The role of national progeny testing programmes to collect phenotypes for dairy and beef cattle evaluations in the genomics era

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Summary

In Ireland there are currently 3 progeny testing programmes - dairy, beef and dairy beef. The main aim of each of these programmes is to efficiently capture information on traits of economic importance for use in genetic and genomic evaluations of dairy and beef bulls. G\textsuperscript{EN}E IRE\textsuperscript{LAND}® (GI) is the general name given to each of these programmes. The dairy programme started in 2005, the beef programme in 2007 and the dairy beef programme started in 2015. The success of these programmes relies on the co-operation of several industry partners such as AI companies, herd books, national advisory bodies, the Department of Agriculture, and farmers. To date 680 dairy bulls, 192 beef bulls and 47 beef bulls have been tested across several thousand herds. Over time the programmes have evolved to changing circumstances such as the introduction of genomics, but the underlying principle has remained the same. That is, the on-going collection of good quality phenotypic information to provide accurate genetic evaluations for these animals. Bulls are put forward to the various programmes by AI companies and the Irish Cattle Breeding Federation (ICBF) provide the mechanisms to enrol participants allocate the bulls to farmers, collect the relevant phenotypic information, and produce genetic evaluations for these animals. The programmes collect data efficiently by having a direct link between the farmer and the national database. Currently, these programmes do not rely on direct financial incentives to the farmer other than a discount in the price of the straws so the costs of maintaining these programmes are not as prohibitive as might have been the case historically. The retention rate of herds participating in these programmes varies from 60 to 75\% year on year which indicates most farmers are very happy to use these bulls. Ireland has collected more than 1.2million genotypes over the last number of years. The phenotypic information collected as part of the progeny test programmes and the genotype information provides a great opportunity to increase the rate of genetic gain through higher reliability, enable rapid introduction of new traits and provide data to validate genomic predictions. In addition to providing valuable data for genetic evaluations these herds are a valuable resource to research institutes conducting field trials, or for the rapid collection of new phenotypes. The objective of this paper is to outline how each of these programmes work, and the benefits that are to be gained in the long term from the continuation of these programmes.

\textit{Keywords: progeny testing, G\textsuperscript{EN}E IRE\textsuperscript{LAND}, dairy, beef, genomics}

Introduction

National progeny testing programmes were formally set up in Ireland in 2005 for dairy, 2007 for beef and 2015 for dairy beef. The main purpose of setting up a national programme was to increase the efficiency with which information is collected for AI bulls
across a range of traits and ultimately increase the accuracy of genetic evaluations. The key to the success of these programmes is built on the national cattle breeding data which houses information on across a large number of traits for over 30 million animals as well as the cooperation of many industry stakeholders. In recent years this phenotypic data has been augmented by genotypes on over 1.2 million animals. Genomic evaluations are now available on Holstein-Friesian dairy bulls and bulls of all beef breeds that enter into progeny testing.

**Dairy progeny testing programme**

Following the successful establishment of the Economic Breeding Index (EBI) for selecting dairy animals, the next step was the establishment of the dairy GI progeny testing programme. It was launched in 2005 and was the first time the majority of test bulls were sourced locally from high EBI cows and herds. Previously progeny testing programme were heavily reliant on young bulls purchased outside of Ireland and imported as calves. Participating AI companies are requested to provide the first 500 doses for their bulls that meet the minimum requirement on EBI for progeny testing. ICBF recruit the farmers to use the bulls, allocate the bull teams, and capture the data once progeny are born. Farmers can choose from either a Holstein/Friesian group or a group of bulls with a mixture of different breeds, primarily Jersey and Norwegian Red bulls. They select to use between 25 and 50 straws for their selected group, with the 35 straws the most common. In this situation, a farmer will receive 7 straws from five different bulls. The group of bulls a farmer receives will be based on straw availability at the time of allocating the bulls, their EBI index, and their pedigree. All bulls are genotyped but currently only genomic evaluations are available for Holstein/Friesian animals. Farmers cannot choose individual bulls. Straws are then distributed directly to the farmer or to the farmers AI technician. Criteria for a herd to participate are enrolment in approved milk recording, record the inseminations, sire and calving ease details and provide health information as it becomes available on daughters of these bulls.

The main driver to establish a national progeny test programme with a link to the national database was the inefficiency of returning milk recorded daughters for test bulls. In the past over 1500 doses of semen would have been required to generate 70 to 80 daughters in milk recording. This would also have included paying for the recording of these daughters. With the introduction of dairy GI this figure has now reduced to 500 doses. Even with the introduction of genomics the continuation of the programme is seen as essential to ensure the testing of all bulls. While young genomic bulls will be marketed outside of the GI programme, invariably it is only the highest EBI bulls that get full tested. By entering the bull into the progeny test programme, it will guarantee all the bulls get a reliable first proof. The benefits of this are that more bulls will be available for the genomic reference population once they are proven and also a chance that some of these bulls can be returned as sires of sons. Since 2005, 266 bulls out of the 680 only have progeny born as a result of participation in the GI dairy programme. In total these bulls have contributed over 18,000 cows to milk recording with an average reliability for EBI of 81%. The success of the programme has meant 67 of the top 75 bulls on the active bull list in 2017 are bred from Irish dairy herds. This is from a base of 0 in 2005.

**Beef progeny testing programme**

In Ireland, beef AI accounts for only approximately 25% of cow matings in the beef...
Typically the focus of breeders and commercial farmers is to produce terminal type animals with good growth and carcass characteristics. Over time this has led to a reduction in the maternal traits (Donnellan, 2017), especially milk and fertility in the beef herd as replacement females from terminal bulls were retained for breeding (Figure 1).

Figure 1. Genetic trend for the terminal and replacement index for beef cattle in Ireland

As demand for more maternal type AI bulls was low due to the low level of beef AI, ICBF started to purchase maternal bulls as part of the GI beef programme in 2014. The aim is to identify bulls that are more suited to breeding good quality replacement females. Bulls that pass minimum criteria such as genotyped with high replacement index values and visual inspections are purchased and 1000 doses of semen are collected. The first 500 of these are used in the commercial suckler herd with the remaining 500 being stored for targeted AI matings in pedigree herds to generate high replacement index stock bulls. This revised programme began in 2014 and the first daughters of these bulls have now calved, so traits like fertility and milk are just being captured. In addition, AI companies can submit bulls to the programme provided they pass the minimum criteria for entry to the programme.

Suckler farming in Ireland is based largely on a farmer choosing a specific breed of bull for mating. Also, cow herd size is much smaller compared to dairy herds with a mean of 20 cows. As a result of these two factors, farmers are allowed to choose their bulls as they would not be prepared to take the risk of using test bulls otherwise. The average number of straws used by a typical herd is 14 and farmers pay €5 per straw. Approximately 50 progeny of GI beef bulls are purchased from participating farmers for individual feed intake performance testing at the national performance test station run by ICBF. Approximately 20 offspring per bull are targeted for deeper phenotyping. Traits include daily feed intake, health and disease traits, body composition (linear and ultrasound) and meat eating quality traits. A mixture of bulls, steers and heifers are selected from each AI bull. Meat eating quality traits include pH, tenderness, flavour, juciness, colour and chemical composition. All animals are genotyped on
the International Dairy and Beef (IDB) genotyping chip to ensure more accurate genomic predictions for feed intake and meat quality traits in the future.

**Dairy beef progeny testing programme**

With the removal of milk production quotas in 2015, the dairy herd has increased by 8% in 2016 with a similar increase expected in 2017. With national fertility of the dairy herd also improving (ICBF, 2017), there is addition scope for farmers to use beef bulls to increase the value of calf over and above those needed for replacements. The number of Hereford and Angus calves coming from the dairy herd has increased by over 10% in the last 3 years (Donnellan, 2017) and it is likely cattle from the dairy herds will constitute more than half of the national beef kill over the next few years. Traits of importance for the farmers are ease of calving and short gestation. However, continual selection of these bulls without due consideration of traits such as carcass characteristics and feed intake could lead to animals that do not meet processor specifications resulting in a much lower value carcass. The aim of the dairy beef programme is to identify bulls with good calving and gestation, but that also produce progeny that grow well and have a saleable carcass.

Since 2015, 45 of bulls across 6 breeds (Angus, Belgian Blue, Hereford, Limousin, Saler and Shorthorn) have been selected for progeny testing in Irish dairy herds. The number of herds involved in 2017 is just over 200. These herds are a subset of the dairy progeny test herds thereby ensuring bulls are used in good quality recording herds. The test straws are sent out to the dairy farmers in packs of 35 straws with the allocation of bulls per pack chosen at random; herd-owners do not get a choice of individual bulls. When calves are born, suitable animals are purchased. These animals are then monitored until they are finished at between 19 and 21 months of age. A subset of these animals enter the national performance test station for further phenotyping similar to that outlined above for the beef progeny testing programme. While the programme is at an early stage, approximately 1500 calves have been purchased to date with 360 slaughtered, initial results clearly demonstrate significant genetic differences exist between progeny born to different sires in terms of growth rate, carcass and feed efficiency. All of the information gathered feeds back into the genetic indexes for these bulls. A new dairy beef index is currently being developed to compliment the current replacement and terminal index for beef bulls. This index will be aimed towards farmers purchasing a beef bull to mate to dairy cows.

**Genotyping in Ireland**

Figure 2 shows the number of animals genotyped in Ireland since 2008. From a low of 1100 dairy genotypes in 2008, on average 340,000 animals per year have been genotyped in Ireland over the last 3 years. In dairy, the pattern of genotyping has remained largely consistent at about 24,000 animals per year since 2014. Genotyping by AI companies and the Holstein-Friesian herdbook accounts for about 10,000 males per year with remainder farmers genotyping females. The Beef Data and Genomics Programme (BDGP) has seen beef genotyping figures rise to over 300,000 per year over the last 3 years. This scheme runs until 2020 and will result in approximately 2 million beef animals being genotyped by the end of the scheme. As part of the scheme farmers are also required to collect phenotypic information on cows and their calves. In total there are just over 1.2 million animals genotyped in Ireland at the end of 2017. Most genotyping is done on a customized Illumina chip (IDB). We are currently on the third version of this chip which was designed for both dairy and beef cattle.
and contains SNPs for genomic selection, 140 major genes, microsatellites and imputation to higher densities.

Figure 2. Number of dairy, beef and total animals genotyped by year in Ireland

Genomic selection has been available in Holstein-Friesians since 2009 and for beef cattle since 2016. Currently only males are included in the reference populations for dairy, with both males and females included for beef. Increasing in reliability vary by breed and by trait. In terms of the overall indexes the average increase in reliability is approximately 20%.

Benefits of on-going progeny testing programmes

While breeding programmes in Ireland have clearly embraced genomic selection, collection of on-going phenotypes is seen as very important for a number of reasons.

Accuracy of genetic evaluations

The on-going collection of phenotypes is paramount for the accuracy of genetic evaluations. In general, farmers receive no direct financial contribution for the use of young bulls, therefore those participating herds are actively engaged in the programme and are prepared to collect information on these animals. By having a core group of herds, we have more confidence that there is good quality data being collected by the majority of herds each year. This information usually forms the basis of the first proof for an AI bulls. Getting an accurate first proof is essential as these bulls will automatically be included in the reference population at the next routine evaluations. Overtime this will also help improve the accuracy of the genomic predictions (Goddard 2009). Recent analysis of trends in the dairy progeny testing programme show significant advantages in terms of reliabilities for bulls that go through Gene Ireland than those that do not.

Collection of new phenotypes

The existing progeny testing structures facilitates enhanced recording of existing traits and the collection of new phenotypes easier. In addition, the use of structured progeny test ensures a rapid feedback mechanism between the farmer and ICBF on issues such as calving difficulty and where a genetic defect may be present. Lowly heritable, difficult to measure traits such as feed intake and greenhouse gases are a prime target for genomics. In Ireland we are collecting, or will collect data, on a number of animals for these traits at either a farm or research farm level. With all animals coming through the progeny test pipeline, data from birth all the way through to slaughter will be captured. All of these animals will be genotyped with some whole genome sequenced allowing predictions to be developed that can be used identify animals at an early age that have superior genetics for these traits.

Genotyping

One of the future aims of these progeny testing programmes is to have participating herds fully genotyped. The benefits of this are numerous at both a farm and industry level. For the farmers they can use genomic information for management decisions, mating optimisation, major gene avoidance, verification of pedigree, and potentially identify females that will be of interest to the breeding programme. At the industry level, there will be greater
numbers of selection candidates from which to contract mates. These females will eventually feed into the reference population for genomic evaluations. As the number of bulls per year remains relatively low, the importance of including females in the reference population will continue to increase (Gonzalez-Recio et al., 2014). This is especially true for minor breeds such as Jersey (Gao et al., 2015) and Scandinavian Red breeds for which we currently have no genomic evaluations for in Ireland.

**Contribution to the next generation**

Dairy progeny testing herds are also a source of genetics for the breeding programme. As they are the first farmers to use the highest genetic merit bulls based on genomics, these herds are of great interest to AI companies sourcing young animals for the breeding programme. Approximately 10,000 young bulls are genotyped each year in Ireland with many coming from progeny testing herds. These herds are also attractive from an AI company perspective as they record very good phenotypes on their cows, with an ever increasing number of these herds also genotyping all their females.

**Conclusions**

With the advent of genomic selection and the widespread use of young genomic bulls the nature and structure of traditional progeny testing has changed (Gonzalez-Recio, 2014). In Ireland, while genomic bulls account for 70% of totals dairy inseminations, the structure and integrity of the original systems built in 2005 are still as relevant, if not even more so, today. The close collaboration of all industry partners will be key to maintaining and enhancing the three programmes in the future.

**References**


