The economics of using DNA markers for bull selection in the beef seedstock sector

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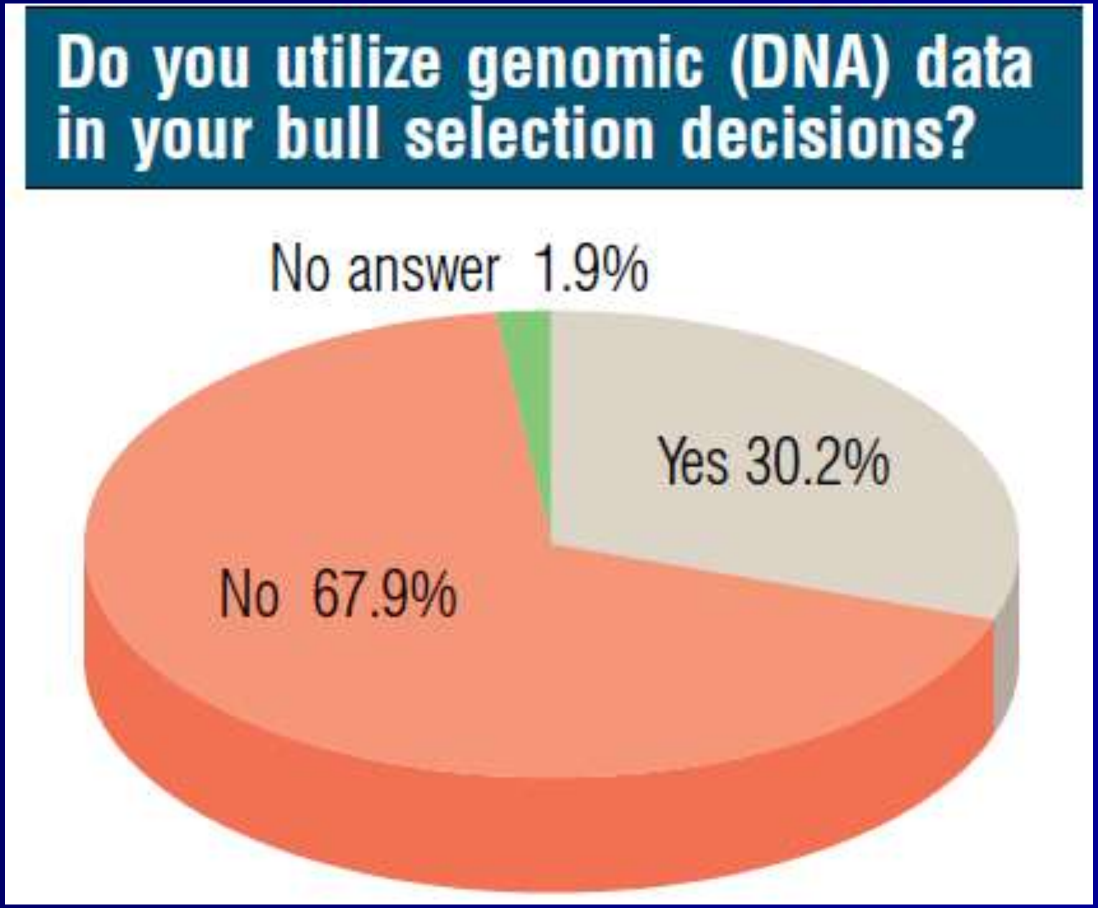


Base = 635 (All Cow-Calf Operations)

TRAIT	Company		
	A	B	C
Average Daily Gain	X	X	X
Net Feed Intake		X	
Dry matter intake		X	
Residual feed intake	X		
Tenderness	X	X	X
Calving Ease (Direct)		X	
Birth weight		X	
Weaning Weight		X	
Yearling Weight	X		
Calving ease (maternal)	X	X	
Milking Ability		X	
Heifer pregnancy rate	X		
Docility	X		
Stayability	X		
Carcass weight		X	
Backfat thickness	X	X	X
Ribeye area	X	X	
Marbling score	X	X	X
Yield Grade	X		X
Percent Choice	X		
COST	**$58**	**$69-129**	**$65/145**

Objective

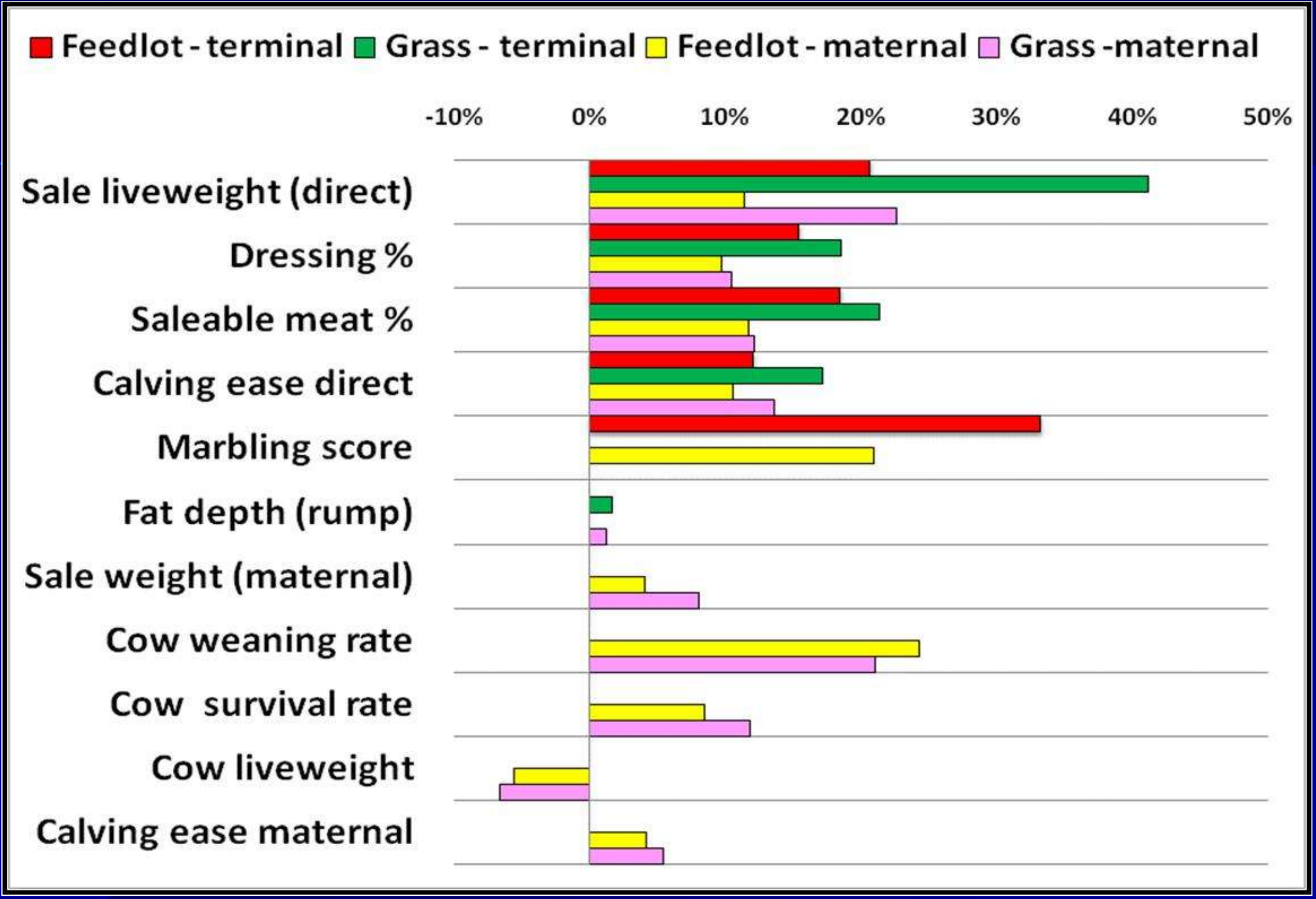
Estimate the value of using DNA test information to increase the accuracy of beef bull selection in a seedstock breeding program

- The expected returns from using a commercial sire sourced from a seedstock herd using DNA testing
- Additionally, the value of marker information in the selection of replacement stud males to be mated in a seedstock breeding program was also estimated.

The following seedstock operation was modeled

Parameters	Value
Number of stud cows	600
Number of bulls calves available for sale/selection	**267 (all get tested with DNA test)**
Number of stud bulls selected each year	8 (~3%; i = 2.27)
Number of bulls sold for breeding (annual)	125 (~50%; i = 0.8)
Maximum age of commercial sire	5 (4 breeding seasons)
Commercial cow:bull ratio	25
Number of commercial females	9225
Planning horizon	20 years
Discount rate for returns	7%
Number of live stud calves available per exposure	**0.89**
Stud cow:bull ratio	**30**
Cull for age threshold of cow	**10**
Age structure of breeding cow herd (2-10 yr)	**0.2, 0.18, 0.17,0.15, 0.12, 0.09, 0.05, 0.03, 0.01**
Bull survival (annual)	**0.8**
Age structure of bulls in stud herd (2-4 yr)	**0.41, 0.33, 0.26**
Age structure of bulls in commercial herd (2-5 yr)	**0.34, 0.27, 0.22, 0.17**

EXAMINED 4 BREEDING OBJECTIVES: PROFIT DRIVERS



Materials and methods

- Selection index theory was used to predict the potential benefit of including DNA information in selection decisions.
- Information from DNA test information was modeled as a molecular breeding value (q_i) explaining a proportion (ρ) of the additive genetic variance (σ_{ai}^2) in trait i; $V_{qi} = \rho.\sigma_{ai}^2$, as described by Lande and Thompson (1990).

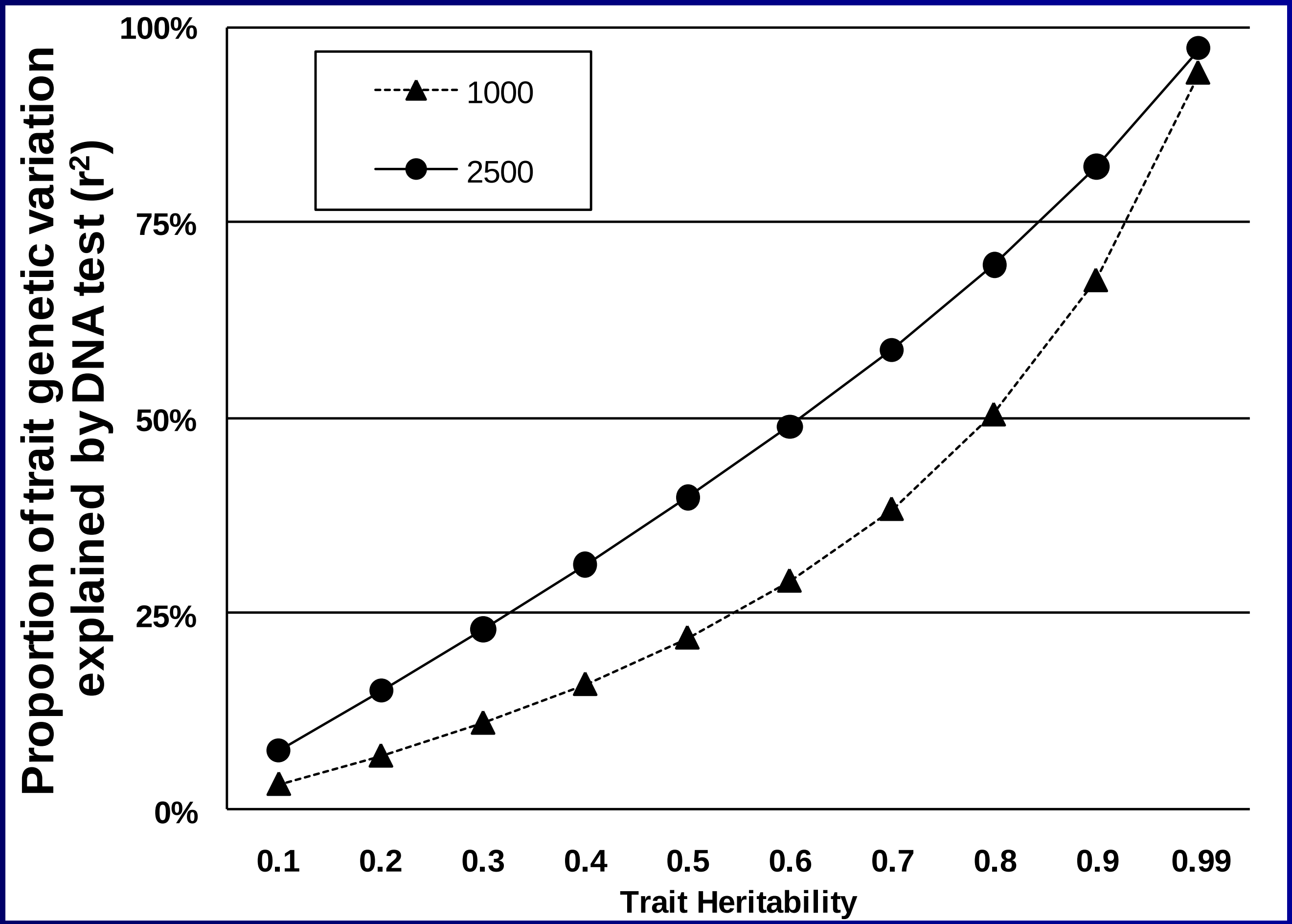
DNA panels explained a percentage of additive genetic variance set to either half ($\rho_i = ½h_i^2$) or the full heritability ($\rho_i = h_i^2$) of all of selection criteria and traits in the breeding objective.

Objective Trait	Heritability
Sale liveweight – direct[A]	0.31
Sale liveweight – maternal[A]	0.04
Dressing Percentage	0.33
Saleable meat Percentage	0.56
Fat depth (rump)	0.41
Marbling score	0.38
Cow weaning rate[a]	0.05
Cow survival rate[a]	0.03
Cow weight[a]	0.41
Calving ease – direct	0.10
Calving ease – maternal	0.10

Selection criteria	Heritability
Birth weight	0.39
200 d Weight	0.18
400 d Weight	0.25
600 d Weight	0.31
P8 fat	0.41
RIB fat	0.34
Eye Muscle Area	0.26
Intramuscular Fat	0.25
Scrotal Size	0.39
Days to Calving	0.07
Mature Cow Weight	0.41

[a] Predicted feed requirements accounted for in the calculation of economic value

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



*** Effective population size (N_e) = 100, length of bovine genome (L) = 30 M, effective number of loci (M_e) = 2NeL, and a normal distribution of QTL effects were assumed. Derived from the formula of Goddard (2009).**

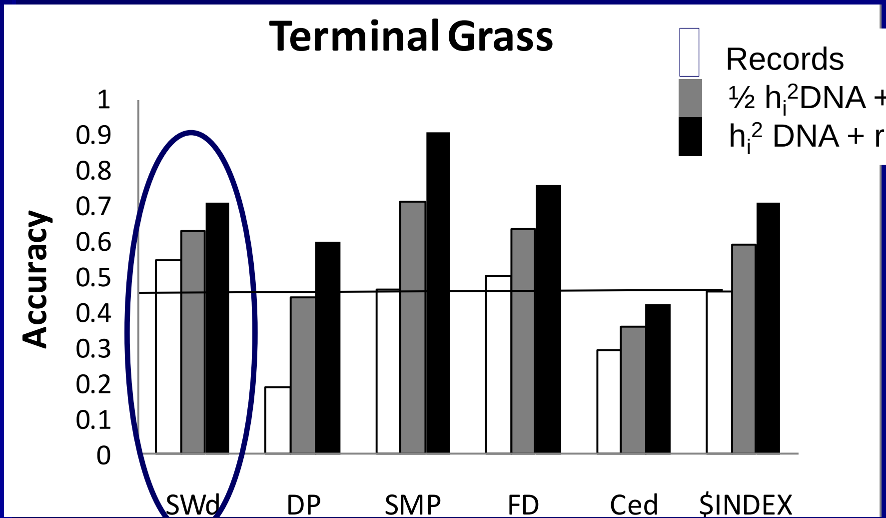
Materials and methods (continued)

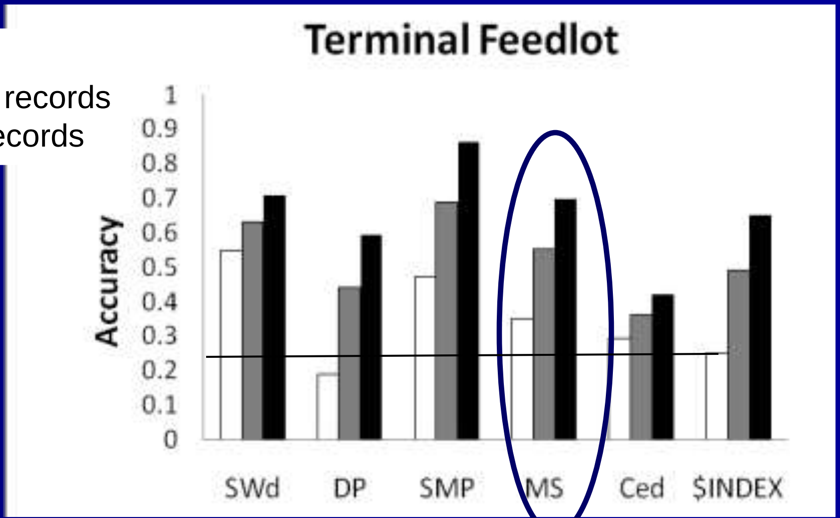
- Indexes were constructed and index accuracies were calculated when information source included DNA test information from one of the two DNA panels **and** performance recording, over that derived from performance recording alone.

- Discounted gene flow methodology (Hill, 1974) was used to calculate the value derived from the use of superior bulls selected using DNA test information **and/or** performance recording. Results were ultimately calculated as discounted returns per DNA test purchased by the seedstock operator.

RESULTS: Improvements in index accuracy derived from DNA testing using tests associated with a percentage of additive genetic variation set to ½ h_i^2 or h_i^2 of all selection criteria and traits in the breeding objective

Variable	Unit	Information available	DNA test used	GRASS INDEX		FEEDLOT INDEX	
				Terminal	Maternal	Terminal	Maternal
Accuracy of Index	r	Performance recording information	No DNA test	0.46	0.27	0.25	0.19
			Accuracy is ½h^2 for all traits	0.59	0.40	0.49	0.38
			Accuracy is h^2 of all traits	0.71	0.49	0.65	0.50



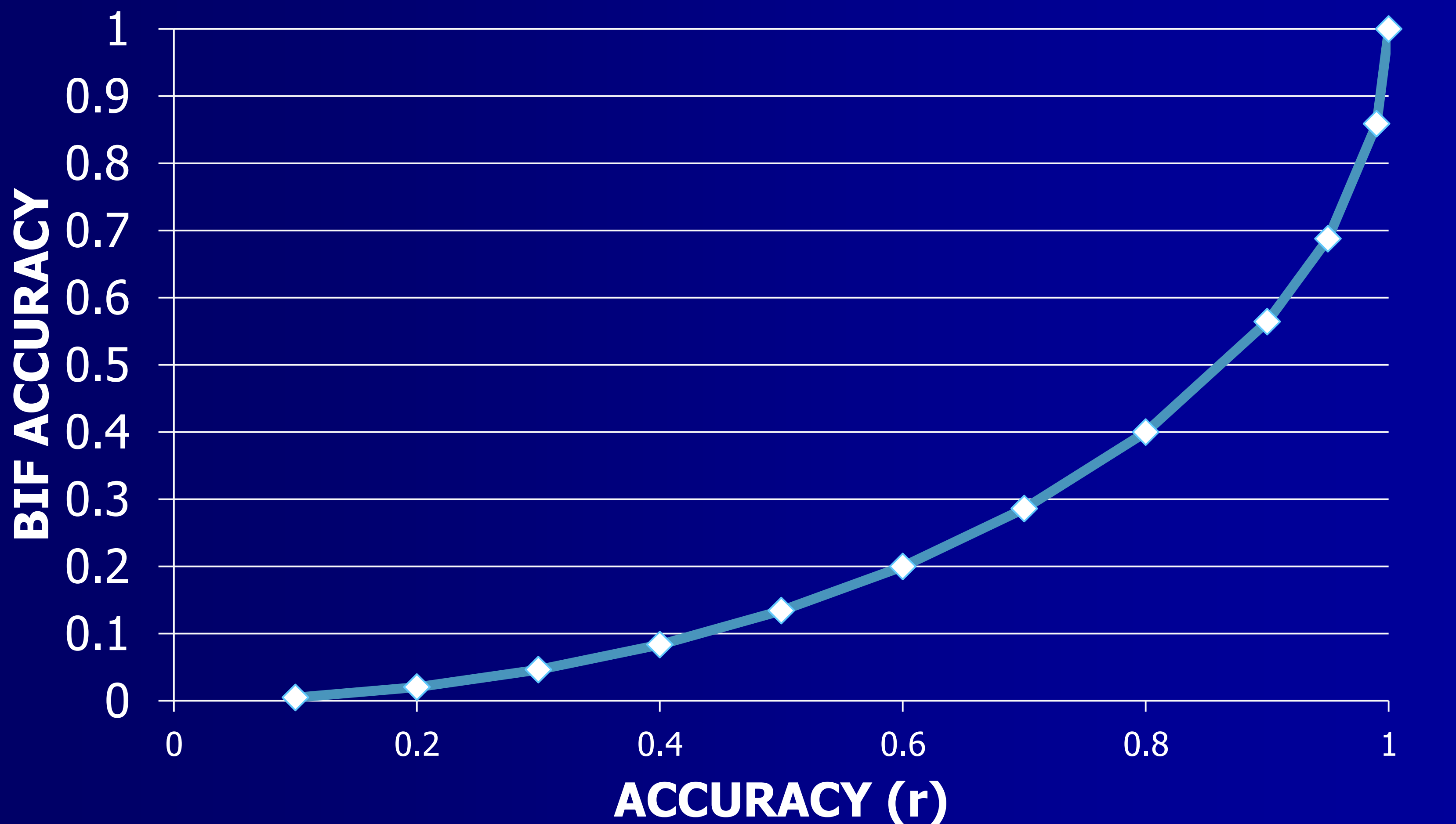


SWd Saleweight, DP Dressing %, SMP Saleable meat %, Ced Calving ease direct

BIF Accuracy versus Accuracy (r)

$$Accuracy(r) = \sqrt{1 - (1 \quad ACC_{BIF})^2}$$

$$ACC_{BIF} = 1 \quad \sqrt{1 - r^2}$$

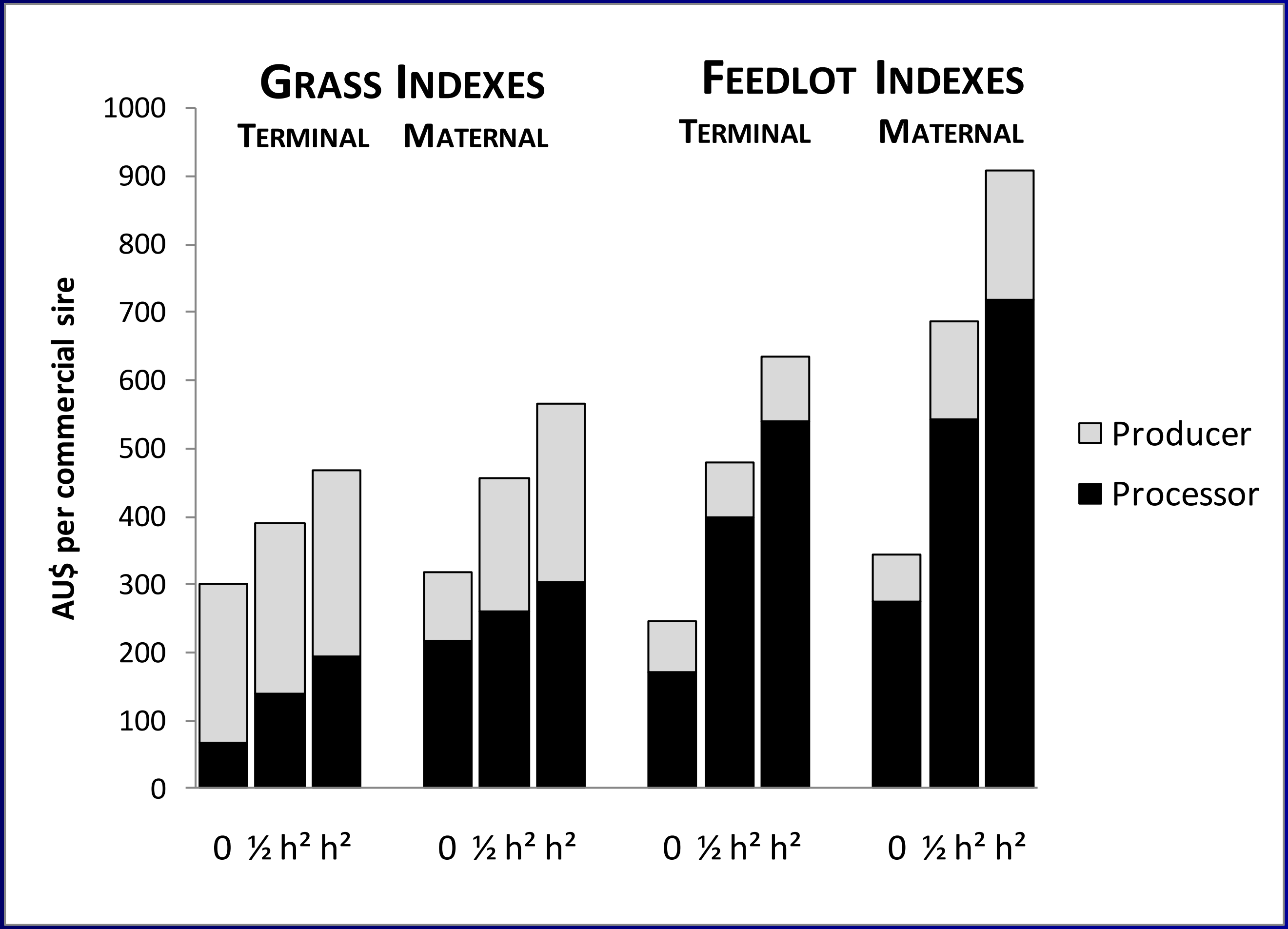


Results

Value of genetic improvement (ΔG) per bull derived from performance recording and DNA testing to increase the accuracy of COMMERCIAL BULL selection in a closed seedstock breeding program

Variable	Unit	Information available	DNA test used	Grass Index		Feedlot Index	
				Terminal	Maternal	Terminal	Maternal
Value of ΔG in commercial sires selected from top half of stud herd	AU$/bull	Performance Records	No DNA test	**301**	**318**	**245**	**345**
		Records + DNA test	Accuracy is ½h^2 for all traits	**390**	**456**	**481**	**686**
			Accuracy is h^2 of all traits	**467**	**567**	**636**	**910**

Most of the value from DNA testing for the Feedlot indexes was derived by the processing sector (i.e. Dressing %, Saleable meat %, Marbling score)



Value of genetic improvement (ΔG) per bull derived from performance recording and DNA testing to increase the accuracy of SEEDSTOCK BULL selection in a closed seedstock breeding program

Variable	Unit	Information available	DNA test used	GRASS INDEX		FEEDLOT INDEX	
				Terminal	Maternal	Terminal	Maternal
Value of ΔG in commercial sires selected from top half of stud herd	AU$/bull	Performance Records	No DNA test	**301**	**318**	**245**	**345**
		Records + DNA test	Accuracy is ½h^2 for all traits	**390**	**456**	**481**	**686**
			Accuracy is h^2 of all traits	**467**	**567**	**636**	**910**
Value of ΔG in stud sires selected from top 3% of stud herd	AU$/bull	Performance Records	No DNA test	**17899**	**15922**	**14579**	**16751**
		Records + DNA test	Accuracy is ½h^2 for all traits	**23231**	**22698**	**28628**	**33633**
			Accuracy is h^2 of all traits	**27820**	**28121**	**37891**	**44661**

Value of genetic improvement (ΔG) per DNA TEST derived from performance recording and DNA testing to increase the accuracy of COMMERCIAL AND SEEDSTOCK BULL selection in a closed seedstock breeding program

Variable	Unit	Information available	DNA test used	GRASS INDEX Terminal	GRASS INDEX Maternal	FEEDLOT INDEX Terminal	FEEDLOT INDEX Maternal
Increased value derived from ΔG in commercial sires	AU$/ DNA test	Records + DNA test	Accuracy is ½h^2 for all traits	**45**	**69**	**118**	**170**
			Accuracy is h^2 of all traits	**83**	**124**	**196**	**282**
Increased value derived from ΔG in stud sires	AU$/ DNA test	Records + DNA test	Accuracy is ½h^2 for all traits	**160**	**203**	**421**	**506**
			Accuracy is h^2 of all traits	**297**	**366**	**701**	**836**

COMBINED VALUE PER DNA TEST

Variable	Unit	Information available	DNA test used	Grass Index Terminal	Grass Index Maternal	Feedlot Index Terminal	Feedlot Index Maternal
Value of ΔG in commercial sires selected from top half of stud herd	AU$/bull	Performance Records	No DNA test	301	318	245	345
		Records + DNA test	Accuracy is ½h^2 for all traits	390	456	481	686
			Accuracy is h^2 of all traits	467	567	636	910
Value of ΔG in stud sires selected from top 3% of stud herd	AU$/bull	Performance Records	No DNA test	17899	15922	14579	16751
		Records + DNA test	Accuracy is ½h^2 for all traits	23231	22698	28628	33633
			Accuracy is h^2 of all traits	27820	28121	37891	44661
Increased value derived from ΔG in commercial sires	AU$/ DNA test	Records + DNA test	Accuracy is ½h^2 for all traits	45	69	118	170
			Accuracy is h^2 of all traits	83	124	196	282
Increased value derived from ΔG in stud sires	AU$/ DNA test	Records + DNA test	Accuracy is ½h^2 for all traits	160	203	421	506
			Accuracy is h^2 of all traits	297	366	701	836
Total value per test to seedstock operator	**AU$/ DNA test**	**Records + DNA test**	**Accuracy is ½h^2 for all traits**	**204**	**272**	**539**	**676**
			Accuracy is h^2 of all traits	**380**	**490**	**897**	**1119**

To determine the value of a multi-trait DNA test you need to know

1. Selection objective being targeted
2. Heritability of the analyzed trait (h^2)
3. Accuracy of genetic estimates already available to inform selection decisions
4. Genetic correlation between MVP and the trait (r_g)
5. Genetic variances and covariances for selection index calculations
6. Regression coefficient of phenotype on MBV (b)
7. Biological attributes and structure of stud and commercial herds
8. Selection intensity of replacement stud sires and bulls for sale (and females)
9. Number of calves per exposure
10. Type of herd (terminal, maternal)
11. Value derived from accelerated genetic progress
12. Sector where value is derived and how that is value is shared
13. Cost of test, and which animals are being tested
14. Planning horizon etc., etc., etc.

Implications

- Value of DNA testing will be enterprise dependent
- DNA information clearly has the potential to provide value to seedstock producers if it is meaningfully incorporated into national cattle evaluations
- It is difficult to make optimal selection decisions or even estimate the value of multi-trait DNA tests in the absence of information on their accuracy, and the incorporation of their target traits into breeding objectives and selection index calculations
- This will likely require the development of multi-trait selection indexes for breeding objectives of relevance to U.S. beef production systems.

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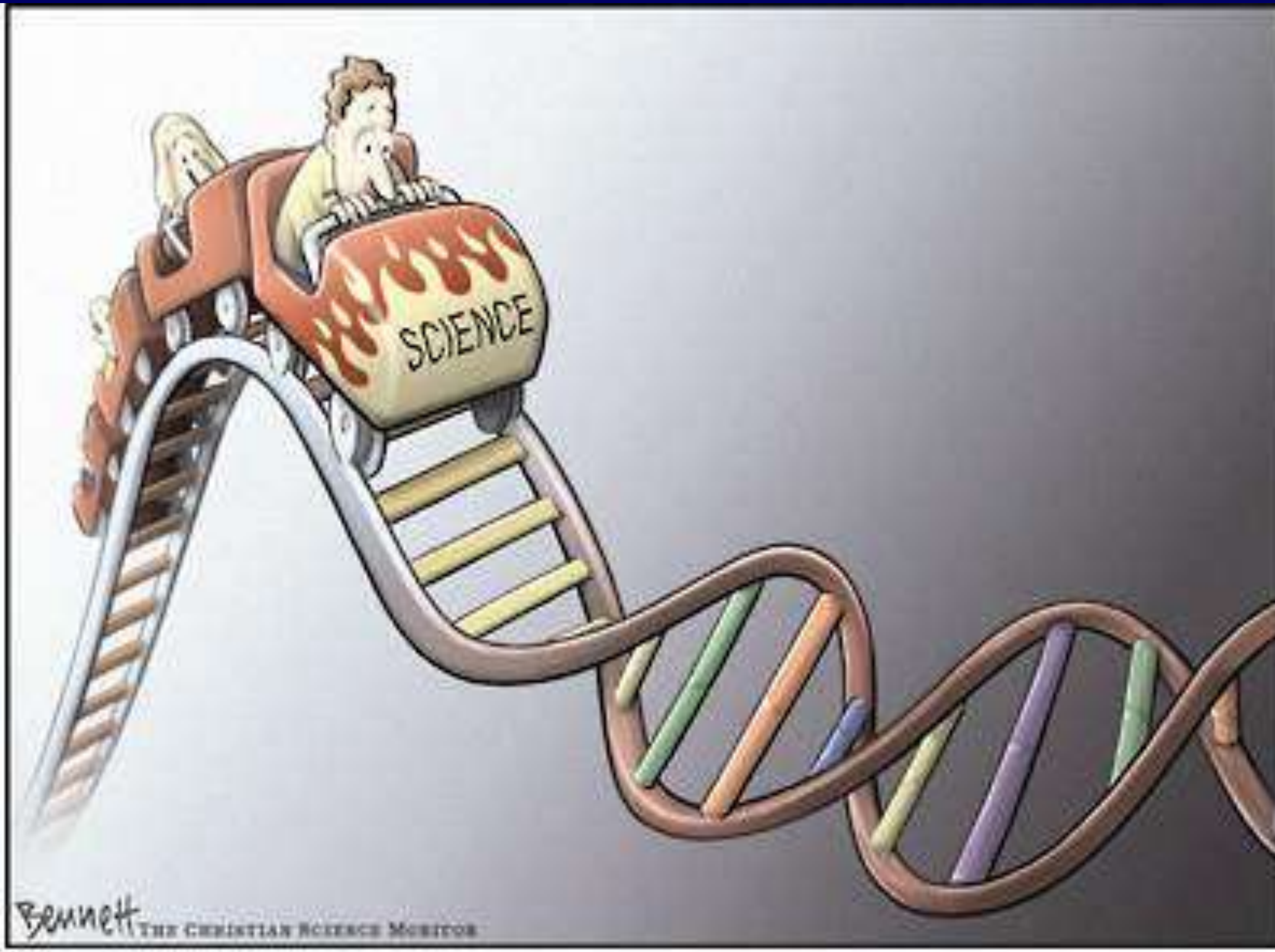
North West, Tasmania

Improvements in index accuracy derived from DNA testing using tests associated with a percentage of additive genetic variation set to ½ h_i^2 or h_i^2 of all selection criteria and traits in the breeding objective Shaded cells show accuracy of $Index of DNA tests in the absence of performance data

Variable	Unit	Information available	DNA test used	GRASS INDEX		FEEDLOT INDEX	
				Terminal	Maternal	Terminal	Maternal
Accuracy of Index	r	Performance recording information	No DNA test	0.46	0.27	0.25	0.19
			Accuracy is ½h^2 for all traits	0.59	0.40	0.49	0.38
			Accuracy is h^2 of all traits	0.71	0.49	0.65	0.50
		DNA test only	No DNA test	0	0	0	0
			Accuracy is ½h^2 for all traits	.45	.33	.44	.34
			Accuracy is h^2 of all traits	.64	.46	.62	.48

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 when the DNA test explained a percentage of additive genetic variance set to the full heritability ($\rho_i=h_i^2$) of just the selection criteria.

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**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