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Selecting AI Beef Sires for Maximum Profit

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Abstract

*Beef producers face a complex decision-making process when selecting from among AI sires that range widely in price and expected progeny difference (**EPD**) for various traits. Although individual producers vary in specific production goals, their goal in genetic improvement is generally motivated by potential profit. Because of the complexity of the sire selection decision and with semen prices as great as $100 per vial, economically optimal choices are not always clearly evident. To assist the producer in this decision, AI service sires were ranked according to their net present value (**NPV**). The analysis considered multiple genetic traits and examined the impact of various production goals and management situations faced by producers. Spring 2003 EPD for weaning BW, yearling BW, and milk of 552 available AI beef sires were used. Seven breeds from four AI semen providers were evaluated, and sires were ranked by NPV from both the crossbred and purebred producer perspective. The analysis examined the impact on ranking of various production goals and management situations faced by producers. The 20 most profitable sires in each ranking offered substantial genetic improvement at less than the cost of average genetic improvement. The average NPV of the most profitable sires was substantially greater than the average NPV of all sires in the analysis. Substantial differences in rankings were found for different production goals and management situations. Thus, proper specification of production goals and risk tolerance is important in accurately selecting AI service sires to maximize profit.*

(Key Words: Artificial Insemination, Sire Selection, Economic Rankings, Crossbred, Purebred.)

Introduction

Purchasing semen of an AI sire is an investment in increased returns because of genetic improvement, as this expenditure does not earn income until offspring are sold. To assist the producer in this decision, AI service sires were ranked according to their net present value (NPV). When accurate data are used, NPV investment analysis identifies the most profitable investment decision for a given planning horizon. This is achieved for an AI sire by discounting the future net income stream from genetic improvement to its value at the time the investment is made (breeding). The difference between the value of the discounted net income earnings from genetic improvement and the cost of semen is the NPV of semen from that sire.

A similar analysis for dairy AI sires was conduced by Wilcox et al. (1984). A linear net merit (NPV) index was computed to rank Holstein AI sires under alternative selection goals for milk income and type score. They also examined the effects on rankings of several variables: conception rate to first service, calving interval, female mortality rate, and changes in semen price and the real interest rate. McMahon et al. (1985) evaluated the effects of planning horizon and conception rate to first service on the NPV rankings of Holstein and Jersey AI sires. Those researchers concluded that although conception rate significantly impacted the rankings of both Jersey and Holstein AI bulls, rankings were nearly the same beyond one generation (daughters) for Jersey and two generations (granddaughters) for Holstein.

No rankings of beef AI sires have been developed based on profitability. Clary et al. (1984) evaluated the economic influences of incorporating a genetically superior herd sire using the NPV of increased weaning BW. They estimated marginal bid prices (the additional amount a producer could pay for a genetically superior herd sire) based on the additional revenues that a superior herd sire would generate. However, their analysis did not examine the profitability of specific AI sires.

Materials and Methods

Because of differences in production and/or genetic goals among pro-

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ducers, multiple rankings of bulls are required to find the most profitable bulls for individual producers. Separate rankings may be needed for purebred producers and for commercial producers because of the difference in production focus. Rankings for crossbred producers are most useful across multiple breeds, as these producers have the option of selecting bulls from various breeds that best complement their cow herd. Rankings for purebred producers are useful within respective breeds.

For both the commercial crossbred and purebred beef producers, an NPV ranking was developed for each of three different ownership or management goals: 1) a one-generation planning horizon with calves sold at weaning, 2) a one-generation planning horizon with calves sold as yearlings, and 3) a multiple-generation planning horizon with a portion of the heifer calves sired by AI bulls used as herd replacements and the remaining calves sold at weaning. In the first ranking scenario, weaning BW (**WW**) EPD values were used to determine the NPV of increased WW of the calf crop for each AI sire. In the second ranking scenario, both WW and yearling BW (**YW**) EPD values were used. In the third ranking scenario, WW and milk EPD, which are additive, were used in combination to determine the present value of future additional gains in WW caused by keeping replacement heifers sired by AI bulls. Rankings 1 and 2 would be most appropriate for selecting terminal sires (with no replacement heifers kept from offspring), and ranking 3 would be most appropriate for selecting maternal sires (with replacement heifers kept from offspring). Because these rankings do not consider birth BW (**BBW**), producers should still select bulls with BBW EPD that are appropriate for their individual cow herd, mature cow size, and acceptable level of calving difficulty. This analysis does not explicitly account for negative impacts on the rest of the biological system, which can occur because of increased WW or YW. Costs incurred because of dystocia, rebreeding performance, or maternal maintenance attributable to increased calf BW will need to be implicitly taken into account.

In the crossbred analysis, across-breed adjustment (**ABA**) factors reported by Van Vleck and Cundiff (2003) were used to adjust each sire's EPD values to an Angus basis. Then, NPV were calculated for each sire in the across-breed analysis using these adjusted EPD. The NPV estimates also assume that average EPD of the cow herd are equal to a zero Angus base, which allows economic evaluations and comparisons between bulls of different breeds to be made. The ABA factors account for the effects of F_1 heterosis (hybrid vigor) displayed by crossbred calves and allow economic gains from heterosis to be included in the NPV evaluation. If heterosis is not 100% of F_1, some adjustment of the ABA factors may be needed.

Results of the NPV rankings reported within breeds used only breed-specific EPD with the average EPD of the cow herd equal to a zero base for the respective breed. The NPV analysis evaluated the changes in bull rankings caused by different management goals at typical conception rates, cattle prices, cost of gain, and real interest rate.

First-service conception rates for AI services can vary from 50 to 70% (Werth et al., 1996; Fike et al., 1997; Purvis and Wittier, 1997; Thundathil et al., 1999). A 62% conception rate was used in the NPV calculations. The analysis assumed that cows were serviced a maximum of two times by AI; all cows were serviced once by AI. Cows that were open after the first service were serviced a second time by AI. Cows still open after the second AI service were bred via natural service. Therefore, genetic gain from AI bulls was a function of conception rate, as not all cows conceived after two AI services.

Average prices were used to measure the returns and costs associated with small BW changes. Calf price was \$1.81/kg, yearling price was \$1.59/kg, and cull cow price was \$0.82/kg, the simple average of respective prices in Washington state for 1993 to 2001 (Washington Agriculture Statistics Service, 2002). An average cost of gain for calves of \$0.44/kg was based on an animal unit month (**AUM**) grazing fee of \$12.00/AUM. This was the average of 2001 AUM fees from 17 Western states for grazing on privately owned land (USDA, 2002). Calves were assumed to gain an average of 0.91 kg/d from birth to weaning. The cost of gain from weaning to yearling of \$0.77/kg was the simple average annual cost of gain for backgrounding steers and heifers from 1993 to 2001 as reported by Cattle-Fax (2001). Because there was little change in the producer price index (**PPI**) over this period, prices were not adjusted for inflation. The PPI for meat animals equaled 100 in both 1993 and 2001. For feed, the PPI equaled 102 in 1993 and 108 in 2001 (USDA, 2002). The period used was considered adequate to capture the full range of a typical beef cattle price cycle.

A real interest rate of 3% (approximately the historical average difference between the nominal interest rate and the inflation rate) was used to discount the future value of genetic gain. Using the real interest rate rather than the nominal rate eliminates the need to adjust future input prices (feed and pasture) by the inflation rate in order to not over-discount the future value of genetic gain.

Depending on producer management and culling criteria, cow replacement rates can vary from 8 to 26% of the herd/yr (Clarke et al., 1982). A cow replacement rate of 20%/yr and a 12-mo calving interval were used in calculating NPV values for planning horizons beyond one generation. Cull cows were sold immediately after weaning. The YW EPD were used as a proxy for the EPD of cull cow BW. Cow mortality was assumed to be 1%/yr, calf mortality (including calves born dead) was 5.5%/yr

(APHIS, 1998), and mortality from weaning to yearling was 1%/yr.

Data used included EPD and accuracies of WW, YW, and milk as well as published semen prices for available US Spring 2003 beef sires. All sires for seven breeds listed by four Studs – ABS Global (ABS), Accelerated Genetics (ACG), All West Select Sires (ALSS), and Genex Cooperative (GEN) – were used (ABS 2003a, b, ACG 2003a, b, ALSS 2003a, b, GEN 2003a, b). Breeds were selected based on the number of available bulls and included Angus, Red Angus, Simmental, Charolais, Hereford, Gelbvieh, and Limousin.

In comparing proven and young sires, it is important to account for the risk associated with the possible future change that could occur in the EPD of sires with low EPD accuracies. Accuracy values reported for each EPD were used to calculate within-breed standard deviations and 67% confidence intervals of EPD estimates for each bull. Formulas that converted accuracy to 1 SD (in kg) were estimated by multiple regression analysis of "Accuracy to Possible Change" tables provided by the breed association of each breed (AAA, 2002; AGA, 2002; AHA, 2002; American Simmental Association, 2002; NACCE, 2002; NALF, 2002; and RAAA, 2002). Possible changes (1 SD) were reported for accuracies from 0 to 1. The dependent variable was standard deviation, and the independent variable was accuracy.

In each analysis, the lesser limit of the 67% confidence interval of the EPD (EPD – 1 SD) was used to calculate a risk-avoiding estimate of the NPV for each bull. The calculation of SD of EPD estimates in the crossbred analysis also used SD of adjusted breed differences, as reported by Van Vleck and Cundiff (2003), which were added to within-breed SD of EPD estimates, as specified by Van Vleck and Cundiff (1995). This was necessary to account for variance associated with the ABA factors. Comparing bulls ranked by the lesser limit of the NPV confidence interval (NPV – 1 SD) with those ranked by expected NPV reveals the effects of lesser accuracy on sire selections for risk-avoiding producers.

The NPV formula for a three-generation planning horizon for a producer who sells calves at weaning (ranking scenario 3) was

$$NPV3\$ = -S\$ + (1 - Rr) * CF1\$ + Rr * [CC1\$ + (1 - Rr) * CF2\$ + Rr * (CC2\$ + CF3\$)]$$

where

NPV3$ = net present value, in dollars, of direct genetic improvement to generation one and, indirectly (via daughters and granddaughters used as replacement heifers), to generations two and three;

S$ = semen cost;

Rr = portion of cow herd replaced per year = 0.20;

CF1$ = present value (PV) of genetic improvement in calves weaned and sold from first generation;

CC1$ = PV of genetic improvement in first-generation calves kept as replacements and sold as cull cows;

CF2$ = PV of genetic improvement in calves weaned and sold from second generation;

CC2$ = PV of genetic improvement in second-generation calves kept as replacements and sold as cull cows; and

CF3$ = PV of genetic improvement in calves weaned and sold from third generation.

The details of the NPV formulas are developed in the Appendix.

Results and Discussion

Sample averages, top-20 sire averages, ranges of across-breed EPD (adjusted to an Angus base), NPV for a three-generation planning horizon (**NPV3$**), and semen prices for the 552 bulls evaluated for NPV are presented in Table 1. This table also provides averages and ranges of within-breed EPD, NPV3$s, and semen prices for each of five breeds for purebred production. In the purebred analyses, there were 264 Angus bulls, 84 Red Angus bulls, 81 Simmental bulls, 42 Charolais bulls, and 37 Hereford bulls. The bulls in the crossbred analysis included each of these bulls plus 24 Gelbvieh bulls and 20 Limousin bulls. Because of the large number of bulls examined, only a portion of the results are presented in the tables.

The 20 most profitable sires as ranked by NPV3$ for crossbreeding to Angus dams are given in Table 2. The sample averages and top-20 sire averages of NPV for a one-generation planning horizon with calves sold at weaning (**WW$**) and as yearlings (**YW$**), EPD, and semen prices for both crossbred and purebred production are presented in Table 3. Additional comparisons are provided in the narrative. Complete details of all analyses are available by accessing the AI Beef Sire Economic Analyzer linked spreadsheets in Baker et al. (2003).

Crossbred Analysis. Estimating NPV to three generations is most appropriate for producers with a relatively long planning horizon who expect to realize benefits of genetic improvement by retaining replacement heifers from their own herd. By comparing the top two rows of Table 1, it can be seen that the average NPV3$ for the 20 most profitable sires was $19 (or seven times) greater than the average of all bulls in the sample. This difference in NPV3$ would total more than $9500/yr for a producer with a herd of 500 cows.

Average EPD of the 20 most profitable bulls were 11.1 kg greater for WW, 1.3 kg greater for milk, and 2.8 kg greater for BBW than for all bulls (Table 1). However, average semen price for the top-20 bulls was $4 less per unit than the average of all bulls,

TABLE 1. Averages and ranges of net present values (NPV) to three generations[a].

Bulls, no.	Breed		NPV		WW		Milk		BBW		Semen price
			NPV3$	LCI	EPD	ACC	EPD	ACC	EPD	ACC	
552	Across breeds	Sample avg.	3.23	–2.03	20.1	0.68	7.6	0.54	1.9	0.72	17.95
		Top 20 avg.	22.51	13.13	31.2	0.55	8.9	0.38	4.7	0.61	13.95
		High	31.14	20.90	43.6	0.99	19.1	0.99	7.3	0.99	100.00
		Low	–112.24	–112.47	7.1	0.00	–5.8	0.00	–1.7	0.00	8.00
264	Angus	Sample avg.	3.07	0.99	19.0	0.80	9.9	0.67	0.9	0.81	18.06
		Top 20 avg.	13.97	11.74	21.6	0.78	11.0	0.65	1.2	0.79	12.85
		High	20.81	18.84	33.6	0.99	17.7	0.99	3.0	0.99	100.00
		Low	–112.24	–112.47	8.6	0.05	2.3	0.05	1.6	0.05	8.00
84	Red Angus	Sample avg.	0.08	–3.52	15.2	0.62	8.4	0.47	0.2	0.70	16.39
		Top 20 avg.	7.90	3.27	18.4	0.50	8.6	0.36	0.9	0.59	12.85
		High	14.41	9.56	23.1	0.96	14.5	0.95	3.5	0.97	30.00
		Low	–22.56	–23.26	8.2	0.22	–0.9	0.12	3.3	0.24	8.00
81	Simmental	Sample avg.	–4.60	–8.98	17.0	0.66	3.1	0.51	0.6	0.70	19.14
		Top 20 avg.	5.98	0.46	20.6	0.57	3.7	0.42	1.2	0.60	14.80
		High	12.01	7.69	29.0	0.97	13.9	0.97	2.6	0.98	40.00
		Low	–36.65	–39.08	5.4	0.20	–2.0	0.13	–1.3	0.20	12.00
42	Charolais	Sample avg.	–9.68	–15.48	10.2	0.69	6.4	0.46	0.2	0.76	18.29
		Top 20 avg.	–2.89	–9.67	12.1	0.63	7.2	0.39	0.5	0.71	15.75
		High	8.64	1.19	25.0	0.95	18.2	0.91	2.5	0.96	30.00
		Low	–23.54	–31.20	–4.9	0.00	0.1	0.00	2.3	0.00	10.00
37	Hereford	Sample avg.	2.87	–1.65	17.9	0.51	8.7	0.35	0.7	0.59	16.78
		Top 20 avg.	7.79	2.97	19.9	0.47	8.9	0.33	0.8	0.54	15.00
		High	15.24	10.14	36.3	0.91	13.2	0.90	3.4	0.93	25.00
		Low	–13.18	–16.46	8.2	0.20	2.7	0.08	1.3	0.21	8.00

[a]Net present values were computed for 62% conception rate, 20% replacement rate, 12-mo calving interval, and 3% real interest rate. Column codes and units: NPV3$ = NPV to three generations ($), LCI = lower limit of 67% confidence interval of NPV3$ ($), EPD = expected progeny difference (kg), ACC = accuracy of EPD, WW = weaning BW, and BBW = birth BW. Semen price is given in $/unit.

which means that producers can benefit from substantial genetic and economic improvement with below-average semen costs by selecting a cross section of the top 20 bulls. The most profitable sires provided sizeable genetic improvement at moderate cost. Semen prices of the 20 most profitable NPV3$ sires ranged from $10 to $20 per unit.

Of the seven breeds in the crossbred analysis, three appeared in the most profitable 20 as ranked by NPV3$ (Table 2): 10 Simmental bulls, 9 Charolais bulls, and 1 Angus bull.

Average NPV3$ for the 20 sires with the greatest WW was $5 less than the average of the 20 most profitable sires as ranked by NPV3$. Had sires been selected to maximize WW rather than NPV3$, a producer with 500 cows could have expected to earn $2500 less/yr and could have risked losing as much as $11,500, depending on the specific sires selected.

Average accuracies of WW and milk for the 20 most profitable bulls by NPV3$ were 0.13 and 0.24 less, respectively, than the average of all bulls in the analysis (Table 1). The risk-avoiding producer may want to use rankings by the lesser limit of the 67% confidence interval (**LCI**) of NPV in choosing sires when considering both high and low accuracy bulls. Although this selection criteria will reduce expected NPV, it will also reduce risk. In all analyses, the reported NPV is the expected (or average) value for the sire, which means the producer has a 50% probability of achieving at least that economic return. Bulls selected based on LCI provide the producer an 83.3% (0.5 × 66.67% + 50% = 83.3%) probability of achieving at least the economic return of the LCI. Although accuracies for the top-20 NPV3$ bulls were less than for the average of all bulls, the LCI of the top 20 was $15 greater than for the average bull. Thus, even a risk-avoiding producer could be well served by selecting bulls that maximize NPV3$.

Even a crossbred producer with a very short (one generation) planning horizon could benefit substantially by selecting bulls based on NPV (Table 3). Average WW$ of the 20 most profitable sires as ranked by WW$ was $18 greater than the average WW$ of all sires. This difference would total nearly $9000/yr for a producer with a one-generation planning horizon and a herd of 500 cows. The average YW$ of the 20 most profit-

TABLE 2. Twenty most profitable bulls for crossbred service to Angus cows[a].

Stud[b]	Breed	Name	NPV		WW		Milk		BBW		Semen price
			NPV3$	LCI	EPD	ACC	EPD	ACC	EPD	ACC	
ACG	Charolais	Duke	$31.14	$20.90	43.6	0.68	8.1	0.15	7.3	0.76	$18.00
ACG	Simmental	Rab Big Time G2158	$25.80	$14.83	34.7	0.34	10.1	0.25	4.1	0.34	$15.00
ALSS	Simmental	Orlando	$24.66	$18.42	34.7	0.76	7.9	0.62	3.8	0.81	$15.00
ALSS	Charolais	Benefit	$24.15	$14.09	30.5	0.65	8.4	0.25	4.8	0.78	$12.00
ALSS	Charolais	Perfect Mark	$22.99	$18.09	28.1	0.89	6.5	0.80	5.1	0.92	$10.00
ACG	Charolais	King	$22.65	$12.06	28.1	0.62	10.8	0.21	6.6	0.70	$12.00
ALSS	Charolais	Choice Plus	$22.50	$15.80	36.7	0.82	12.3	0.57	5.4	0.89	$20.00
ACG	Simmental	Ddc Backdraft H852	$22.34	$12.42	34.2	0.47	4.9	0.28	4.0	0.47	$15.00
GEN	Simmental	Right Time	$22.09	$17.81	33.4	0.92	5.9	0.89	4.6	0.93	$15.00
ALSS	Simmental	Mighty Mike Ysp-II	$21.99	$10.05	28.6	0.23	8.6	0.21	4.2	0.24	$12.00
ACG	Simmental	Bf K065 Talladega	$21.91	$10.73	32.5	0.32	7.7	0.23	4.7	0.32	$15.00
ABS	Simmental	Future Moderator	$21.48	$16.22	27.5	0.84	10.0	0.80	4.0	0.86	$12.00
ALSS	Simmental	Autobahn	$21.39	$13.07	27.9	0.66	9.0	0.32	3.7	0.75	$12.00
ALSS	Charolais	Kojack	$21.38	$7.63	31.3	0.28	9.3	0.19	3.3	0.41	$15.00
GEN	Charolais	Sir Pride	$21.16	$3.51	34.5	0.00	9.6	0.00	6.4	0.00	$18.00
GEN	Angus	Trendsetter	$20.81	$18.72	30.8	0.82	9.1	0.65	1.8	0.85	$15.00
ALSS	Simmental	Red Answer Ysp-II	$20.68	$9.37	28.4	0.32	6.7	0.23	4.4	0.35	$12.00
ALSS	Charolais	King	$20.50	$12.50	22.4	0.73	19.1	0.52	4.9	0.81	$12.00
ALSS	Charolais	Victory	$20.47	$7.06	27.9	0.36	7.3	0.15	6.2	0.59	$12.00
ACG	Simmental	Rab Red Man G2134	$20.20	$9.21	27.6	0.34	7.5	0.25	4.6	0.34	$12.00
		Average of top 20 sires	$22.51	$13.13	31.2	0.55	8.9	0.38	4.7	0.61	$13.95
		Average of 552 sires	$3.23	–$2.03	20.1	0.68	7.6	0.54	1.9	0.72	$17.95

[a]Net present values (NPV) were computed for 62% conception rate, 20% replacement rate, 12-mo calving interval, and 3% real interest rate. Column codes and units: NPV3$ = NPV to three generations ($), LCI = lesser limit of 67% confidence interval of NPV3$ ($), EPD = expected progeny difference (kg), ACC = accuracy of EPD, WW = weaning BW, and BBW = birth BW. Semen price is given in $/unit.

[b]Stud abbreviations: ABS = ABS Global Inc. (DeForest, WI), ACG = Accelerated Genetics (Baraboo, WI), ALSS = All West Select Sires (Plain City, OH), and GEN = Genex Cooperative (Shawano, WI).

able sires ranked by YW$ was $19 greater than the average of YW$ for all sires. This difference would total more than $9500/yr for a producer with 500 cows.

The length of the planning horizon had little impact on sire rankings: 18 (90%) of the most profitable sires by WW$ appeared among the most profitable sires for NPV3$. Differences were greater between profit-maximizing and risk-avoiding producers: 13 (65%) of the top 20 NPV3$ sires remained in the top 20 after ranking by the LCI of NPV3$, and 12 (60%) of the top 20 WW$ sires remained in the top 20 when ranked by the LCI of WW$. Differences were greatest between profit-maximizing and genetic-maximizing producers: only eight (40%) of the top 20 NPV3$ sires remained in the top 20 when ranked by WW EPD, and only seven (35%) of the top 20 YW$ sires remained in the top 20 when ranked by YW EPD. Differences were comparable for producers who were unclear about length of ownership: only eight (40%) of the top 20 WW$ sires remained in the top 20 when ranked by YW$.

Purebred Analysis. Economic ranking information for purebred producers of five breeds (Angus, Red Angus, Simmental, Charolais, and Hereford) is also reported in Tables 1 and 3. Sample and top-20 sire averages and ranges for NPV3$, EPD, accuracies, and semen prices are reported in Table 1. Information relevant to WW$ and YW$ ranking is included in Table 3.

The top-20 bulls represented 8% of the available Angus AI sires and 54% of Hereford AI sires (Table 1). The top-20 bulls ranked by NPV3$ averaged $5 (Hereford) to $11 (Angus and Simmental) greater NPV3$ than the average of all sample AI sires for their respective breeds. For a 500-cow herd, these differences ranged from $2500 to $5500/yr.

The top 20 bulls ranked by NPV3$ averaged 1.9 (Charolais) to 3.6 (Simmental) kg greater WW EPD, 0.2 (Red Angus) to 1.1 (Angus) kg greater milk EPD, and 0.1 (Hereford) to 1.1 (Red Angus) kg greater BBW EPD than the average of all sample sires for the breed (Table 1). In addition, average semen cost for the top 20 bulls was consistently less than the average for all sample bulls of each breed. The re-

TABLE 3. Averages of net present values (NPV) to one generation for calves sold at weaning (WW$) and calves sold as yearlings (YW$)[a].

		NPV		WW			NPV		YW		
Item		WW$	LCI	EPD	ACC	Semen price	YW$	LCI	EPD	ACC	Semen price
Across breed	Sample avg.	–2.40	–5.42	20.1	0.68	17.95	11.42	6.25	34.3	0.62	17.95
	Top 20 avg.	15.30	9.52	30.4	0.50	13.40	30.57	24.82	49.1	0.62	15.40
Angus	Sample avg.	–3.81	–5.00	19.0	0.80	18.06	14.77	12.64	36.8	0.74	18.06
	Top 20 avg.	7.35	6.11	22.0	0.79	12.40	27.85	25.13	43.9	0.67	14.05
Red Angus	Sample avg.	–5.65	–7.92	15.2	0.62	16.39	7.07	4.25	27.8	0.59	16.39
	Top 20 avg.	1.98	–0.95	18.5	0.52	13.50	16.31	12.93	34.0	0.50	14.35
Simmental	Sample avg.	–7.52	–10.28	17.0	0.66	19.14	5.05	0.64	29.7	0.64	19.14
	Top 20 avg.	2.68	–0.79	20.6	0.58	14.65	17.99	12.74	37.8	0.57	16.10
Charolais	Sample avg.	–13.90	–16.80	10.2	0.69	18.29	–7.35	–14.06	17.1	0.54	18.29
	Top 20 avg.	–7.74	–13.90	12.8	0.63	15.75	–0.13	–7.63	21.8	0.48	16.65
Hereford	Sample avg.	–3.21	–5.91	17.9	0.51	16.78	8.98	2.81	30.5	0.47	16.78
	Top 20 avg.	1.55	–1.32	19.6	0.48	14.70	15.05	8.28	34.5	0.41	15.40

[a]Net present values were computed for 62% conception rate, 20% replacement rate, 12-mo calving interval, and 3% real interest rate. Column codes and units: NPV3$ = NPV to three generations ($), LCI = lower limit of 67% confidence interval of NPV3$ ($), EPD = expected progeny difference (kg), ACC = accuracy of EPD, WW = weaning BW, and BBW = birth BW. Semen price is given in $/unit.

duction in average semen cost ranged from $2 (Hereford) to $5 (Angus) per unit of semen.

Average semen prices of the most profitable group of bulls (NPV3$) were similar for all breeds (Table 1). They averaged $13 (Angus and Red Angus) to $16 (Charolais) per unit. The range of semen prices for the most profitable bulls (NPV3$) were $6 to $20 per unit, which included the least price available but excluded many of the greatest prices.

Average accuracies of WW, milk, and BBW for the top 20 bulls ranked by NPV3$ were less than the average of all sample bulls for their respective breed (Table 1). Average accuracies for the top 20 bulls ranked by NPV3$ ranged from 0.02 (Angus) to 0.12 (Red Angus) less for WW, from 0.02 (Angus and Hereford) to 0.11 (Red Angus) less for milk, and from 0.02 (Angus) to 0.11 (Red Angus) less for BBW than the average of all sample bulls for their respective breed.

The top 20 bulls ranked by WW$ (Table 3) averaged $5 (Hereford) to $11 (Angus) greater WW$ than the average of all sample sires for their respective breed. The top 20 bulls ranked by YW$ averaged $6 (Hereford) to $13 (Angus and Simmental) greater YW$ than the average of all sample sires for their respective breed, and averaged $8 (Hereford) to $30 (Angus) greater NPV than the top 20 bulls with WW$.

Comparing Tables 1 and 3 reveals the additional value from genetic improvement that accrues from the longer three-generation planning horizon in which a portion of AI-sired calves are used as herd replacements. The increase in NPV (top 20 sires by NPV3$ *vs* top 20 sires by WW$) from the longer planning horizon ranged from $3 (Simmental) to $7 (Angus and across breed).

Implications

The most profitable sires in all rankings offered substantial genetic improvement at moderate cost. In fact, producers can consistently purchase profit-maximizing genetic improvement at less than the cost of average genetic improvement. By selecting among the top 20 sires to maximize NPV over three generations, a crossbred producer with 500 cows could realize an increase of >$9500/yr in discounted annual net income and would consider as few as seven bulls that ranked in the top 20 by expected progeny differences. Important changes in rankings were seen for different management goals (sale of calves *vs* yearlings) and risk tolerance (expected NPV *vs* LCI of NPV). Considering a shorter planning horizon, however, had little influence on rankings.

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Appendix

The net present value formula for a one-generation planning horizon for a producer who sells calves at weaning (management goal one) was

$$WW1\$ = -S\$ + Cw \times [WW \times (Pc - Cgw)] \times (1 + i)^{-tw}$$

where

WW1$ = net present value of semen (genetic improvement to first generation sold at weaning) in dollars,
S$ = semen cost = Su × Ps,
Su = average number of units of semen per cow = 1 + (1 – Cr),
Cr = conception rate first service = 0.62,
Ps = price of semen ($/unit),
Cw = portion of calf crop weaned = Acr2 (1 – Mr – Dc),
Acr2 = actual conception rate from two AI breedings = Cr + [(1 – Cr) × Cr],
Mr = cow mortality rate = 0.01,
Dc = calf death loss, calving to weaning (includes calves born dead) = 0.055,
WW = weaning weight EPD (kg live BW),
Pc = market price of calves ($/kg live BW) = $1.82/kg,
Cgw = cost of gain to weaning ($/kg live BW gain) = $12/AUM/(30.5 × 0.91 kg gain/d) = $0.44/kg,
AUM = animal unit month,
i = real interest rate = 0.03, and
tw = time in years from first breeding of dam to sale of calf = 1.33 = time from breeding to calving (0.77, which is the weighted average from two AI breedings 21 d apart) + time to weaning (0.56, which is 205 d).

The net present value formula for a one-generation planning horizon for a producer who sells calves as yearlings (management goal two) was

$$YW1\$ = -S\$ + Cy \times [(YW \times (Py - Cg)] \times (1 + i)^{-ty}$$

where

YW1$ = net present value of semen (genetic improvement to first generation sold as yearlings) in dollars,
Cy = portion of calf crop sold as yearlings = Cw × (1 – Dy),

Dy = yearling death loss (weaning to sale) = 0.01,
YW = yearling weight EPD (kg live BW),
Py = market price of yearlings (\$/kg live BW) = \$1.59/kg,
Cg = yearling cost of gain (\$/kg live BW) = [WW × Cgw + (YW – WW) × Cgy]/YW,
Cgy = cost of gain from weaning to yearling = \$0.77/kg, and
ty = time in years from first breeding of dam to sale of yearling calf = tw + 0.44 yr (160 d) = 1.77 yr.

The NPV formula for a three-generation planning horizon for a producer who sells calves at weaning (management goal three) was given in the text. According to such,

$$CF1\$ = Cw \times [WW \times (Pc - Cgw)] \times (1 + i)^{-tw},$$

$$CC1\$ = Cw \times Cc \times [YW \times (Cp - Cg)] \times (1 + i)^{-v},$$

$$CF2\$ = \sum_{n=1}^{C} [1 - (n - 1) \times Rr] \times Cwr \times [0.5 \times WW \times (Pc - Cgw) + milk \times (Pc - Cmg)] \times (1 + i)^{-yn},$$

$$CC2\$ = \sum_{n=1}^{C} [1 - (n - 1) \times Rr] \times Cwr \times Cc \times [0.5 \times YW \times (Cp - Cg)] \times (1 + i)^{-vn},$$

$$CF3\$ = \sum_{m=1}^{C} \sum_{n=1}^{C} [1 - (n - 1) \times Rr] \times Cwr \times [0.5^2 \times WW \times (Pc - Cgw) + 0.5 \times milk \times (Pc - Cmg)] \times (1 + i)^{-ym},$$

where

Cwr = portion of calf crop weaned from replacements = Acr3 × (1 – Mr – Dc),
Acr3 = actual calving rate from three breedings by a zero-base bull = Cr + [(1 – Cr) × Cr] + [$(1 - Cr)^2$ × Cr],
Cc = portion of weaned calves held as replacements that were later culled = 0.96,
YW = EPD of yearling BW is used as proxy for the expected difference in mature size of cull cows,
Cp = market price of cull cows (\$/kg live BW),
v = average time in years from first breeding of dam to culling of daughter = u + tw + w,
u = time in years from first breeding of dam to first breeding of daughter = 2.0 yr,
w = average time in years from weaning daughter's first calf to culling daughter = (0.5/Rr – 0.5) × CI = 2.0 yr for a 0.20 replacement rate and a 12-mo calving interval,
CI = calving interval in yr (1.0 yr),
vn = average time in years from first breeding of dam to culling of granddaughter = 2 × u + tw + w + (n – 1) × CI,
n = birth order number of calf produced by replacement daughter or granddaughter,
C = average number of calves produced by a daughter in her lifetime = 3 for a 0.20 replacement rate,
Milk = milk EPD,
Cmg = cost of gain in calves from increased milk production by dam = \$0.40/kg,
yn = time in years from breeding of dam to sale of daughter's calf = u + tw + (n – 1) × CI, and
ym = time in years from breeding of dam to sale of granddaughter's calf = 2 × u + tw + [(m – 1) + (n – 1)] × CI, and
m = birth order number of calf produced by replacement granddaughter.