A model for, and early implementation of, genomic selection in the Australian honey bee population

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Abstract

Genetic improvement has been limited in the Australian honey bee population, despite the direct and indirect economic significance of the industry. Recently, significant industry and community investment has established the foundation for a national R&D and improvement program centred on objective evaluation and genomic selection, underpinning strong industry and community engagement. This paper outlines the key elements of that program, its goals, and early steps in implementation, and highlights the transformative potential of the program.

Introduction

The Western honey bee (*Apis mellifera*) was introduced to Australia within the wider process of colonisation and development of British/European agricultural practices, and now contributes to the Australian economy in two ways:

- Directly, through honey production, which is worth an estimated $AUD150m per year, and
- Indirectly, through pollination "services" provided to a range of introduced crops. In the absence of alternative means of pollination, the value of these services has been estimated at upwards of $AUD5-6bn per year

In recent years the critical importance of the honey bee has been brought into sharper focus by awareness of threats affecting honey bee populations globally, and in particular by the risk posed by the Varroa mite (*Varroa destructor*), which is currently not present in Australia. Australia maintains strict border quarantine protocols against Varroa (and other threats to honey bees), but it is generally accepted that the mite will enter and establish in the country at some point. Further, importation of genetic material from overseas populations is very limited, again reflecting the quarantine protocols.

A further challenge is the highly variable nature of the Australian climate, with frequent droughts impacting production, and making performance recording across time challenging.

Despite these contributions and recognition of threats, there have been limited systematic wide-scale attempts at genetic improvement of the population. There have been studies outlining scope for improvement via selection and estimating potential value of such improvement (Oldroyd, 1984, Banks *et al*, 2020). It has become apparent that this situation likely reflects, firstly, very limited performance recording, meaning that queens are marketed primarily on the

reputation of the breeder, and secondly (and essentially the flipside of the same issue) no real incentive for queen breeders to invest time and effort in such recording.
Together, these facts mean that the industry has little or no awareness of objectively described differences in genetic merit and what they mean for honey production and/or pollination economics, and extremely limited datasets. While genetic improvement focussed on honey production and health traits would deliver private benefits, there is clear evidence of a market failure in their delivery, and a strong case for government and industry intervention.
A recent response to this risky situation has developed through two investment steps:

- Establishment of a research honey bee population at Tocal College, a research and outreach centre of the NSW Department of Primary Industries, with capacity to manage upwards of 250 hives/colonies for phenotyping at any one time;
- Support for a collaborative R&D program known as Plan Bee, which aims to build on the infrastructure establishment of the facility at Tocal.

This paper outlines how these responses establish a platform for industry-wide implementation of genomic selection, and the opportunities that would present.

Key Elements of Plan Bee

As noted above, systematic performance recording in honey bees is very limited in Australia, with essentially three sustained programs of any scale. These three programs have provided queens to the research facility at Tocal College, augmented by sampling from a range of smaller queen breeding operations across Australia, to establish initial samples of c. 250 queens. These queens have been introduced to hives, and detailed recording of performance, including weight of honey produced, temperament, and health traits, has commenced, along with sampling for genotyping.
Alongside, and complementing this core activity, are:

- Widespread industry consultation to establish a Data Definition Manual (Chapman and Frost, 2021)– describing and defining traits which could be recorded
- Development of an industry database and procedures for analysis of data collected to produce estimates of genetic merit
- A strong engagement effort to encourage performance recording and submission of data to the industry database, and
- Careful data collection focussed on pollination activities in conjunction with key providers and users of pollination services

The target outcomes of the first, current phase of Plan Bee activity include:

- The trait definition manual (Chapman and Frost, 2021)
- Extension materials for performance recording
- Extension materials on genetic information and principles of genetic improvement
- Objectively evaluated queens, as potential sources of genetic material for industry
- The initial core of a genomic reference population, incorporating queens sampled at Tocal along with queens managed by industry queen breeders
- Initial models for wider industry participation in recording and utilisation of evaluated genetic material, including industry consultation around feasibility, practicality etc.

While there is much to be done in development of these models, the combination of a sound reference population with large-scale multiplication of elite material provides scope for relatively rapid industry change and return on industry and government co-investment. In this sense the timing of this initiative in terms of availability of genomic technologies, coupled with

the inherent reproductive capacity of honey bees and use of techniques such as AI, is extremely serendipitous (and change may be less limited by the need to achieve very widespread performance recording).
Current funding has a limited term, but it is anticipated that momentum from early progress will underpin continued co-investment by industry and government to maintain a program.

Potential impacts of a successful Plan Bee

Plan Bee has the potential to transform the Australian honey bee industry and community, through a range of important outcomes.
The scope for direct utilisation of elite genetic material is essentially unlimited, and is already being taken up. Backed by strong communication around the expected differences in hive performance, and the value of performance data, it is expected that this access could rapidly lift the performance of hives on a wide scale, which in turn should strengthen already widespread community interest in bees and beekeeping, and stimulate increased data collection. The awareness of how widely people can contribute to "helping our bees" should develop a sense of community responsibility and opportunity.
At the professional level, the scope for accessing elite material can establish the basis of a more certain business model for queen breeders, multipliers and providers of pollination services. In this context, strong extension of the concept of genetic merit and how to use objective estimates of it, will be fundamental.
Together, these point to a much more engaged and integrated industry and beekeeping community, which is in itself valuable.
Earlier studies have suggested ample scope for genetic improvement in honey bees in Australia, and there is no reason why this cannot be realised given a sufficiently large recorded population and use of sound genetic analysis. The most challenging aspect of this outcome will be to develop methods to mitigate risks around Varroa. Plan Bee data recording will include hygienic tests, but the opportunity will also exist to collaborate with research and industry in other countries to screen genomic variation in the Australian population against reference datasets that include survival and performance in the presence of Varroa. Should Varroa enter Australia, the infrastructure of a well-recorded and genomically characterised population should enable a more rapid response. In this context, it is valuable that a small importation of Varroa-resistant genetic material has been sampled for inclusion in the first-year intake for Plan Bee.
The wide sampling of the Australian honey bee population already underway, coupled with genotyping of all sampled material, will provide a basis for immediate implementation of selection using genomic information to maintain diversity. Previous work suggests the existence of diversity at specific loci and between small samples of the population, but establishing as wide a sample base of the population as possible will maximise capacity to maintain genetic progress in the absence of importation from overseas.
While the model for an ongoing program is to be developed, initial modelling suggests (Banks *et al*, 2021) that a program centred on recording and genotyping of c. 2,000 queens per year, can generate valuable progress and be attractive economically, simply based on increased honey production. The modelling assumed ongoing national costs (database and analysis, extension

and communication), but there is scope to develop approaches that combine collective (government and/or industry) and private contributions. Such models will need to incorporate suitable forms of participation or membership, with a wide range of options potentially available.

Collaboration with overseas programs has been flagged earlier in the context of Varroa, but more generally, having a sound and broadly based recording and evaluation program in place in Australia will greatly enhance scope for international collaboration, both in breeding and more broadly in R&D. In particular, understanding of genomic relatedness between countries' populations may enable a more nuanced approach to import and export of genetic material, which could benefit both Australia and international partners.

Conclusions

Plan Bee offers, and is already starting to deliver, a unique opportunity for transformation in the Australian honey bee industry. This transformation can include wide involvement and participation, very valuable genetic progress, and massive reduction of production and disease risk.

While this is obviously exciting for Australia and its own honey bee industry, there may be valuable outcomes for other countries, and at the same time, a model of industry transformation focussed on genomic selection underpinned by mixed (ie public and private) investment and strong industry and community engagement. This may provide learnings useful to other industries in both the "developed" and "developing" countries (Marshall et al, 2019).

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