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GENETIC PREDICTORS OF REPRODUCTION

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Introduction

Genetic predictions in the form of expected progeny differences (EPDs) represent the beef industry's most powerful source of information for selection and genetic improvement. While EPDs are widely available for traits associated with calving ease, growth, milk and carcass traits, EPDs for reproductive traits are limited. Given the relative economic importance, development of EPDs for reproductive traits should be a priority for the beef industry. Fortunately, recent breakthroughs in analytical procedures have opened the door for potential development of genetic predictions for reproductive traits.

Defining Reproduction

To most cattlemen, successful reproduction means pregnancy and a live calf produced every year. Reproductive failure is represented by open and late bred cows, as well as by cows that abort prior to calving. More specifically, to most cattlemen, successful reproduction means:

- yearling replacement heifers which are cycling and become pregnant early in their first breeding season,
- wet two year olds which breed back early in their second breeding season,
- consistent annual calving after limited fixed breeding seasons until at least break-even age, and
- as much longevity as possible to minimize annual replacement rates.

This definition of reproduction is fairly involved, and implies that EPDs for several reproductive traits might be necessary to adequately describe economically important genetic differences. Specifically, genetic predictions for the fertility of replacement heifers might be needed in addition to predictions for sustained reproductive performance. Procedures have been developed to calculate EPDs for two such traits which are direct measures of reproduction, heifer pregnancy and stayability.

A Note about Economically Important Traits Versus Indicator Traits

In their paper titled "New EPDs: A Rational Vision for the Future," Dr. Bruce Golden and Dr. Rick Bourdon discuss the concept of *economically relevant traits* and *indicator traits*. These authors define economically relevant traits as the traits that directly effect profit by being directly associated with a specific cost of production or an income stream from the sale of a product. Traits which do not directly affect profit, but are used to indicate the merit an animal has for another trait are called indicator traits. Almost all economically relevant traits have multiple indicator traits.

This concept is applicable to the topic of genetic predictors of reproduction. The traits which are economically relevant, such as heifer pregnancy and stayability, have multiple indicator traits such as scrotal circumference, age at puberty, condition at breeding, etc. Arguably, indicator traits such as age at puberty and condition score are only as important as their relationship to the economically relevant trait – pregnancy. These authors go on to point out that while information from an indicator trait can be used to add accuracy to genetic predictions for the economically relevant trait, having EPDs for both types of traits may add confusion to the selection process, and can actually increase the likelihood of a bad selection decision because the indicator trait information may be inappropriately "double counted" during selection (Golden, 1997).

Genetic Predictors of Reproduction - Economically Relevant Traits

Heifer Pregnancy EPDs

Researchers at Colorado State University have worked for the past several years in the development of genetic predictions for heifer pregnancy (Evans, et al. 1996). Several different populations have been studied, including Hereford, Limousin and Angus cattle. As well, at least two breeds, Limousin and Red Angus are actively pursuing development of heifer pregnancy EPDs to include to their breed wide performance programs.

Historically, fertility traits have been thought to be lowly heritable, with estimates projected at around .10 (Koots et al. 1994). However, when heifer pregnancy was defined as the observation of a heifer conceiving and remaining pregnant to palpation, given the heifer had an opportunity to breed, and when using more appropriate analytical procedures, several studies have indicated that the heritability of heifer pregnancy may be higher (.14 to .30) than previously thought (Doyle et al. 1996, Evans et al. 1996, Snelling et al. 1996 and Summers et al. 1999). As a point of reference, "heritability" is a population statistic which measures the proportion of observed differences in a trait that are caused by genes passes from parents to offspring.

Experimental EPDs for heifer pregnancy are expressed in units of probability, and predict genetic differences in the likelihood that daughters (retained replacement heifers) will become pregnant during their first breeding season. Higher heifer pregnancy EPDs are preferred, and indicate genetics for a better likelihood of pregnancy. For example, consider the heifer pregnancy EPDs of the following two sires:

	Heifer Pregnancy EPD
Sire A	+10%
Sire B	-5%
Difference	15%

If sires A and B were bred to comparable sets of cows and all heifer offspring were retained for breeding, 15% more of sire A's daughters are expected to be diagnosed as pregnant following the first breeding season as compared to daughters of sire B. In other words, heifers from sire A have a 15% greater likelihood of pregnancy as compared to sire B's daughters.

In a heifer pregnancy study conducted by Colorado State University for the North American Limousin Foundation, records from 2,665 heifers representing 290 sires with at least one daughter were used to compute a heritability estimate and experimental heifer pregnancy EPDs. The heritability of heifer pregnancy was estimated at .20, with EPDs ranging from -14% to +11%. While the standard error associated with the heritability estimate was high because of the size of the data set, this study helps to demonstrate the possibility of breed wide heifer pregnancy EPDs.

In order for heifer pregnancy EPDs to become widely available, breed associations will have to develop protocols for data submission and processing. At present, at least two associations are actively engaged in this process. Additional research using larger data sets will help to shed further light on the heritability of heifer pregnancy in different populations of cattle.

Stayability EPDS

For several years, EPDs for stayability have been computed for the Red Angus and Limousin breeds. Stayability EPDs predict genetic differences in the likelihood or probability that daughters will remain in production until six years of age or beyond, given that daughters had at least one calf reported prior to six years of age. Since the primary reason cows are culled is because of reproductive failure, EPDs for stayability are primarily thought to indicate genetic differences in sustained reproduction. To a lesser extent, stayability EPDs may also represent genetic differences in a multitude of additional factors which contribute to reasons why daughters are "liked" by breeders, and as a result have calves reported before and after six years of age. Nonetheless, stayability EPDs help predict sustained reproduction and longevity.

The following example illustrates the use of stayability EPDs:

	Stayability EPD
Sire A	+15%
Sire B	+5%
Difference	10%

If sires A and B above were bred to comparable groups of cows, 10% more of sire A's daughters are expected to remain in production until the age of six years as compared to sire B's daughters (15% - 5% = 10%). Said another way, each daughter of sire A is expected to have a 10% greater likelihood of staying in production to the break-even age (defined as six years) as compared to daughters of sire B.

To better understand the tradeoffs between selection for stayability and selection for other traits, the Limousin Foundation has studied the relationships between EPDs for traits included in its performance program. Favorable, but small relationships exist between EPDs for stayability and EPDs for all other traits, except birth weight. The magnitude of the relationships ranged from only .01 between stayability and scrotal circumference EPDs, to .25 for the relationship with yearling weight EPD. The correlation with scrotal circumference suggests that puberty and sustained reproduction are traits controlled by different sets of genes in the Limousin population. The correlation between EPDs for stayability and birth weight was .17.

Based on these correlation, it should be possible to simultaneously select for genetic improvement in stayability and in other production traits.

Because of how stayability is defined, it is important to note that compared to other traits, considerably more time is required for animals to achieve high levels of accuracy for stayability. Adoption of inventory based record keeping systems by several breeds should help to insure the integrity of reproduction and cow disposal data, which in turn will provide opportunities for development of genetic predictions for "survival" traits.

Genetic Predictors of Reproduction - Indicator Traits

Scrotal Circumference EPDs

The most widely used indicator trait for reproduction is scrotal circumference. Several breeds have routinely calculated and published scrotal circumference EPDs for both bulls and females in their populations. Scrotal circumference is relatively easy to measure, is highly heritable, is an excellent indicator of puberty and is normally distributed and easy to analyze. In terms of genetic predictors for reproduction in bulls, scrotal circumference is favorable associated with both semen quality and quantity. For both bulls and females, it goes without saying that puberty is a prerequisite for reproduction.

However, it appears that scrotal circumference primarily accounts for genetic variation in puberty, and not much variation in observed pregnancy, especially after the first breeding season. There appear to be other genetic factors which determine heifer pregnancy and sustained reproductive performance which are not accounted for by genetic differences in scrotal circumference and age at puberty.

Milk, Mature Size and Body Condition

While genetic potentials for milk production, mature size and fleshing ability are not necessarily reproductive traits, depending upon the available nutritional resources, these traits can significantly influence expressed pregnancy rates. Conventional wisdom would support the notion that matching genetic levels for these traits to available feed resources will serve as an insurance policy for acceptable reproductive performance.

To go one step further, important genetic interactions exist between an animal's inherent genetics for fertility, the animal's nutritional requirements which are largely determined by genetic potentials for milk production and mature size, the available feed resources, and ultimately the expressed pregnancy rate. High levels of genetic merit for fertility should provide greater flexibility when matching levels of milk production, mature size and other traits to available resources and targeted markets. As well, high levels of inherent fertility might allow for money to be saved on feed, if cows can exhibit acceptable levels of expressed pregnancy despite lower levels of available nutrition and perhaps body condition.

Genetic predictions for maintenance energy requirements, which take into account genetic differences in traits such as milk and mature size, would be extremely useful in balancing selection for reproduction and other economically important traits. Recognizing the

challenges of developing such predictions, EPDs for mature size and perhaps body condition score would help to provide useful information.

Calving Ease and Reproduction

Research has also shown that heifers which required assistance at calving had lower pregnancy rates following the second breeding season by three to five percent, and were about a week later in terms of day of second calving as compared to heifers not requiring assistance (Andersen, 1991). Similarly, in a subtle way, gestation length can also impact reproductive performance. Shorter gestation length equates to slightly more time between calving and the start of fixed breeding seasons, thus allowing more time to recover and begin cycling. Consequently, selection and management for calving ease, especially in replacement heifers, favorably impacts reproductive performance.

Heterosis and Reproduction

The focus of this paper has been on genetic predictors of reproduction. Genetic predictions (EPD) estimate additive genetic differences which are passed onto offspring. The importance of heterosis, or non-additive genetic value, and breed complimentarity which is gained through smart crossbreeding should not be underestimated. The value of heterosis is substantiated in a recent report from the U.S. Meat Animal Research Center entitled, "Composite Breeds To Use Heterosis and Breed Differences To Improve Efficiency of Beef Production." The following excerpt summarizes the value of heterosis:

> *Heterosis (hybrid vigor) for major bioeconomic traits, including* ***reproduction****, growth rate, and* ***longevity*** *of beef cattle is important. Heterosis can be used to increase weight of calf per cow exposed to breeding by up 20 percent. Crossbred cows remain in the herd 1.3 years longer and have a 30 percent greater lifetime production than straight bred cows. Large breed differences exist among breeds of beef cattle for major bioeconomic traits, including growth rate and size, composition of gain, milk production, calving difficulty, age at puberty, and climatic nutritive adaptability. These are traits where the optimum is determined by production environment and by market requirements (Gregory, Cundiff and Koch, 1999).*

Conclusion

Recent breakthroughs in analytical procedures look promising relative to calculation of genetic predictions for economically relevant reproductive traits. Experimental results suggest that when modeled appropriately, heifer pregnancy may be more highly heritable than previously thought. Preliminary EPDs for heifer pregnancy, and EPDs for the trait "stayability", offer information as to the genetic differences in the likelihood that heifers are pregnant after the first breeding season, and remain in production until break-even age. Genetic predictions for indicator traits, such as scrotal circumference, effectively describe genetic differences in age a puberty, but may not adequately describe genetics for heifer pregnancy and sustained reproductive performance. As it relates to expressed fertility, interactions exist between genetic

potentials for inherent fertility and traits such as milk production, mature size, and maintenance requirements. To help ensure acceptable reproductive performance, the value of heterosis and breed complimentarity derived through smart crossbreeding should not be overlooked.

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