FIVE YEARS EXPERIENCE WITH THE ANIMAL MODEL FOR DAIRY EVALUATIONS IN AUSTRALIA

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SUMMARY

The Australian Dairy Herd Improvement Scheme has been using animal-model best linear unbiased prediction (BLUP) since 1984 with almost 1 million cows in the largest breed. An algorithm is used to accelerate convergence. Cow breeding values now are used in selecting bull dams.

INTRODUCTION

In the last 2 years, the national dairy evaluation programs of a number of countries have changed their method of estimating breeding values to animal-model BLUP. This model requires more computer resources for both time and memory than does a sire model. Research of Wiggans and Misztal (1987) indicated that use of a supercomputer made implementation of an animal model feasible for large data sets.

The Australian Dairy Herd Improvement Scheme has been using animal-model BLUP since 1984 on relatively old computers (Burroughs 6800, 7700). For the largest breed (Holstein-Friesian), 961,344 cows and 27,849 bulls were included in the 1989 analysis without the use of a supercomputer.

MAIN FEATURES OF THE AUSTRALIAN SYSTEM

The Australian system is similar to the animal model implemented by the United States Department of Agriculture in 1989. Single-trait analyses for milk, fat, and protein yields are computed. A repeatability model is used with all lactations included but with reduced weight given to later lactations. All relationships are used except those between dams and daughters in different herds. Herd-year-season is the only fixed effect in the model. Groups are not used although the program was written to accommodate them if required.

A number of special features are included in the system and are believed to be as important as use of the animal model in producing accurate estimates of breeding value.

Individual sample-day yield

Yields on individual sample days are used. Sample-day yields are adjusted for age and stage of lactation and then expressed as a deviation from sample-day average. These sample-day deviations are combined into an index of overall lactation performance. This method conveniently handles lactations in progress (Beard, 1983) and seems to produce a more heritable measure than conventional lactation yield (Meyer *et al.*, 1989). Because all comparisons are between yields measured on the same day, longer herd-year-seasons (6 months) can be used. This in turn allows different age groups to be placed in different herd-year-seasons and so minimizes importance of herd-by-age interactions.

Standardized phenotypic variance

Phenotypic variances are standardized within herd. Herds vary in variance of milk yield independent of their mean yield. To account for this, yields are standardized so that all herds have the same variance. This seems preferable to use of a logarithmic transformation.

Weighted analysis

A weighted analysis is done. Later lactations are assumed to have a higher error variance than do first lactations partly because of preferential treatment. Weight given to later lactations is reduced by 15% for each additional year of age. Weight also depends on number of sample days included in the lactation.

Consideration of foreign breeding values

For imported bulls and semen, foreign estimates of breeding value are taken into account by Goddard and Smith's Bayesian approach (1990). Equations for converting foreign evaluations to the Australian scale are calculated by Goddard's method (1985). These converted evaluations are used as starting values for estimated breeding value (EBV). The method considers that genetic correlations between evaluations in different countries may be less than 1 and that relationships already have been used in calculation of foreign evaluations. These relationships are not reused for foreign data but are used for Australian data. Before this method was used, breeding value of outstanding foreign bulls was seriously underestimated when their initial Australian evaluations were released.

COMPUTING STRATEGY

Analysis of data is done one herd at a time to minimize memory requirements. The only extra solutions that need to be kept in core are those for bulls. The disadvantage of this is the cost of reading equations and solutions for each round of iteration. At present, this accounts for much of the cost of each round. The obvious advantage of a supercomputer is that most of the data and solutions can be kept in core, and consequently required computer time is reduced. After all herds have been processed, solutions for bull breeding values are obtained. Then the next round of iteration is begun. Relationships between dams and daughters in different herds could be accommodated by storing solutions for these animals in core as is done for bulls.

Robinson (1988) developed a method of accelerating convergence of solutions. A sample of solutions for breeding values and permanent environmental effects are stored each round of iteration. After several rounds (e.g., 10), these stored solutions are used to predict the values to which the complete vector of solutions is converging. This method is at least as effective as the optimum overrelaxation factor and achieves a degree of accuracy in 30 rounds of iteration that normally would require 200 rounds without it.

ADVANTAGES OF THE ANIMAL MODEL

Selection of bull dams

Availability of accurate EBV for cows allows better selection of elite cows to become bull dams. Semen production centers now rely heavily on cow EBV when selecting cows for contract matings. This can be quantified by selection differentials currently being achieved on cows-to-breed-bulls pathway. Mean fat EBV of the dams of artificial-insemination (AI) bulls born in 1988 was 32 kg (1.1 phenotypic standard deviations) above mean of cows of the same age. These cows were also relatively young (mean age at birth of son = 5.2 years). Prior to 1984, selection differential applied to bull dams was approximately 19 kg fat, and generation length on this pathway was over 7 years.

Selection of bull dams on EBV, however, can cause concentration on just a few bloodlines. In 1989, 18 of the top 20 cows were sired by one bull. In the three previous years, this number was 18, 18, and 8. In selecting bull dams, a deliberate method of trading off EBV against future inbreeding is required. Goddard and Smith (unpublished) propose that this can be done by selecting on EBV – bR where R is average relationship of this animal to the bull breeding nucleus and b is a regression coefficient measuring cost of inbreeding.

Measurement of genetic progress in the cow population

In principle, increase in mean cow EBV each year is a direct measure of genetic improvement. For the Australian Holstein-Friesian population, this increase is 3 kg fat/year compared with cows born in 1984 through 1986. However, trend in cow EBV relies on completeness of cow pedigree information. Incomplete pedigree data will result in underestimation of genetic trend.

Inclusion of later lactation records

Inclusion of later lactation information with an animal model is much more straightforward than with a sire model. If the repeatability model is correct, reliability of bull and cow EBV is increased. If milk yields in different lactations are to some degree different traits, including later lactation information is even more important. Otherwise, a bull could retain a high EBV even though his daughters performed poorly after their first lactations.

Accounting for preferential mating

An animal model accounts for genetic merit of a bull's mates better than does a sire-maternal grandsire model. This is especially important for expensive imported bulls, which usually are mated to high producing cows.

DISADVANTAGES OF THE ANIMAL MODEL

Cost

For a single trait, the animal model costs little more than would a sire model. With a sire model, however, much of the cost is involved in absorbing fixed effects, and extra traits do not add much to cost. With an animal model, solving equations is a major cost and is roughly proportional to the number of traits. Consequently, for analysis of several traits, an animal model is much more expensive than a sire model.

Preferential treatment

The animal model (like other models) cannot account for unequal treatment of individual cows. However, use of the relationship matrix tends to spread resulting biases to relatives of favored cows. For instance, a cow used as an embryo donor may have several daughters milking in the herd. Since these daughters were expensive to produce, they may be given preferential treatment that increases their milk yield. Because this happens in a group of related cows, bias in EBV will be magnified and affect EBV of other animals such as the dam and her sons.

Incomplete pedigrees

A sire usually is contract mated to better than average cows to produce young bulls for progeny testing. If the dams are not identified, they will be treated as average cows. Then the excellence of the young bulls will be credited all to their sire, and his EBV will be biased upwards. This is another example of errors spreading through the relationship matrix to other animals.

EXTENSION PROBLEMS

Sire influence on cow EBV

At a heritability of .25, sire EBV has almost as much effect on daughter EBV as her own production. Dairy producers find it difficult to accept that this is correct, probably because they expect cow EBV to identify which cows should be culled from the herd. The EBV is not intended for this purpose, and providing dairy producers with a separate "culling index" may be necessary.

Cow EBV is of limited use to commercial dairy producers. An extension effort is needed to explain that EBV are intended to predict merit of a cow's daughters and not her own merit. Consequently, the time for a commercial producer to consider cow EBV is when choosing from which of two cows to retain a heifer calf.

Fluctuations in bull EBV

Inclusion of later lactation records causes a bull's evaluation to fluctuate from year to year as more lactations are added. If genetic correlation between lactations is less than 1, even highly reliable EBV will fluctuate because of changing distribution of age groups among a bull's daughters.

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