Value of DNA information for beef bull selection

Written by Alison Van Eenennaam

Alison Van Eenennaam, PhD
Cooperative Extension Specialist
University of California
Department of Animal Science
One Shields Avenue Ph:(530) 752-7942
Davis, CA 95616 Fax:(530) 752-0175
Email: alvaneenennaam@ucdavis.edu

There is value associated with using DNA information to identify animals that are carriers of recessive alleles. Tests are now available for specific genetic defects, color, and horned/polled status. Prior to the advent of DNA tests, the only way to test if a bull was a carrier of a genetic defect was to do progeny testing. Even then, definitive conclusions could only be drawn if he sired an afflicted calf. DNA-marker technology can also be used to verify or assign parentage, and this has value in terms of pedigree integrity or assigning paternity to calves conceived in multi-sire breeding pastures. Recently, a range of genetic tests have been developed to test for production traits ranging from fertility and longevity to growth and carcass merit. A question that often arises in conversations with producers is "What is the value of these tests?"

The answer to that question depends on what the tests are being used for. Some breeders are testing animals and listing the results as an additional source of information in sale catalogs. If this adds value, increasing the animal's sale price beyond the cost of the test, then this makes economic sense. Other people are using tests to make culling or selection decisions on traits that are not currently in breed EPDs (e.g. feed efficiency or tenderness). Working out whether this pays is a little more complicated. While these traits have obvious value, without more information, it is not possible to decide how much emphasis should be placed on these traits versus other important traits. For example, should you eliminate animals from your herd based solely on a poor feed efficiency DNA test result? That depends on how accurate[1] the test is at predicting superior versus inferior animals. The more accurate a test is, the more opportunity there is to accelerate genetic improvement. It also depends on the importance of feed efficiency versus all the other traits contributing to your overall profitability. One way to make this decision is to develop a "selection index" that weights all traits on their relative economic importance. Indexes consider both the "input" or expense side and the income side of selection decisions and enable cattle producers to make balanced selection decisions, taking into account the economically-relevant growth, carcass and fertility attributes of each animal to identify which animals are the most profitable for their particular commercial enterprise.

From the perspective of a seedstock breeder, the response to selection and therefore the value associated with the use of a DNA test is dependent upon how much the DNA information improves the accuracy of genetic evaluations at the time of selection, and the value of a unit of genetic improvement. To determine that value I recently did a simulation study to determine "**What is the value of DNA tests to increase the accuracy of beef bull selection in the seedstock sector?**"

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[1] Note that the term accuracy here is referring to the genetic correlation (r) between the test result and the true breeding value, not the "BIF" accuracy. If a DNA test has a genetic correlation of 0.5 with the trait of interest, it would be associated with 25% of the trait genetic variation, and a genetic estimate based on that DNA test alone would have BIF-accuracy of 0.13.

Structure of the seedstock herd. A simple two-tier industry example was modeled where the seedstock breeder was incurring the costs of DNA testing to improve the accuracy of bull selection. In this example the seedstock tier consisted of a closed nucleus of 600 breeding females. It was assumed that in the absence of DNA test information, breeding value estimates on young, untested bulls were informed by their own performance records on selection criteria (**Table 1**) along with those of their sire, dam and 20 paternal-half sibs. Each year the top 8 bulls were selected to be stud sires, and 125 (remaining bulls from the top half of the calf crop) were made available for sale to commercial producers. Commercial sires were then used to sire four calf crops at a mating ratio of 25 females: 1 male (i.e. they were exposed to a total of 100 cows).

Breeding objectives and index accuracy. Breeding objectives were developed for both maternal (self-replacing) and terminal herds targeting either the domestic Australian market where steers are finished on pasture (GRASS), or a high value market where steers are finished on concentrate rations in feedlots and marbling has a high value (FEEDLOT). The proportion of trait genetic variation explained by the DNA test (r^2) was set to the heritability (h^2) of all selection traits in Table 1 (i.e. the hypothetical DNA test explained 39% of the genetic component of birth weight, 18% of 200 d weight, etc.). Selection index theory was used to predict index accuracy. Discounted gene flow methodology was used to calculate the value derived from the use of superior bulls.

Selection Criteria	Unit	Heritability
Birth weight	kg	0.39
200 d Weight	kg	0.18
400 d Weight	kg	0.25
600 d Weight	kg	0.31
P8 fat	mm	0.41
RIB fat	mm	0.34
Eye Muscle Area	cm^2	0.26
Intramuscular Fat	%	0.25
Scrotal Size	cm	0.39
Days to Calving	days	0.07
Mature Cow Weight	kg	0.41

Table 1. Selection criteria, units, and heritabilities (h^2).

Results[2]. DNA test information was combined with performance records to increase the accuracy of EPDs. This increased selection response 20-41% over that obtained with performance recording alone, depending upon the breeding objective (**Table 2**). ***BOTTOM LINE**:* The value of DNA-tests to enable more accurate selection of genetically-superior commercial bulls ranged from AU$61-135 for commercial bulls, and AU$3,631-6,359 for stud bulls. Assuming that the entire bull calf crop (n = 267) was tested and that the top 3% (n=8) bulls were selected as stud sires, and the remaining top half of the bulls (n=125) were sold as commercial sires, the breakeven value of the genetic gain derived from DNA testing ranged from AU$143-258 per test.

These values assumed commercial producers were willing to pay a price premium for genetically-superior bulls, and some form of industry vertical integration or profit sharing between sectors such that the rewards for improvement in processor traits (e.g. dressing %, marbling score, etc.) were transferred along to commercial producers and breeders. The value of DNA tests to improve traits of direct value to commercial cattle enterprises (e.g. maternal traits like weaning rate or cow weight) would be less than that calculated for the total industry merit indexes modeled in this study. For example, 69% of the returns from including DNA data in commercial sire selection for the terminal feedlot index were derived from improved dressing %, saleable meat %, and marbling score; traits that generate a direct return to processors.

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[2] Study reported in Van Eenennaam, A. L., J.H. van der Werf, and M.E. Goddard. 2010. Value of DNA information for beef bull selection. 9th World Congress of Genetics Applied to Livestock Production, Leipzig, Germany.

Variable	Unit	Information available	GRASS INDEX		FEEDLOT INDEX	
			Terminal	Maternal	Terminal	Maternal
Selection response improvement resulting from DNA testing	%	Performance records	.	.	.	.
		Records + DNA test	20%	26%	24%	41%
Value of ΔG in commercial sires selected from top half of stud herd	(AU$/ bull)	Performance records	301	318	245	345
		Records + DNA test	363	396	306	480
Value of ΔG in stud sires selected from top 3% of stud herd	(AU$/ bull)	Performance records	17899	15922	14579	16751
		Records + DNA test	21617	19724	18211	23110
Increased value derived from DNA testing commercial sires	(AU$/ DNA test)	Performance records	.	.	.	.
		Records + DNA test	31	39	30	67
Increased value derived from DNA testing stud sires	(AU$/ DNA test)	Performance records	.	.	.	.
		Records + DNA test	111	114	109	191
Total value per DNA test to seedstock operator	(AU$/ DNA test)	Performance records	.	.	.	.
		Records + DNA test	143	153	139	258

Table 2. Improvement in selection response (%) resulting from a DNA-test enabled increases in index accuracy as compared to performance recording alone, value of genetic gain (ΔG) in commercial and stud sires, and value derived per DNA test used to increase the accuracy of male selection in a closed seedstock breeding program.

These results were based on using a relatively powerful hypothetical DNA test panel that predicted ***ALL*** of the selection traits with an accuracy that was set to h^2. The accuracy of DNA-based predictions of breeding value is dependent on trait heritability and the size of the training set used to develop the test. Large training populations increase the accuracy of DNA tests. **Figure 1** shows the relationship between trait heritability and the expected power of a DNA test when trained on a population of a given size. A DNA test like the one modeled in this simulation study might be expected if it was developed using a relatively large (~2,500 animals) genotyped training population. It can be seen that more animals are required in the training population to develop DNA tests that explain a lot of the variation associated with traits that have low heritability. Ironically, the potential benefit of DNA tests is expected to be greatest for traits that have low heritable (e.g. reproduction), and those that are not routinely recorded before selection decisions are made (e.g. carcass traits).

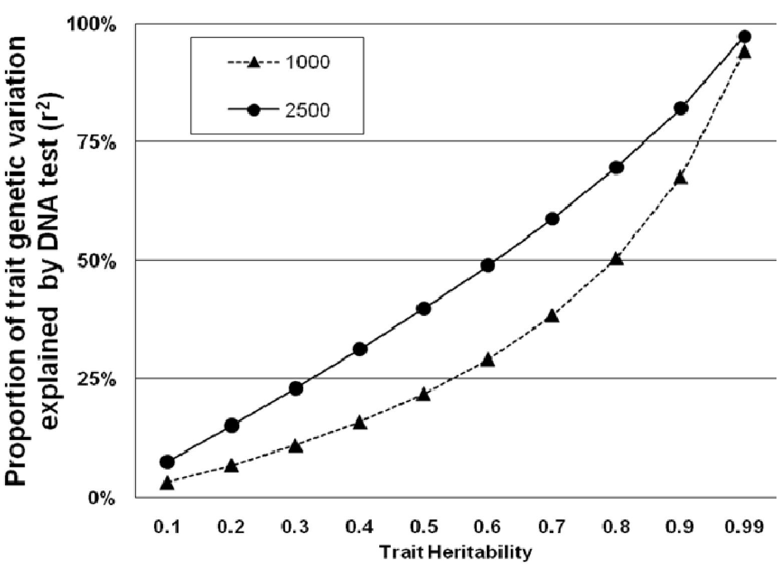

Figure 1. Effect of trait heritability (h^2) on the theoretical proportion of trait genetic variation explained by DNA tests trained in populations of 1000 (▲) or 2500 (●) individuals with phenotypic observations.

Until recently, commercialized DNA tests for beef cattle targeted only a handful of traits (e.g. marbling score, tenderness and feed efficiency). As DNA testing becomes more comprehensive and encompasses a larger number of traits, it will become increasingly important to integrate this information into national cattle evaluations. Separately publishing marker values for traits that have traditional EPDs does little to increase the accuracy of EPDs. Having to make a decision based on marker scores and EPDs can lead to a suboptimal decision if too much emphasis is placed on marker scores that predict only a small proportion of the genetic variation. It is therefore crucial to know this proportion. In its absence, there is no way to determine how much relative weight should be given to DNA test results. Placing a lot of selection emphasis on the results of a low accuracy DNA test, or on a trait of little economic importance, can actually diminish the overall rate of genetic improvement.

The values obtained in this study assumed that the commercial bull:cow ratio was 1:25. A 20% increase in this ratio (i.e. increasing it from 1:25 to 1:30) would increase the values in Table 2 by 20%. A major determinant of seedstock profitability is the proportion of young bulls that can be sold for breeding, and eliminating half of possible sale bulls from contention based on DNA testing may be unrealistic. Some seedstock breeders may only be interested in using DNA information to improve the accuracy of replacement stud sire selection for their own herd, and not to additionally select the better half of the commercial bulls for sale as was modeled in this study.

If a breeder instead chose to sell the entire physically-sound bull calf crop, the value associated with testing commercial sire candidates disappears, because selection intensity in commercial bulls would become zero. However, it would increase the value of replacement stud bulls due to the larger number of marketable descendants each stud bull would produce. For example selling 80% of the bull crop as commercial sires, assuming 20% were culled for non-genetic reasons, would increase the value of a stud bull selected based on performance records for the terminal feedlot market from $14,579 to $24,143. If the DNA information from the hypothetical DNA test modeled in this study was additionally used to select those replacement stud bulls, the value derived from each stud bull would also increase ~ 66% to $30,157. The value per DNA test in this case would depend upon what proportion of the bull crop was tested to select replacement stud bulls. If the seedstock operator continued to test 100% of the bull calves, this value would be ~ $180/test.

SUMMARY: It is difficult to make best selection decisions or estimate the value of multi-trait DNA tests in the absence of information on their accuracy, and the incorporation of DNA test results and target traits into genetic evaluations. Although DNA information clearly has the potential to provide value to seedstock producers, inclusion of DNA information to increase the accuracy of genetic evaluations will be required to make optimal use of this information. This will likely require the concurrent development of multi-trait selection indexes that include traits for breeding objectives of relevance to U.S. beef production systems.