DairyBio DairyFeedbase

Annual progress report

2019–20

AGRICULTURE VICTORIA Dairy Australia GARDINER FOUNDATION


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Chair's review

The 2019–20 year has been a year of significant progress for both DairyBio and DairyFeedbase. DairyBio completed its fourth year of operations and has strengthened the technology platforms that are key to delivering high-value outcomes for industry. DairyFeedbase completed its second full year and is developing and delivering transformational innovation from its five key projects.

The value of operating at scale in both bioscience (DairyBio) and agronomy/nutrition (DairyFeedbase) is significantly improving the outcomes in each initiative. This allows for the seamless movement of technology, staff, and delivered products. For example, the progress made in measurements of plants in breeding fields is proving to be essential for addressing core challenges in measuring pasture performance in both variety trials and commercial dairy paddocks.

Governance arrangements in DairyBio and DairyFeedbase are working well, with a common Board and management. Our focus as a Board is to deliver on the outcome objectives for both initiatives.

A feature of DairyBio and DairyFeedbase is the strong support of project partners who are investing for both commercial and industry-good outcomes. There continues to be opportunities to fund additional well-established projects within both programs where further investment can leverage existing successes. The project partners bring both essential experience and know-how as well as the ability to generate widespread adoption of project outcomes.

There has been continued focus on the F1 Hybrid program ramping up activities on short-term ryegrass and development of seed production protocols. Plans are well underway for a DairyBio 2021–26 forage and animal program.

Pasture Smarts' within DairyFeedbase has been working with six commercial farmers on developing an exciting commercial prototype to develop an automated pasture measurement technology which is planned to be launched commercially to farmers next year.

The single biggest risk and challenge in 2020 has been the COVID-19 pandemic. Plans were developed to deliver the core outputs of DairyBio and DairyFeedbase while being able to comply with social distance restrictions to keep people safe, and not compromise valuable materials, animal health and welfare, infrastructure and capability. Several projects requiring on field functions and on farm experiments have needed to be rescheduled however this should not impact delivery.

Both DairyBio and DairyFeedbase will continue to face restrictions and uncertainty over the 2020–21 year due to the COVID-19 pandemic.

The run of challenges for industry, from feed shortages through to COVID-19, has reinforced the importance of the dairy supply chain to the wider community and the need to adopt a whole of industry strategy guided by the Australian Dairy Plan. Research and innovation will continue to be a major contributor to the competitiveness of the Australian dairy industry.

I would like to acknowledge the strength of the joint venture model that is based on the ongoing commitment of Agriculture Victoria, Dairy Australia and the Gardiner Foundation to lead and invest in world-class innovation initiatives.

During the 2019–20 period there were some changes on the Board. We would like to thank and acknowledge the outstanding contribution Mary Corbett made to the DairyBio and DairyFeedbase Boards since their inception (Mary opted to not extend her term in December). The Board welcomed Robert Cooper to the Board and looks forward to his contribution.

In summary, it has been a year of strong performance and has included increased strategic focus, delivery and achievement of key milestones within projects. The ongoing difficult conditions being experienced in the dairy industry continue to highlight the critical importance of delivering new innovations to support a sustainable Australian dairy industry into the future.

I would like to recognise the contribution and performance of the Co-Directors – Mr Kevin Argyle and Prof. Ben Cocks, the Project Leaders and the contributions from fellow Directors.

Peter Reading Chair

Co-directors' review

The DairyBio and DairyFeedbase initiatives are on track to generate far-reaching and positive impacts for the dairy industry.

DairyBio is on target to deliver by 2030 an improvement in pasture productivity of $800 per hectare per year, with a concurrent target to improve animal productivity by $350 per cow per year. DairyFeedbase is on target to significantly improve pasture productivity and utilisation and improve animal productivity by $100 million per annum within 10 years. This scale of impact is major and will be required for the dairy industry to remain strong and better handle diverse challenges over the next two decades and beyond.

As in many parts of industry and the economy, DairyBio and DairyFeedbase faced restrictions and uncertainty due to the COVID-19 pandemic and the required industry and government response. From March to June 2020 plans were enacted to continue to deliver the core outputs of the programs while complying with social distancing restrictions. A number of project developments requiring lab, glasshouse, and field functions have had schedules adapted that enable project progress.

DairyBio

Two critical innovations in forages were put into practice with commercial partners – genomic selection and hybrid breeding. These technologies deliver improved yields of pasture between 10% to over 20%. Genomic selection in ryegrass is delivering a significant boost to genetic gain (3-5 times) and is now implemented in commercial breeding programs. The work has demonstrated the power of these technologies with significant gains in yield obtained in commercial breeding operations and gives confidence to all investors that the projects are on track to deliver forecasted impact with new cultivars to be released by the Barenbrug Group.

F1 Hybrid parental pool development has presented some challenges and the Operating Plan for 2020–21 provides for a shared responsibility between the parties to deliver more than enough diversity in crosses to develop an outstanding product. Based on this success with ryegrass and broader Australian industry requirements, a focus on short term ryegrass F1 Hybrid development continues.

Great progress has been made on de-risking doubled haploid and editing approaches for improved forage quality with generation of the world's first gene edited ryegrass plants.

Animal improvement impacts are on track – economic analysis on farm has demonstrated that genomic technology tools already provide significant benefits. In a breakthrough, milk mid-infrared (MIR) data has been shown to predict the probability of pregnancy to first insemination as a tool to help manage individual cow fertility.

There has been significant progress in adoption of research outputs working closely with DataGene who have introduced eight new or revised ABV from DairyBio with their improved genetic evaluation service. Heat tolerance is now an established trait, and genomic calving ease and gestation length traits have been implemented and available to farmers. Mastitis resistance ABV has been introduced for the first time using a model that combines clinical disease records, somatic cell count and udder depth.

Milestone-based measurement of performance continues to drive delivery with 37 of 44 milestones achieved in DairyBio in 2019–20, with components discontinued where challenged due to biological processes, and progress accelerated in other areas.

Significant progress has been made in generating and using big data effectively across the Animal and forage programs with investments and innovations in computation and modelling.

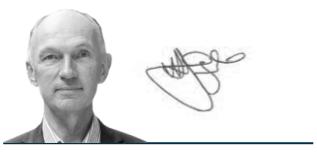
DairyFeedbase

All five projects have achieved planned milestones and delivered a range of exciting new innovations.

Pasture Smarts' automation technology commercial path to market is progressing for delivery to farmers in 2021. Smart Feeding has developed insights into the different feed on offer to the first and last cows returning to the paddock to graze. First 100 Days has found through innovative feeding a bankable opportunity. A heat stress risk assessment tool has been developed within Cool Cows. The 2020 Forage Value Index (FVI) tables have been updated and a protocol for non-destructive pasture assessment has been published

33 of 38 milestones were achieved in DairyFeedbase. For the milestones not achieved, five milestones have short term delays which are contained and do not affect subsequent project milestones or outcomes.

We would like to recognise the important contributions of the Board over the past year. Their insightful governance is critical for the programs and to the benefit of industry, project partners, and management. All of the projects are complex and require quality governance, management, science, research and innovation and we thank all the project leaders and their respective teams for their contribution. We also thank our collaboration and industry partners.



Kevin Argyle Co-Director

Ben Cocks Co-Director

Dairy's innovation framework

DairyBio and DairyFeedbase collaborative research projects are working together to deliver for Australian dairy farmers a more productive, resilient and nutritious feedbase and greater cow health, fertility, efficiency and longevity outcomes, and the right tools to manage both. This step-change innovation will lead to higher farm income, improved sustainability and improved animal welfare – all vital for the vibrant future of the dairy industry.

DairyBio and DairyFeedbase are joint ventures of Dairy Australia, Agriculture Victoria and the Gardiner Foundation who each invest in dairy research and innovation to deliver transformational herd and forage productivity gains for Australian dairy farmers.

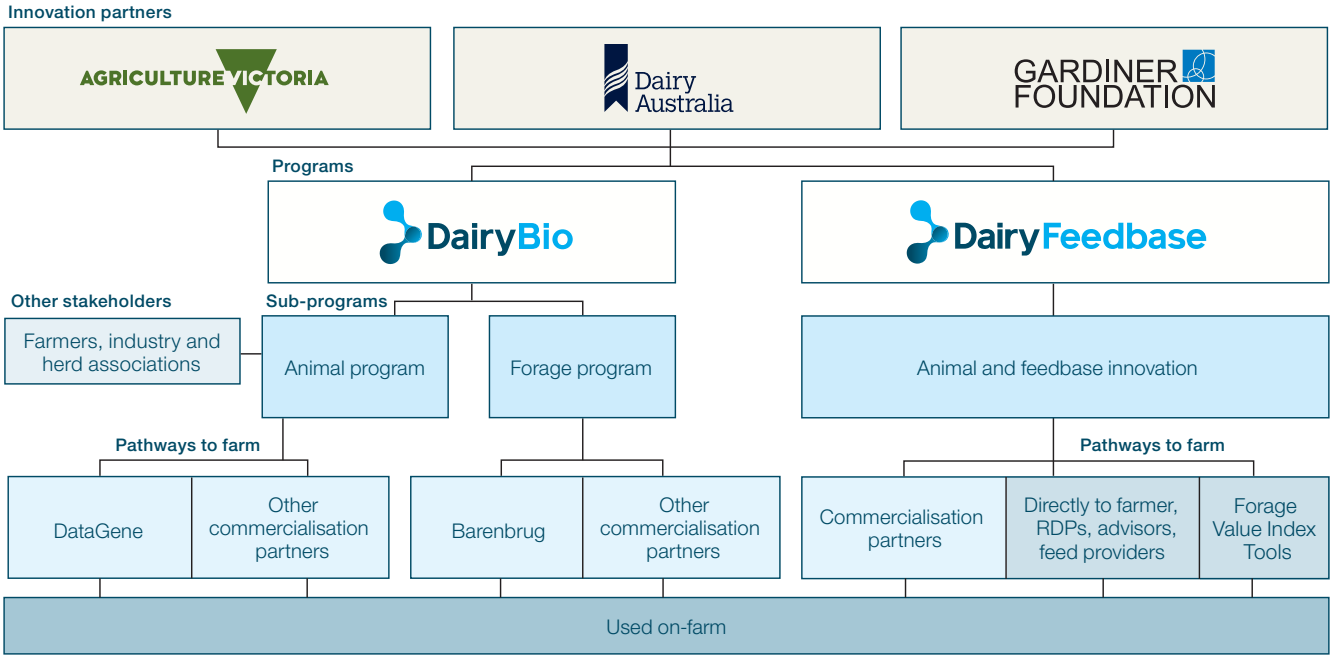
The diagram below shows the main links program outputs have to farmers. DataGene, seed companies and other companies also invest and codesign R&D in DairyBio on a project by project basis.

Launched in 2016 the DairyBio program is based at the AgriBio – the Centre for AgriBioscience facility at Bundoora on the outskirts of Melbourne. DairyBio is focused on creating improved pastures and herd improvement for the Australian dairy industry through the latest approaches in bioscience. DairyBio has International collaboration agreements with universities, industry and farmer organisations. To enable the DairyBio projects to get the innovation on farm they partner with organisations such as DataGene and Barenbrug and other investors.

DairyFeedbase focuses on applied research to gain individual cow, herd feeding and forage productivity improvements. These projects are mainly based at Agriculture Victoria's Ellinbank and Hamilton research farms where the research is conducted on the commercial dairy farm and large-scale pasture plots.

The DairyFeedbase projects are only 21 months into a six-year program. The most significant route to farm is through the Dairy Australia regional extension and service advisor networks and commercial agreements are being put in place where required to take innovation to farmers.

Dairy's innovation framework



Joint venture partners comments

Australian dairy farmers produce milk that is world-class in terms of its quality, its food safety and its provenance.

The current levels of profitability for milk production are not sustainable and have to improve. Successful innovations that improve the core drivers of productivity on farm are critical – growing and utilising more pasture, increasing the quality of cow diets, improving animal performance with a particular focus on fertility and health, and making operational decisions easier with management data and better forecasting.

DairyBio and DairyFeedbase are major investments for Dairy Australia, demonstrating a commitment to critically important innovation that is shared with Agriculture Victoria and Gardiner Foundation, with commercial and academic partners, and with the talented people in the science and innovation community.

DairyBio and DairyFeedbase are 'innovation magnets' on a global scale. This includes attracting investment to create large innovation projects as well as key linkages to commercial markets. This unlocks funding and resources that would otherwise not or only partly be available for the dairy industry.

Dairy Australia investment of farmer levies and matching funds from the Commonwealth Government is a core element of these innovation initiatives. Investment in research is by its nature risky and uncertain, and the ability to operate at this scale and level of inter-connectedness with the commercial sector is critical for success.

The track record of success in dairy bioscience is a feature of this investment partnership, and further demonstration of this success with improved cattle, new pasture varieties, and new farm management practices is now a priority.

Dr. David Nation
Managing Director
Dairy Australia

Dairy is vital to regional Victoria. Victoria's dairy sector is valued at over $2.76 billion annually, including $2.16 billion in export value. The sector is underpinned by more than 3,500 farm businesses and employs around 28,900 people through the supply chain. These businesses depend on research and innovation to remain productive and globally competitive.

Agriculture Victoria leads the nation in dairy research and innovation as part of the National Primary Industries Research, Development and Extension Framework. Pasture and herds are the key drivers of profitability for the dairy industry. Through DairyBio and DairyFeedbase, Agriculture Victoria undertakes innovation in transformational genetics in pastures and cows, and in the feedbase for the dairy industry. These innovations deliver accelerated precision breeding, tripling progress in pasture breeding and increasing genetic gain in dairy herds. The research programs are co-designed, co-developed and co-delivered with industry and other agri-business partners to maximise the uptake of new technologies.

The Dairy Innovation Precinct in Ellinbank is a leading national site delivering critical productivity research and innovation outcomes for the dairy industry. The precinct is also home to Agriculture Victoria's dairy SmartFarm, which demonstrates future-oriented dairy science and technology, increasing adoption of innovations on dairy farm businesses and supporting PhD students to become the passionate and talented knowledge workforce of the future for the dairy industry.

Collaborative research and innovation underpin the dairy industry and the rural communities that depend on a thriving food and agriculture industry for employment and economic prosperity in their regions.

Professor German Spangenberg FTSE PSM
Head Agriculture Victoria Research, Agriculture Victoria

Lifting the profitability of dairy farms is fundamental to a confident and growing dairy industry. Decreasing the cost of production and making complex farm management decisions easier and more reliable are keys to rapid and long lasting lifts in farm profitability and production. This is where the DairyBio and DairyFeedbase initiatives come to the fore. Both initiatives are using recognised world class scientists and technologies to make step changes in pasture and animal genetics, as well as the ease and accuracy of on-farm production and management information.

Plus, both DairyBio and DairyFeedbase have well established collaborations with commercial and industry service organisations to get the results of research rapidly and routinely into the hands of farmers.

Gardiner Dairy Foundation's purpose is to invest funds to maximise benefits to all sectors of the Victorian dairy industry and dairy communities. As part of achieving our purpose we invest in RD&E for the development and application of innovations to improve the profitability, sustainability and growth of Victoria's dairy industry, with a focus upon a small number of large investments in strategically important priorities.

DairyBio and DairyFeedbase are a perfect fit and are already delivering benefits to our dairy farmers, with many more to come.

Dr Clive Noble
Chief Executive Officer
Gardiner Foundation

DairyBio profile

DairyBio animal program

The DairyBio Animal Program is targeting an additional value of $350 per cow per year in Australian dairy herds by 2030 through genetic improvement, lower costs by enabling selection for health traits and developing improved breeding management tools. Genetic improvement for traits associated with cow health, fertility, efficiency and longevity will lead to greater farm income and improved sustainability and animal welfare, all are vital for a vibrant future of the dairy industry.

Economic analysis on farm has demonstrated that the genomic technology tools provided by DairyBio offer significant benefits and with the planned further improvements is on track to deliver our target of $350 per cow per year.

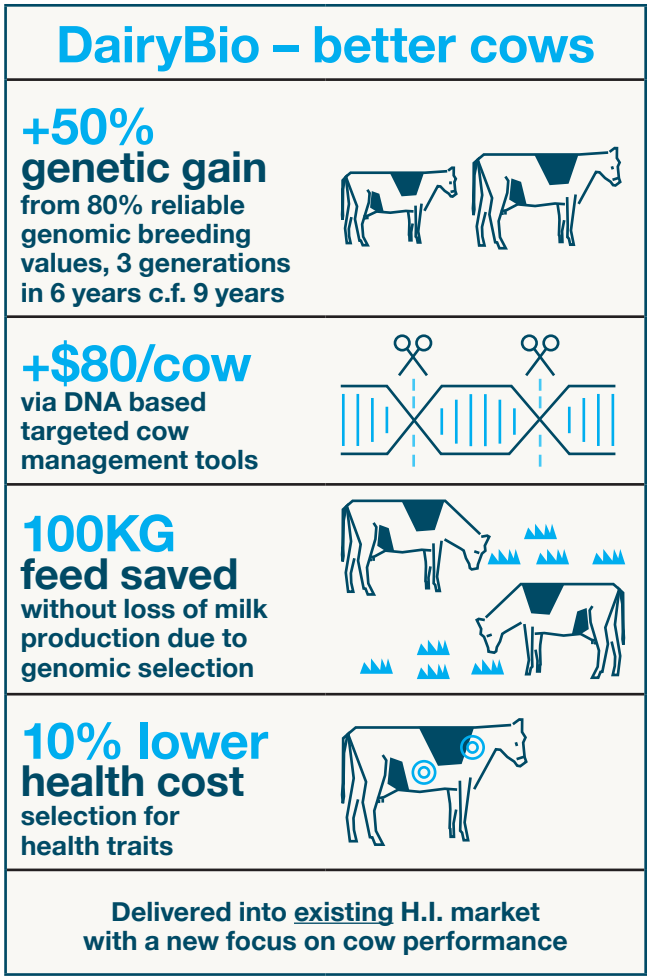
In a significant breakthrough, milk mid-infrared (MIR) data has been shown to reliably predict individual fertility of high and low fertility cows and in 2020–21 we plan a trial of a new type of management product with commercial partner DataGene.

There has also been progress in the adoption of the eight latest new or revised ABVs from DairyBio research with DataGene using their improved genetic evaluation service. Heat tolerance is now an established trait, and since April 2020, genomic calving ease and gestation length traits have been implemented and available to farmers.

Mastitis resistance has been introduced for the first time also in April 2020 using a model that combines clinical disease records, somatic cell count and udder depth. Improvements to established traits and breeding values have been delivered and progress on crossbreed breeding values is being made leveraging international partnerships to achieve progress.

Key achievements

- **Delivery to market of new ABVs such as mastitis resistance, genomic calving ease, gestation length, and improvements to existing breeding values such as conformation traits.**
- **A method to predict the fertility of cows using early herd-test data including mid-infrared spectroscopy.**
- **New methods under development for genomic selection of cattle on an across-breed basis.**
- **Commercial data that clearly demonstrates the value of genetic improvement and herd testing.**
- **Expanded datasets and computational approaches improving accuracy of genomic prediction for a range of traits.**
- **On track to deliver impact on dairy profitability $350 per cow per year.**
- **Eight PhD candidates, one awaiting thesis review and 4 visiting PhD and Masters students.**



DairyBio forage program

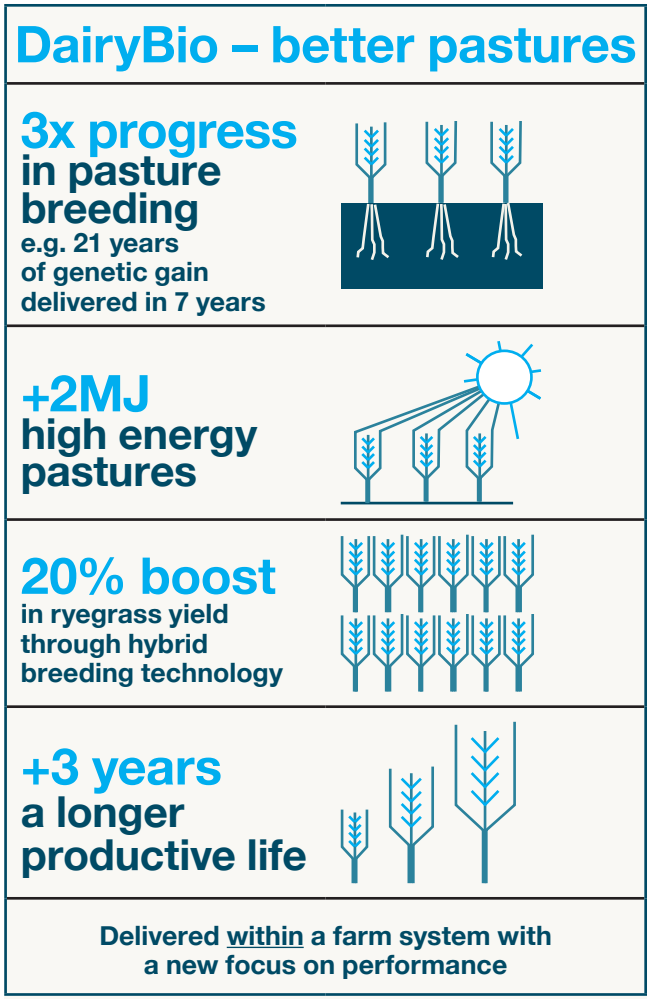
The DairyBio forage program projects are developing technologies and capabilities that will transform commercial breeding of pasture plants, generating plants with higher yield, higher energy and higher persistence. From an independent analysis of the achieved technology that DairyBio is delivering the benefit on farm is expected to be $800 per hectare per year. The DairyBio forage program focuses on three key areas of pasture performance – yield, persistence and quality.

Two critical innovations in forages that have been implemented with commercial partners include genomic selection and hybrid breeding. These technologies deliver improved yields of pasture of over 20% with hybrids whilst genomic selection in ryegrass is delivering a significant boost to genetic gain (3-5X) and is now powering commercial breeding programs.

These technologies have allowed significant gains in yield obtained in commercial breeding operations and gives confidence to all investors that the projects are on track to deliver forecast impact with new cultivars to be released by the Barenbrug Group.

Key achievements

- **Transformation of the pasture commercial breeding sector through implementation of genomic selection into the Barenbrug Agriseeds breeding program for four successive years of breeding with outstanding results.**
- **Validation of F1 Hybrid breeding technology in short term ryegrass and generation of F1 Hybrid experimental varieties for testing.**
- **Demonstration of F1 Hybrid boost in variety performance trials in both Australia and New Zealand confirming expected levels of heterosis and anticipated elite performance.**
- **Creation of the first genome edited ryegrass plants with improved quality traits being crossed into elite germplasm.**
- **New prospective technology applications in other forage species including microbiome and other species.**
- **Breakthroughs in high throughput phenomics for pasture plants, endophytes and animals facilitating a new wave of innovation.**
- **Nine PhD students, with two awaiting thesis reviews.**



Project status and snapshots

ANIMAL PROJECT 1

Enabling multiple generations of highly reliable genomic selection to accelerate genetic gain in dairy cattle

OVERVIEW

Status Ongoing

Expenditure $1.9 million

Purpose

This project is designed to underpin all the animal improvement projects and increase genetic gain in the Australian dairy industry by 50% for traits that contribute to profit, over and above what can be achieved with genomic estimated breeding values (GEBV) delivered in previous programs.

Key achievements

- Effective use and impact for trait improvement validating advanced genomics provided.
- Ongoing genotyping of Ginfo cows using a new SNP chip (XT-custom SNP panel) that includes SNPs that have been found to be more predictive of performance in Australian conditions than current industry chips. The newest iteration of the XT SNP chip has increased genomic prediction accuracy in animals less related to the reference population (Jersey, Aussie Reds, crossbreds).
- Run 7 of the 1000 Bull Genomes project has genomes from 4000 cattle and is the dataset that DairyBio and 40 partner institutions rely on to capture global cattle genetic variation for downstream analyses and improved selection.
- The inventory of 32 million high quality DNA variants imputed into 200,000 dairy cattle (new Reference Genome) has improved the quality of imputed sequence (an extra 15% of variants in high imputation accuracy category >0.8).
- DairyBio hosted a workshop on 'implementation of genomic prediction in crossbreds'. Due to COVID-19 restrictions, the workshop was convened as a virtual meeting with ~20 participants: including academic and industry experts from New Zealand, Netherlands, Victoria, New South Wales and Queensland.

Current activities

- Run 8 of the 1000 Bull Genomes project will include over 5500 cattle and have substantial increases in Oceania relevant breeds: Jersey (+70), Crossbred Holstein-Jersey (+40) and Scandinavian Reds (+370).
- Genomic selection on an across-breeds basis and for crossbred cows and bulls. The solutions being investigated are ambitious and complex.
- A plan to evaluate implementing prioritised SNP and new variants in a multi-breed genomic evaluation with DataGene.

ANIMAL PROJECT 2

At the cutting edge: World leading breeding values and genomic services for the Australian dairy industry

OVERVIEW

Status Ongoing

Expenditure $0.8 million

Purpose

This project supports the implementation of key innovations, maintaining and improving existing services and reduces cost and increases access to major components of genetic evaluation (such as cow genotyping).

Key achievements

- Delivery to market of new traits such as genomic calving ease, gestation length, and improvements to existing breeding values such as conformation traits.
- Genomic prediction of production and cell count in red breeds using a multi-breed genomic reference population.

Current activities

- Update of the Feed Saved ABV using feed efficiency data from Australia, North America and Europe.
- The use of intermediate phenotypes, such as MIR to improve the genomic prediction accuracy of fertility.
- Exploring inbreeding trends in Ginfo and national herd since the introduction of genomic selection.

ANIMAL PROJECT 3

Accelerating improvement in health and resilience and reducing the environmental impact of the Australian dairy herd

OVERVIEW

Status Ongoing

Expenditure $0.4 million

Purpose

The project will develop breeding values for new functional traits, especially traits associated with health and resilience, to enable improvement in these traits, and to lower health costs by 10% and to reduce labour costs associated with dairy cow health. It is anticipated that the new traits will contribute to an increase in genetic gain of up to 5% increase in profit.

Key achievements

- Some serum metabolites indicative of early lactation disease are heritable.
- Preliminary accuracies of genomic prediction of early lactation disease.
- Contributed individual cow feed efficiency and methane data to an international repository.

Current activities

- Assess accuracy of genomic prediction of early lactation disease traits using measured data in addition to MIR predictions.
- Collaboration with USA, Canada and several European countries to evaluate the accuracy of genomic prediction of methane emissions phenotypes.
- Options for reducing greenhouse gases using genetic selection under investigation

ANIMAL PROJECT 4

Massive throughput phenotyping for complex traits in dairy cattle

OVERVIEW

Status Ongoing

Expenditure $0.9 million

Purpose

Oversight of existing projects (Improving Herds and MIR for Profit) with a focus on planning future activities.

Key achievements

- MIR prediction of probability of conception in high and low fertility cows.
- MIR prediction of metabolites indicative of early lactation disease.
- Collection of lameness scores at the same time as herd-testing and MIR prediction of these scores.

Current activities

- Refine MIR prediction of fertility and support for field trials conducted by DataGene.
- Detailed analysis of high and low fertility cows.

ANIMAL PROJECT 5

CRV collaboration project

OVERVIEW

Status Ongoing

Expenditure Integrated into Project 1

Purpose

The aim of this project is to deliver a range of outcomes of mutual interest with CRV.

Key achievements

- The shared cow reference population has increased to a total of 52,000 CRV-NZ cows and 78,000 AU cows.
- All CRV cow XT-10K genotypes imputed to 32 million sequence variants.
- Investigation of several methods for crossbred genomic prediction, including proportional use of purebred predictions for crossbreds based on their breed composition.

Current activities

- This research will build on research of the value of joint reference populations for core traits.
- Consultation with CRV to decide on research in final year of DairyBio that would support their implementation of crossbred genomic predictions using a multi-breed reference population.

ANIMAL PROJECT 6

Improved prediction of the daughter fertility breeding value

OVERVIEW

Status Ongoing

Expenditure $0.15 million

Purpose

The aim of this project is to develop and deliver the next generation fertility ABVs. This will be achieved through extensive use of MIR defined predictor traits, advanced phenotyping (using sensor technology etc) and genes identified to explain some of the genetic variation in fertility to deliver a biologically more precise genomic breeding value of fertility.

Key achievements

- Developed a method to identify herds that use synchronization of AI, the approach uses the observed cows mated on a given day versus the expected cows mated.

Current activities

- Genomic analysis of high and low genetic lines for fertility.
- To evaluate whether MIR can enhance the prediction accuracy of fertility ABVs.

FORAGE PROJECT 1

Integrative genomics-assisted F1 Hybrid breeding of perennial ryegrass-endophyte symbiota for pasture improvement

OVERVIEW

Status Ongoing

Expenditure $5.2 million

Purpose

This project aims to develop a novel F1 Hybrid breeding system for perennial ryegrass and a suite of accompanying technologies. Genomic selection will triple the rate of genetic gain in commercial breeding programs.

Key achievements

- F1 Hybrids from initial experimental parental pools already delivered are still outperforming current advanced commercial varieties.
- Field data has now been generated from a range of target environments in Australia and New Zealand and the benefit of heterosis from the F1 Hybrids have been widely seen, with some variation in ranking between the varieties.
- The commercial partner has extended the replacement of steps within their breeding program to remove three years by designing crosses for new varieties even earlier using genomics.

Future activities

- Field trials will be established for a total of 22 new F1 experimental varieties in Australia and New Zealand.
- Additional F1 experimental varieties will be generated and delivered for field evaluation.
- Cohorts of initial parental pools will be delivered that have next-generation endophytes inoculated into.
- Hand-over of seed from all sub-selected populations to the commercial partner will conclude the initial phase of rapid genomic sub-selection.

FORAGE PROJECT 2

Endophyte technologies for pasture improvement

OVERVIEW

Status Ongoing

Expenditure $0.8 million

Purpose

To deliver current and future ryegrass cultivars with a compatible endophyte that will improve and protect the plants' performance including an additional three years productive life through the informed delivery of optimal endophytes to provide optimal insect protection, while not being detrimental to dairy productivity.

Key achievements

- Tools and technologies that can non-destructively detect and evaluate endophyte in seed through the application of phenomics have been developed.

Future activities

- Through insect bioassays, the quantification of optimal toxin profiles for maximum insect protection with minimal animal detriment are being identified.
- The next generation of advanced ryegrass endophyte combinations will have specific toxin profiles suitable for use in dairy farming systems.

FORAGE PROJECT 3

This project will migrate and validate the F1 Hybrid breeding scheme into short-term ryegrass

OVERVIEW

Status Ongoing

Expenditure $0.5 million

Purpose

This project supports the implementation of key innovations, maintaining and improving existing services and reduces cost and increases access to major components of genetic evaluation (such as cow genotyping).

Key achievements

- Transfer of F1 Hybrid breeding technology into the species from perennial ryegrass.
- Initiation of an additional 10 parental pools to significantly expand the possible F1 experimental varieties that could be taken to market.

Future activities

- Parental pools for F1 Hybrid production will be generated from a range of current and future cultivars selected by commercial partners.

FORAGE PROJECT 4

Increased digestibility and productivity through EXZACT genome editing and development of F1 Hybrid breeding for tall fescue (Discontinued)

OVERVIEW

Status Discontinued

Expenditure $0 million

Purpose

This project has been discontinued and the avenues now being pursued to improve forage quality in tall fescue is through Project 5 with a focus on generating a haploid-inducing plant genotype for producing doubled haploid tall fescue plants.

FORAGE PROJECT 5

Efficient targeted gene editing in Lolium and Festuca spp

OVERVIEW

Status Ongoing

Expenditure $0.4 million

Purpose

To deliver new tools for accelerated precision breeding in forage grasses. Success will create opportunities for new breeding methods to rapidly introduce new traits into existing elite breeding lines (of the same species, and possibly also across the entire Lolium genus).

Key achievements

- Recovery and molecular characterisation of gene edited events is well advanced.

Future activities

- Sequence characterisation of the induced mutations in the targeted native genes of these events is required to determine if they have the expected genotype.

FORAGE PROJECT 6

Exploiting the Lolium microbiome to enhance performance of pasture and turf temperate grasses

OVERVIEW

Status Ongoing

Expenditure $0.4 million

Purpose

The project aims to harness the power of microbes, other than *Epichloë* endophytes, to enhance the performance of pasture grasses. The target discovery and application species belong to the genus Lolium – namely, perennial ryegrass (L. *perenne*) and tall fescue (L. *arundinaceum*); the most important temperate grasses of global pastoral agriculture.

Key achievements

- Identification and characterisation of microbes that have beneficial traits, such as biofertigant or bioprotectant.

Future activities

- Extension of knowledge of novel microbes and continued interaction with commercial partners to deliver benefit on farm.

FORAGE PROJECT 7

Field evaluation of high energy transgenic perennial ryegrass in Argentina

OVERVIEW

Status Ongoing

Expenditure $0.3 million

Purpose

This project is focused on undertaking seed multiplication and grazing trials of elite high energy ryegrass transgenic events introgressed into commercially relevant ryegrass cultivar backgrounds. The initial phase of the project will occur in Argentina via a collaboration with the University of Buenos Aires, which will undertake field trials under a dairy grazing regime with sheep and cattle.

Key achievements

- All transgene tracking and tracing requirements for safe evaluation of the GM crop achieved.
- GM seeds that have a relevant elite commercial background generated and supplied to the University of Buenos Aires for multiplication and animal feeding trials.

Future activities

- Conclusion of animal performance trials.

DairyBio financial position 2019–20

Cash position	
Opening balance	$1,606,477
Income received	$9,977,250
Expenditure	$12,375,746
Closing balance at 30 June 2020	**-$792,019**

Expenditure	
Forage improvement projects	$7,784,979
Animal improvement projects	$4,290,233
Education and management activities	$300,534
Total expenditure	**$12,375,746**

Notes on the financial position

- Financial position is reported on a cash basis.
- 2019–20 DairyBio had an income of $12,300,000 with an invoice of $2,322,750 paid in 2020–21.
- A five-year cash position analysis is routinely provided to the board to ensure that the joint venture remains in a positive cash position.

BARENBRUG

Barenbrug chooses to work with DairyBio as our main provider of future focused pasture research and technology. The Barenbrug/DairyBio partnership is focused on improving pasture breeding systems which lead to products that will provide maximum benefit on farm. Continual improvement through adoption of pasture development technology is a core focus at Barenbrug and the reason for choosing to work with DairyBio as a long-term research partner.

DairyBio has world class people, facilities, and technology which we believe gives Barenbrug the best opportunity to supply farmers with pasture solutions that add value on farm.

As a breeder and supplier of premium pasture species globally having a research partnership with the scale and expertise of DairyBio at the beginning of the development process helps to ensure that we continue to innovate while developing improved pastures.

The research and development work undertaken at DairyBio should give farmers confidence to choose the latest cultivars on farm and reap the benefits of Barenbrug's investment in research and development in their own seed investments.

Courtney Inch
Research and Development Manager
Barenbrug Agriseeds

Commercialisation activities (2019–20)

Forage Projects – F1 Hybrid perennial ryegrass and short-term ryegrass

- In collaboration with the commercial partner of DairyBio forage project one (1), the Royal Barenbrug Group, commercialisation agent Agriculture Victoria Services Pty Ltd (AVS) with the DairyBio Management Committee (DBMC) has further developed and advanced a DairyBio forages commercialisation plan to deliver the world's first superior F1 Hybrid perennial ryegrass and short-term (Italian) ryegrass products with improved herbage yield in Australia and New Zealand.
- Following population field trials to identify heterotic groups in perennial ryegrass, parental pool combinations have been determined for test-crossing to generate the best commercial F1 Hybrid populations.
- An analogous commercialisation timeline for the delivery in Australia and New Zealand of elite new F1 Hybrids for short-term (Italian) ryegrass has also now been devised by DairyBio and Barenbrug.

Forage Projects – Genome edited perennial and short-term ryegrass

- The DairyBio forages commercialisation plan also contemplates the delivery of other DairyBio technologies in an integrative manner, including genomic selection and gene editing in the Barenbrug ryegrass and tall fescue genetics pipelines.
- AVS and Barenbrug have this year further advanced commercialisation planning for the evaluation and commercial release of future gene-edited, commercial perennial ryegrass events, based on Barenbrug's licence option rights to a non-exclusive licence for DairyBio genome edited perennial ryegrass events, specifically populations of perennial ryegrass, tall fescue and lucerne with gene edits of key lignification and/or pollen allergen genes.
- Licence option invocation rights have now been framed by AVS and Barenbrug and the parties have met to commence agreeing upon the terms of a Licence Agreement for the commercial release of novel ryegrass edited products, which will follow DairyBio's delivery of gene-edited ryegrass, tall fescue and lucerne populations.

Forage Projects – Beneficial *Lolium*-derived microbiomes

- DairyBio forage project six (6) has led to the discovery and characterisation of several novel Lolium-derived bacterial strains, for complementary industry and commercial benefits, to assist varietal development and seed production for global pasture, turf and lawn grass production (for improved production, environmental and amenity outcomes). In 2019–20, these strains were provisionally protected through IP filings.
- A Commercialisation (Agency) Agreement was signed by DJPR (Agriculture Victoria), Dairy Australia, Gardiner Foundation and AVS on 30 April 2019 to commercialise these project outputs. In alignment with the DairyBio Commercialisation Objectives and DairyBio forage project 6 Licence Rights Frameworks, this year AVS, with the DBMC, devised a Lolium-derived microbiome commercialisation plan for the full protection and commercialisation of DairyBio Lolium-derived microbiome IP assets, for delivering bioprotection, biofertiliser and biostimulant benefits in forage grasses in Australia and New Zealand via an evaluation and licence option agreement with a suitable commercial partner.

Forage Projects – High Energy Ryegrass

- In 2019–20 AVS actively monitored Material Transfer Agreement reporting obligations of the University of Buenos Aires (FAUBA) in the conduct of seed production activities, in advance of animal performance field trials of the technology to be conducted by FAUBA in Argentina in 2020–21 under a dairy grazing regime with sheep and cattle.
- This included a visit with FAUBA (University of Buenos Aires) in Argentina in November 2019, which determined that the FAUBA animal performance trial program for high-energy perennial ryegrass was progressing well, with seed multiplication for the 2020 trials now completed. It has since also been confirmed by FAUBA that COVID-19 is not likely to impact the FAUBA animal performance trial program, and that CONABIA has approved proceeding with animal grazing trials in 2020–21.

Animal Projects – Genomic selection

In alignment with the DairyBio Commercialisation Objectives, a commercialisation strategy has been devised by AVS with the DBMC to deliver a novel DairyBio animal project one (1) genomic selection methodology for the benefit of Australian dairy farmers. Preliminary economic modelling on the industry benefits and commercial value of the technology has been completed by AVS resulting in provisional DairyBio AP1 IP asset filings in 2019–20.

Animal Projects – Fertility Prediction

In alignment with the DairyBio commercialisation objectives, a commercialisation strategy has been devised by AVS with the DBMC to deliver a novel DairyBio forage project 4 fertility prediction technology for the benefit of Australian dairy farmers. Preliminary economic modelling on the industry benefits and commercial value of the novel fertility prediction technology has been completed by AVS, resulting in provisional DairyBio IP asset filings in 2019–20.

DairyFeedbase Pasture Smarts'

AVS is currently advancing the commercialisation strategy for the Pasture Smarts' automation technology consistent with the terms signed off by the DairyFeedbase board in May 2020 with expected delivery to farmers in 2021.

Genetic improvement

Imagine trying to feed the world on what a dairy cow produced 50 years ago – the milk yield per cow has doubled since 1970 in Australia and this would not be possible without animal breeding. Not only have our cows been bred to be more productive, they have become much more efficient in utilising the feed they have.

Under the leadership of Professor Jennie Pryce the DairyBio animal program is focused on driving productivity and profitability gains through genetic improvement, lowering costs by enabling selection for health traits and developing improved breeding management tools. DairyBio is on track to deliver an additional value of $350 per cow per year.

English sheep stud owner Robert Bakewell, who became the world's first "scientific breeder" 250 years ago by selecting parents to breed from according to observable characteristics, could have had no concept of the massive gains that have led from Gregor Mendels' genetics research using peas in 1865 to a facility like AgriBio in Melbourne where supercomputers crunch millions of calculations per minute across multiple machines and there is a library of the entire genomic sequence of over 200,000 cows and bulls (DairyBio animal project 1). That library contains details of genetic markers – the variation in the DNA that influences animal performance – and is used to identify the multiple markers (sometimes thousands) linked to a performance trait like fertility, heat tolerance and feed efficiency.

The large-scale step change innovation projects that the DairyBio animal program are conducting (see pages 8 and 9) are having an ongoing significant impact on productivity through greater accuracy of selection of breeding stock, reduction in generation intervals through genomic selection and driving the use of technology – like MIR – to make herd management decisions. Increasingly reliable genetic information also drives reliable management decisions as understanding your cows genetic makeup will make decisions about pasture, supplementary feed, infrastructure and culling more reliable.

Genomic Selection is the identification of superior genotypes (which dictate characteristics like body features, milk production and resistance to disease) to enable selection of the best parent to breed plants and animals from according to your objectives. It drives rapid genetic gain (improvement) by reducing the generation intervals by evaluating traits at an early age. The DairyBio forage program is also using this tool to successfully drive rapid improvement in pasture yield, persistence and quality.

Like Robert Bakewell the main objective of modern breeding programs is to select the best parent for the next generation according to your objectives. Unlike Bakewell though we now combine information from progeny, ancestors, genomics and performance records from Australia and overseas to select according to unobservable characteristics and in Australia the main focus is on traits that improve animal productivity, health outcomes, feed efficiency and resilience (including resilience to environmental factors like heat).

DairyBio (since 2016) and Dairy Futures CRC (2010-16) have delivered significant bioscience research outcomes including being the first in the world to identify and enable selection according to a heat tolerance ABV, in addition to reversing the fertility rate trend, developing genomic selection tools that have enabled a threefold increase in genetic gain for cow profitability and developing a feed efficiency ABV (Feed Saved ABV) – where some bulls can have daughters that eat 100kg less of dry matter per year for the same milk yield and body weight – a significant cost saving.

Professor Jennie Pryce

The genetic research being conducted by DairyBio has also developed new ABVs and improved the reliability of existing ABVs to assist the dairy industry to respond to the changing societal demands around health and welfare including being able to select for daughter fertility, mastitis resistance, heat tolerance, feed efficiency, functional conformation, reduced lameness, reduced greenhouse gas emissions and improved metabolic health.

DataGene's Good Bulls Guide utilises the DairyBio new and improved ways to calculate ABVs to rank bulls available in Australia so that farmers and advisers can use the Balanced Performance Index (BPI) and the Health Weighted Index (HWI) for the selection of bulls to meet their breeding objectives.

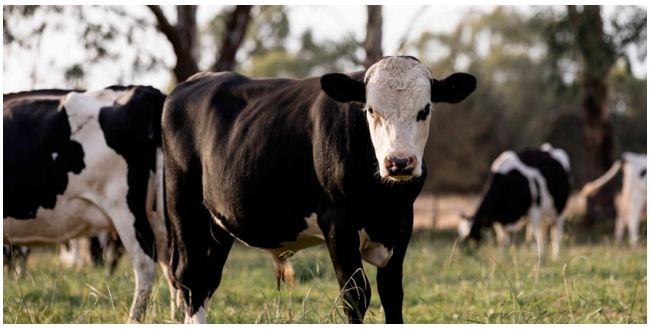


Figure 1 shows the milk yield productivity gains through genetic improvement and management practice advances since 1970. These advances have enabled the dairy industry to remain competitive internationally against strongly subsidised competition and maintain productivity against rising input costs and dropping dairy cow numbers. From 1970–2018 between 25-31% of the annual gain in milk yield is attributable to genetic improvement. As genetic improvement in herds is permanent and cumulative, with rising input costs and climatic uncertainty they are one of the most important profitability improvement drivers in a dairy farmers business.

The environment in which the dairy cows are maintained (including dry matter availability, supplementary feeding systems, cooling and shade infrastructure) also have an instrumental part to play in productivity improvement. DairyFeedbase has applied research outcomes and both programs are focused on working collaboratively to ensure that these combined genetic and management advances continue.

Genetic improvement has resulted in dairy cows that eat more, convert more efficiently and waste less and through the DairyBio initiative we will continue to see greater productivity gains as highly sophisticated breeding programs – driven by genomic selection – are adopted by industry.

Figure 1 Genetic improvement and management advances have consistently improved productivity in the Australian dairy herd as shown for milk yield gains from 1970–2018.

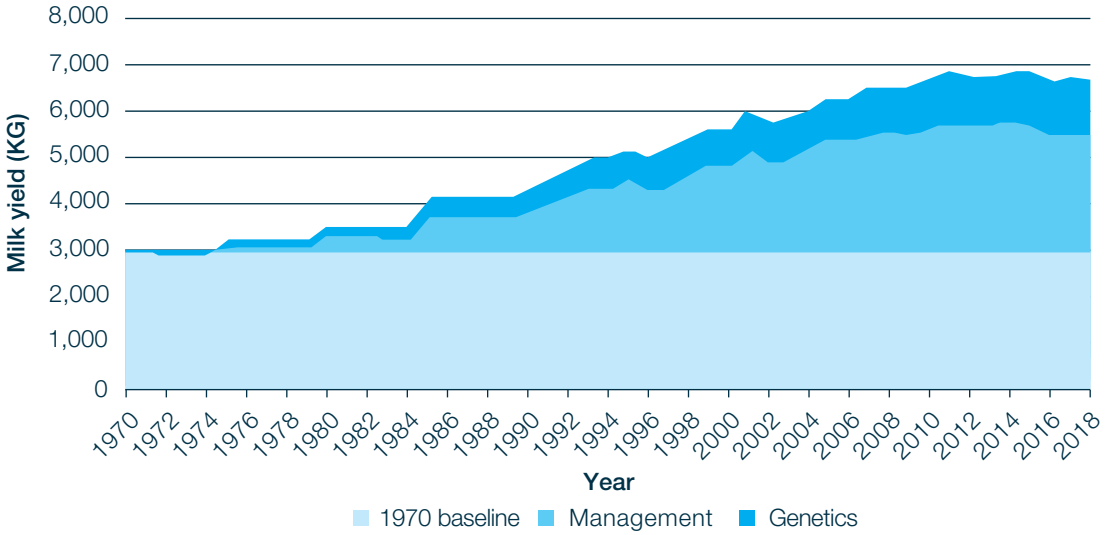


Figure courtesy of DataGene.

DairyFeedbase profile

Launched in 2018, DairyFeedbase aims to use the latest science and research to deliver management tools and strategies that will enable productivity and profitability gains with individual cow, herd feeding and forage productivity improvements. Each project has a substantial scale of impact – which is what the Australian dairy industry needs to drive productivity gains to remain competitive and be able to handle diverse challenges over the next two decades and beyond.

DairyFeedbase is on track to reach the goal of significantly improving pasture productivity and utilisation. The program has the potential to see returns to the industry of $100 million per year in 10 years' time.

Key achievements

First 100 Days – Increased profit of 73 cents per cow per day in first 100 days of lactation; plus 50c per cow per day carryover.

Smart Feeding – Innovative feeding can produce up to an extra 5 litres of milk per cow daily for some cows in some herds.

Pasture Smarts' – On-farm proving of prototypes for automated technology measuring pasture dry matter and other pasture characteristics.

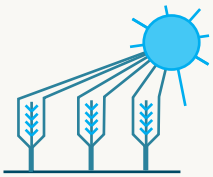
Future Forage Value Index – Delivered benchmarked pasture cultivars for optimal performance for different regions.

Cool Cows – $20 per cow per lactation benefit through adding fat to the diet before and after heat events.

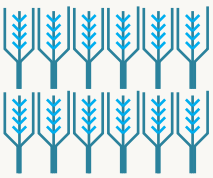
Cool Cows – Heat stress risk assessment developed.

DairyFeedbase – more pasture value

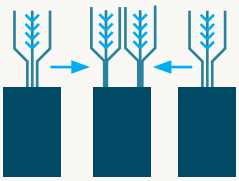
+20% increased utilisation across the industry



+20% productivity through measurement technologies



+20% greater value through improved cultivar selection

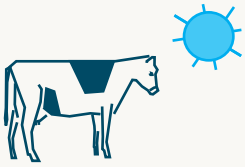


Delivered <u>into</u> a farm system with a focus on improved selection and utilisation of pastures

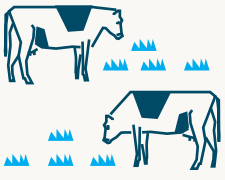
DairyFeedbase – improved animal performance

+$300 per cow from higher peaks and greater lactation persistence

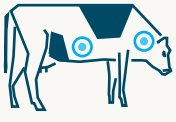
+$160 per cow less impact of hot weather



+$120 per cow via new feed allocation methods and tools



+$50 per cow health cost savings from less metabolic disease



Delivered <u>within</u> a farm system with a on cow performance and efficiency

Project status and snapshots

PASTURE SMARTS

Helping to make smarter pasture decisions

OVERVIEW

Status Ongoing
Expenditure $1.8 million

The Pasture Smarts' project was established to develop a robust and reliable automated pasture measurement process that will simplify the day-to-day management of farmers pasture assets and lead to productivity improvements through improved pasture assessment and utilisation. This is being achieved through leveraging innovative technologies and tools that have been extensively ground-truthed to provide Australian dairy farmers with the best resources for them to optimise measurement and management of their pasture.

The technologies under investigation range from sensors that measure pasture height mounted on farm vehicles, to multispectral cameras mounted on drones, to multispectral sensors on satellites and refinement and testing of pasture growth models. The technology suite is currently being developed in three phases and is an exciting step forward for the remote pasture sensing market.

Pasture Smarts' phase one prototypes are currently being assessed on seven partner dairy farms including Agriculture Victoria's Ellinbank research centre and the feedback received will help refine the final products that will be trialled on a further 20 farms. Phase one (of three) will be released next year to all farmers. The final phase will combine data from the Bureau of Meteorology, pasture growth modelling and predictive tools from remote sensing technology to create a reliable and accurate pasture forecasting system.

While adhering strictly to COVID-19 restrictions, Dr Elizabeth Morse-McNabb and her team are pushing ahead with the program and are busy undertaking computer-based testing and refinement of the product with a view that, when restrictions are raised, they can proceed with further on-farm testing.

SMART FEEDING

More effective allocation of feed resources

OVERVIEW

Status Ongoing
Expenditure $1.7 million

The Smart Feeding project aims to deliver tools and technologies for the measurement of dry matter intake in individual cows on pasture, at both a research and farm scale. These technologies will help develop farm management strategies that enable more efficient and profitable allocation of pasture and supplementary feed resources to dairy cattle within a herd. It is hoped that this will lead to optimised nutrient intake and increased average per-lactation milk yields, valued at $120 per cow per lactation, without increasing total feed requirements.

Smart Feeding project leader AVR research scientist Dr Martin Auldist and his team – including research scientists Dr Marlie Wright, Meaghan Douglas and Dr Pablo Alvarez, along with PhD student Nima Norbu – have found that the first cows in the milking order and therefore the first ones back in the paddock produce around 5 litres more milk than the last cows. They have been working on comparing individual cow dry matter intake and grazing behaviour to identify feeding strategies to overcome these differences in milk yield.

Their research has shown that the milk yield difference is mainly correlated with changes to the pasture sward during grazing rather than the later cows not having enough time to graze. Depending on the time cows are away from the paddock, up to 40 percent of the pasture dry matter has been consumed by the time the last cows get there, with the remaining grass containing less energy and protein and more fibre.

The key question that the team is now looking to answer is whether the better fed first cows have reduced marginal milk responses than the last cows. If so, developing feeding strategies and farm management systems that allocate feed more evenly could increase whole herd milk production and average per cow milk yield from the same feed resource.

COOL COWS

Reduced economic impact from heat events

OVERVIEW

Status Ongoing
Expenditure $1.5 million

The Cool Cows project aims to assess the cost of hot weather in terms of individual cow milk production and then devise on-farm nutritional management strategies for implementation at the herd level to minimise the impact of heat events on dairy farm productivity. As part of that objective the Cool Cows team is also looking to understand the impact of hot weather at the plant level and how to use nutrition in conjunction with genomic selection to boost heat tolerance and profitability.

Research by project leader and AVR research scientist Dr Leah Marett and her team – Dr Peter Moate, Richard Williams, Dr Josie Garner and Dr Mary-Jane Rogers – have confirmed that, as cows are exposed to hot weather, the cow's internal temperature increases resulting in changes to behaviour, including less time spent lying down to rest and less time spent eating or grazing. The consequence of this is reduced dry matter intake and ultimately less milk produced per cow, presenting an opportunity to mitigate these losses through nutrition. Other research on partner farms has shown a decrease in the nutritive characteristics of all forages with temperatures above 25ºC, highlighting the important role and impact that home-grown feed has during summer.

The Cool Cows team are now working towards understanding the interaction between the diet of the cow, and the cow herself, to answer the question – should heat tolerant and susceptible cows be fed differentially during summer?

The major outcome from this research will be an economic framework which combines feeding, infrastructure, and herd assembly options to provide detailed information on the cost and benefit of a range of interventions available to farmers, with a focus on nutrition. The end integrated solution to minimise the impact of heat stress will be a whole-of-farm system with guidelines well supported by science.

FUTURE FORAGE VALUE INDEX

More confident selection of pasture cultivars

OVERVIEW

Status Ongoing
Expenditure $0.9 million

This project will develop a 'next generation' Forage Value Index (FVI) for the Australian dairy industry that delivers at least 20% more value from purchase of proven varieties. Value will be created through provision of additional traits (such as persistence and nutritive characteristics), enhanced measurement technologies based on new advances in the automated measurement of pasture dry mass yield and nutritive characteristics, and the deployment of genomic tools in the prediction of cultivar performance across a broader range of species and environments. The development of a FVI that incorporates nutritive characteristics and persistence is enabled by the economic frameworks that were developed by this project in 2019–2020. The FVI developed in this project will incorporate new plant and endophyte technologies and be suited to new breeding technologies such as F1 Hybrids.

The project will continue to develop and validate sensor-based technologies for species other than perennial ryegrass as there is increasing emphasis on these species and the ability for sensor-based assessment of dry mass yield, nutritive characteristics and persistence with new technologies is currently unknown. During 2020/21 image-based protocols will be further enhanced to quantify the persistence of perennial ryegrass in pasture cultivar plots.

FIRST 100 DAYS

Increased profitable cow performance through feed intake and health outcomes

OVERVIEW

Status Ongoing

Expenditure $2.1 million

The First 100 Days project aims to assist Australian dairy farmers make management decisions about supplementary feeding to economically increase production, while maintaining good animal health. The project is targeting outcomes of an extra $2 per cow per day profit (milk income minus supplement cost) in the first 100 days of lactation, plus an additional benefit of $100 per cow from days 100 to 300 of lactation, and $50 per cow from avoiding metabolic issues over the entire lactation cycle.

Dr Bill Wales and his team – including Dr Vicky Russo, Dr Christie Ho and Dr Rodrigo Albornoz have identified gains of about 73c per cow per day in the first 100 days in milk (DIM) by managing the amount and type of supplement fed to grazing cows in early lactation; and a carryover increase of 50c per cow per day after they return to the main herd and are fed a common diet. Even though it is early in the project, three different experiments have shown consistent economic outcomes and Dr Wales is confident this information can be readily adopted by dairy farmers.

The team are currently planning further experiments under different conditions and are beginning to quantify the benefits of early detection of metabolic disease.

DairyFeedbase financial position 2019–20

Cash position	
Opening balance	$3,449,040
Income received	$6,296,023
Expenditure	$8,450,386
Closing balance at 30 June 2020	**$1,294,677**

Expenditure	
Project expenditure	$8,270,266
Total expenditure	**$8,450,386**

Notes on the financial position

– Financial position is reported on a cash basis.

– A six-year cash position analysis is routinely provided to the board to ensure that the joint venture remains in a positive cash position.

Education and engagement

Engagement with industry has been challenging with COVID-19 through the latter part of the year forcing the cancellation of conferences, field days and events. However, the shift to virtual events has created an opportunity for our researchers to engage in forums that they would not normally be able to, including the advent of Regional Extension team forums. As part of this, planning is well underway for monthly virtual forums bringing together researchers, farmers and service providers and a quarterly 'Dairy Innovation News' magazine that will disseminate information about the world class, and in most cases world first, innovation and research being conducted. We have had various articles published in magazines and journals and our social media posts have been very successful. A regional engagement plan has been developed with the assistance of the Dairy Australia regional networks to deliver the research direction and innovation directly to farmers and service providers. The DairyBio and DairyFeedbase programs recognise the need to deliver innovation and research outcomes to farmers and service providers as soon as they become available to help drive profitability and productivity improvements in the Australian dairy industry.

PhD Program candidates

The DairyBio and DairyFeedbase PhD Program provides a great opportunity for early career scientists to establish their careers and for the dairy industry to attract, nurture and retain the next generation of talented researchers – which is vitally important to drive the productivity gains that are necessary to keep the Australian dairy industry competitive and profitable. In the 2019–20 financial year, 27 PhD candidates formed our PhD community that enables access to large-scale projects, diverse science teams, and modern facilities. Each project has a direct link to industry in terms of its subject matter as well as personal connections through mentoring and participation in industry events. Recruiting of new students is ongoing, and we welcome enquiries for our PhD program.

Successful PhD students

Name	Research topic	University	Academic supervisor	Dairy industry mentor
Paula Giraldo Parra	Field evaluation of transgenic high-energy ryegrass under grazing	The University of Melbourne	Prof Kevin Smith and Dr Noel Cogan	Cath Lescun, Dairy Australia Feedbase and Animal Nutrition Development Manager
Meaghan Douglas	To determine optimal supplementary feeding strategies at four key stages of pasture growth for lactating dairy cows in pasture-based systems	University of Sydney	Prof Joe Jacobs and Prof Bill Wales	NA
Alem Gebremedhin	Advanced phenomic tools for molecular breeding of yield improvement in Ryegrass	The University of Melbourne	Prof Kevin Smith	Matt Reid, Carlisle River dairy farmer
Min Wang	Identifying functional regulatory regions in the bovine genome	La Trobe University	Prof Ben Cocks and Prof Jennie Pryce	Aubrey Pellett, Farmer and Boniac Supply Director
Natasha Brohier	Genome editing technology for modification of fungal endophytes of pasture grasses	La Trobe University	Prof German Spangenberg and Dr Noel Cogan	Lee-Ann Monks, DataGene Communications

Successful Visiting PhD students

Name	Research topic	University	Academic supervisor	Dairy industry mentor
Shilja Shaji	The effects of feeding different grains on body temperature and milk production of heat stressed dairy cows	University of Western Australia	Prof Shane K Maloney	Dr Leah C Marett
Gabriela Riberio	Identification of alternative splicing regulators associated with feed efficiency in cattle	University of São Paulo, Faculty of Animal Science and Food	Prof Heidge Fukumasu	Dr Amanda Chamberlain, Dr Ruidong Xiang
Pauline Delhez	Can modelling MIR spectra across the lactation improve its usefulness in pregnancy testing?	University of Liege, Belgium	Prof Nicolas Gengler and Prof Helene Soyeurt	Prof Jennie Pryce

Current PhD students

Name	Research Topic	University	Academic Supervisor	Dairy Industry mentor
Nicholas Collinson	Investigating tri-trophic interactions between insects, endophytic fungi and pasture grasses	School of Applied Systems Biology, La Trobe University	Dr Mallik Malipatil	Brian Anderson, Gippsland dairy farmer
Ian Tannenbaum	Perennial ryegrass microbiome discovery and application	School of Applied Systems Biology, La Trobe University	Dr Tim Sawbridge	Peter Thurn, Breeding, Genetics Australia Genetics and Production Manager
Jigme Dorji	Role of the X chromosome and mitochondrial DNA in the prediction of dairy traits and understanding cow families	School of Applied Systems Biology, La Trobe University	Dr Hans Daetwyler	Tony Francis, formerly DataGene Software Services Manager
Caeli Richardson	Incorporation of international data in breeding programs for evaluation of novel traits: feed efficiency and methane emissions	School of Applied Systems Biology, La Trobe University	Prof Jennie Pryce	Craig Lister, Calivil dairy farmer and DataGene director
Claire Prowse-Wilkins	Functional genomics to discover biologically relevant regulatory variation	The University of Melbourne	Prof Mike Goddard	Tony Francis, formerly DataGene Software Services Manager
Evans Cheruiyot	Genetic aspects of heat tolerance in Australian dairy cattle	School of Applied Systems Biology, La Trobe University	Prof Jennie Pryce	To be allocated
Tim Luke	Digestive microbiome in healthy, productive dairy cows	School of Applied Systems Biology, La Trobe University	Prof Jennie Pryce and Dr Simone Rochfort	To be allocated
Beth Scott	Optimising the use of genomics on-farm	School of Applied Systems Biology, La Trobe University	Prof Jennie Pryce	Richard Shephard, Herd Health Managing Director
Sailajah Vishwanathan	Advancing genotyping – by-sequencing and genome resources for perennial ryegrass	School of Applied Systems Biology, La Trobe University	Dr Noel Cogan	Travis Wild Chobani CFO

Tongda Li	Molecularly characterise fungal and bacterial microbiome enhanced associations of perennial and short-term ryegrasses for improved pasture performance	School of Applied Systems Biology, La Trobe University	Dr Tim Sawbridge	Tim Humphries, Tongala dairy farmer
Krishni Fernando	Metabolomics and bioactivity – the novel chemistry of endophyte – perennial ryegrass symbiota	School of Applied Systems Biology, La Trobe University	Dr Simone Rochfort	Ron Paynter, Ellinbank dairy farmer
Saba Rabab	Genomic selection using novel forage phenomics for perennial ryegrass	School of Applied Systems Biology, La Trobe University	Dr Hans Daetwyler	Cath Lescun, Dairy Australia
Nima Norbu	Use of on-cow sensors for the measurement of dry matter intake of grazing cows	The University of Melbourne	Prof Brian Leury and A/Prof Martin Auldist	To be allocated
Emma Ockenden	Early life-stage nutrition and its effects on physiological mechanisms and lifetime performance of the dairy cow	The University of Melbourne	Prof Brian Leury and A/Prof Bill Wales	To be allocated
Chinthaka Jayasinghe	Genomic and phenomic indicators of persistence in perennial ryegrass cultivar evaluation	The University of Melbourne	Prof Kevin Smith	To be allocated
Phat (Tan) Nguyen	Phenome-informatics: Development of an integrated data acquisition and analysis system for a ground-based forage phenomics platform	School of Applied Systems Biology, La Trobe University	Dr Hans Daetwyler	To be allocated
Chaya Smith	Forage nutritive quality predictions using novel forage phenomics for perennial ryegrass	School of Applied Systems Biology, La Trobe University	Dr Noel Cogan	Naomi Pye, Bessiebelle dairy farmer and Gardiner Dairy Foundation Director
Cheng Li	Lipidomics of bovine milk and plasma	School of Applied Systems Biology, La Trobe University	Dr Simone Rochfort	To be allocated
Ee Cheng Ooi	Dairy fertility and genetic selection: validation of the Daughter Fertility ABV	The University of Melbourne	Prof Mike Goddard and Prof Jennie Pryce	To be allocated

Current Supervised/Visiting PhD students

Name	Research topic	University	Academic supervisor	Dairy industry mentor
Melissa Stevens	Improved genomic prediction of fertility through NZ and Australian dairy data	Massey University, New Zealand	Prof Dorian Garrick	Prof Jennie Pryce
Laura Jensen	Validating Australian breeding values for heat tolerance in US dairy farms	University of Florida	Prof Peter Hansen	Prof Jennie Pryce

Two new PhD students were expected to commence in April 2020, Boris Sepulveda and Seyed Mohammad Ghoreishifar, however, due to the COVID-19 pandemic La Trobe University have postponed Higher Degree Research enrolment to the 2020–21 financial year.

Successful PhD candidates profiles

Meaghan Douglas

PhD University of Sydney

PhD research: The nutritive characteristics of perennial ryegrass and implications for diet formulation for grazing dairy cows

Current role: Research Scientist, Agriculture Victoria

Context: The dairy industry in south-eastern Australia is dominated by pasture-based feeding systems, where perennial ryegrass is the most common pasture species grown. However, pasture alone cannot provide optimal nutrition for high milk production, therefore the majority of farmers feed supplementary grains and concentrates to grazing dairy cows. The nutritive characteristics of pasture vary throughout the year, influenced by stage of growth and climatic conditions, as well as the ploidy and heading date of each perennial ryegrass cultivar. My PhD research investigated the nutritive and degradation characteristics of perennial ryegrass pasture during each season of the year in the dairying regions of Victoria to quantify the variation in nutritive characteristics and subsequently inform the formulation of supplementary diets for grazing dairy cows.

Industry impact: The research undertaken in the thesis investigated and quantified effects of individual perennial ryegrass cultivars in different seasons and regions on nutritive and degradation characteristics. It is hoped that the research can provide practical information for improvements in dairy cow feeding on farm leading to a more sustainable and profitable dairy industry in Australia.

Education program: I was able to attend a public speaking and communication workshop hosted by DairyBio in the early stages of my candidature, which helped to set me up for the future domestic and international conferences I was able to attend. It also helped me immensely when discussing my research with visitors to Ellinbank, particularly dairy farmers and service providers who would benefit from this research.

Min Wang

PhD La Trobe University

PhD research: Identifying functional regulatory regions in the bovine genome

Current role: Bioinformatician (Postdoctoral), Murdoch Children's Research Institute

Context: Accurate and reliable breeding values are essential for improving dairy farmers' future prosperity through herd improvement. To produce the most reliable genomic estimated breeding values, and make genomic prediction persistently accurate across generations, identifying causative changes of DNA bases (called 'causative variants') is ultimately required. Years of dairy genomic research have shown that traits of economic importance to the dairy industry are affected by many causative variants, each of a small effect, mostly in genomic regions that do not encode protein (`noncoding regions') rather than in coding regions. Comprising the majority of the bovine genome, the noncoding regions encode many regulatory elements that instruct when and how the proteins should be produced and function.

Industry Impact: Genomic prediction is widely used in dairy cattle breeding programs in Australia and around the world. The genetic gain for traits of economic importance could be continually improved if whole genome sequence variants, rather than high density SNP chip panels, are used, because the causative variants are more likely to be included for prediction. However, the major challenge in using whole genome sequence data in genomic predictions is computational, a result of many millions of variants that are present in the genomes of cattle. This PhD project provides catalogues of regulatory elements in the bovine genome that allows a more targeted approach for optimal genomic prediction of complex mammalian traits, including those important to the dairy industry.

Education Program: With the support of Dairy Futures CRC and DairyBio, I was able to attend and present at international and national conferences, including the Lorne Genome conference 2015, Herd 17 in Bendigo, Australia Dairy Science conference 2018 in Melbourne, Chromatin Architecture and Chromosome Organization in Canada, and International Symposium on Animal Functional Genomics in Adelaide. Another valuable experience through the Education Program is the 2-day communication workshop with Esther Jones in 2017. Also cannot be forgotten are the spring and autumn outings that the Education program organised, such as the visits to the Devondale milk processing site, to a cheese and yogurt research lab, to the farms of our mentors, and to the headquarters of Dairy Australia.

Paula Giraldo

PhD The University of Melbourne

PhD research: Application of new technologies in the safety assessment of genetically modified feed

Current role: Plant Biosecurity Contingency Planning Officer, Agriculture Victoria

Context: Agricultural biotechnology, such as genetic modification, has been proposed as a way to face food security and climate change. All new crop varieties with altered genetics must be subjected to safety assessments to fulfil regulatory requirements, prior to marketing and/or commercial release. The aim of my thesis was to undertake part of the safety assessment of transgenic plants, using emerging molecular biology technologies. Initially, the molecular characterisation of two genetically modified plants were performed using long-read DNA sequencing. Results demonstrate the capability of this technique to characterise transgenes located in complex and/or repetitive regions of the plant genomes, in a fast and cost-effective way with simple and robust bioinformatic pipelines that would be broadly applicable and accessible.

Then, a reliable methodology was developed using droplet digital PCR tools for the detection of transgenes in a variety of complex pasture-based products relevant to livestock industries. Later, a toxicological assessment of the high-energy perennial ryegrass was performed using a metabolomics approach. The current study indicates that the new technologies can provide a highly reliable and efficient solution for the safety assessment of genetically modified feed.

Science Outcomes: My scientific work represents a contribution in the use of new technologies to improve the risk assessment procedure of genetically modified plants. Three journal articles from my PhD have been accepted for publication in reputable journals and an additional one has been recently submitted for publication.

Industry Impact: The research conducted provide guidelines for the use of new technologies to improve the safety assessment of transgenic forages species. This will enable the delivery of safe and improved feed, which can improve agricultural profitability through achievement of higher productivity, more efficient use of natural resources and decreases in environmental impacts.

Education program: The DairyBio education program gave me the opportunity to understand the dairy industry needs, in order to be able to identify innovative solutions using plant biotechnology. During the course of my PhD, I felt highly supported by projects geared to my professional development, such as the mentoring program, science communication training, and participation in national and international conferences.

Natasha Brohier

PhD La Trobe University

PhD research: Genome editing technology for modification of fungal endophytes of pasture grasses

Current role: Research Scientist, Agriculture Victoria

Context: Perennial ryegrass is an important forage species in south east Australia and New Zealand grazing systems. Elite cultivars of perennial ryegrass can be further improved by the introduction of asexual *Epichloë* endophyte strains which are known to be systemic symbionts of C3 cool-season grasses (Poaceae subfamily Poöideae) such as perennial ryegrass. These asexual endophytes are known to confer abiotic and biotic stress tolerances that enhance host plant persistence. Some of these enhances are known to be caused by secondary metabolites, such as peramine and ergovaline (in low quantities) which confer well-characterised insect deterrence to their host plant. However, secondary metabolites such as lolitrem B, are known to cause neuromuscular effects, called 'ryegrass staggers'. Effects include tetanic muscle spasms that result in staggering and incoordination, hypersensitivity to external stimulation, and in severe cases, clonic seizures and death in grazing animals.

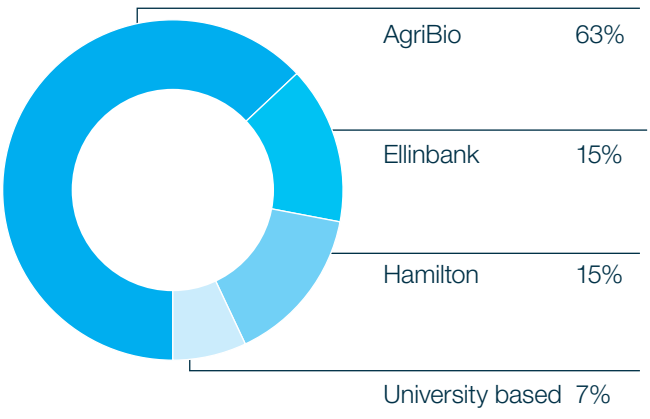
Previous genome modification tools have been used to elucidate the biosynthetic pathway of these secondary metabolites, hence it is well understood. Applying this knowledge, *Epichloë* endophytes of pasture grasses can be modified using genome editing technology to eliminate animal toxicity, while retaining the benefits of enhanced pasture persistence. Genome editing technology is a powerful tool for improving agricultural productivity and end-product quality. This thesis investigates the development of EXZACT™ Delete (i.e. loss-of-function) genome editing technology using zinc finger nucleases (ZFNs) in *Epichloë* to aid in creating the perfect perennial ryegrass endophyte with low or no regulatory burden.

Science outcomes: Genome editing technology utilizes site-specific nucleases (SSNs) to cause double stranded breaks at a precise location to edit DNA. To avoid any regulatory burden, an error-prone DSB repair pathway is required which I have identified and verified putative genes involved in *Epichloë* spp. in silico. The research conducted also demonstrated unique protocols that can be applied for the application of genome editing tools onto asexual *Epichloë* endophytes. This includes an improved transfection protocol compared to previous protocols and detection protocols to identify and quantify genome edited *Epichloë* protoplasts (single cells).

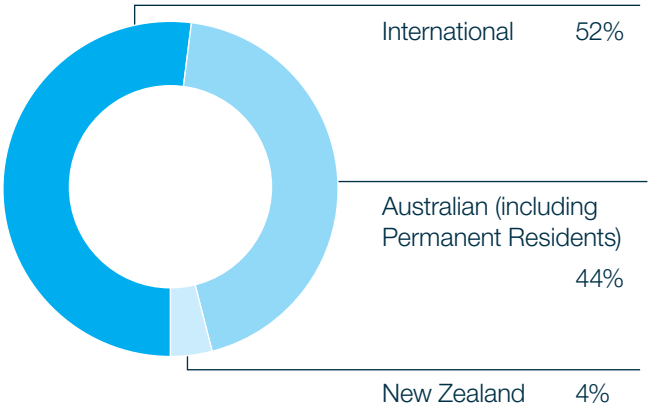
Industry impact: In Australia, the economic loss to the pasture-based livestock industry from 'ryegrass staggers' caused by lolitrem B is estimated to be ~$AU100 million annually. In the USA, where ergovaline toxicity is a major cause of loss in animal production, the economic loss is estimated to be close to $US2 billion annually. By establishing genome editing techniques on *Epichloë*, the production of these alkaloids can be blocked, mitigating these losses of profit while retaining benefits of enhanced pasture persistence of *Epichloë*.

Education program: The Dairy Futures CRC and DairyBio education program has provided multiple opportunities to grow personally and professionally. This includes multiple well-organised workshops, field and factory visits/tours to understand the flow of the dairy industry, a great mentoring program and the exposure to other research conducted by my fellow DairyBio PhD mates. This program also effectively connected me to the end-users of my work giving it meaning and purpose. Furthermore, this program has trained us to look at agricultural issues from a different perspective. As pressures from climate change and for sustainability builds and animal activism rises, as scientists, we need to do our part to alleviate the problem, be it by coming up with solutions within our expertise or even advocating for science. The training we have had around science communication (explaining complex scientific research in plain words) was invaluable.

PhD Candidate Research locations



Where our PhD Candidate come from



Get into Genes

Get into Genes is a bioscience education program comprising of workshops linked to the Victorian Curriculum and Assessment Authority (VCAA) science and technology curricula. The program comprises a suite of workshops which provide a distinctly agricultural context to the syllabus of senior school students. Nationally it is recognised that we need to encourage school students to pursue careers in STEM. Research projects sponsored by DairyBio, which showcase cutting edge applications of science, technology, engineering and maths, provide valuable examples for setting school science within an agricultural context and inspire students into considering agricultural research careers. The workshops use fun, hands-on activities to set previously abstracted concepts within examples of bioscience research and industry applications, such as the use of genomics in the dairy sector. Workshops are conducted for visiting schools at Agriculture Victoria Research sites across Victoria, university campuses and centrally located regional schools.

Get into Genes program workshops 2019–20

Location	Participants total	Students	Teachers	Girls	Boys	Indigenous	Sessions total
Metropolitan	4228	3936	292	2493	1443	14	161
Regional	635	588	47	341	247	34	34
Total	**4863**	**4524**	**339**	**2834**	**1690**	**48**	**195**

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