How is the AI Industry using Genomic Tools in Practice?

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Abstract

Genomic selection is leading to many changes in the artificial insemination (AI) industry in North America, which is now in a transition period. In 2009, 7,894 males and 6,850 Holstein females were genotyped with the Illumina 50K panel, bringing the total number of Holstein animals genotyped to date to 34,323. The short time required to obtain a genomic evaluation on young males more than compensates for their reduced accuracy of evaluation compared to progeny tested bulls, so that theoretically a young bull scheme based on genomic information is more efficient than one based on organized progeny testing. However, several questions remain to answer before AI organizations fully change their breeding strategies. In particular, what will be the producer acceptance of unproven versus proven bulls, how many progeny tested bulls will be required each year to compensate for the loss of prediction accuracy of marker effects over time, and what will be the impact of a decrease in performance recording incentives linked to organized progeny testing on the ability to generate adequate phenotypic data and bull proofs in the future? For the time being, genomic selection has led AI organizations to increase the number of planned matings compared to bulls on the ground, revise contracts with breeders to accommodate the genotyping of progeny from these matings, and collect more embryos from top females. Over all competition has markedly increased for access to these top females. At least one AI organization has been purchasing or leasing females. Top young genotyped bulls are primarily from three well-known proven sires and their sons, which could have a negative impact on the genetic variability of the breed unless new superior sires with different pedigrees are found. Relatively few young bulls were from unproven sires in 2009, but this number will likely increase in 2010. Bulls entering AI may now be used either in progeny testing programs or commercially as unproven bulls. The number of bulls entering AI was similar in 2006, 2007 and 2008. Numbers for 2009 are down for some companies and up for others, but the general trend is a decrease. Data about the relative market share of unproven bulls is not readily available, but individual companies have reported sales ranging from 5% to 40% of their total semen sales. Some of the new genomic tools that will impact the work of dairy cattle breeding organizations in future include low density panels, high density panels and eventually sequencing.

Introduction

As expected, genomic selection is having a large impact on the operations of dairy cattle breeding organizations. This article describes some of this impact in Canada and the US. Given the competitive situation in dairy cattle breeding, statistics on individual companies are not generally available. However, information from national evaluation centers can be used to indicate trends in the way the industry is using genomic tools.

The Current Situation in North America

Research genomic evaluations have been available in the US and Canada since early in 2008, and official evaluations since 2009. Genomic evaluations are currently based on the use of the Illumina 50K panel. For new animals, they are produced on a monthly or bi-monthly basis by CDN or AIPL. These genomic evaluations result in substantial increases in accuracy for young animals, as shown in Table 1 for young bulls or heifers in Canada. Reliability increases obtained from validation studies in the US are very similar to those in Canada, although published reliabilities tend to be slightly higher due to the way in which they are computed.

Table 1. Gains in published reliabilities for young bulls (CDN, January 2010).

Trait	Average reliability		
	Parent Average (PA)	Genomic Parent Average (GPA)	Gain with genomics
Lifetime Profit Index (LPI)	34	61	27
Milk yield	37	66	29
Fat Yield	37	66	29
Protein Yield	36	65	29
Fat Deviation	37	66	29
Protein Deviation	36	65	29
Conformation	34	61	27
Mammary System	35	62	27
Feet & Legs	33	56	23
Dairy Strength	35	61	26
Rump	32	55	23

Generally, the use of genomics nearly doubles evaluation accuracy for young animals, regardless of the trait. This is particularly important for low heritability traits such as fertility, herd life or productive life, since it provides an opportunity to make substantial genetic gains for traits that were difficult to improve previously.

Given the positive validation results in both the US and Canada, genotyping by AI organizations has proceeded at an increasing pace. As of the end of December 2009, 34,323 animals have been genotyped with the 50K panel, of which about 9,300 contribute to the training population from which SNP effects are estimated, about 15,000 are young bulls, and the remaining 10,700 are cows and heifers, usually potential bull dams.

Impact of Genomics on Sampling Programs

The genomic parent averages of young animals are significantly less accurate than bull proofs based on 100 daughters. For production traits, their reliabilities are in the 60-70% range instead of the 90% range, with means standard errors of prediction are nearly twice as large. However, genomic parent averages are available much sooner than proofs in the life of the animal. Using young genotyped males and females as parents results in a shorter generation interval, which more than compensates for their lower accuracy of evaluation and leads to an increase of about 60% in the yearly rate of genetic progress compared to a scheme that is based on progeny testing, as indicated in Table 2 below. Stochastic simulations have produced even higher increases, about double the rate of genetic gain from progeny testing.

Table 2. Genetic progress for three selection schemes when the reliability of genomic parent averages is 60%.

Selection scheme	proof REL	Sire-son interval	LPI points per year	% add. gain
Progeny testing only	90	5.5	171	0
Pre-selection of young bulls on GPA, then progeny testing	90	5.5	187	10
Genotyped young bulls used as sires of bulls and cows	60	1.8	272	59

Given this, AI companies could replace their progeny testing schemes by young bull schemes. A number of young bulls, but significantly less than before, would be progeny tested “by default” through commercial semen sales.

There are, however, a number of theoretical and practical questions that remain to be answered before most North American AI companies decide to fully convert to young bull schemes. One question is the size of the reduction in the accuracy of prediction in the next generation, especially what is the level of accuracy of unproven bulls whose sires are also unproven. While this reduction in accuracy has been estimated in some simulation studies and can be obtained from theoretical reliabilities, it has not yet been measured in a validation study based on real data. Some related questions are the number of bulls that must be progeny tested each year in order to restore the original accuracy, the number of young genotyped bulls that will be adequately proven through commercial sales rather than through organized progeny testing programs, and the rate of replacement of top genotyped young bulls. In addition, organized progeny testing programs provide incentives which help support milk recording and type classification programs. If these incentives are discontinued, the number of services required to prove each bull will increase. Producers may be less inclined to participate in these programs, or to report the data that they collect in their herds for management purposes. Less and less new data may be available for the periodic re-estimation of SNP effects for existing traits, or for the estimation of SNP effects for new traits.

Finally, there is a need for a transition phase. Producer acceptance of unproven bulls may not be immediate, especially since proven bulls have more accurate evaluations than unproven ones, and therefore may seem less risky in some situations. AI organizations also have to manage the transition from their current schemes to new ones, which imply large structural changes. Given the above questions and the need for a transition period, most AI organizations in North America have not made drastic reductions in their bull testing capacity yet. Rather, they have used genomic tools to screen large numbers of elite females and bull calves, sell semen from the top unproven genotyped bulls either individually or in groups, and put many of those in their progeny testing programs. At the same time, they have continued to use their top proven bulls to satisfy the proven bull market, which is still the largest one currently.

The number of males genotyped by all AI organizations in Canada and the US is shown in Table 3. Almost as many females were genotyped, but genotyping was done most often by the breeders who owned these females rather than by the AI industry.

Table 3. Number of young Holstein bulls genotyped with the 50K panel in North America by year of birth (CDN, 2010).

Year of birth	Number of young bulls genotyped
2006	1,819
2007	2,619
2008	4,645
2009	5,710

Impact on AI Industry Operations

Selection of bull dams. The number of bulls acquired from planned matings has increased compared to the number of bulls bred by breeders and available “on the ground”. Contracts with breeders have been revised to accommodate the selection of progeny based on genotype. There is increased competition for top females and their progeny, and payments for calves with top genomic values in the breed have gone up significantly. Many potential bull dams have been genotyped, which has generally meant lower breeding values for the very top females. In Canada, only genotyped cows or heifers are now listed on the elite cow list. Collection of embryos from top females has increased, and at least one AI organization has been purchasing or leasing females. One organization already has a nucleus herd. Contrary to expectations, the proportion of heifers among bull dams has not yet increased substantially.

Selection of sires of sons. Most of the top genotyped young bulls in North America originate from a few key bulls (O Man , Goldwyn, Shottle) and their sons. Potentially, this could have a negative impact on the genetic variability of the breed unless sires with different pedigrees are introduced. A growing number of unproven bulls have been used as sires of sons, but in 2009, only 5% of genotyped sons had an unproven bull as a sire.

Number of bulls entering AI. The number of bulls entering AI was similar for bulls born in 2006, 2007 and 2008, and was about 1,650 bulls per year for the six major AI organizations in North America. This number is not available for 2009 since most bulls born in 2009 did not have an opportunity to enter AI yet. The number of bulls progeny tested was up for some companies and down for others, based on what they told their clients or the media. In previous years, bulls that entered AI were all destined for progeny testing. Now, however, bulls can enter AI either to be put into organized progeny testing, or to be used as unproven bulls for commercial semen sales, or both. Since the total number of bulls born in 2008 which subsequently entered AI was the same as in previous years, one can conclude that the number of bulls that went into organized progeny testing in 2009 went down.

Market share of unproven bulls. This information is not readily available for each AI organization. However, based on industry and press reports, the market share of unproven bulls currently varies between 5% and 40% depending on the AI organization. The semen price of young genotyped bulls is also very variable depending on the type of bull and the company marketing it.

Current Issues Impacting the Use of Genomics

Aside from the issues indicated above, there have been questions regarding the computation of reliabilities, and the scale of genomic evaluations of young bulls compared to that of proven bulls. These can differ across evaluation centers, and even relatively small differences can affect the choices made by breeders and the international trade. Also, as pointed out earlier, there are concerns that the current race for top genomic values leads to the use of very few sire and even maternal grand sire families, which could in the long term markedly reduce genetic variability. Finally, there are still questions regarding the accuracy of evaluation of unproven sons from unproven sires, and if possible a validation study should be carried out to address this issue.

Future Genomic Tools

Several new tools are likely to accelerate the pace in the use of genomics by the dairy cattle industry in the near future. In particular, the 3,000 SNP panel, given its low expected cost and relatively high accuracy after imputation to the 50K panel, is likely to greatly increase pre-screening of male calves and potential bull dams. In addition, it could lead to the widespread adoption of genomics on commercial farms, particularly for the selection of replacement heifers in herds that use sexed semen.

Conclusions

The AI industry in North America is in a period of transition currently. It is already using genomic selection on a wide scale, but the full impact of this new technology on selection schemes has not occurred yet. Future trends include more intense selection of young bulls based on their genotype, the use of an increasing number of unproven bulls as sires of sons, less organized progeny testing, and more rapid bull turn-over. Producer acceptance will dictate in large measure the use of proven versus unproven bulls. Over time, however, the impact of genomics over the dairy cattle breeding industry is expected to be considerable and could greatly affect genetic improvement structures, from AI organizations to performance recording programs.