

Selection of Dairy Cow Bulls for Artificial Insemination

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ABSTRACT

Genetic progress in dairy cattle is largely determined by the merit of bulls used as sires of each generation. The aim of this essay is to evaluate the traditional selection of dairy cow bulls by artificial insemination (AI) organizations, based upon pedigree selection (PS) and progeny testing (PT). Pros and cons of PS and possible accuracy from using Quantitative Trait Loci (QTL) linked genetic markers-called marker-assisted selection (MAS), in selection of candidate bulls to enter PT is discussed. The achievable benefits of MAS prior to PT are increasing selection differentials, shortening generation intervals and increasing genetic gain. Regardless of present progress in genetic markers, selection of dairy sires in Australia is dependent primarily on a successful AI based PT program. The BLUP (Best Linear Un-biased Prediction) "animal model" is used to calculate the "Australian breeding values" for dairy cow breeding bulls from given measurements of PT. This allows breeders to identify with greater confidence genetically superior sires from the wider population, resulting in substantial genetic progress in production and non-production traits of dairy cattle.

Key Words: Bull selection; Progeny testing; Australian breeding values

INTRODUCTION

The basis of cattle breeding programmes is the identification of superior individuals and their widespread use within the cattle population. This is a two-stage operation in which the superior individuals are first identified and are then used as seed stock for future generations (Cunningham, 1982). Genetic progress in dairy cattle is largely determined by the merit of bulls used as sires of each generation, so selection of young dairy bulls is an important step in any cattle-breeding programme. The merit of these sires is impacted by the combination of the pedigree merit of parents, number of bulls sampled, speed and accuracy of progeny testing (PT), intensity of selection following the test and maximum use of the best of the retained bulls (Powell *et al.*, 2003). From a genetic standpoint, the principal object of selection is to change the mean value of a given population by increasing the frequency of desirable genes and genotypes. Therefore, traditional selection of dairy bulls by artificial insemination (AI) organizations is based upon pedigree selection (PS) and PT (Abdallah & McDaniel, 2002).

Pedigree selection. Pedigree selection is most useful when very little information is available about the individuals themselves either, because they are still very young and have not yet demonstrated their own performance, or because the trait under consideration is sex limited (Dekkers, 1992). PS consists of identifying young bulls of high genetic merit using pedigree information (Abdallah & McDaniel, 2002). Pedigree estimates include the PTA

(predicted transmitting abilities) of sire, dam and maternal grandsires or indexes including these measures, such as parent average (PA) = .5 PTA of sire + .5 PTA of dam and pedigree index (PI) = .5 PTA of sire + .25 PTA of maternal grandsire (Samuelson & Pearson, 1994). Possible sources of pedigree information used for evaluating candidates in a PS scheme are illustrated in Fig. 1 (Syrstad & Ruane, 1998).

According to Mao *et al.* (1990), bulls selected from herds of high genetic level were significantly superior to those from herds of low level and bulls selected from herds with high intraherd genetic variation tended to have a higher average PTA than those from herds with low intraherd genetic variation. Also parent indices based on PTA from the same animal model tended to be greater than bull PTA in herds of lower genetic level, but less than bull PTA in herds of higher genetic level. Samuelson and Pearson (1994) found that PA is more accurate predictor than PI of DYD (daughter yield deviation) and concluded that PTA of production traits should be the primary criterion for selecting bulls for PT.

Regression coefficients of a recent study on prediction of evaluation of dairy bulls from first available pedigree information (sire & dam) for PA were lower than the expected value of .5 and accuracy of predicting bull's evaluation from the first PA was low, ranging from 5 - 15% (Abdallah & McDaniel, 2002). Also fitting PTA of maternal grandsire after PTA of sire and dam resulted in only slight improvement in accuracy of prediction and was more accurate using sire and dam than using sire and maternal grandsire (Abdallah & McDaniel, 2002). Therefore, the low

accuracy of bull PTA from PA encourages the use of complementary techniques to assist in early selection of young dairy bulls. Potential use of marker-assisted selection (MAS) can improve accuracy of selection of candidate bulls to enter PT programs (Khatkar *et al.*, 2004).

Marker-assisted pre-selection of young dairy bulls prior to progeny testing. In recent years, dramatic improvements in genetic marker technology have permitted the systematic dissection of genetically complex traits into their Mendelian components (Mackinnon & Georges, 1998). This information can increase the efficiency of genetic selection programs for dairy cattle (Gomez-Raya & Klemetsdal, 1999). For milk production, a number of regions of the genome with quantitative trait loci (QTL) have been located (Geldermann *et al.*, 1985; Cowan *et al.*, 1990; Georges *et al.*, 1995; Spelman *et al.*, 1996) and further exploration is underway. Benefits from using QTL-linked genetic markers in breeding programmes (called MAS) can arise in three ways (Khatkar *et al.*, 2004):

- First markers can be used to increase the accuracy of selection by providing more information on an animal's genotype than otherwise obtained using just phenotypic information (Mackinnon & Georges, 1998). Increase in selection accuracy can be achieved if there is across population disequilibrium between markers and QTL (Smith & Simpson, 1986; Zhang & Smith, 1993) or through explaining more of the within-family Mendelian sampling variation (Meuwissen & Van Arendonk, 1992; Meuwissen & Goddard, 1996).

- Second markers can be used to decrease generation intervals by allowing selection at earlier stages in life (Kinghorn *et al.*, 1991).

- Third, markers can be used to increase selection differential by allowing screening and pre-selection among larger numbers of candidates for later selection (Kashi *et al.*, 1990).

The challenge remains, however, to devise breeding programmes, which maximise the benefit of this information in dairy cow bull selection (Mackinnon & Georges, 1998; Khatkar *et al.*, 2004).

Progeny testing. Despite the abundance of current research in genetic markers, genetic improvement for dairy cattle is still dependent primarily on a successful AI-PT programme (Norman *et al.*, 2003). PT is conducted to obtain an evaluation of genetic merit of individual animals based on performance of offspring (Norman *et al.*, 2003) and can result in rates of genetic gain of 2 - 3% per year (Dekkers, 1992). PT of bulls (Fig. 2; Simm, 2000) traditionally forms the backbone of most dairy cattle breeding programmes in temperate countries (Syrstad & Ruane, 1998), as it is potentially the most accurate way to determine an animal's EBV (estimated breeding values). However, generally there is more information available such as pedigree, performance of sibs or correlated traits, which may help in achieving accurate EBVs.

The basis of PT schemes is the comparison of the milk

Fig. 1. Sources of pedigree information for evaluating candidate dairy cow bulls for selection

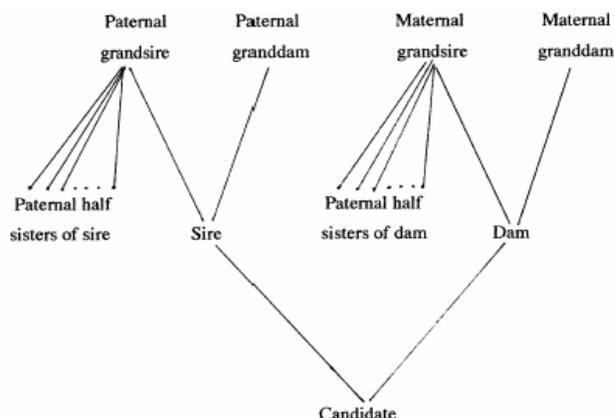
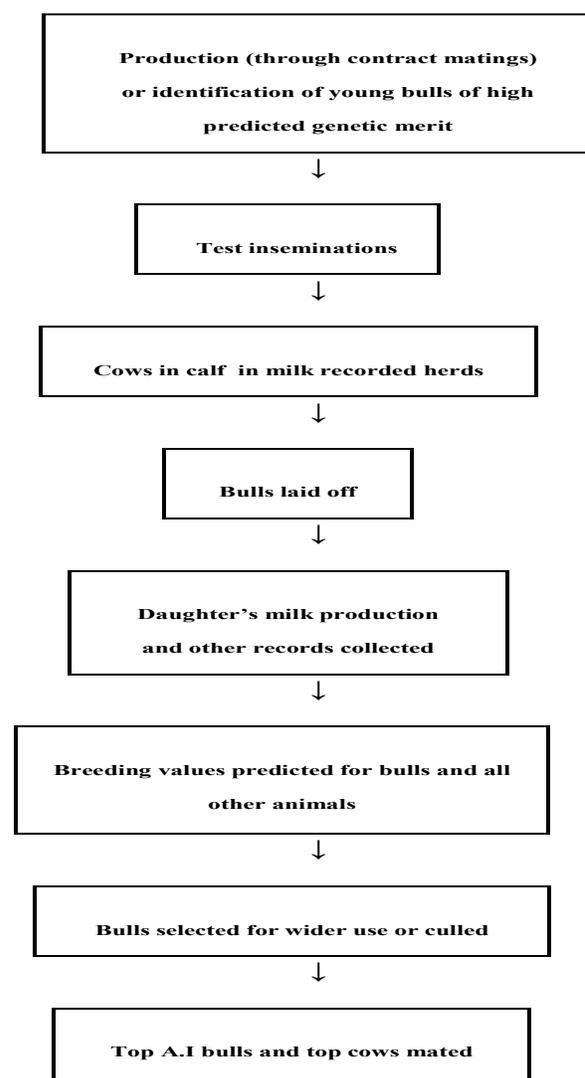


Fig. 2. The main features of progeny testing programmes for dairy cow bulls



production of the daughters of young bulls being tested with the daughters of other bulls recorded in the same herd, year and season (Simm, 2000). Results are then combined across herds, years and seasons and used to predict the genetic merit of the bulls being tested and of other animals in the recorded population. Dairy cow bull PT schemes in most countries (Dekkers, 1992) including Australia, share the following features:

- The identification of young bulls of high-predicted genetic merit for PT.

- The young bulls are bred specially for PT by contract matings between the top cows available and the best available AI bulls. These matings are arranged by the breeding organizations or individual breeders engaged in PT. Pedigree indices are widely used to identify young bulls of interest and to monitor their predicted merit at various stages throughout testing.

- Cows in milk-recorded herds are inseminated with semen from young bulls being progeny tested. For example in Australia, the Australian Dairy Herd Improvement Scheme (ADHIS) organises the PT. The aim is to have about 30 daughters of a bull with completed first lactations. To achieve this about 200 to 300 cows are inseminated, over a period of few months, per young bull being tested. This number allows for about 50% conception, 50% of calves born being female and for subsequent losses during rearing and lactation. The herds used for PT are commercial dairy herds, but they are expected to have high standards of recording and to treat their animals uniformly. They are engaged to rear, milk and record female calves resulting from these test inseminations alongside the daughters of other bulls used in their herds (Moran, 2004).

- At this point the young bulls are laid off, or temporarily retired, until their daughters milk production and other records have been collected and their breeding values have been predicted. In some countries (not Australia) larger quantities of semen are collected and frozen at the start of testing and bulls are slaughtered before the results of PT are known.

- Milk production and other performance records on daughters are collated and the bull's breeding values are estimated. In most countries breeding values are estimated for kg milk, kg fat, kg protein, % fat and % protein. Additionally, in most countries, the appearance, conformation or type, is scored for range of characteristics including body size, the size, shape and placement of udders and teats and the shape and angle of feet and legs.

- Bulls are used for breeding from 24 months of age and only 1 of every 10 progeny tested bulls is returned to active service (Vierhout *et al.*, 1998).

Pathways of genetic improvement with progeny testing.

In order to predict the rate of genetic progress in cattle population through PT, one has to consider each of the four pathways along, which genetic material is transmitted from one generation to the next (Robertson & Rendel, 1950; Syrstad & Ruane, 1998):

1. From sires to their sons
2. From sires to their daughters
3. From dams to their sons
4. From dams to their daughters.

Each of the above pathways uses different information to predict the breeding values of animals within the pathway. The contributions of these four pathways to overall genetic improvement in a dairy cattle population are potentially about 30%, 28%, 39% and 3%, respectively (Woolliams & Smith, 1988). In other words, about 70% of the progress made in population is down to the choice of parents to breed next generation of bulls for testing. Response to selection in each of the four pathways is summarised in Table I (Syrstad & Ruane, 1998).

Description of Australian genetic evaluation model for dairy cow bulls. Selecting dairy sires for breeding replacements can be best achieved by using "Australian breeding values" (ABVs). These are produced by the Australian Dairy Herd Improvement Scheme (ADHIS, Melbourne) and are a measure of an animal's potential to produce superior offspring. ABVs for sires are calculated for production traits, workability traits, survival, calving ease and for type. ABVs calculated for a number of production traits are expressed in their respective units, for example, milk in litres, butterfat and protein yields in kilograms and butterfat and protein test percentages in deviations. Therefore, when selecting sires on their production ABVs, it is essential that the bulls with the best possible ABVs are used (Anonymous, 2004).

ADHIS uses the BLUP (Best Linear Un-biased Prediction) "animal model" to predict the ABVs of sires from given measurements of PT and this technique for genetic evaluation represents a major improvement over previous methods of estimating the true genetic merit. The method uses all records available on an animal and its relatives and separates genetic from other non-genetic effects (Table II; Wilcox *et al.*, 1992). It also lists the relationships between traits to improve the accuracy of estimation. Evaluations are usually based on multiple lactations (Schneeberger, 1992). Another important property of BLUP, which result from the optimal separation of genetic and non-genetic effects, is that EBVs can be compared across herds and years. This allows breeders to identify with greater confidence genetically superior sires from the wider population (Mrode, 2000).

CONCLUSION

Potential use of marker-assisted selection can improve accuracy of early selection of candidate bulls to enter PT programs. The challenge remains, however to devise breeding programmes, which maximise the benefit of this information in dairy cow bull selection. PT is conducted to obtain an evaluation of genetic merit of individual animals based on performance of offspring and can result in rates of genetic gain of 2 - 3% per year in dairy cattle. The BLUP

Table I. Summary of predicted genetic gains by the four pathways of genetic transmission

| | Genetic superiority of parents (in genetic standard deviations) | Generation interval (in months) |
|--------------------|---|---------------------------------|
| Sires of sons | 0.95 | 114 |
| Sires of daughters | 0.09 | 47 |
| Dams of sons | 1.23 | 96 |
| Dams of daughters | 0.32 | 69 |
| TOTAL | 2.59 | 326 |

Table II. Summary of characteristics of BLUP “animal model”

| Characteristics | |
|--------------------------------|--|
| Animal evaluated | All (simultaneously) |
| Merit of mates considered | Yes |
| Dams contribute to sons | Yes |
| Sons contribute to parents | Yes |
| Daughters contribute to dams | Yes |
| Lactations included | 1-5 |
| First lactation required | Yes (cow without first lactation records evaluated separately) |
| Later herd lactations included | Yes (in separate evaluations) |
| Reliability components | |
| Parents for males | Yes |
| Daughters for females | Yes |
| Sons | Yes |
| Environmental group definition | Management group (registered grade 2 mo, flexible) |
| Base definition | Birth year |

“animal model” is used to calculate the ABVs for dairy sires from given measurements of PT. This allows breeders to identify with greater confidence genetically superior sires from the wider population, resulting in substantial genetic progress in production and non-production traits of dairy cattle.

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