

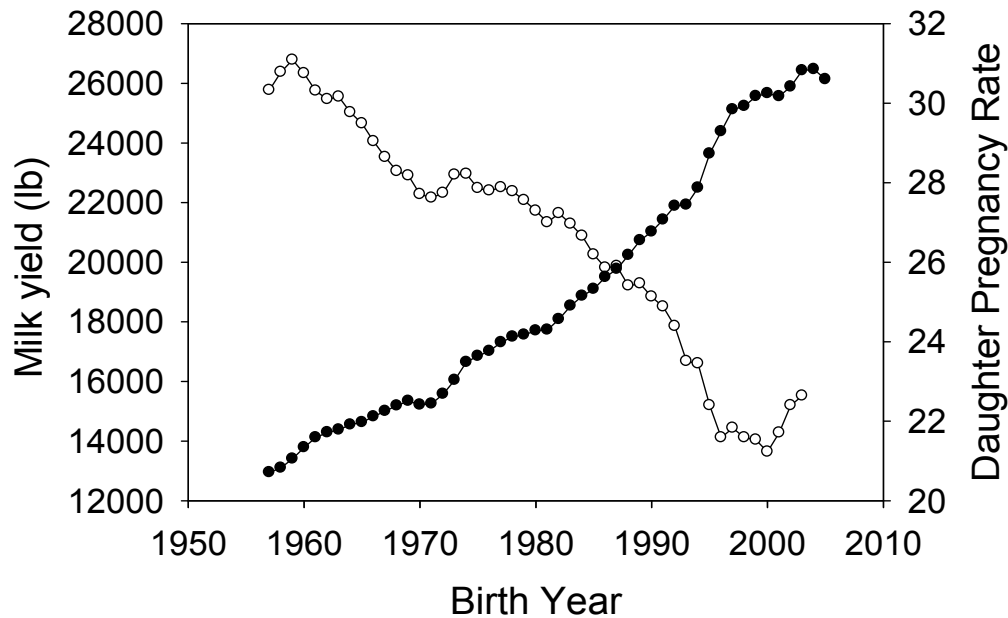
# Improving Dairy Cow Fertility through Genetics

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## Introduction

Dairy cows today produce twice as much milk per lactation as cows did in 1957 (Figure 1). This improvement has come about because of genetic selection for milk yield, improved feeding practices and other changes in management. Unfortunately, reproductive function has declined steadily for most of that period, and has only recently made a slight recovery. The reasons for the decline in fertility are complex and not completely understood. Inbreeding, lack of selection for reproduction, stress of lactation, and changes in cow environment have all been implicated. This paper discusses two effective genetic solutions to the problem of infertility in dairy cattle: crossbreeding and selection for reproductive traits.



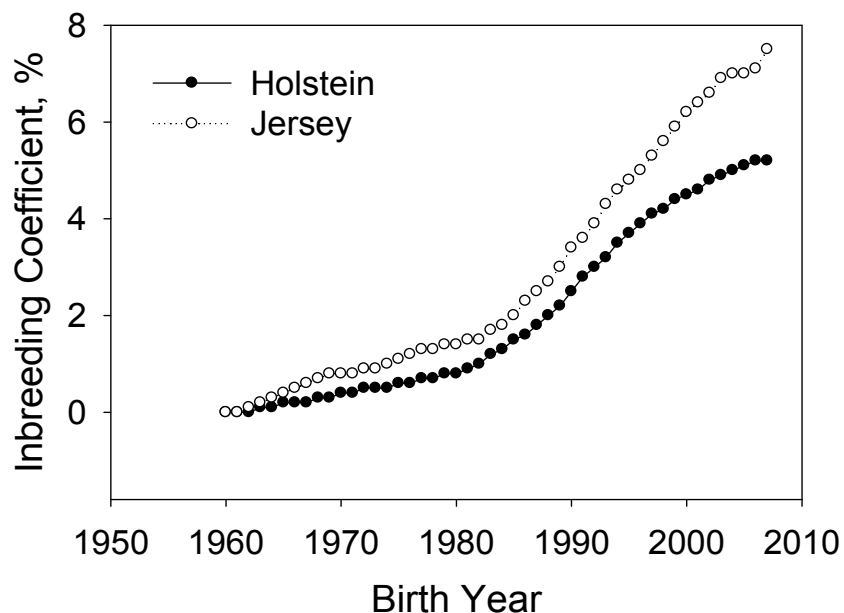
**Figure 1.** Trends in milk yield (●) and Daughter Pregnancy Rate (○) for US Holsteins. Data are from USDA-ARS Animal Improvement Programs Laboratory, February 2007 (available at <http://aipl.arsusda.gov/ARSWeb/eval/summary/trend.cfm>).

## Crossbreeding

Crossbreeding in dairy cattle is generating renewed interest. Concern over inbreeding is a major reason. As shown in Figure 2, the inbreeding coefficient for US Holsteins and Jerseys has increased steadily from 1960 to 2007 (1960 is the 'base' year for U.S. inbreeding calculations; the inbreeding coefficient for animals born that year is assumed to be zero).

Cattle have about 21,000 functional genes on 30 pairs of chromosomes. As pairs, the chromosomes carry paired (2) copies of each gene— one inherited from the father and one from the mother. Inbreeding increases the likelihood that the two inherited copies of a gene are identical. The negative effects of inbreeding are seen when identical undesirable genes are inherited from both parents. An inbreeding coefficient is an estimate of the percentage of these identical genes pairs inherited by an animal. As a rule of thumb, mating selection should keep the inbreeding coefficients of offspring to less than 6.25%. Average inbreeding coefficient for animals born in 2007 was estimated at 5.1% for Holsteins and 7.5% for Jerseys. Thus, many animals in both breeds surpass the 6.25% threshold.

Crossbreeding takes advantage of heterosis (improved performance of offspring over the average performance of parents). Essentially, heterosis results from the opposite of inbreeding depression. Increasing the chances that gene pairs include a different copy from each parent increases the chances that a 'better' version is used by the animal.



**Figure 2.** Trends in inbreeding coefficient for US Holsteins (●) and Jerseys (○). Data are from USDA-ARS Animal Improvement Programs Laboratory, February 2007 (available at <http://aipl.arsusda.gov/ARSWeb/eval/summary/trend.cfm>).

Crossbreeding also provides opportunities to exploit superior fertility and health traits of some dairy breeds. Researchers from the University of Minnesota have been studying the performance of the Holstein crosses of several of these breeds including Normande, Montebeliarde and Scandinavian Red (includes Norwegian Red and Swedish Red breeds). The most recent data are posted by the University of Minnesota at: <http://www.ansci.umn.edu/research/crossbreeding.htm>. This research has shown that crossbreeding can improve fertility and longevity at the expense of a decrease in milk yield.

As can be seen in Table 1, days open during first lactation averaged 19-27 days less for the crossbred groups than for purebred Holsteins. In addition, conception rate at first insemination was significantly higher for Normande x Holstein and Montebeliarde x Holstein than for Holstein. Note, however, that Holsteins had higher milk yields. For first lactation, Holsteins produced 2,706 lb more milk than Normande x Holstein, 1,317 lb more milk than Montebeliarde x Holstein and 1,050 lb more milk than Scandinavian Red x Holstein (Table 1). The difference between breed groups in milk yield increased in second lactation: the 305-day milk yield averaged 26,194 lb for Holstein, 21,863 for Normande x Holstein, 23,547 for Montebeliarde x Holstein and 23,683 for Scandinavian Red x Holstein.

**Table 1.** Reproduction and lactation traits in first lactation for purebred Holsteins and Holstein crossbreds<sup>a,b</sup>

Trait	Holstein	Normande x Holstein	Montebeliarde x Holstein	Scandinavian Red x Holstein <sup>c</sup>
Days to first breeding	69	62**	65*	66
Conception rate at first insemination	22	35*	31**	30
Days open	150	123**	131**	129**
305-day milk yield, lb	21,511	18,805**	20,194**	20,461**

<sup>a</sup> Data are from Heins et al. (2006ab)

<sup>b</sup> Number of observations varies from 245-536

<sup>c</sup> Scandinavian Red is a term to describe both Swedish Red and Norwegian Red sires. Differences with Holsteins indicated by \* (P<0.05) and \*\* (P<0.01).

In addition to improvements in reproduction traits, the California study also indicates advantages in reduced stillbirths and increased cow longevity associated with crossbreeding. Despite the beneficial effects of crossbreeding, there are at least two concerns about this breeding practice. The first relates to the loss of heterosis and loss of uniformity in the offspring of the crossbreds. The loss of heterosis can largely be prevented by the use of a three or four-breed rotation in sires. Use of a three-breed

rotation allows a herd to maintain 86-88% of the heterosis of the first cross and use of a four-breed rotation maintains 93-94% of the maximum heterosis possible. The second concern with crossbreeding relates to the loss of milk yield as compared to pure Holsteins. No single answer can be given as to whether the improvements in fertility and health traits caused by crossbreeding compensates for this loss of milk yield. Rather, differences between farms or regions in milk price, feed costs, fertility, etc. mean that crossbreeding may be economical for some operations and not for others. In Florida, there is little information on the production responses to crossbreeding although an upcoming nationwide study to evaluate Norwegian Red x Holstein cattle is currently planned to include some Florida dairy farms.

### **Selection for Reproduction – Daughter Pregnancy Rate**

Until recently, there has been little interest in using genetic selection to improve reproduction in dairy cattle. Because the heritability of reproductive traits is relatively low compared to production traits like milk yield, it is more difficult to make genetic improvement. Heritability is the proportion (percentage) of the observed variation in a trait that is due to genetics. When heritability is low, it is difficult to make much progress in genetic selection because the probability that the best animal is best for genetic reasons is relatively low.

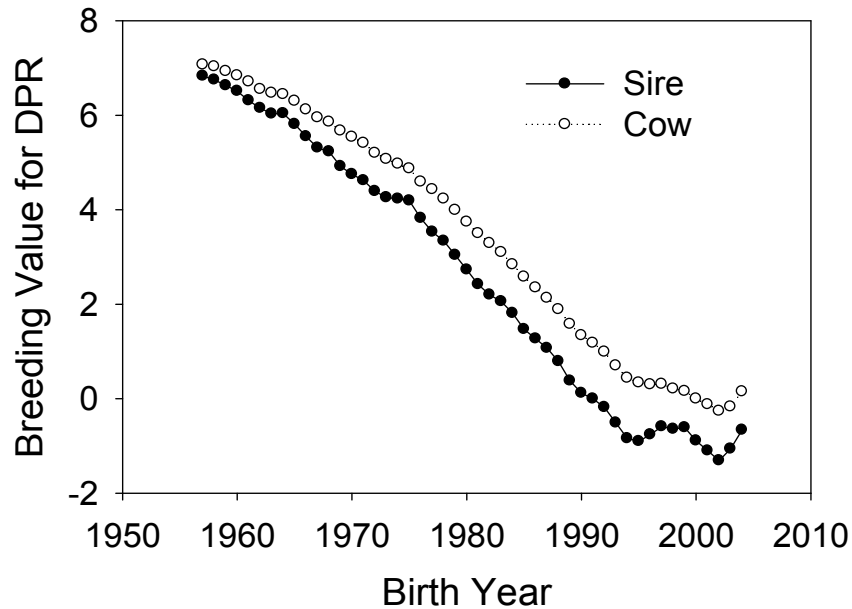
Heritability estimates for reproductive traits are 0.05 or less. In other words, less than 5% of the variation between cows in their reproductive function is caused by differences in genes. This is not surprising because reproduction is greatly affected by non-genetic factors – level of feeding, air temperature, skill of the inseminator, etc. It is a mistake, however, to conclude that low heritability means that there are no genes controlling reproduction. In fact, scientists are now finding specific genes that affect reproduction function.

In 2003, the USDA began estimating the genetic merit of bulls for reproduction. The trait used is Daughter Pregnancy Rate (DPR). This term is calculated from days open and is directly related to the proportion of females eligible to become pregnant in a 21-day period that actually become pregnant (i.e. the 21-day pregnancy rate).

The heritability of DPR is only 0.04 but work is underway to control for some factors affecting days open to improve the accuracy of the estimate of genetic ability for reproduction. Weigel (2006) reported that the top 10% of Holstein bulls had a DPR 4.9% higher than bulls in the lowest 10%. This difference corresponds to a difference in days open of 20 days (a 1% difference in DPR is equal to a 4 day difference in days open).

Although low heritability makes progress more challenging, reproduction can be improved through genetic selection. As shown in Figure 1, the continual decline in DPR from 1959 to 1995 was arrested in the latter 1990s and has been increasing since 2000. This increase is likely to have resulted from increased management attention to reproduction and the implementation of timed artificial insemination protocols.

Additionally, selection for Productive Life (first evaluated in 1994), which is highly related to reproduction, has likely contributed to recent improvements. Changes in sire and cow breeding value for DPR are shown in Figure 3. It is apparent that the long-term decline in genetic merit for fertility also stopped beginning in the mid-1990s and has since improved slightly.



**Figure 3.** Trends in the sire (●) and cow (○) breeding value for DPR as a function of birth year for US Holsteins. Data are from USDA-ARS Animal Improvement Programs Laboratory, March 2007 (available at <http://aipl.arsusda.gov/ARSWeb/eval/summary/trend.cfm>).

Alta Genetics, which markets bulls with high breeding values for DPR, has posted data on their website that support the idea that selection of bulls for DPR can affect cow fertility. In one dairy, fertility of two-year old daughters of Blastoff, the number one ranked Holstein bull for DPR, was compared to fertility of contemporary herd mates. As can be seen in Table 2, reproductive function in Blastoff daughters was much better than for contemporary controls. Caution should be used when interpreting these data – number of Blastoff daughters was low and data are not from an independently-conducted, controlled experiment.

**Table 2.** Reproductive performance of daughters sired by Blastoff as compared to contemporary controls in a Midwestern dairy.<sup>a</sup>

	Number	Conception rate (%)	Pregnancy rate (%)	Days open	Milk yield, 305-day mature equiv. (lb)
Blastoff daughters	58	51	29	94	23,398
Two-year old herd mates	755	30	16	120	22,836

<sup>a</sup> Data from Alta Genetics (<http://www.altagenetics.com>).

Improvements in DPR will pay off economically. De Vries (personal communication) has estimated that a 1-percentage unit increase in 21-day pregnancy rate is worth about \$20/cow/year. The value is greater when pregnancy rates are low. The marginal return on 1 lb extra milk achieved by genetic selection is about \$0.10/lbs. In other words, improving 21-day pregnancy rate by 1% is equivalent economically to improving milk yield by 200 lb per cow per year.

### Take Home Messages

- Dairy cattle fertility is determined largely by environmental factors but the genetic component should not be ignored.
- The decline in fertility in dairy cattle that has occurred in the last 50 years was caused in part by changes in genetic composition of dairy breeds.
- Crossbreeding can result in an improvement in fertility and longevity and a decrease in milk yield.
- The profitability of crossbreeding will vary from farm to farm; good estimates of the economic value of crossbreeding have not been made.
- A genetic evaluation tool for reproduction now exists in the form of Daughter Pregnancy Rate and one can expect that daughters of bulls with high Daughter Pregnancy Rates will be more fertile than contemporary herd mates.

### Acknowledgements

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### References

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## Notes

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