Developments in multi-source genetic evaluations for beef cattle: A BREEDPLAN perspective

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Abstract

ABRI provides the BREEDPLAN® genetic evaluation service to both Australian and international clients, and so represents the most widely used genetic evaluation service for beef cattle internationally. Approximately 63 separate BREEDPLAN evaluations have been developed, representing over 40 million animals, almost 40 beef cattle breeds and at least 100 breed associations distributed across 14 countries. This paper provides an overview of current initiatives and developments being undertaken by ABRI regarding multi-country and multi-breed BREEDPLAN evaluations.

Keywords: BREEDPLAN, beef cattle, genetic evaluation, multi-country, multi-breed.

Introduction

The provision of commercial services for the genetic evaluation of beef cattle represents a rapidly changing context. With advancements in computational speed and analytical approaches as well as the increasing needs of beef seed-stock breeders for gains in production efficiency and sustainability, we are seeing the development of more complex, more frequent and globally-focused initiatives as service providers. Where national breed-specific evaluations were once common place, there is now a growing interest and opportunity for countries to combine their pedigree and performance data into larger-scale multi-country genetic evaluations. This allows individual animals to be compared directly on EBV across countries, allowing breeders to take a more informed approach to the selection of possible genetics from "beyond the borders". This also means that superior local genetics can be more accurately identified when benchmarked within the wider international gene pool.

The Agricultural Business Research Institute (ABRI) is a commercial company founded in 1970 at the University of New England, Armidale Australia. The primary business of ABRI is to provide both domestic and international livestock industries with a wide range of multi-species agribusiness information services, including: integrated pedigree and performance database systems (ILR2), genetic analyses, breed registry services and extension services.

One of ABRI's flagship products is BREEDPLAN®, a comprehensive suite of multi-trait genetic evaluation technologies developed by the Animal Genetics and Breeding Unit (AGBU)[1] for the beef cattle industry. As a member of ICAR, ABRI currently facilitates the inclusion of Australian data on behalf of the Charolais and Limousin breeds participating in the respective INTERBEEF evaluations.

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[1] AGBU is a joint venture of the University of New England (UNE) and NSW Department of Primary Industries (NSW DPI), with support from Meat and Livestock Australia (MLA).

ABRI provides the BREEDPLAN service to both Australian and international clients under a commercialisation licence from the owners of the **BREEDPLAN technology**.[2] At present, approximately 63 separate BREEDPLAN genetic evaluations have been developed, with most conducted either monthly or fortnightly. This represents over 40 million animals, almost 40 beef cattle breeds and at least 100 breed associations distributed across 14 countries, with most BREEDPLAN clients accessing 12-24 genetic evaluations per year, subject to the needs of their members. This makes BREEDPLAN the most widely used genetic evaluation service for beef cattle internationally.

A detailed description of the traits and models associated with BREEDPLAN is provided by Graser *et al* (2005). For the purposes of the present paper, it is worth emphasising that all subsequent developments of the commercial BREEDPLAN service, including the transition towards multi-source evaluations and the incorporation of genomics, have sought to uphold the integrity of a multi-trait model combining birth, growth, fertility, ultra-sound and carcase traits and the potential opportunities afforded to participants where complete recording of all such traits is either financially prohibitive or impractical. Likewise, the BREEDPLAN analytical software makes provision for database-specific trait definitions and pre-adjustment of phenotypes, heterogeneity of variances, sire by herd interactions and a comprehensive approach to genetic groupings, all of which can assist in accommodating some of the considerations required when combining datasets from different sources, whether countries or breeds.

ABRI has facilitated multi-source BREEDPLAN evaluations for over 20 years (e.g. Australia with New Zealand; South Africa with Namibia) and a number of larger scale evaluations for the last 10 years (e.g. Pan American Hereford evaluation: joint analysis of the USA, Canada, Uruguay and Argentina). However, the changing commercial

Table 1. Example of beef breeds available for International BREEDPLAN evaluation.

Breed	Countries[1]	Evaluations[2]	Total animals	Total WW
Hereford	7	3	4,003,689	2,280,596
Angus	5	3	2,974,496	1,817,725
Brahman	4	2	1,038,349	385,023
South Devon	4	3	396,786	197,138

[1] Separate databases
[2] Separate BREEDPLAN genetic evaluations, with each evaluation conducted monthly or fortnightly

context of beef cattle genetic evaluation means we have now moved towards significantly larger and more complex evaluations that combine multiple sources of pedigree, phenotypic and genomic information.

At present, there are two primary initiatives being undertaken by ABRI. The first involves progression towards International evaluations, working with client countries of ABRI where performance (and genomic) data is recorded on the same breed and for which there is some degree of genetic linkage between the respective populations. A summary of breeds for which developments in multi-country evaluations can be considered is given in table 1. This paper will focus on the Hereford and Brahman breeds only. The second initiative involves multi-breed evaluations, using intentionally-designed multi-breed populations that allow the wider population of component breeds to be combined for genetic evaluation within the one analysis. The focus here will be a domestic one,

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[1] The owners of the BREEDPLAN technology are: MLA, UNE and NSW DPI.

featuring advances made in the genetic evaluation of tropically adapted breeds in Northern Australia. This paper provides an overview of these initiatives and developments to date.

Multi-country BREEDPLAN evaluations

As the international trade in beef cattle genetics increases, so too does the exchange of information that allows for developments in the provision of commercial services for multi-country and international beef genetic evaluations. One topic of primary focus at the 14th World Hereford Conference (2004) was how to provide Hereford breeders around the world with access to genetics best suited to their respective breeding objective, regardless of where those genetics originated. Interest in a global evaluation of the Hereford breed fostered a genetic linkage project (Donoghue, 2004), development of a web-based global cross-reference table (Johnston, 2004), plus a range of analytical approaches (Graser, 2004) and customised software (Donoghue *et al*, 2007). However, progression towards a commercial outcome and a strategy for ongoing maintenance of the global cross-reference table did not proceed.

An alternative strategy is now being evaluated by ABRI, in collaboration with 7 Hereford breed associations. This initiative is facilitated via the ABRI ILR2 database system, used by the Hereford associations in Australia, New Zealand, Canada, the UK and Namibia. For the associations in Uruguay and Argentina, where domestic registry systems are used, data extracts are supplied to ABRI and loaded to ILR2 systems configured for each country. A parallel strategy is also being progressed for the Brahman breed, based on previous research and development undertaken by ABRI for clients in Australia, South Africa, Namibia and the USA. This initiative represents an international first, in that a *Bos indicus* breed is now being represented in what has long been the domain of *Bos taurus* developments.

The ABRI ILR2 system provides a global language by which data can be extracted automatically in a standardised format for BREEDPLAN genetic analysis, and also provides cross-referencing capability. This means new imported genetics can be recorded using conventional country-specific identifiers, while also providing storage of the animal's identification as recorded in the country of export. ABRI software then extracts and collates this information across ILR2 systems to create global cross-reference files as required for various combinations of data. This removes any additional demand on breed association staff to create data extracts or engage directly in the cross-referencing process. Furthermore, access to the ILR2 DNA table allows genomic data (if collected) to be integrated with the pedigree and performance data residing on the breed association's ILR2 system – and provides ready access to SNP data extracts for use in Single-Step BREEDPLAN evaluations (Johnston *et al*, 2018). This provides a standardised approach for the inclusion of genomic information in International BREEDPLAN evaluations.

Table 2 summarises the traits currently considered in developing an International BREEDPLAN evaluation for the Hereford and Brahman breeds, as well as the total number of phenotypes included across all countries within breed. Importantly, while certain traits are recorded in all countries (e.g. weaning and yearling weights), the remaining traits are more variable, with either low levels of recording relative to weaning weights in some countries, or no recording of the trait at all. It is also worth noting that countries differ in their approach to whole-herd recording and completeness of recording, such that one country might represent a higher percentage of records for a particular trait, even though they account for a smaller percentage of animals in the total analysis. In this way, the combining of data across countries can afford opportunities to all participants.

Table 2. Performance records in multi-country BREEDPLAN evaluations: Hereford and Brahman.

Trait	Hereford	Brahman
Birth weight	1,749,276	795,466
Weaning weight	2,229,446	540,945
Yearling weight	1,374,949	260,690
Final weight	769,455	234,152
Mature cow weight	128,461	60,079
Scrotal circumference	243,519	52,922
Eye muscle area (EMA) - scan	469,172	45,814
Rib fat (RIB) - scan	471,333	43,474
Intramuscular fat% (IMF) - scan	270,090	-
Total records	7,705,701	2,033,542
Number of countries	7	4

The approach taken by ABRI in developing an international evaluation for any given breed is summarised as follows:

A. *For each country*:

- Use ILR2 software to create BREEDPLAN-ready data extracts à conversion to metric units;

- Use ILR2 software to extract cross-referencing information;

- Estimate adjustment factors (per trait) relating to significant non-genetic sources of variation (e.g. age of animal at measurement; age of dam; sex-specific);

- Estimate variance components (per trait): including maternal genetic and dam permanent environment effects (birth weight; weaning weight) and sire by herd interactions (SxH);

B. *For multi-country analysis*:

- Estimate across-country correlations (per trait), for those countries where sufficient records are available;

- Create multi-country covariance matrix using pooled variance components (per trait, including SxH) and off-diagonals based on country representing the most comprehensively recorded multi-trait data source;

- Configure genetic groupings parameter file to allow for country, year and "other breed" representations among base animal population;

- Create global cross-reference file and create multi-country (merged) BREEDPLAN extracts;

- Conduct International analysis using current BREEDPLAN software;

C. *Assessment of outcomes*:

- Conduct single-country analyses:

  - model 1: using current "national" (co)variance matrix;

  - model 2: using country-specific variances and multi-country off-diagonals;

- model 3: using multi-country (co)variance matrix;

- comparison of EBVs from models 1-3 à evaluation of assumptions regarding multi-country (co)variance matrix;

- Single vs multi-country:

    - comparison of multi-country EBVs with single-country (model 3) EBVs;

    - cross-validation studies using LR method (Legarra and Reverter, 2018) to demonstrate prediction of future phenotypes, per country: using both single-country (model 3) and multi-country models;

D. *Web-based search engine*:

- collation of within-country listing of published sires;

- display of multi-country results on ABRI's web-based search engine;

Run time for these international evaluations is relatively quick, at 9 hours for Hereford and 3 hours for Brahman, making them an extremely attractive option for a regular, commercial service. These processing speeds are achieved by ABRI's ongoing investment in computer processing capacity combined with more recent enhancements made by AGBU to the solver algorithm used in BREEDPLAN evaluations. This enhanced solver algorithm has the capacity to solve more than 450 million equations in less than 24 hours, thus facilitating the implementation of single-step GBPLUP procedures into routine BREEDPLAN evaluations (Johnston *et al*, 2018).

The main BREEDPLAN multi-trait model can readily accommodate a wider range of traits, including: gestation length; days-to-calving; carcase traits; eating quality traits; net feed intake; % normal sperm. Furthermore, there are additional BREEDPLAN models for analysis of calving ease scores, docility scores and structural trait scores. Phenotypic data is available for most of these traits in both the Hereford and Brahman breeds, and preliminary multi-country evaluations including these traits have been completed to determine the impact on convergence and run times. Similarly, genomic data has been incorporated using single-step GBPLUP procedures, to determine impact on convergence and run time. Initial indications suggest that completion of complex multi-trait International BREEDPLAN evaluations, including those with genomic information, could be achieved in less than 24 hours.

To date, ABRI has completed the single-country and multi-country analyses required for developing an International BREEDPLAN evaluation for the Hereford and Brahman breeds. Assessments of outcomes and the undertaking of validation studies have been scheduled for later in the current year.

Multi-breed BREEDPLAN evaluations

In contrast to ABRI's development of multi-country BREEDPLAN evaluations, where the priority has been set by our international (breed-specific) clients, our development of multi-breed BREEDPLAN evaluations has been driven by the research, development and extension priorities as set by the Australian beef industry (MLA, 2016). Primary focus has been given to multi-breed evaluations involving the tropically-adapted breeds of northern Australia, such as the Brahman, Santa Gertrudis and Droughtmaster breeds, which account for 22% of Australian seedstock registrations but have overall lower levels of performance recording (especially fertility traits) relative to breeds in southern Australia.

It is beyond the scope of this paper to outline the research and development undertaken to improve the levels of performance recording, especially of fertility-based traits, in these northern breeds. However, Johnston *et al.* (2017) provides a concise description of a large-scale phenotyping and genotyping project using designed multi-breed matings. Pedigree and performance information has been loaded to an ILR2 database, complete with cross-reference details that facilitate linkage to individual breed ILR2 system. This Northern Multi-breed (NMB) ILR2 database has provided one of the critical components necessary in developing a range of multi-breed BREEDPLAN evaluations for northern Australia. To date, collaboration between ABRI and AGBU has enabled the NMB data to be included in the monthly BREEDPLAN evaluations of the Australian Brahman and Santa Gertrudis breeds, with the Brahman analysis using single-step GBLUP procedures. Work is currently underway to combine the NMB data with that of the Droughtmaster and Belmont Red breeds, as well as a database representing Tropical Composites.

While these developments may fall in the "multi-breed" category, they are in fact single-breed evaluations that make use of a multi-breed data set to improve the accuracy of prediction of traits relevant to the main breed. As a consequence, how the NMB data is used in a BREEDPLAN analysis depends on the model and (co)variance matrix specific to the main breed for which the analysis is being conducted. Furthermore, EBVs are only reported for animals relevant to the main breed. Currently there is no provision to report on how one breed compares to another, or to rank sires on genetic merit across breeds. ABRI has therefore undertaken development of a more practical and dynamic pathway for combining data from each of the four main tropical breeds, along with the NMB data, to create a "Northern Tropical" BREEDPLAN extract. Running this extract through a test analysis configured as per the current Brahman Single-Step BREEDPLAN analysis - including Brahman-specific parameter files, complete multi-trait (birth, growth, fertility, scan, carcase, eating quality traits) and a G-matrix comprising Brahman genotypes only – convergence was reached in just 2 hours. Admittedly, this represents a very basic first step only. Further work is needed to determine an appropriate (co)variance matrix, or whether multiple (breed-specific) matrices might be required, as well as enhancing the single-step GBLUP procedures to accommodate genotypes from multiple breed sources.

Conclusion

Every multi-source evaluation to be developed requires a range of assumptions and validations to be made and agreed upon by the participating parties and the commercial service provider, if such an evaluation is to move beyond the "research project" into commercial production. The development pathway used by ABRI for multi-country BREEDPLAN evaluations is no different. We assume that a multi-trait model holds more appeal to our clients and we assume that across-country correlations are sufficiently high to negate the need for modelling country-specific genetic expressions of a trait. Our research to date for the Hereford and Brahman breeds gives some validity to these assumptions. We also assume that this will be assisted by accommodating sire by herd interactions, heterogeneity of variances and comprehensive genetic groupings in the model. We also assume that our clients will require an assessment of outcomes, including validation studies to demonstrate the accuracy of prediction of future phenotypes based on multi-country EBVs. We see this as a logical extension of our commercial service, because the outcome would be an international evaluation using ILR2 systems and BREEDPLAN software.

In terms of multi-breed initiatives, ABRI continues to explore the opportunities available to our clients in combining breed-specific databases where linkage exists via shared information: whether by linkage to other multi-breed research databases or via registers

of cross-bred animals recorded on a breed association's ILR2 system. Our expertise in agribusiness information services allows ABRI to provide critical input in the development of multi-breed BREEDPLAN evaluations.

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