Economics of improved dairy reproduction considering conventional, sexed and beef semen

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Introduction

Dairy cattle reproduction efficiency is important for profitability of dairy farms. Average 21-day cow pregnancy rate as measured by DHIA in 2016 was about 19% (De Vries, 2016) and is increasing. Phenotypic daughter pregnancy rates, as calculated by the CDCB (2022) from days open data, has increased since 2000 by at least 5 percentage points. Cow pregnancy rates greater than 30% are becoming more common. Breeding values for daughter pregnancy rate have increased less since 2000. Most of the improvement in reproduction efficiency in the last two decades is due to management.

We know from older studies that there is a diminishing value to greater reproduction efficiency. Although a 100% pregnancy rate is still the goal, this means that less could spent to continue to increase reproduction efficiency. For example, figure 1 shows how greater pregnancy rates are associated with increased profit per cow per year for six studies conducted a decade ago (Overton and Cabrera, 2017). In figure 1, net return gain is set at $0 at 10% pregnancy rates for all studies. The increases in profit in figure 1 are a mixture of net gains that include the cost of the technology to achieve that change in pregnancy rate, and gross gains that do not include the cost to obtain the change in pregnancy rate. In all six studies, a greater pregnancy rate leads to a greater profit. Even in the two studies that report pregnancy rates over 30%, profit keeps increasing. The studies in figure 1 were all conducted assuming conventional semen. Calves were sold for a fixed price, and cow cull rates were independent of the number of calves produced. Genetics were not considered in these studies.

In the last decade we have seen a dramatic uptake of reproduction options like genomic testing, sexed semen, and beef-on-dairy (Fourdraine, 2022). The question is how the value of improving reproduction efficiency depends on these expanded options. One hypothesis is that dairy reproduction efficiency is worth more when using combinations of these options, compared to the traditional use of conventional semen only, because genetic merit of the herd can be higher and more valuable calves can be sold. The objective of this paper is therefore to explore how the value of improving reproduction efficiency depends on the combinations of sexed, conventional, and beef semen, with and without the use of genomic testing.

Herd budget calculator

Like the studies in figure 1, I used logic and detailed calculations to obtain results. A herd budget calculator spreadsheet was developed with the goal to evaluate the genetic and economic consequences of changes in prices, reproduction, and strategic mating. The calculator has virtual heifers and cows and many biological inputs such as milk production curves, feed intake, forced culling, and many prices. Herd profit is expressed per milking cow per year because profit should be expressed per most limiting factor, which is milking capacity on many farms.

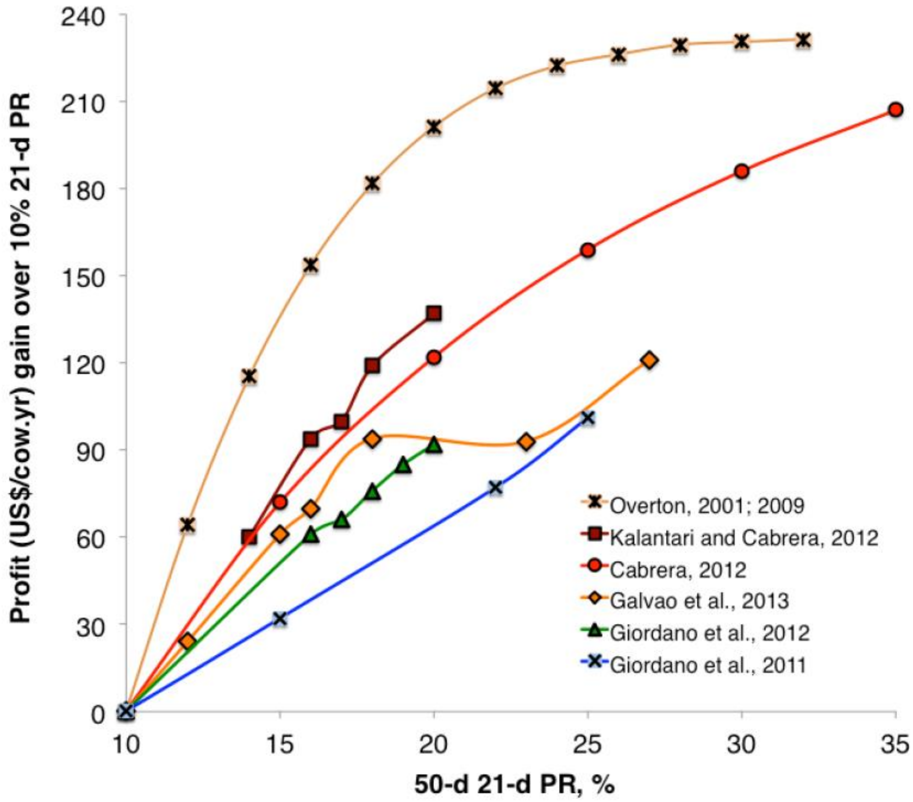

Figure 1. Profit gain of increasing 21-d pregnancy rate (PR) at a 50-day voluntary waiting period reported in six older studies that were conducted around a decade ago. Profit per cow per year was standardized at $0 at 10% PR. The costs to obtain the increased pregnancy rates were included within some studies but not in others. Source: Overton and Cabrera (2017) (with permission). Published also in De Vries (2016). All studies assumed that only conventional semen was used. Genetics was not considered.

Strategic mating refers to how the different semen types are used within the herd. For example, it is now common to use sexed semen in heifers and beef semen in older cows. Crossbred calves out of a beef-on-dairy mating are generally worth more than surplus purebred dairy calves. Conventional semen may or may not be used. Perhaps genetic merit differences within the same lactation and breeding number are considered and the best animals receive sexed semen while others receive conventional or beef semen. Genomic testing may be used so animals can be better ranked for genetic merit, which may affect culling and mating decisions. Many combinations are possible. A strategic mating plan often depends on the farm's wish to produce a certain number of dairy heifer calves to replace cows in the future. It is usually not clear what strategic mating plan maximizes profitability.

Genetic assumptions

The calculator puts an economic value on the genetic lag of the herd. Genetic lag is the genetic difference between the best available service sires and the average cow in the herd. The idea is that sires contain the best available genetic "package" and cows are on average lagging in genetic merit. Genetic lag is therefore an opportunity cost. It is money not made because the genetics in the herd is older that what is available on the market.

Genetic progress in sires is approximately $75 predicted transmitting ability (PTA) of Lifetime Net Merit Dollars (NM$) per year (CDCB, 2022). The result is that on average the genetic merit in heifers is greater than in younger cows, and even greater compared to older cows. But there is genetic variation within the same age, as figure 2 shows. You can find some good cows with higher genetic merit than some heifers. Genomic testing improves the reliability of estimates of genetic merit, which means more certainty about their true genetic merit.

The value of improving reproduction efficiency depends on the genetic merit of the service sires and potential dams in several ways. First, we could create a surplus of dairy heifer calves and keep only the number we need to replace cows, by selling the genetically worst calves. This practice reduces the genetic lag. Secondly, we can use the genetic merit of individual heifers and cows for mating decisions, for example by mating heifers and cows with the highest genetic merit to sexed semen. A simpler strategy is to only look at the age of the animals for mating decisions. Age is a good predictor of genetic merit.

The goal of a genetics program is to reduce the genetic lag, but this goal needs to be balanced with the productive life of the animals in the herd. A high cow cull rate would result in a young herd but a short average productive life. Such a strategy would lead to high cow turn over costs, too few mature cows, and is likely less profitable (De Vries, 2020).

In the calculator, the genetic trend of PTA of NM$ was set at $75 per year. Within the same age, the variation in the PTA of NM$ had a standard deviation of $197 before selection of surplus dairy heifer calves (if any). The PTA of NM$ of sires was set at $1000. The traditional reliability PTA of NM$ in calves was set at 20%. For heifers it was 21%. For cows in lactations 1 to 4+, the traditional reliability increased from 40% to 48%. While traditional reliabilities come for free, genomic testing of calves at an assumed cost of $50 per test increased reliabilities from 71% for calves to 74% for cows in lactations 4+. Thus, the genomic test information could be used to first select surplus dairy calves better and later for mating decisions with beef, conventional, or sexed semen.

Crossbred (beef x dairy) calves were sold for $200. Surplus dairy heifer and bull calves were sold for $50 per head. The value of the kept dairy heifer calves was the result of the genetic merit of the sire and dam and, if any, surplus dairy calf selection. Insemination expenses were $35 for sexed dairy semen, and $15 for beef and conventional dairy semen. In addition, there were costs for feed, and other variable cost for heifer, milking cow, and dry cows. Mature cows produced more milk than first lactation cows.

Heifers were eligible for insemination between 400 and 550 days of age. Cows were eligible for insemination between 70 and 300 days in milk. The number of inseminations of open animals depended on the 21-day service rate and conception rate (Table 1). Annual cow cull rate was set at 37% for the baseline reproductive efficiency level. The cow cull rate decreased when reproductive efficiency increased because fewer animals would be culled for failure to get pregnant on time.

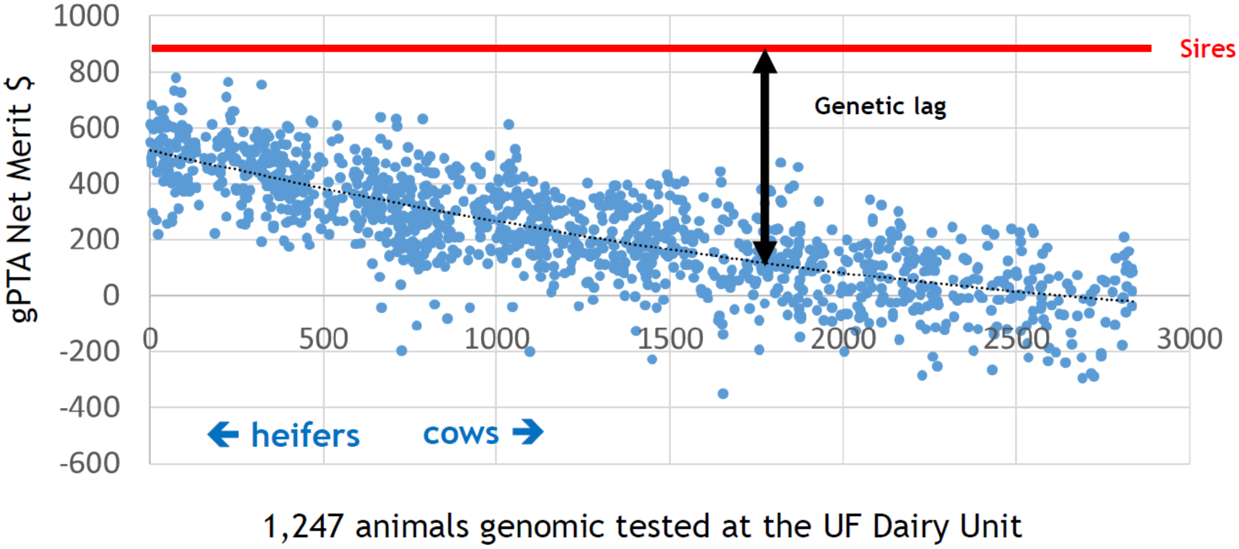

Figure 2. Genomic predicted transmitting ability (PTA) of the economic selection index Net Merit (NM$) for 1247 animals at the University of Florida Dairy Unit. The graph illustrates the trend and variation in PTA of NM$ of animals, and the genetic lag of two animals with the service sires, which are assumed to have a PTA of NM$ of $900. The goal of a genetics program is to reduce the genetic lag balanced with the longevity of the animals in the herd.

Lactations 0 (heifers) to 4 (older cows) each had four distinct breeding numbers with choices of the fraction of the type of semen (beef, conventional, sexed). Greater breeding numbers had choices equal to the 4th breeding number choices. Thus, there were 20 different breeding opportunities (ages) where the fractions of semen types could be varied. For example, the mating decisions for first inseminations in first lactation cows could be 26% beef semen, 43% conventional semen, and 31% sexed semen (total 100%).

The herd budget calculator was used to evaluate profit per milking cow per year at five levels of reproduction efficiency. These five levels are shows in table 1. In increasing order of reproduction efficiency, the levels are referred to as baseline, improved, good, great, and best.

Table 1. Input assumptions of 21-d service rates and conception rates for five levels of reproduction efficiency.

	baseline	improved	good	great	best
Heifers					
21-day service rate	70%	70%	70%	70%	70%
beef semen conception rate	44%	50%	56%	62%	68%
conventional semen conception rate	44%	50%	56%	62%	68%
sexed semen conception rate	40%	46%	51%	57%	62%
Lactation 1					
21-day service rate	60%	60%	60%	60%	60%
beef semen conception rate	36%	41%	46%	51%	56%
conventional semen conception rate	36%	41%	46%	51%	56%
sexed semen conception rate	32%	36%	41%	45%	50%
Lactation 2+					
21-day service rate	60%	60%	60%	60%	60%
beef semen conception rate	32%	36%	41%	45%	50%
conventional semen conception rate	32%	36%	41%	45%	50%
sexed semen conception rate	28%	32%	36%	40%	43%

Conception rates of second and later inseminations are 90%, 80%, 70% of the conception rate in the table for heifers. For cows, later inseminations have 90% of the conception rate in the table. Sexed semen conception rates of ≥4th inseminations are 72% of those in the table.

Mating Strategies

In addition, four mating strategies were evaluated at each of the five levels of reproduction efficiency. Each strategy was evaluated with and without genomic testing.

The **conventional** strategies used only conventional semen on all heifers and cows. Surplus dairy heifer calves were sold. The genetically best dairy heifer calves were kept after ranking based on traditional or genomic reliabilities. Genetic reliabilities were only used to select surplus dairy calves, but obviously not for mating decisions.

The **beef-by-age** strategies used 100% sexed semen on heifers and the youngest cows until enough dairy heifer calves were produced to replace culled cows. The remainder of the cows were inseminated with beef semen. No conventional semen was used. Genetic reliabilities were only used for some mating decisions, but not to select surplus dairy calves because close to no extras were produced.

The **beef-by-PTA** strategies also used only beef and sexed semen. Heifers and cows below a threshold of PTA of NM$ received beef semen whereas animals above the threshold received sexed semen. The threshold was varied such that just enough dairy heifer calves were produced to replace culled cows. Genetic reliabilities were used extensively for mating decisions because a fraction of the dams was below the threshold in all 20 breeding numbers.

The **optimal** strategies were discovered by varying the fractions of beef, conventional and sexed semen for every one of the 20 breeding numbers, and allowed the generation of surplus dairy calves. This optimization was done with a non-linear solver (a mathematical optimization technique). Because a great number of combinations are possible, there was no guarantee that the absolute best mating strategy could be found.

All analyses were done for a herd with 1000 milking cows.

Results

Figure 3 shows results for the (near) optimal mating strategies using genomic testing of calves, to illustrate some of the key statistics of the calculator. The 20 breeding numbers are shown vertically. The left column within one of the five reproduction efficiencies shows the fraction beef semen (Be), the middle column the fraction conventional semen (Co), and the right column shows the fraction sexed semen (Se). A bigger fraction is identified by a thicker line. The three fractions add up to 100%.

The breeding numbers show an increasing fraction of beef semen for older cows. Sexed semen is primarily used in heifers and first lactation cows. There is some use of conventional semen, primarily in breedings 4 and greater in heifers. The strategies generate only the number of dairy heifer calves needed to replace culled cows (surplus 0%). The annual cow cull rate decreased from 37% for the baseline (lowest) reproduction efficiency to 30% for the best reproduction efficiency. Therefore, the number dairy heifer calves kept per year decreased from 558 to 397 per 1000 milking cows per year. The cow pregnancy rate increased from 18% for the baseline scenario to the 30% for the best scenario.

The lower annual cow cull rate increased the average age of the cows in the herd from 3.91 years for the baseline reproduction efficiency to 4.13 for the best reproduction efficiency. This implies that the genetic lag increased because more cows got older. However, the age of the dams of the kept dairy calves decreased from 2.78 years to 2.66 years. The PTA of NM$ of the kept dairy heifer calves increased by $13.

Profit per milking cow increased from $533 for the baseline reproduction efficiency to $811 for the best reproduction efficiency. This gain is mostly due to more mature cows, lower replacement costs, reduced genetic lag, and an increase in the value of sold crossbred calves. Therefore, at 30% cow pregnancy rate (best), the profit per milking cow per year was $278 greater than at 18% cow pregnancy rate (baseline).

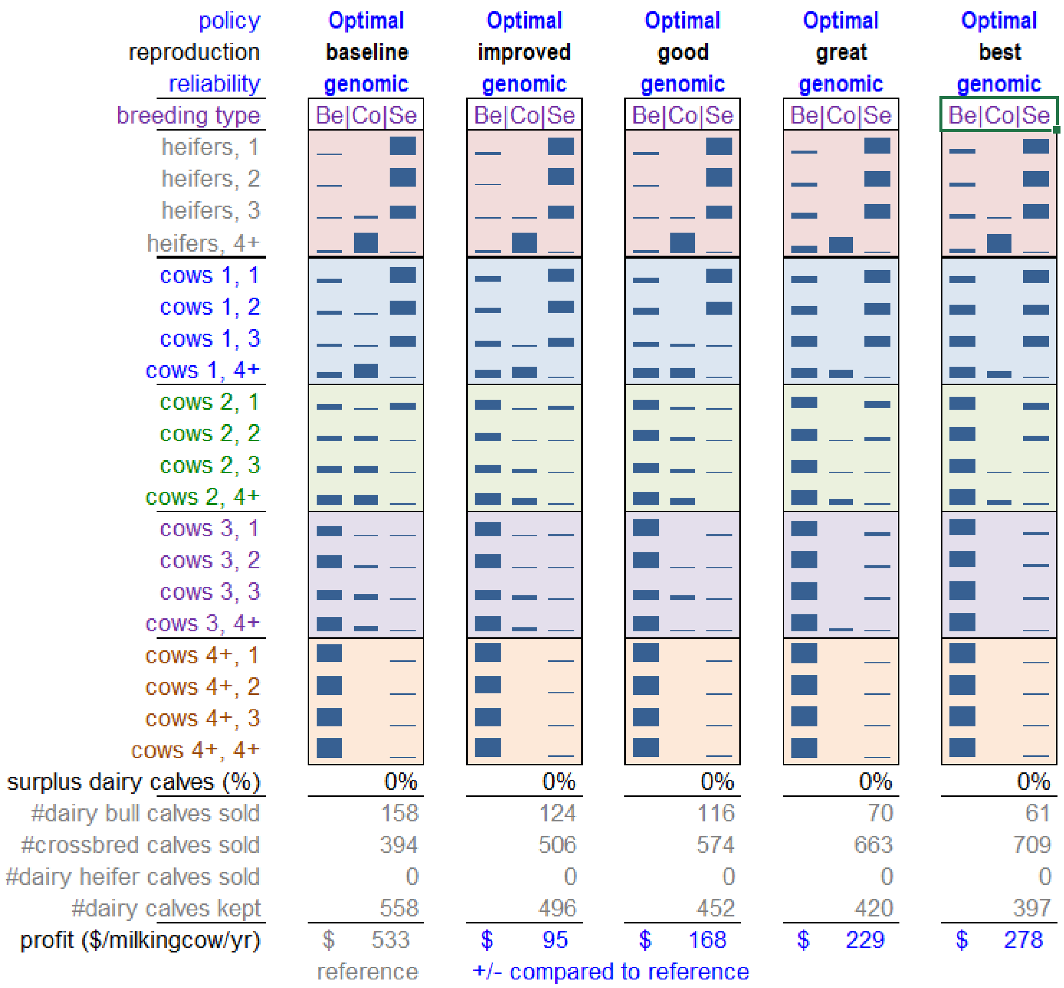

Figure 3. Visual display of the mating strategies for the optimal scenario with genomic testing for the five reproduction efficiencies in a herd of 1000 milking cows. The left column is the fraction beef semen (Be), the middle column is the fraction conventional semen (Co) and the right column is the fraction sexed semen (Se). A thicker line implies a greater fraction. Be + Co + Se = 100%. Profit per milking cow per year increased by $278 in the best reproduction efficiency compared to the baseline reproduction efficiency.

Table 2 shows profit per milking cow per year for all evaluations. The cow pregnancy rates varied slightly among mating strategies. The beef-by-age, beef-by-pta, and optimal strategies all resulted in substantial greater profit compared the use of conventional semen only. The optimal strategy was not really optimal because the profit was slightly less than for the beef-by-age and beef-by-pta strategies. This is due to the solver not being able to find the best strategy.

Both optimal strategies did not generate a surplus of dairy heifer calves. Genomic testing of dairy calves was only used later in their lives for mating decisions. A beef-by-age mating strategy did not benefit from any genomic testing information. Therefore, its profit was lower for the genomic reliabilities compared to the traditional reliabilities for all five reproduction efficiencies. Genomic testing was profitable in the other strategies when reproduction efficiency was great to best, but not at the lower reproduction efficiencies.

Table 2 shows that profitability clearly increased with better reproduction efficiency. Second, the increase was greater for all strategies when genomic testing is used. Third, the increase was the lowest for the conventional semen strategies, both with traditional and genomic reliabilities. The value of improved reproduction efficiency was greater in the strategies where more valuable beef calves were produced. Figure 4 shows increases in profit per milking cow per year for the mating strategies with genomic testing. The beef-by-pta and optimal strategies benefit the most from increases in reproduction efficiency. The finding that improvements in reproduction efficiency is greater when beef-on-dairy is practiced was also reported in Sweden (Clasen et al., 2020) and Wisconsin (Cabrera, 2022).

Table 2. Profit per milking cow per year ($) for the five reproduction efficiencies (baseline to best), four mating strategies, and with or without genomic testing.

	baseline	improved	good	great	best
cow pregnancy rate	18%	21%	24%	28%	31%
mating strategy			traditional reliabilities		
conventional	489	541	583	617	646
beef-by-age	546	634	700	753	795
beef-by-pta	549	638	707	763	808
optimal	547	626	707	764	805
mating strategy			genomic reliabilities		
conventional	471	533	582	621	654
beef-by-age	523	614	683	737	779
beef-by-pta	539	634	707	765	813
optimal	533	628	701	762	811

Conclusions

There is a decreasing economic return on improving reproduction efficiency when reproduction efficiency is already higher. Reproduction options such as sexed semen, beef semen, and genomic testing allow dairy producers to make strategic mating decisions on heifers and cows. Strategic mating opportunities increase the value of improving reproduction efficiency significantly compared to the use of conventional semen only. Mating strategies beef-by-age and beef-by-pta are likely to be near optimal.

References

Cabrera, V. 2022. Economics of using beef semen on dairy herds. JDS Communications 3 (article in press) https://doi.org/10.3168/jdsc.2021-0155

CDCB (Council on Dairy Cattle Breeding). 2022. Genetic and phenotypic trend. Daughter Preg Rate. https://queries.uscdcb.com/eval/summary/trend.cfm Accessed 1/9/2022

Clasen, J. B., M. Kargo, S. Østergaard, W. F. Fikse, L. Rydhmer, and E. Strandberg. 2020. Genetic consequences of terminal crossbreeding, genomic test, sexed semen, and beef semen in dairy herds. Journal of Dairy Science 104:8062–8075. https://doi.org/10.3168/jds.2020-20028

De Vries, A. 2016. What is the optimal pregnancy rate? Is being too efficient a benefit or hindrance? Proceedings Dairy Cattle Reproduction Council, Columbus, OH. Pages 5-13.

De Vries, A. 2020. Symposium Review: Why revisit dairy cattle productive lifespan? J. Dairy Sci. 103: 3838-3845. https://doi.org/10.3168/jds.2019-17361

Fourdraine, R. 2021. Maximize returns from your beef x dairy breeding program in 2022. Progressive Dairy, 12/31/2021. https://www.progressivedairy.com/topics/a-i-breeding/maximize-returns-from-your-beef-x-dairy-breeding-program-in-2022

Overton, M.W. and V.E. Cabrera. 2017. Monitoring and quantifying the value of change in reproductive performance. In: Beebe DK (ed.), Large dairy herd management (3rd edn.), USA. pp. 549-564.

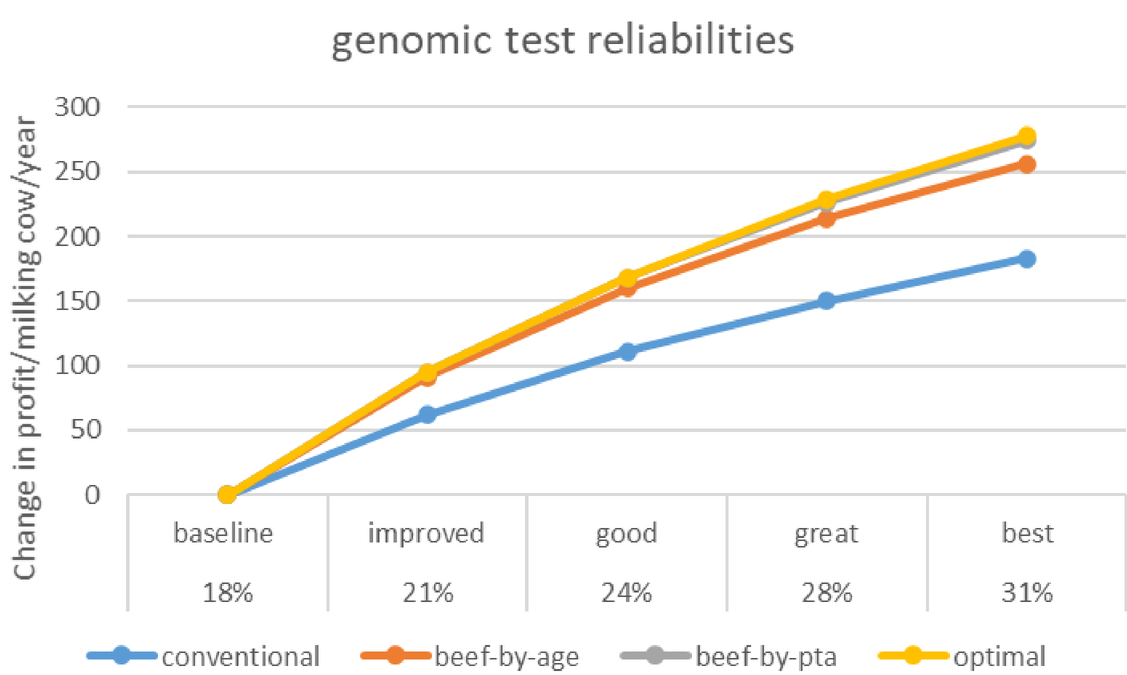

Figure 4. Change in profit per milking cow per year compared to the lowest reproduction efficiency (baseline; 18% cow pregnancy rate) for four mating strategies. The beef-by-age, beef-by-pta, and optimal mating strategies show greater benefit from increased reproduction efficiency than them mating strategy that uses conventional semen only.