rather than the thousands. ICBF and Teagasc will be targeting herds with cross bred cows to gather information on cows to be used as part of the reference population. Four cows is equivalent to 1 bull so we would need at least 4000 cows in production to be genotyped to have a reference population equivalent to 1000 bulls which is the minimum required to do genomic selection. We hope to be in a position to publish genomic evaluations for other dairy breeds subject to getting the required numbers of animals genotyped and a positive outcome to the research work.

The Next Generation Herd

Genetic gain in the Irish dairy herd is accelerating at an ever-increasing pace. The acceleration in genetic gain has been made possible through the use of genomic selection combined with other advances in reproductive technologies. With the exploitation of genomic selection of females on-farm now intensifying, genetic gain in the Irish national dairy herd is set to increase even further. The nationwide increase in genetic gain has obvious benefits, most notably the increased profit per lactation. However as we continue to pick-up pace in genetic gain, we must ensure that we are consistently moving in the correct direction for all traits of importance. Most dairy farmers will remember the impact which sole selection for milk production had on the fertility of Holsteins globally. As dairy breeders we have spent a decade correcting this mistake and improving the genetic capability of Holstein fertility to

where it once was. We need to ensure deleterious trends like this are not unknowingly happening from selection on the Economic Breeding Index (EBI).

To identify any possible deleterious consequences of selection on our current selection index, the EBI, it is proposed to set up a new research herd. The research herd will be known as the '*Next generation*' dairy herd and will act as a sentinel herd whereby detailed observations regarding the direction of the EBI will be undertaken and. The Next Generation herd will represent the future of the national dairy herd and will act as a very important strategic resource, giving us a "forward view" to the picture of the future national herd. The Next Generation herd is an industry good herd and is supported from all aspects of the Irish breeding industry signifying the importance to the future of cattle breeding.

The three key objectives of the Next Generation Herd are:

1. To act as an important research resource to provide answers to the compatibility of cows of extremely high EBI to meet increased milk production demands from alternative intensive grass based production systems.
2. To monitor difficult to measure traits such as Green House Gas emissions, feed intake and scarcely recorded traits like indicators of cow health and welfare. Such information cannot be feasibly collated from the national herd and so is not currently available, yet is important to ensure against deleterious associations of current rapid selection technologies.
3. To enhance the development of the Economic Breeding Index through the identification of new traits and ensure that well co-ordinated and sustainable genetic gain ensues

Selection of stock for the Next Generation Herd

It is proposed that the Next Generation Herd will comprise 180 Holstein-Friesians, 75% of which will be elite genetic merit, with the remaining 25% representative of the national dairy herd. The elite genetic merit animals will represent the highest genetic merit heifers born in Ireland in any given year whilst the national average heifers will represent the average dairy heifer born in Ireland in any given year in genetic merit terms. The national average heifers

are essential to disentangle any possible genotype-environment interactions which may be encountered throughout the project.

A group of 800 elite heifers suitable for entry to the Next Generation Herd have been identified from the national herd based on their expected genetic merit and genetic diversity. To ensure genetic diversity of the group selected, the 800 heifers identified include only the top 30 daughters per bull and the top 80 granddaughters per bull for EBI. Subject to their availability for purchase, genomic breeding value, and health test results, the 200 highest genomic merit heifers from this group will be purchased for entry to the Next Generation Herd. The final 200 heifers purchased will represent a minimum of 24 sires.

Summary statistics of the initial 800 heifers identified are provided in Table 3. The 800 heifers identified have a group average EBI of €177 and are representative of 141 sires. The individual EBI of the identified heifers range from €135 to €244. Genetic diversity is key to long term genetic gain and therefore was accounted for in selecting these animals. If 800 heifers were selected without cognisance of ensuring genetic diversity, the average EBI of the animals was €193 but heifers were from only 70 sires, with one sire accountable for 43% of heifers selected. Similarly, if no restrictions were placed on genetic diversity, 3 grandsires accounted for over 69% of all heifers identified.

Each year throughout the duration of the project, a proportion of high genetic merit replacement calves will sourced from the national herd according to similar selection principles, that is genetic (and genomic) merit and genetic diversity, as applied to the initial heifers identified. This is to ensure good representation of the family lines of the future.

Table 3. Summary statistics of the 800 elite heifers identified from the national herd as suitable for entry to the Next Generation Herd

Variable	Average	Minimum	Maximum
Economic Breeding Index	177	135	244
Milk SubIndex	54	11	122
Fertility SubIndex	105	30	165
Calving SubIndex	24	1	42
Beef SubIndex	-15	-57	13
Health SubIndex	0	-9	7
Maintenance SubIndex	8	-9	47

Management of the Next Generation Herd

A replacement rate of 33% will operate in the Next Generation Herd to maintain maximal rates of genetic gain. Each year, 50% of replacements will be purchased into the Next Generation Herd from the national herd. Sires selected to breed replacements from within the herd will be selected according to genetic merit, genetic diversity and compatibility to the herd objectives.

The Next Generation Herd will be managed across a range of alternative grass-based systems of production. Traits routinely monitored across the herd will include detailed milk composition analysis, body weight and body condition score, reproductive efficiency, health and wellbeing and environmental footprint. In addition, traits such as individual feed intake, greenhouse gas emissions, and energy balance status will be monitored throughout the project. Research will be undertaken on calves, heifers and mature animals.

Through detailed monitoring of important traits that otherwise could not be investigated in the national herd, the impact of selection for EBI on these traits amongst others, can be closely monitored, and possible deleterious associations of selection detected and rectified before problems become widespread in the national herd.

Conclusions

Overall the implementation of genomic evaluations in Ireland has been very successful. The uptake of the GS bulls has been very encouraging with farmers using several bulls as recommended to reduce the risks. It is imperative farmers continue to use at least 4 GS bulls in during the breeding season, **and to use an even spread across the bulls selected**. Initial results on how the technology is working are promising and the introduction of genomic evaluations will generate greater genetic gain in the future. The Next Generation Herd is an exciting and critically important development for Irish dairying. It will provide sound independent research on how EBI is delivering for Irish farmers and it will collect valuable information on traits such as emissions and feed intake that will play a key role in the future.