INTERBULL guides through the labyrinth of national genetic evaluations

W.F. Fikse*, Interbull Centre, P.O. Box 7023, 750 07, Uppsala, Sweden
Freddy.Fikse@hgen.slu.se

Ten years ago the first international genetic evaluation of dairy bulls were released by INTERBULL as a tool for comparison of genetic merit of dairy bulls across countries. The Nordic countries were the first to participate with data on Holstein and Ayrshire bulls. Today 25 countries subscribe to the service that is offered for six breeds (Ayrshire, Brown Swiss, Guernsey, Holstein, Jersey, and Simmental) and four trait groups (production, conformation, udder health, and longevity). Evaluations are computed four times per year, and considers almost 125 000 bulls. The international genetic evaluation is based on a joint statistical analysis of national genetic evaluation results of participating countries. International genetic evaluation results are expressed on the scale of each country, and reflect locally prevailing conditions. Performance of imported bulls has been shown to be predicted accurately by INTERBULL evaluations. Participating countries can thus choose among domestic as well as foreign bulls to select superior animals to breed the next generation, enhancing the possibilities for genetic progress. Activities of INTERBULL have also had a large impact on the development of national genetic evaluations systems. Exchange of information is a major benefit for member countries. In addition, the requirements for participation in INTERBULL evaluations have had a positive influence on the quality of national genetic evaluations results.

1. Introduction

The development of new reproductive techniques during the last decades have opened possibilities for global selection of genetic material. Comparison of the genetic level of the seedstock available in the various countries was difficult, due to differences in genetic evaluations between countries. During the mid-seventies, both the Genetic Commission of the European Association for Animal Production (EAAP) and the International Dairy Federation (IDF) formed working groups, recognizing the need for research and harmonization of methods for genetic evaluation.

Early work to genetically compare dairy populations from different countries has been experimental (Hinkovski et al., 1979; Stolzman et al., 1982). Such experiments just provide information at a given point in time, but because the rate of genetic progress differs between countries more continuous comparisons are needed.

The recognition of the need for international genetic evaluations led to the foundation of Interbull in 1983, as a joint venture between the EAAP, IDF and the International Committee of Animal Recording (ICAR) in 1983. INTERBULL became a permanent subcommittee of ICAR in 1988. An operational unit, INTERBULL Centre, was established in 1991 in Sweden.

The objective of this paper is to review the current role and activities of INTERBULL, and to discuss the implications of and new developments in international genetic evaluations.

2. Organisation

The overall objectives of INTERBULL are to coordinate and assist participating member organisations in the international genetic evaluation of cattle for economically important traits. Activities of INTERBULL to reach these objectives can be categorized as follows:

a) *International Communication*. INTERBULL facilitates exchange of information among member countries through the use of meetings, workshops, surveys, presentations, publications and an Internet site (www.interbull.org).

b) *International Research & Development.* The INTERBULL Centre provides international leadership in researching and developing methods for generating international genetic evaluations. It achieves this through co-ordinating and reviewing research done in member countries, as well as running it's own research program.

c) *International Genetic Evaluation Service.* The International Genetic Evaluation Service provided by the INTERBULL Centre includes routine international genetic evaluations for cattle. Over 26 countries currently subscribe to this service.

d) *International Technical Support.* INTERBULL provides member countries with advice and assistance on all matters relating to the genetic evaluation of cattle. This includes guidance for countries developing joint evaluation or recording schemes, and recommended codes of practice for national evaluation systems.

INTERBULL is managed by a Steering Committee, currently consisting of nine members plus the Interbull Secretary. Business Meetings are held regularly (once per year) to provide INTERBULL member organisations with a forum for discussion of services provided by INTERBULL. The conclusions and recommendations of the Business Meetings are brought to the Steering Committee for decision.

The Steering Committee is furthermore assisted by two expert groups: a Scientific Advisory Committee (SAC) and a Technical Committee (ITC). The objective of the SAC is to propose methodological developments that are needed to ensure the strategic direction, scientific soundness, and long-term progress of the INTERBULL services. The ITC has as objective to identify and review technical issues essential for providing a high quality service of international genetic evaluation.

The main focus of Interbull's operational unit, Interbull Centre, is to perform international genetic evaluations. In addition, the INTERBULL Centre is responsible for research and development activities in accordance with the priorities set by the Steering Committee. Currently, the INTERBULL Centre employs five full-time animal geneticists, assisted by a programmer and a secretary, both working part-time. Activities at the INTERBULL Centre are nearly completely financed by income generated from services offered to the member countries, with a budget of just over 600 thousand euros for 2004.

3. International genetic evaluation service

International genetic evaluations are computed with a multiple-trait sire model (Multiple across country evaluations, MACE). Performance in each country is considered as a different trait, allowing for different genetic parameters in different countries and less than unity genetic correlations among countries (Schaeffer, 1994).

The most important properties of MACE can be summarized as follows:

– MACE allows using data on all bulls from all countries, thereby avoiding the use of selected – biased – subsets of bulls. In addition, known relationships between bulls can be utilized by means of a relationship matrix. For example, information on daughters of two full-brothers can be combined in an efficient way, even if these bulls were progeny tested in two different countries.

– Genetic correlations among countries that are less than unity indicate that performance is different from one country to another. In other words, animals may perform better in certain productions system than in others. Such genotype-environment interaction can be accounted for in MACE, leading to different bull rankings per country. Hence, a separate list of breeding values is computed for each participating

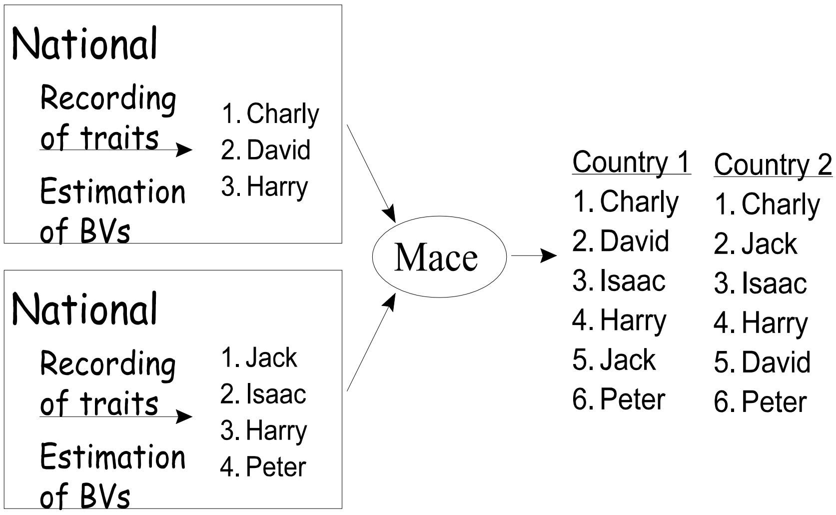

Figure 1 Schematic illustration of the international genetic evaluation model.

country, expressed in their own units and relative to their own base group of animals (Figure 1).

The first step in the process of routine international genetic evaluations is collection of official national genetic evaluations from designated organisations in all participating countries (Figure 2). Incoming data goes through extensive checks (Klei et al., 2002). Subsequently, the pedigree information from all countries is combined, in order to determine all different IDs a bull is known under. This comprehensive list of cross-references is used to assign a unique international ID to each bull.

The next step involves deregression of national breeding values and estimation of genetic variances, both done within country. The purpose of deregression is to remove the effects that subsequently are included in the prediction of international breeding values (Jairath et al., 1998). Genetic variances are estimated using an EM-REML algorithm (Sullivan, 1999).

In the final step, international breeding values are predicted based on the

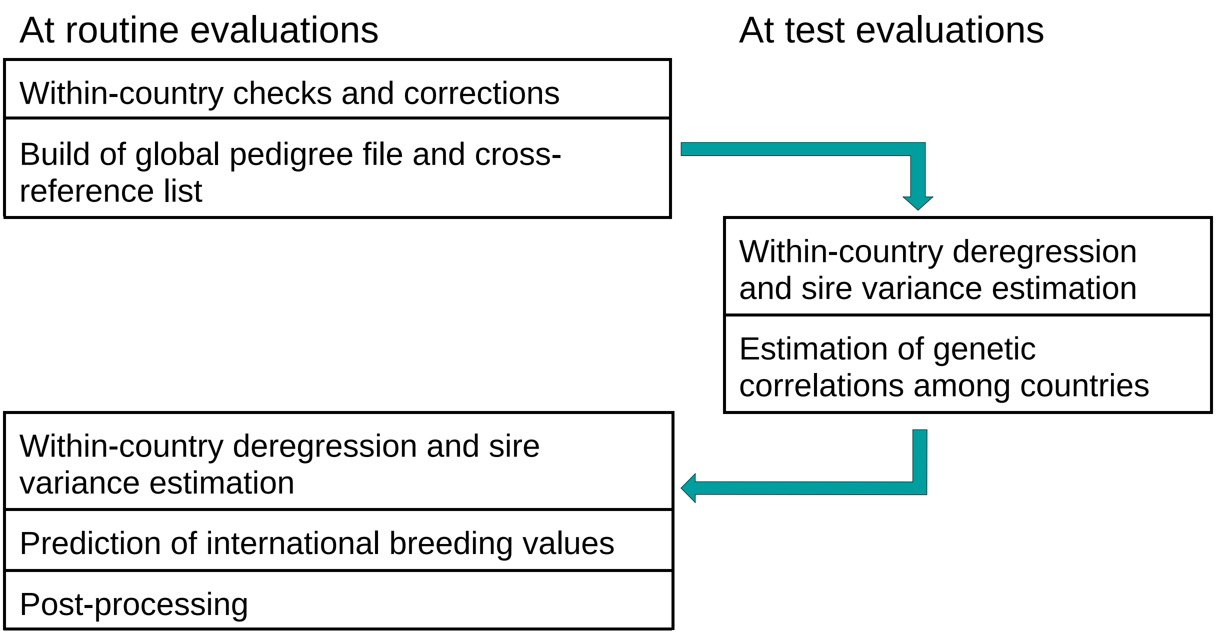

Figure 2. Schematic illustration of the process of international genetic evaluations.

deregressed national evaluations and the estimated genetic parameters. Each bull receives a breeding value for each country scale. These figures together with approximated reliabilities (Harris and Johnson, 1998) are finally returned to all participating countries for distribution to breeders and farmers.

Individual countries may only publish Interbull evaluations expressed on their own official scale and base. For example, in 2004 about 80 thousand Holstein bulls from around the world received international breeding values for protein yield expressed in PTA lbs on the US base, EBV kg on the Dutch base, in RBV on the Swedish scale, and so on. Individual farmers and sire analysts thus can compare bulls from around the world using figures and units that they are accustomed to.

It should be noted that INTERBULL does not publish international breeding values. It is the responsibility of participating countries to rank bulls according to their own breeding objectives, and publish these results.

Routine international genetic evaluations are done four times per year (February, May, August, and November). Each evaluation has a turnaround time of thirteen days, allowing for time for communication between the INTERBULL Centre and member countries in case anomalies or unexpected deviations are discovered in the data. In addition, two test evaluations are done per year (turnaround time is approximately one month), to provide the opportunity to include new traits or countries, to check modified national evaluations, and to introduce modification in the international genetic evaluation process. In addition, genetic correlations between countries are estimated during test evaluations.

Table 1. Number of bull populations per breed and trait group (August 2004).

Breed	Production	Conformation	Udder Health	Longevity
Ays	12	9	10	
Bsw	9	7	5	
Gue	6	3	4	
Hol	27	22	21	16
Jer	10	8	7	
Sim	9			

In 2004, routine international genetic evaluations are done for six breeds and three trait groups, involving data from 26 countries (Table 1). Two new trait groups, longevity and calving traits, are being added. Thus, international genetic evaluations are offered for all economically important traits, with the exception of female fertility, which is currently investigated at the INTERBULL Centre.

Experiences

Ten years of experience has learned that quality of pedigree information, quality of input data, and estimation of genetic correlations are critical to international genetic evaluations.

New registration numbers are often assigned when live animals or semen is imported, and thus animals can have various registration numbers in different countries. In addition, pedigree information on export certificates can be difficult to decipher, and sire-dam information stored in other countries frequently differs from the records in the country of first registration. Thus, some bulls may receive more than one evaluation, for example one evaluation based on daughters in certain countries and another evaluation based on daughters in other countries, or one evaluation based on daughter information and another based on information from sons and grandsons. Obviously, inconsistent pedigree information reduces the value of international genetic evaluations.

INTERBULL therefore developed together with the member countries several routines to improve the quality of pedigree information. Examples hereof are the distribution of pedigree information of young bulls as stored in the country of first registration, routine screening for potential duplicates in the pedigree database, and a system to report invalid registration numbers, such that countries providing these can improve their pedigree database. On top of that there is a large amount of email communication with and between member countries that deals with corrections of pedigree information.

Quality of data used in international evaluations are checked at two levels: breeding values from two subsequent evaluations are compared, to identify changes that are larger than expected based on statistical properties of breeding values (Klei et al., 2002). In addition, estimated genetic trends are validated such to assure that breeding values are unbiased (Bonaiti et al., 1995). The use of biased national breeding values would result in unfair international comparison (Banos, 1999). Several research projects are ongoing with the aim to improve detection of inconsistencies between subsequent evaluations (e.g., Banos et al., 2003; Diplaris et al., 2004) and to check whether national breeding values comply with the assumptions made in the statistical models for national and international genetic evaluations (Fikse et al., 2003).

Genetic correlations for milk production between countries are generally high, ranging from 0.85 to 0.96 among countries in the Northern hemisphere, around 0.90 among countries in Oceania, and from 0.75 to 0.84 between Northen and Southern hemispherical countries. The level of genetic correlations for somatic cells are of the same order of magnitude as for production traits. Genetic correlations for conformation traits, however, are somewhat lower and more variable. The variability can be attributed to both the degree of trait harmonization and genotype-environment interaction. Genetic correlations for longevity range from 0.30 to 0.90, reflecting that culling reasons differ between countries.

Genetic correlations influences the emphasis put on different information sources (pedigree and daughter performance in multiple countries; Klei et al., 1999). An example of this the so-called home court advantage, the phenomena that bulls have the best chance to excel in the country where they were tested. This reflects the reduced value of foreign information to predict performance under local production circumstances, and illustrates the importance of obtaining precise estimations of genetic correlations.

Estimation of genetic correlations has become a challenge with the increase in number of countries and the weak ties between some of them. The use of subsets of countries and bulls is currently practised to estimate genetic correlations (Sigurdsson et al., 1996). In addition, for some traits and breeds information from other breeds is used as prior information in a Bayesian framework (Mark et al., 2003). More recent research focuses on exploiting patterns in the genetic correlation matrix by means of structural models (Rekaya et al., 2001; Minéry et al., 2003; Leclerc et al., 2004a) or principal component analyses (Mäntysaari, 2004; Leclerc, 2004b).

4. Implications of international genetic evaluations

4.1. Predictive ability of international evaluations

Combining information from daughters in several countries in an international evaluation has been shown to improve the precision of predictions of genetic merit for US bulls (Powell et al., 2000). Their comparison of national and international breeding values from 1995 with national breeding values of 1998, showed that standard deviations of the differences were lower for international than for national breeding values, suggesting improved prediction from inclusion of foreign data.

Recent studies also indicated that INTERBULL evaluations based solely on foreign daughters are useful predictors of the domestic breeding values for production, conformation and udder health (Powell et al., 2004; McClintock et al., 2003; Van der

Linde and Nooijen, 2004). The precision of the prediction was found to be in agreement with the reliabilities of international breeding values (Powell et al., 2004). Van der Linde and Nooijen (2004) concluded also that international breeding values were better predictors of future performance than breeding values in the country of test.

4.2. Selection differentials

Selection intensity is expected to increase with the availability of international evaluations, and especially numerically small and genetically inferior populations could benefit (Banos and Smith, 1991; Lohuis and Dekkers, 1998). Based on data from the routine INTERBULLevaluations of August 2004, potential selection differentials for the Holstein breed achieved by selecting the top ten bulls nationally ranged from 0.4 to 1.7 genetic standard deviations for protein yield. The corresponding range for somatic cells was from 0.3 to 1.5. By selecting across countries, the potential selection differentials increased to 1.3 to 2.5 and 1.0 to 1.6 for protein yield and somatic cells, respectively. Thus, selection across countries on average can increase genetic gain by up to 1.7 genetic standard deviations, depending on the genetic correlations among countries and differences in the genetic level between countries.

5. New developments

5.1. Female fertility

The next trait in line to be added to INTERBULL's service portfolio is female fertility. Farmers around the world suffer from economic losses due to impaired female fertility. As a reaction, many countries have developed national genetic evaluations for female fertility, thereby creating a demand for international evaluations. The complex biological nature of female fertility (Roxström, 2001) would yield suboptimal international comparisons with the current procedure where only one breeding value per bull and country can be considered. The development therefore focuses on multiple-trait MACE (Schaeffer, 2001), which can handle several breeding values per bull and country. A major challenge will be to estimate the genetic correlations between all traits in all countries.

5.2. Beef breeds and traits

Three national organisations from Ireland, United Kingdom and France initiated in 2001 the development of an international genetic evaluation system of beef cattle. A major effort was to improve animal identification and to find all registration numbers an animal is known under, such to be able to identify the genetic links that exist between countries.

Harmonization of definition of traits across countries has been stimulated by the ICAR recommendations for recording of beef performance. This is for example reflected in the high genetic correlations among countries for weaning weight (0.80-0.90 for well-connected countries; Renand et al., 2003). Differences between countries in recording of performance data should be as low as possible to realize the potential benefits of across country selection (Banos and Smith, 1991).

Dairy cattle populations are characterised be large progeny groups, for which MACE in combination with deregressed of national breeding values works satisfactory. In beef cattle breeding, natural service matings are prevailing in many countries, and progeny groups are usually small. In addition, the traits of interest are expressed at an early age, because of which maternal genetic effects are often included in the genetic evaluation model. These differences in population and data structure make straightforward application of the international genetic system for dairy cattle to beef cattle problematic, which was observed by Phocas et al. (2004).

5.3. Joint evaluation of animal performance records

Routine international genetic evaluations thus far used deregressed national evaluations as input, but joint evaluation of raw performance data has been advocated (e.g. Weigel, 2002). The benefits of this approach include international breeding values for bulls and cows, avoidance of complete reliance on national genetic evaluation systems, and the opportunity to consider production system rather than country for the interaction between genotype and environment. Computational difficulties and difficulties of geneticists at the international level to understand all the complexities of the local production circumstances are alleviated by the use of yield deviation for cows calculated by each country (Canavesi et al., 2001).

6. Conclusion

The activities of INTERBULL improve the transparency of the global market for genetic material in several ways. The service of international evaluations for dairy sires is the most obvious example. However, the organization of international meetings and publications of proceedings, surveys and recommendations also increases the knowledge about genetic evaluation practices around the world. Lastly, the quality standards aimed for by INTERBULL improves both national and international genetic evaluations.

7. References

Banos, G., Smith, C., 1991. Selecting bulls across countries to maximize genetic improvement in dairy cattle. J. Anim. Breed. Genet. 108, 174-181.

Banos, G., 1999. Review of international genetic evaluation procedures in dairy cattle. Anim. Breed. Abstr. 66, 585-591.

Banos, G., Mitkas, P.A., Abas, Z., Symeonidis, A.L., Milis, G., Emanuelson, U., 2003. Quality control of national genetic evaluation results using data-mining techniques - a progress report. Interbull Bull. 31, 8-15.

Boichard,, D., Bonaiti, B., Barbat, A., Mattalia, S., 1995. Three methods to validate the estimation of genetic trend for dairy cattle. J. Diary Sci. 78, 431-437.

Canavesi, F., Boichard, D., Ducrocq, V., Gengler, N., De Jong, G., Liu, Z., 2001. PROduction Traits European Joint Evaluation (PROTEJE). Interbull Bull. 27, 32-34

Diplaris, S., Symeonidis, A.L., Mitkas, P.A., Banos. G., Abas, Z., 2004. An alarm firing system for national genetic evaluation quality control. Interbull Bull. 32, 146-150.

Fikse, W.F., Klei, L., Liu, Z., Sullivan, P.G., 2003. Procedure for validation of trends in genetic variance. Interbull Bull. 31, 30-36.

Harris, B., Johnson, D., 1998. Information source reliability method applied to MACE. Interbull Bull. 17, 31-36.

Hinkovski, T., Alexiev, A., Lindhé, B., Hickman, G.G., 1979. The red and red-and-white cattle breeding comparison in Bulgaria. World Anim. Rev. 29, 8-12.

Jairath, L., Dekker, J.C.M., Schaeffer, L.R., Liu, Z., Burnside, E.B., Kolstad, B., 1998. Genetic evaluation for herd life. J. Dairy Sci. 81, 550-562.

Klei, L., Weigel K., Lawlor, T., 1999. Mace, the relative importance of information sources. Interbull Bull. 22, 9-13.

Klei, L., Mark, T., Fikse, W.F., Lawlor, T., 2002. A method for verifying genetic evaluation results. Interbull Bull. 29, 178-182.

Leclerc, H., Minéry, S., Fikse, W.F., Ducrocq, V., Druet., T., 2004a. Estimation of genetic correlations using a structural model for milk and type traits: limits and opportunities. Interbull Bull. 32, 65-69.

Leclerc, H., 2004b. A structural model and principal components approach to estimate genetic correlations between countries. MSc thesis. Institut National Agronomique Paris-Grignon.

Lohuis, M.M., Dekkers, J.C.M., 1998. Merits of borderless evaluations. Proc 6th World Congr. Genet. Appl. Livest. Prod. 26, 169-172.

Mäntysaari, E., 2004. Multiple-trait across-country evaluations using singular (co)variance matrix and random regression model. Interbull Bull. 32, 70-74.

Mark, T., Madsen, P., Jensen, J., Fikse, W.F., 2003. MACE for Ayrshire conformation: Impact of different uses of prior genetic correlations. Interbull Bull. 30, 126-135.

McClintock,S., Beard, K., Poole, R., 2003. Interbull proofs are a reasonably unbiased prediction of future performance in Australia for imported bulls. Interbull Bull. 31, 169-170.

Phocas, F., Donoghue, K., Graser, H., 2004. Comparison of alternative strategies for an internatinoal genetic evaluation of beef cattle breeds. Interbull Bull. 32, 18-24.

Powell, R.L., Norman, H.D., Banos, G., 2000. Improving prediction of national evaluations by use of data from other countries. J. Dairy Sci. 83 (February). Online.

Powell, R.L., Sanders, A.H., Norman, H.D., 2004. Accuracy of foreign dairy bull evaluations in predicting United States evaluations for yield. J. Dairy Sci. 87, 2621-2626.

Rekaya, R., Weigel, K.A., Gianola, D., 2001. Application of a structural moodel for genetic covariances in international dairy sire evaluations. J. Dairy Sci. 84, 1525-1530.

Renand, G., Laloë, D., Quintanilla, R., Fouilloux, M.N., 2003. A first attempt of an international genetic evaluation of beef breeds in Europe. Interbull. Bull. 31, 151-155.

Roxström, A., 2001. Genetic aspects of fertility and longevity in dairy cattle. PhD thesis. Acta Universitatis Agriculturae Sueciae, Agraria 276. Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences.

Schaeffer, L.R., 1994. Multiple-country comparison of dairy sires. J. Dairy Sci. 77, 2671-2678.

Schaeffer, L.R., 2001. Multiple trait international bull comparisons. Livest. Prod. Sci. 69, 145-153.

Stolzman, M., Jasiorowski, H. Reklewski, Z., 1992. Friesian cattle in Poland. World Anim. Rev. 41, 46-47.

Sullivan, P., 1999. Appendix: REML estimation of heterogeneous sire (co)variances for MACE. Interbull Bull. 22, 146-148.

Van der Linde, R., Nooijen, M., 2004. De waarde van INTERBULL [The value of INTERBULL]. Veeteelt January 1/2, 12-14. [in Dutch]

Weigel, K.A., 2002. Prediction of international breeding values of dairy sires using individual animal performance records. Proc. 7th World Congr. Genet. Appl. Livest. Prod.29, 83-90.