DAIRY MOVING FORWARD

National Dairy Forages R&D Strategy

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The National Dairy Forages R&D Strategy panel members extend their gratitude to all individuals and organisations that participated in the strategy development process.

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The Steering Committee comprised Allan Cameron (CEO – Gardiner Foundation), Jay Mody (Head of Research Investments – Dairy Australia), John Penry (Principal Scientist – Dairy Australia) and Rodrigo Albornoz (Technical Lead, Feedbase & Nutrition – Dairy Australia).

The panel members acknowledge the Traditional Owners of Country where the review was conducted and recognise the continuing connection to lands, waters, and communities. The reviewers pay their respect to Aboriginal and Torres Strait Islander cultures, and to Elders past and present.

Foreword

David Beca

**Chair,
Dairy Moving Forward
Steering Committee**

Forage is at the heart of dairy farming in Australia. It is the foundation of productive and profitable dairy systems, and one of the biggest levers available to farmers in managing costs, improving efficiency, and ensuring long-term sustainability.

In recognition of this, the Australian dairy industry has taken a significant step forward with the development of a National Dairy Forages R&D Strategy – a clear, cohesive, and future-focused roadmap to guide research and development (R&D) investment in forages. Led by Dairy Moving Forward, with representatives from industry, state governments, Dairy Australia, Australian Dairy Farmers, and Gardiner Foundation, this strategy should underpin a nationally coordinated effort shaped through broad research and industry input, and supported by Dairy Australia in its development.

The strategy is designed to foster greater collaboration, drive co-investment, and direct efforts towards the most pressing challenges faced by dairy farmers – from improving forage utilisation and nitrogen efficiency to better adapting to seasonal variability and dry conditions. It recognises that effective R&D must balance genetics, environment, and management practices, and that a coordinated, national approach is vital to keep pace with global innovation and ensure meaningful outcomes for Australian dairy farmers.

By providing a definitive roadmap for researchers, farmers, seed companies, and technology developers to follow, this strategy should ensure that every investment in forage R&D is both strategic and impactful. The Dairy Moving Forward Steering Committee believes this should mark a new chapter for dairy innovation – one where shared goals, clear priorities, and industry-wide collaboration will underpin the next phase of growth and resilience for our sector.

We commend the collective effort behind this strategy and look forward to the benefits it will deliver across the Australian dairy landscape.

About Dairy Moving Forward

Dairy Moving Forward is an initiative of the Australian dairy industry that informs and guides industry and government on the priorities required for Australian dairy research and development to improve performance, productivity and sustainability.

Dairy Moving Forward is comprised of representatives from:

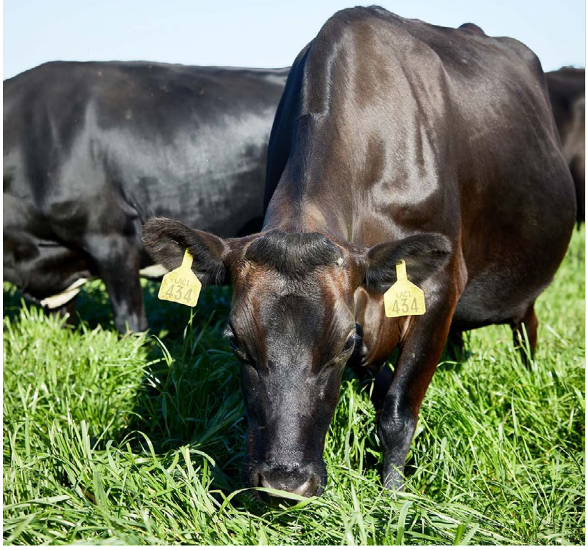
- Industry organisations (Dairy Australia and Australian Dairy Farmers)
- Gardiner Foundation
- Five state government departments (New South Wales, Queensland, Victoria, Tasmania and South Australia)

Dairy Moving Forward aims to enhance national collaboration, coordination and effectiveness of Australian dairy research and development. This is achieved through well-informed and regular scanning of the horizon to identify key trends that could impact the industry.

1

Executive summary

The National Dairy Forages R&D Strategy provides a forward-looking, comprehensive vision for strengthening productivity, profitability, resilience, and sustainability across Australia's dairy forage systems.



Recognising the complex interplay between Genetics (G) × Environment (E) × Management (M), the strategy highlights key industry challenges, identifies research gaps, and proposes a more integrated approach to forage innovation.

A key insight is that while Australia's dairy industry benefits from highly skilled researchers and a history of valuable feedbase projects, there is a clear opportunity to re-establish strategic focus in this area. Reinvigorating this focus will provide a platform for addressing increasing production challenges, rising production costs and enhance the industry's competitive edge. Although considerable investment has gone into forage breeding, there is now a timely opportunity to rebalance efforts by placing greater emphasis on the adoption of modern plant breeding advancements, management practices and systems-level innovation. For dairy forage R&D to move forward there needs to be a strategic shift from the current **G × e × m** thinking to **G × E × M**. This is urgently required, ensuring a more balanced effort across genetics, environmental adaptation, and – most importantly – management.

A major opportunity lies in strengthening national data collection on forage species composition, pasture usage, regeneration rates and genetic improvements. Establishing consistent and robust data systems will significantly enhance long-term planning, the ability to measure impact, and identify the key future research opportunities. Stakeholders consistently highlighted the potential of well-coordinated national R&D programs, clearer commercialisation pathways, deeper international partnerships, and more defined roles for seed companies and technology providers in translating research into on-farm benefits.

While current forage R&D is fragmented, this presents an exciting chance to integrate skills and resources through collaborative, cross sector, multi-state and multi-institutional programs. Programs using genetic improvement to address industry challenges or opportunities will be most effective if they are directly aligned with a set of agreed national plant breeding objectives. With dedicated five to seven-year funding commitments, such initiatives can deliver meaningful and lasting outcomes for the industry. Moreover, stronger global collaboration – particularly with countries like New Zealand and Ireland that share similar pasture-based dairy systems – represents an untapped source of innovation and learning that should strengthen Australia's position.

Drivers

The key drivers identified in this forage R&D strategy are the major forces shaping forage choices, farm decisions, and the long-term sustainability of the dairy industry over the next 30 years. They guide priorities for forage selection, management, and innovation across dairy systems.

Productivity

- There is strong potential to revitalise productivity gains in pasture-based systems by complementing past investments with renewed focus on grazing and feed management. While historical gains have stemmed from fertiliser use and stocking rates, evidence shows several tonnes per hectare could be unlocked through improved utilisation practices.
- Plant breeding holds significant untapped value for dairy's future, especially in enhancing resilience to climate extremes and improving environmental outcomes. Establishing National Breeding Objectives for annual and perennial forage species and focusing on high-impact traits will better position the sector for long-term success.
- New Breeding Technologies (NBTs) present promising frontiers, with the potential to transform productivity and sustainability. With targeted investment, improved commercial pathways, and coordinated collaborative research, these innovations can be more effectively translated to 'on-farm' adoption and scale.
- Expanding access to advanced forage crop genetics can accelerate progress, particularly through the evaluation of elite global germplasm and support for local breeding programs. Coordinated multi-environment trials will empower growers and advisors to make more informed cultivar choices.

Profitability

- Optimising grazed forage production and utilisation presents a major opportunity to boost profitability in temperate dairy systems. While pasture yields have increased, there is clear potential to lift utilisation rates through refined grazing, stocking rate, and feed system strategies.
- Improved, region-specific data on forage capacity and performance is urgently needed to quantify the true gap between current and potential productivity.
- Changing farm systems in response to climate and water constraints – such as increased reliance on supplements and reduced pasture use – underscore the importance of strategies that minimise feed substitution losses and maximise efficiency of all feed inputs.
- Revisiting best management practices for pasture is essential to unlock significant gains in forage harvest and quality, especially given evolving climate, genetic resources, and feedbase systems.
- There is a strong case for rethinking how technology adoption is supported across the sector. Tools exist to enhance decision-making, but farmer uptake remains low. Coordinated programs involving training, demonstration, and collaboration with tech providers are needed to translate innovations into practical on-farm gains.

Resilience

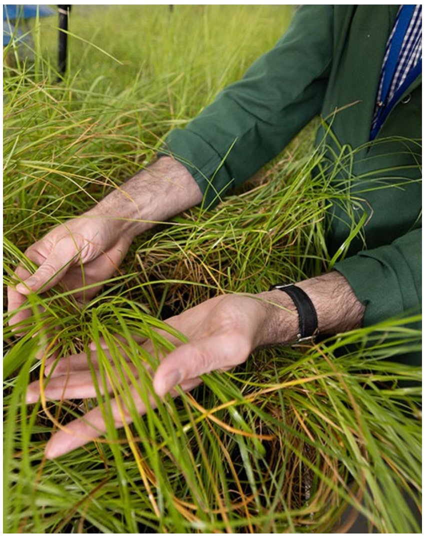
- Evolving dairy systems are under growing pressure, with intensification and climate variability challenging the traditional balance between feed supply and demand.
- Climate change is already reshaping forage performance, with more frequent extreme weather events and shifting seasonal patterns. These changes require both tactical short-term responses and longer-term strategic adaptation in forage systems and farm planning.
- Adapting to climate extremes demands scalable, practical solutions, including more heat-and drought-tolerant forage species, refined agronomic practices, and better alignment of forage breeding goals with environmental realities.
- Investing in next-generation technologies and practices will be essential, particularly in areas such as water-efficient forages, tolerance to extremities in temperature, precision nutrient management, and integrated soil health strategies to sustain productivity in a changing climate.
- The soil and plant microbiome presents an emerging frontier for productivity and resilience, offering potential for novel solutions in nutrient uptake, pest and disease resistance, and stress tolerance.

Sustainability

- Market and regulatory pressures are driving the need for on-farm reductions of greenhouse gas emissions and stricter compliance with environmental standards related to water, soil, biodiversity and pesticide use.
- Compliance costs and community expectations are rising, prompting the search for cost-effective, environmentally sustainable practices within forage systems.
- Forages have potential to address key environmental challenges, including nutrient runoff, soil degradation, emissions, pesticide impacts and sediment loss.
- Forage R&D must align with industry sustainability priorities, including climate risk management, water efficiency, emissions reduction, and enhanced nutrient and biodiversity outcomes.

Input volatility

- Rising forage input costs are significantly impacting farm profitability, with real increases of 66% per hectare over the past decade. Fertiliser, seed, fuel, and pesticide costs have all surged due to global supply chain issues, industry consolidation and regulatory challenges.
- Access to irrigation water is increasingly constrained, particularly in the Murray-Darling Basin. Rising water allocation prices are pushing farmers toward more water-efficient forage options or even prompting exits from the industry.
- Soaring dairy land prices, particularly in key regions like Gippsland and Tasmania, are driving system intensification, shifts toward high-yield forage crops, and relocation to more affordable areas.
- Land and water availability and cost pressures are emerging as central, long-term drivers of change in forage systems, underscoring the need for targeted R&D to improve input efficiency and system resilience.



Strategic recommendations

Areas to increase effort, funding, or attention

Set National Breeding Objectives (NBOs) and implement evaluation systems to drive progress on regional benchmarks:

- Establish industry-agreed NBOs for key annual and perennial forage species (perennial grasses, legumes, etc.) with associated evaluation systems to gather baseline data and track progress toward achieving the objectives regionally and nationally.
- Rigorously assess whether potential genetic gains in yield (and possibly other traits) are being realised on-farm and, if not, what barriers need to be addressed to capture the potential.

Design integrated forage systems for low-emissions dairying that deliver productivity, profitability, and sustainability:

- Develop forage systems that balance productivity, profitability, and sustainability while minimising environmental footprints.
- Improve species-specific nitrogen response understanding and develop advanced fertiliser management techniques to lower costs and farm gate nitrogen surplus.

Harness next-generation technologies to transform forage management:

- Collaborate with technology developers to strengthen the development and adoption of remote sensing, data technologies, and decision support systems to improve forage management.

Strengthen collaboration & leadership:

- DMF must enhance leadership in fostering strategic collaborations, avoiding duplication, and ensuring efficient use of resources.
- Facilitate strategic partnerships between Australian research institutions and with international peers.
- Improve alignment between Australian researchers and plant breeding companies to accelerate forage innovation.

Refresh forage management practices to maximise genetic potential and to adapt to changing conditions:

- Update best-management grazing practices for new forage genetics, considering climate variability.
- Revise guidelines for species like tall fescue and cocksfoot and improve data on forage species to match plant needs with environmental conditions.

Optimise yield, quality, and system performance of mechanically harvested forages:

- Invest in improving forage yield and nutritive value, with consideration for balancing agronomic goals and animal nutritional needs.
- Ensure future forage systems align with the dairy Industry Action Panel (IAP) for Intensification Final Report, addressing potential trade-offs between yield and nutrition.

Track emerging insights into soil-plant microbiomes to guide future innovation:

- Actively monitor emerging research on soil and plant microbiomes by engaging with scientific literature, research networks, and expert forums to identify developments relevant to dairy forage resilience.

Strategic recommendations

Areas to refocus or reduce efforts

Refocus new breeding technologies to overcoming limitations to yield potential (NUE, WUE, and drought recovery) and increasing nutritive value in targeted species:

- To maximise impact and ensure focus, pre-breeding[1] efforts using NBTs should prioritise key traits with the greatest potential to enhance resilience and productivity – namely, Nutrient Use Efficiency (NUE), Water Use Efficiency (WUE), and drought recovery in priority forage species. These foundational efforts will pave the way for future trait selection to be guided by well-defined NBOs once established.

Reduce emphasis on further agronomic research into multispecies swards:

- Future investment in multispecies swards should be approached with caution and guided by the latest knowledge, which indicates limited evidence for their superiority in agronomic performance or animal productivity over conventional mixed swards. However, given emerging indications of potential environmental benefits – particularly in reducing nitrogen losses – any future research should focus on accurately quantifying environmental outcomes. This work should explicitly identify the plant traits proposed as providing environmental benefits, select species that bring those traits accordingly, and identify the simplest-possible mixture combinations that can achieve the expected benefits.

Refocus R&D investment to maximise impact through strategic pre-breeding:

- Redirect levy and public R&D funding toward NBO-guided pre-breeding in priority forage species to support and strengthen commercial breeding programs.
- Cease pre-breeding investment in lower-priority or alternative species unless there is a clear, viable pathway to commercialisation and on-farm adoption.

Increasing the use of pasture and home-grown forage was identified as a top priority during the strategy consultation process, strongly linked to improved farm profitability. While proven knowledge and tools exist to boost pasture harvest efficiency – and are already used effectively by leading farmers – adoption across the broader industry remains limited. Given this persistent barrier, further investment in traditional D&E is difficult to justify. Instead, the priority area 'Harness next-generation technologies to transform forage management' has been included with the expectation that automation and easy-to-use, cost-effective technologies could remove some of the known impediments to adoption (e.g. time and skills constraints on-farm preventing regular data gathering and analysis) and act as a circuit-breaker to drive wider uptake and improve on-farm performance.

1. Pre-breeding refers to the research activities undertaken before the formal breeding process, specifically focusing on identifying desirable traits or genes from unadapted materials and transferring them to a more usable genetic background.

Pathway to market

The pathway to market for forage plant breeding is complex and evolving, involving a broad network of stakeholders from R&D through to seed production, distribution, and on-farm use. Global industry consolidation and reliance on international seed supply have increased market volatility and complicated adoption, with farmers accessing seed through a variety of informal and formal channels. Successful translation of R&D into farm-level outcomes requires clearer role definition and stronger alignment across the supply chain.

To maximise the impact of future investments, DMF should clarify its role and invest strategically in focused pre-breeding R&D that supports industry-wide benefits. This includes developing strategic traits, enhancing genetic resources, and leveraging advanced technologies in collaboration with commercial partners. Technology providers and seed companies are central to delivering these innovations to farmers – developing traits, navigating regulation, managing intellectual property, and engaging directly with end users.

Collaboration

The success of the National Dairy Forages R&D Strategy relies on strong, end-to-end collaboration across the dairy supply chain to convert research into practical, on-farm impact. This includes clear role alignment between research investors, R&D providers, seed companies, and farmers, especially as the sector increasingly adopts advanced technologies such as NBTs. Current R&D capacity is limited to a small number of providers, underscoring the need to expand partnerships within and beyond the Australian dairy sector – drawing on expertise from grains, horticulture, and international collaborators to accelerate innovation and adoption.

To secure and grow future investment, the strategy must focus on maximising returns from existing funding, strengthening co-investment models, and building collaborative platforms. This includes aligning with national funding initiatives, expanding global research partnerships, and exploring commercialisation pathways such as spin-out companies. Establishing a dedicated forage R&D consortium and reviving a national pasture collaboration platform will help coordinate efforts, address capability gaps, and ensure forage research delivers tangible productivity, sustainability, and profitability gains for the Australian dairy industry.

The National Dairy Forages R&D Strategy concludes that a more resilient, profitable, and sustainable feedbase can be achieved through sustained investment, improved coordination, and renewed focus. However, success will depend on addressing inconsistent data, leadership gaps, and systemic inefficiencies within the current R&D framework. By implementing the Strategic R&D recommendations, Australia's dairy industry can reclaim its competitive edge and drive future growth in a rapidly evolving landscape.

Plan on a Page

	Productivity	Profitability	Resilience	Sustainability	Input volatility
Strategic context	• Stagnant productivity gains • Unrealised genetic gains • Forage breeding critical but undervalued • New Breeding Technologies (NBTs) excluded or underused	• Forage performance impacting profitability • Lack of credible data limiting progress • Rising pressures, costs and risks of farm systems change • Resistance to technology adoption	• Climate shifls reshaping forage performance • Tactical adaptation needed for extreme events • Strategic adaptation required for long-term climate shifts • Soil and plant microbiome holds promise	• Industry priorities are: • Managing climate risk • Improving water use efficiency • Reducing greenhouse gas emissions • Enhancing nutrient management and biodiversity	• Forage input costs rising • Difficulty in access to irrigation water • Dairy land prices soaring
Drivers	Productivity	Profitability	Resilience	Sustainability	Input volatility
R&D outcomes	Improved efficiency in forage system resource use – while minimising environmental impacts.	Improved competitiveness and reduced cost of production for forage systems.	Improved stability and consistency of forage yields.	Forage production systems with low environmental footprints.	Reduced dependency on key inputs for forage production.

Strategic R&D priorities

- Set National Breeding Objectives and implement evaluation systems to drive progress on regional benchmarks.
- Design integrated forage systems for low emissions dairying that deliver productivity, profitability, and sustainability.
- Harness next generation technologies to transform forage management.
- Refresh forage management practices to maximise genetic potential and to adapt to changing conditions.
- Optimise yield, quality, and system performance of mechanically harvested forages.
- Track emerging insights into soil-plant microbiomes to guide future innovation.

High-priority enabling factors

Pathway to market
- Collaborate effectively with technology providers and seed companies
- Invest strategically in focused pre-breeding R&D

Leadership & collaboration
- Stronger leadership in initiating, enabling, and funding forage R&D collaboration
- Expand local and global research partnerships

Farm systems & development capability
- Ensure adequate resourcing and capability in Development and Extension (D&E)
- Incorporate whole-of-farm systems thinking

TABLE OF CONTENTS

3 Foreword

4 About Dairy Moving Forward

5 (1) **Executive summary**

12 Plan on a Page

14 (2) **Introduction**

15 2.1 Definitions

18 (3) **Strategic context**

18 3.1 Current forage types and areas

19 3.2 Forage R&D expenditure

20 3.3 Future importance of forage species

24 (4) **Key drivers**

26 4.1 Productivity

31 4.2 Profitability

33 4.3 Resilience

35 4.4 Sustainability imperatives

37 4.5 Input volatility

38 4.6 Enabling factors

39 (5) **Strategic R&D priorities**

39 5.1 Areas to increase effort, funding, or attention

43 5.2 Areas to refocus or reduce efforts

45 (6) **National Breeding Objectives**

45 6.1 Background

46 6.2 Importance of forage NBOs for the dairy industry

47 6.3 Establishing NBOs for dairy forages

52 (7) **Pathway to market for plant breeding R&D**

53 7.1 Translating forage R&D to on-farm outcomes

53 7.2 Role of DMF in forage pre-breeding R&D

54 7.3 Role of technology providers

55 7.4 Role of seed companies

56 (8) **Current research assessment**

56 8.1 Alignment with future research priorities

58 8.2 Alignment with future forage importance

63 (9) **Funding and collaboration opportunities**

63 9.1 Background

63 9.2 Future forage R&D collaborations

65 9.3 Future forage R&D investment

Appendix 1:
67 **Glossary**

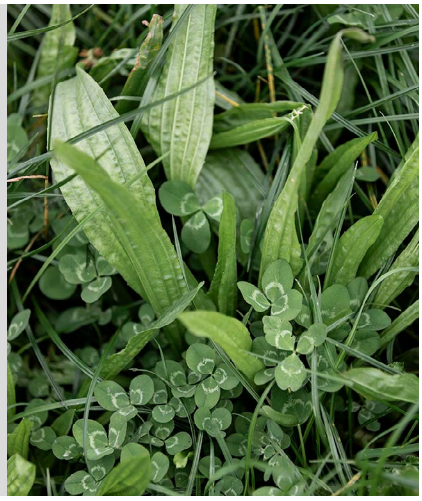
Appendix 2:
68 **Future research investment criteria**

Appendix 3:
70 **Australian dairy forage market**

75 **Acknowledged contributions**

2

Introduction



The National Dairy Forages R&D Strategy aims to guide and prioritise research and development to ensure economically and environmentally sustainable, forage supply for the Australian dairy industry over the next two to three decades.

Key objectives include:

- Identify and understand the key decision-making drivers that will influence forage performance and shape farmer choices in forage selection over the next 30 years.
- Map current forage research capabilities, capacity and infrastructure resources and the pathway to market for forage research.
- Identify regional variations in current forage composition and future needs.
- Provide recommendations for future forage investment priorities to support the dairy industry's sustainability, profitability, and innovation goals, in consideration of commercialisation pathways.

By providing clear direction, the strategy seeks to advance forage R&D in ways that meet evolving demands, promote environmental stewardship, and strengthen the competitive edge of Australia's dairy sector in changing domestic and global markets.

The logic flow is summarised in Figure 1.

The development of the strategy is guided by the equation:

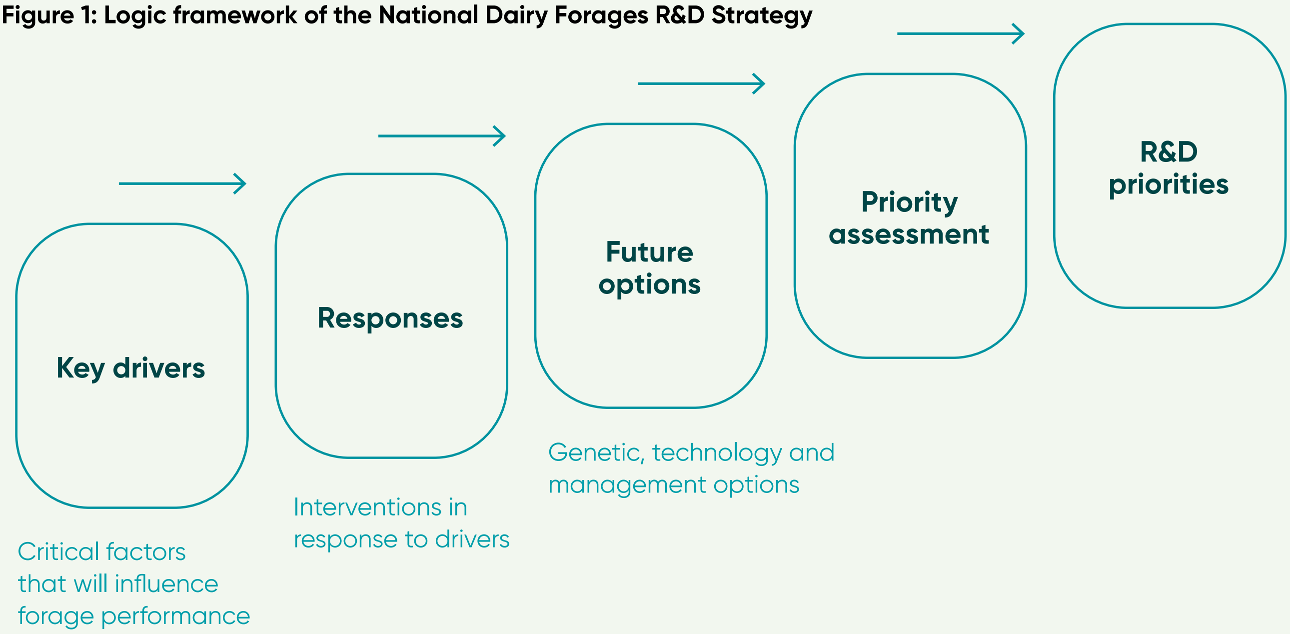
Yield (Y) = Genetics (G) x Environment (E) x Management (M)

Yield (Y): Represents the outcomes targeted through research, innovation, and adoption within the dairy industry. In addition to the traditional agronomic or economic definitions of yield, it can include the emissions of methane, nitrous oxide and nitrates from farm systems to the wider environment. Changing societal expectations, consumer preferences, and the regulatory environment mean they must all be considered in the strategic development of the dairy industry feedbase.

Genetics (G), Environment (E), and Management (M): Define the key factors influencing outcomes, offering both flexibility and focus for strategy development within the context of the pathway to market for innovation.

This methodology ensures a holistic approach to identifying and prioritising research and development that drives sustainable improvements in forage yield and quality, their adoption, and overall dairy industry performance.

Figure 1: Logic framework of the National Dairy Forages R&D Strategy



2.1 Definitions

Forages

Forages, including grasses, legumes, herbs, and crops, are essential for feeding dairy cattle in Australia, either through grazing or by conserving silage or hay. They support milk production, animal health, and farm profitability.
Key forage types and uses are:

- Direct-grazed Forages: Clovers, herbs (e.g., chicory, plantain), forage brassicas, lucerne, perennial grasses, ryegrasses, summer forages, tropical grasses and legumes, and multi-species mixes.
- Mechanically Harvested Forages: Lucerne, summer forages (e.g., maize, sorghum), temperate and tropical legumes, winter cereals, and mixed crops.

Dairy feedbase management strategies integrate grazed fodder crops (e.g., turnips, ryegrass, millet), hay (e.g., oats, lucerne, vetch), silage (e.g., maize, ryegrass, legumes), and crop-based concentrates (e.g., feed barley or wheat, canola meal, soybean meal).

Innovation

Thriving in a complex and evolving environment requires a culture of innovation that combines targeted research with practical application and a pathway to market. Innovations must meet the needs of dairy farmers and the industry through a structured approach to R&D, ensuring relevance and utility.

Two widely cited definitions of innovation provide clarity:

- Joseph Schumpeter[2]: Innovation is "the process of combining existing resources in new ways to create new products, processes, or services that generate value."
- Organisation for Economic Co-operation and Development (OECD) Oslo Manual[3]: Innovation is "a new or improved product or process that differs significantly from previous ones and is made available to users (product) or implemented in use (process)."

Both definitions emphasise novelty, value creation, and implementation as critical components, distinguishing innovation from mere invention. Innovations must be applied or made accessible to create meaningful impact. Innovation is not limited to laboratory settings. Applied R&D, which integrates practical insights from end-users, is vital for delivering impactful solutions directly to farm systems. Stakeholder engagement in R&D ensures innovations are relevant, accessible, and effective, fostering greater adoption and lasting industry benefits.

2. Schumpeter, Joseph A., 1883–1950 (1983). The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle. Opie, Redvers, Elliott, John E. New Brunswick, New Jersey. ISBN 0-87855-698-2.

3. OECD/Eurostat (2018), Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris, https://doi.org/10.1787/9789264304604-en.

Mixed swards

Mixed swards typically refer to pastures composed of two or more plant species, most commonly a single grass and a single legume species, such as perennial ryegrass and white clover. Unlike multispecies swards – which prioritise higher functional diversity – mixed swards often focus on enhancing outcomes such as nitrogen fixation, forage quality, and seasonal productivity by exploiting trait complementarity among species.

Multispecies swards

Refer to pastures deliberately sown with a very broad diversity of plant species – commonly a mix of grasses (e.g., perennial ryegrass, phalaris), legumes (e.g., white clover, lucerne), and herbs (e.g., chicory, plantain) – to enhance ecosystem function, productivity, and resilience[4].

New Breeding Technologies (NBTs)

NBTs refer to a suite of advanced molecular and biotechnological tools that accelerate and enhance the precision of developing improved forage varieties. These technologies go beyond traditional plant breeding methods by enabling targeted genetic changes, trait enhancement, and faster breeding cycles.

Pre-breeding

Pre-breeding refers to the research activities undertaken before the formal breeding process, specifically focusing on identifying desirable traits or genes from unadapted materials and transferring them to a more usable genetic background.

Research & Development (R&D)

The term R&D[5] covers three types of activity: basic research, applied research and experimental development.

- **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
- **Applied research** is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. Two levels can be distinguished: 1) 'proof-of-concept' research to confirm that basic science principles can be successfully translated into practical solutions; 2) 'proof-of-practice' research that confirms solutions work in practical settings.
- **Experimental development** is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

Timeframes

The definitions of short, medium, and long-term timeframes in R&D can vary depending on the industry, the nature of the research, and the organisation. However, in general terms, these timeframes are commonly defined as:

- **Short-term (0–2 years):** Focus on immediate priorities, rapid deployment of known solutions, or early-stage testing. Examples include validating an existing pest management strategy in a new region, conducting a survey of current farmer practices, or running a one-season forage trial for rapid feedback.
- **Medium-term (3–5 years):** Focus on applied R&D with a pathway to adoption; development and validation of new tools, systems, or practices. Examples include developing and refining a new forage mix, rolling out decision-support tools with on-farm testing, or evaluating the environmental or economic impact of new practices over time.
- **Long-term (6–10+ years)**: Focus on transformational research, capacity building, and foundational science with broad, lasting impact. Examples include breeding programs for climate-resilient forages or livestock, longitudinal studies on soil health, water use efficiency, or carbon sequestration, or developing entirely new farming systems or biotechnology platforms.

Trait definitions

- Drought recovery in forage plants refers to the plant's ability to resume growth and productivity after a period of water stress or drought. It reflects how quickly and effectively a plant can recover once favourable moisture conditions return.
- Persistence in forage plants refers to their ability to survive and remain productive over multiple seasons or years under grazing, environmental stress, and management conditions. With respect to genetic improvement, 'persistence' is defined as the persistence of the advantage in trait expression measured in 'improved' cultivars relative to baseline (genetic base) cultivars: for example, the persistence over the medium- to long-term of a clear yield advantage created by breeding. This definition encompasses both the physical survival (or otherwise) of improved cultivars, plus the continued expression (or otherwise) of the trait in the surviving population.

4. Pembleton, K.G., et al. (2021). "Multispecies pastures: Potential benefits for Australian grazing systems." Agronomy Australia Conference Proceedings. Available via: https://www.agronomyaustraliaproceedings.org .
5. OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris, https://doi.org/10.1787/9789264239012-en.

Innovations must be applied or made accessible to create meaningful impact.

3

Strategic context

The Terms of Reference for National Dairy Forages R&D Strategy strongly emphasise forage species used in the Australian dairy feedbase, including:

- available species and their management requirements
- their relative importance
- current and future research investments
- prospects for commercial partnerships to bring new options to market.

This section provides a brief overview of the first three points and 'pathways to market' are covered in detail in Section 7.

While the focus of the Terms of Reference is on species, it's important to note that forage management often has a greater impact on performance (e.g., poor management can easily override genetic gains). Accordingly, the analysis of R&D priorities uses the G x E x M framework, with significant attention to the management (M) component.

3.1 Current forage types and areas

Recognising the inconsistent and limited quality of forage data collection in Australia, estimated contributions[6] to Australian milk production by forage type are:

- Perennial forages account for approximately 27–33% of the total feed required
- Annual forages contribute roughly 15–25%
- Crops and herbs provide around 10%.

The remaining feed requirement is met through supplementary feeds, which have grown from about 30% of the total dairy diet in the early 2000s to around 38% today (based on an arithmetic average across all states). This rise in supplementary feeding corresponds with a decline in the proportion of feed sourced from grazed pasture.

Key takeaways:

- Data limitations: The available data used to estimate these contributions is sparse and difficult to interpret with confidence – highlighting a significant knowledge and data gap that must be addressed.
- Shift in forage composition: Perennial forages now represent only about 30% of the national dairy feedbase (averaged across two estimation methods), while short-term (annual) pastures likely account for at least 20% – and their share is growing.

Given the 8,376 million litres of milk produced in 2023-24 was worth $6.237 billion in farmgate value, it is assumed that forages contributed to about $3.9 billion or 62% of this value.

It is estimated that nationally there is around 960,000 hectares of irrigated and rain-fed land supporting dairy forage production – although it is not clear if the available data refers to milking platform area only, or milking platform plus support land (e.g., for rearing replacement stock, feeding dry cows or growing feed for the milking herd). Approximately 400,000 hectares of dairy land in Australia (42% of total dairy land area) is resown in pastures or crops each year (Australian Seed Industry, pers. comm., January 2025). The main forage types currently planted (ranked by estimated planting area) are shown in Table 1.

6. Assumptions include: the percentage of total pasture area sown annually to short-term pastures is assumed to equal their proportion in the total diet (Australian Seed Industry, pers. comm., January 2025); because perennial pasture areas are uncertain, their contribution is estimated as the difference between total grazed pasture and the more reliably known short-term pasture area, which is sown annually; alternatively, the total perennial pasture area for dairy feed is estimated by multiplying the annual sown area by the average pasture lifespan in each region.

Table 1: Estimated annual planting area (ha) of main forage systems

Forage type planted	Estimated annual planting area (ha)
Annual ryegrass (pure sward)	81,170
Annual ryegrass + annual clover	46,190
Brassicas	40,030
Perennial ryegrass + white clover	37,920
Italian ryegrass + annual clover	35,200
Italian ryegrass (pure sward)	34,350

Source: Australian Seed Industry – pers. comm. (January 2025)

See Appendix 3 for more detailed information on the Australian forage market.

3.2 Forage R&D expenditure

Analysis of expenditure by Dairy Moving Forward partners shows that approximately $13.5–15.0 million in levy and public R&D funding is invested annually in dairy forage research projects across Australia.

In addition, the private sector – including technology providers and seed companies – is estimated to invest a further $25 million each year into forage R&D relevant to dairy production in Australia and New Zealand.

Table 2: Estimated proportion of levy and public forage R&D funding by project category

Category	Estimated proportion of levy and public forage R&D funding
New breeding technologies	53%
Soil, water & nutrient cycle management	19%
Precision technologies	13%
Strategic forage and crop selection	9%
Optimised use of inputs	4%
Sustainable and resilient production systems	1%
Efficient grazing and pasture management	<1%
Conventional breeding	<1%

Source: DMF project documentation

Together, public and private investments represent only around 0.35% of the estimated $3.9 billion in Australian farmgate value that forages underpin. By comparison, New Zealand invests approximately 0.5% of its $18.4 billion in annual dairy export revenue (after adjusting for purchased feed) into forage-related R&D.

Investment in forage R&D relative to the economic value it supports is low by comparable standards, indicating a critical opportunity to strengthen Australia's forage R&D effort.

The primary areas of levy and public project investment in forage R&D in Australia are shown in Table 2. The majority (53%) of the investment is currently allocated to projects involving new breeding technologies (NBTs)[7].

7. NBTs refer to a suite of advanced molecular and biotechnological tools that accelerate and enhance the precision of developing improved forage varieties. These technologies go beyond traditional plant breeding methods by enabling targeted genetic changes, trait enhancement, and faster breeding cycles.

The top five forage species by estimated current levy and public forage R&D project funding in Australia are shown in Table 3. These estimates do not include plant breeding or other R&D expenditure by the commercial sector, which are estimated to fall in the range $25-$35 million per year across New Zealand and Australia.

Table 3: Estimated proportion of levy and public forage R&D funding by forage species

Forage species	Estimated proportion of levy and public forage R&D funding
Perennial ryegrass	29%
Lucerne	21%
Cocksfoot	12%
Kikuyu	9%
Annual and perennial multispecies mixtures	8%
All other species	21%

Source: DMF project documentation.

Explanatory note: future importance of forage species by 2040

The anticipated importance of different forage species by 2040, as presented here, represents a consensus view from experts on the most likely scenario based on current trends and expected developments. It does not necessarily reflect the preferred or ideal future for the industry. For instance, a predicted increase in the use of annual species relative to perennials may not align with long-term sustainability goals but is considered probable given the key drivers. This summary aims to provide a realistic outlook to guide strategic planning, while acknowledging that actual future outcomes may differ as priorities and technologies evolve.

3.3 Future importance of forage species

The strategy's expert panel, supported by input from a wide range of industry specialists with deep sector knowledge, assessed the expected importance of key forage species by 2040. Species were rated on a 10-point scale (1 = Not at All Important; 10 = Extremely Important).

This analysis highlights potential investment gaps, identifying species that may become more critical but are currently underfunded, as well as species that may be overfunded relative to their future importance. Tables 4-6 present the regional importance ratings for grazed forages and mechanically harvested forages for respective agroecological zones.

Categories for importance ratings are:

	Very High
	High or Moderately High
	Above Average or Medium
	Moderately Low or Low
	Very Low or Not at All Important

Table 4: Future importance of forage species by 2040 – wet temperate agroecological zones (coast and highlands)

The wet temperate agroecological zones (coast and highlands) are characterised by a cool, moist climate with high annual rainfall, often exceeding 800 mm, distributed fairly evenly or concentrated in winter months. Dairy farms in the wet temperate agroecological zones produce approximately 67% of Australia's total milk production.

Grazed forages	Annual and perennial mixes	Perennial ryegrass	Annual ryegrass	Brassicas	Herbs (chicory, plantain)	Italian ryegrass	White clover	Other clovers	Lucerne	Tall fescue	Cocksfoot	Oats
Gippsland and South East NSW	8.1	8.0	6.6	6.0	7.0	6.9	7.3	5.6	4.8	5.0	4.5	3.3
South West Victoria and South East SA	7.6	7.5	6.8	8.0	6.1	6.4	5.5	6.1	5.6	4.0	3.9	3.9
Tasmania	7.7	9.0	4.6	5.5	5.9	4.9	7.1	4.9	3.9	3.7	4.2	3.1
South West WA	6.5	3.5	9.3	1.0	4.0	6.0	2.3	5.0	2.7	3.3	3.0	5.5
Weighted average	**7.8**	**7.7**	**6.5**	**6.4**	**6.3**	**6.3**	**6.2**	**5.7**	**4.8**	**4.3**	**4.1**	**3.6**

Mechanically harvested forages	Maize	Lucerne	Oats	Sorghum	Vetch	Wheat	Barley	Other species – mixed/multispecies	Millet	Mixed cropping	Triticale	Fabaceae
Gippsland and South East NSW	6.6	4.9	3.6	2.8	2.6	2.5	2.5	2.6	2.8	2.0	1.4	1.5
South West Victoria and South East SA	5.3	5.0	3.3	3.9	3.6	3.0	2.8	2.8	2.4	2.8	2.5	1.8
Tasmania	4.6	3.8	2.1	1.7	1.6	2.0	2.0	2.2	1.2	1.8	1.8	1.0
South West WA	5.6	2.4	4.2	3.0	3.2	3.2	3.4	2.0	3.0	2.4	2.4	1.2
Weighted average	**5.7**	**4.6**	**3.3**	**3.0**	**2.9**	**2.7**	**2.6**	**2.6**	**2.4**	**2.3**	**1.9**	**1.5**

Table 5: Future importance of forage species by 2040 – temperate seasonally dry slopes and plains

The temperate seasonally dry slopes and plains agroecological zone is characterised by a semi-arid to subhumid climate with distinct seasonal variations. Rainfall is moderate (400–800 mm annually) and typically concentrated in the cooler months, while summers are warm to hot and dry. The temperate seasonally dry slopes and plains agroecological zone produces approximately 25% of Australia's total milk production.

Grazed forages	Annual ryegrass	Italian ryegrass	Other clovers	Oats	Forage sorghum	Annual and perennial mixes	Lucerne	Barley	Wheat	Millet	White clover	Herbs (chicory, plantain)
Northern Victoria, Riverina, Inland NSW, Rest of SA	8.6	7.3	6.6	6.5	6.5	6.4	6.3	5.3	5.3	4.8	4.5	4.9

Mechanically harvested forages	Maize	Lucerne	Sorghum	Vetch	Oats	Wheat	Millet	Mixed cropping	Barley	Triticale	Other species – mixed/multispecies swards	Soybean
Northern Victoria, Riverina, Inland NSW, Rest of SA	8.6	7.3	5.9	5.5	4.9	4.9	3.9	3.5	3.4	3.0	2.8	2.6

Table 6: Future importance of forage species by 2040 – wet subtropical coast and sub-humid subtropical zones

The wet subtropical coast and sub-humid subtropical zones (slopes, plains, and highlands) are characterised by a warm, humid to sub-humid climate with high annual rainfall, typically exceeding 800 mm, often concentrated in summer. Approximately 8% of Australia's total milk production comes from wet subtropical coast and sub-humid subtropical zones.

Grazed forages	Annual ryegrass	Kikuyu	Brachiara	Lucerne	Oats	Annual and perennial mixes	Italian ryegrass	Rhodes grass	Millet	Forage sorghum	Tropical legumes	Herbs (chicory, plantain)
Queensland/North Coast NSW	8.4	7.1	6.7	6.6	6.4	5.9	5.6	5.4	5.1	5.0	5.0	4.9

Mechanically harvested forages	Maize	Lucerne	Sorghum	Millet	Oats	Soybean	Barley	Wheat	Triticale	Fabaceae	Mixed cropping	Vetch
Queensland/North Coast NSW	7.6	6.4	6.0	5.7	5.3	4.9	4.1	4.0	4.0	3.7	3.3	3.1

4

Key drivers

Key drivers in this forage R&D strategy are the major forces that will shape future forage selection, on-farm decision-making, and the long-term sustainability of the dairy industry over the next 30 years. These drivers influence priorities for forage selection, management, and innovation – whether in extensive grazing systems or intensive housed operations (e.g., total mixed ration (TMR) systems).

It's important to distinguish drivers from responses.

- **Drivers** are high-level external or internal forces – such as market trends, regulatory shifts, environmental pressures, or industry-level changes in profitability and productivity – that impact the sector's competitive[8] and comparative advantage[9].
- **Responses** are the on-farm actions or interventions that can be used to adapt to, mitigate, or take advantage of these drivers.

For instance, intensification (shifting from grazed forage to low-grazing or TMR systems) is not a driver itself but a response to drivers like climate variability, water access, or economic conditions.

8. 'Competitive advantage', refers to the competitiveness of products from the Australian dairy industry in international markets, relative to other dairy product exporting nations (e.g. New Zealand, European Union). Cost of production of raw milk is a key driver of competitive advantage.
9. 'Comparative advantage' refers to the strength of dairying in generating a return on all assets employed in production (land, machinery, animals etc.) relative to other uses for the capital consumed in those assets within Australia. Assets such as good quality land can be used for multiple purposes and land use patterns will tend to follow trends in return on assets.

At the highest level, there are five key drivers:

1 **Productivity**	The efficiency with which inputs are converted to outputs (for the purposes of this analysis, outputs = homegrown forage harvest, milk production, profit, but also environmentally important emissions such as enteric methane, nitrous oxide, and nitrates) and measured in terms of efficiency ratios, e.g., home gown forage utilisation efficiency, nutrient use efficiency, water use efficiency, etc.
2 **Profitability**	Maintaining or improving competitive advantage and comparative advantage, measured in terms of return on capital and cost of production.
3 **Resilience**	The ability to withstand and bounce back from abiotic and biotic-related stresses to plant growth, deal with input volatility, and maintain soil health and animal welfare, which can be measured in terms of the variability (within and between years) in key production and profit performance indicators.
4 **Sustainability imperatives**	Societal and market pressures to reduce enteric methane, nitrous oxide, and nitrate (leaching) and improve biodiversity, which can be measured in terms of intensity ratios, e.g., grams of methane per unit livestock production, or total outputs.
5 **Input volatility**	Variability in cost and availability of key inputs: fertiliser, water, land, pesticides and seed.

Guide to impact and implementation rankings

Potential impact criteria:

- Expected impact
- Potential effect on cost of production
- Co-benefits
- Scale
- Timeframe

Ease of implementation criteria:

- Path to market
- Adoptability
- Market acceptance
- Risk profile
- Established capability, capacity & infrastructure

Forage R&D focus areas were initially identified by mapping response options against the five key industry drivers of forage performance and selection decision-making factors. These focus areas were then assessed by the expert panel taking account of ten criteria – covering both potential impact (five criteria) and ease of implementation (five criteria) – see to the left.

The draft list of R&D focus areas was subsequently shared with a broader group of stakeholders through interviews, where they provided feedback and priority ratings. The potential impact for each R&D focus areas was ranked on a ten-point scale (1 = Very Low impact; 10 = Very High impact), allowing a clear and structured identification of the most critical priorities for future investment. Ease of implementation was ranked on a ten-point scale (1 = Extremely Difficult – Not currently feasible; would require breakthroughs or transformation; 10 = Very Easy – Readily implementable with existing knowledge, tools, infrastructure, and minimal cost or risk).

Categories for ratings are:

Potential impact:		Ease of implementation:	
[VH]	Very High	[VE]	Very Easy
[H]	High	[E]	Easy
[M]	Moderate	[M]	Moderate
[L]	Low	[D]	Difficult
[VL]	Very Low	[VD]	Very Difficult

4.1 Productivity

4.1.1 Expected R&D outcome

Improved efficiency in forage system resource use – while also minimising environmental impacts.

4.1.2 Issue

Dairy forage productivity gains are likely to slow – if they haven't already – reflecting trends seen in crop and forage systems both in Australia and globally. This decline stems from several factors, including:

- Direct impacts of climate change on plant growth and yield.
- Reduced resource availability (e.g. lower irrigation water allocations).
- Regulatory limits on inputs to protect the environment (e.g. water quality).
- Approaching the ceiling of yield potential given current genetics, management, and environmental conditions.

Some of these challenges are already affecting Australian agriculture, while others are likely to emerge. Sustained improvements in forage productivity are essential to maintaining farm profitability and industry growth.

4.1.3 Context

Stagnant productivity gains

- In southern dairying regions (Victoria and Tasmania), most gains in pasture harvest over the past two decades can be mainly explained by increases in nitrogen fertiliser use and/or stocking rate. Contributions from plant breeding, management or technological advancements are not obvious from industry benchmarking data.
- In general, the efficiency of utilisation of pasture remains well below potential, limiting productivity gains and profitability despite substantial past investments in developing grazing and pasture management practices that lead to higher utilisation.
- Research suggests several tonnes per hectare of forage utilised could be gained through better grazing and feed management.
- However, despite this evidence, adoption of improved practices is low – as many farmers are confident in their current methods and, according to industry survey data (e.g., 2019 Dairy Australia Feed and Nutrition Survey), report that they are already achieving close to the full potential of their pastures and crops.
- Formal grazing and feeding decision-support tools (e.g., Pasture.io, Farmax, etc.) exist but are significantly underutilised.
- Limited data hinders informed industry-level forage R&D investment and prioritisation decision-making and prevents meaningful measurement of trends over time in key forage performance indicators such as pasture and home-grown forage crop harvest rates, pasture longevity, and productivity (e.g., dry matter harvest relative to inputs such as nutrient or water use).

Unrealised genetic potential

- Genetic gains in pastures and other forages are poorly tracked and inconsistently realised on-farm. Yield improvements are more strongly linked to the introduction of endophytes in perennial ryegrass, and improvements in agronomy and climate than plant genetics alone.
- Potential genetic gain is typically estimated using tightly controlled small-plot trials, such as the EU National Cultivar Listing, Australia's Pasture Trial Network (PTN), and New Zealand's National Forage Variety Trial (NFVT). These trials focus mainly on ryegrass species and measure traits like yield and, in some cases, digestibility.
- While useful for ranking cultivars, these trials do not clearly reflect how yield gains translate to performance in commercial farm systems. Globally, only Teagasc's PastureBase Ireland (PBI) system attempts[10] to estimate on-farm genetic gain, relying on data from its own decision-support tool; data from private tools are excluded.
- Unlike in animal breeding, no national system exists in Australia or New Zealand to systematically monitor realised genetic gain in forages in dairy farm systems – such as the rate of uptake of 'improved' cultivars and their impact on productivity.

10. Hanrahan, L. et al. 2017. PastureBase Ireland: A grassland decision support system and national database. Computers and Electronics in Agriculture, 136: 193-201.

- Estimated gains in perennial ryegrass based on data from small-plot evaluation trials range between 0.3-1.0% per annum (equivalent to $12–$18 per hectare), however information from industry farm benchmarking and anecdotal comments from industry stakeholders suggest these rates of gain are not being captured on-farm.
- Early results from PBI show it can detect meaningful differences between perennial ryegrass cultivars[11], suggesting this approach could be adapted in Australia and New Zealand to better assess the real-world impact of breeding at both system and industry levels.
- Data on genetic gains in forage crops (and other non-ryegrass pasture species) in Australia is severely limited.
- Realising genetic potential will require:
  - A deeper understanding of how well the traits that plant breeders have been selecting for (e.g., dry matter yield) are expressed in commercial farm systems, and where and why expression is failing.
  - Changes and improvements in on-farm management practices to capture the potential of new phenotypes.
- Closing the gap requires better monitoring, addressing adoption barriers, and aligning breeding priorities with on-farm needs.

Inadequate access to forage genetics

- Commercially available forage crop germplasm for Australian dairy systems is limited and outdated compared to global standards.
- Global seed companies (often headquartered in the US or Europe) may prioritise larger or more profitable markets rather than Australia's dairy and forage sector which is relatively small.
- Many elite US maize hybrids are genetically modified – which are not approved for commercial use in Australia, restricting access to top-tier hybrids and traits such as resistance to Fall Army Worm.
- There are few dedicated forage breeding programs focused on dairy production systems in Australia, particularly for species like lucerne and maize.
- Without widespread, coordinated multi-environment trials (METs) of imported and local genetics, it's difficult for growers and advisors to compare performance.

Forage breeding critical but undervalued

- Notwithstanding the observations above, plant breeding is a very important tool for improving future forage productivity, increasing resilience of the feedbase to climate change, and reducing the environmental footprint of dairy systems.
- Australia and New Zealand are leaders in pasture breeding, yet the plant breeding sector is undervalued compared with the animal breeding sector, relative to its potential contribution to industry development.
- Plant breeding has a long lead time with new cultivar development taking eight to 12-years – with an estimated average cost of developing a new ryegrass cultivar in Australia or New Zealand falling in the range of $2-5 million per cultivar.
- The short commercial lifespan of cultivars – typically five to six years – with the resultant high turnover of cultivars, plus the increased range of cultivars available makes cultivar selection and adoption increasingly complex for farmers and advisors.
- Forage value indices (FVI in Australia and New Zealand; Pasture Profit Index in Ireland) help but have limitations in guiding farmer decisions.

11. Hearn, C. et al. 2021. Agronomic performance of ten perennial ryegrass varieties on commercial grassland farms. Journal of Agricultural Science, 159: 604-614.

- Future plant breeding should prioritise traits that improve water and nutrient use efficiency, resilience to climate extremes, and reduce nutrient losses and greenhouse gas emissions – placing less emphasis on yield, where gains have already been made, and potential further progress is limited.
- No framework currently exists to assess the full economic and environmental value of key future traits. While the Forage Value Index (FVI) includes economic values for yield and quality, it does not cover traits like water or nutrient use efficiency, environmental footprint, or climate resilience for perennial species.
- The establishment of National Breeding Objectives for dairy forages is needed – similar to those in animal breeding and broadacre cropping – to assign economic values to critical traits and guide breeding priorities by region and resource constraints (e.g., irrigation water). This will enable future trait priorities conferring best overall systems performance to be identified for the main species (e.g. abiotic and biotic resistance).
- The absence of formal, industry-agreed breeding objectives limits the ability to define and support future long-term breeding direction via levy and/or public funding sources.
- The objectives embedded in National Breeding Objectives could be met in some cases by using 'other' species (e.g., non-ryegrass) in farm systems. Where those existing opportunities are not present, then breeding becomes the critical path to future success.

Potential of New Breeding Technologies (NBTs) underutilised

- NBTs remain excluded or underutilised in Australian forage systems despite significant investments and adoption across a range of crops in Australia and internationally. Without action, these innovations risk becoming stranded technologies.
- Barriers to adoption of NBTs include:
  - Poor alignment of path-to-market stakeholders in translation of research to commercialisation and farmer adoption.
  - Unclear translation of research outputs into farmer benefits.
  - Value-capture challenges for stakeholders such as plant breeding companies.
  - Market access and market acceptance challenges.
  - Limited understanding of farm system impacts.
- NBT examples are high-lipid perennial ryegrass (for reduced methane), high condensed tannin clover (to reduce bloat), F1 hybrid perennial ryegrass (exploiting the potential for hybrid vigour), nitrogen-efficient clover, and herbicide-tolerant lucerne.
- Globally adopted NBTs include insect-resistant maize (since 1996), herbicide-tolerant alfalfa (2007), low lignin alfalfa (2017) and Double Team™ sorghum (2021).
- Genomic selection is now being adopted by the major forage plant breeding companies operating in New Zealand and Australia, albeit cautiously given the associated additional costs and potential for disruption of such a major change to established breeding methods. This contrasts to the adoption of genomic selection in forage breeding programs internationally where adoption has been accelerated.
- A program for genomic selection in forage species requires a large, diverse training population that is both genotyped and phenotyped across multiple environments. Programs benefit from early diversity in the training set and rigorous validation to ensure prediction accuracy. This process involves:
  - High-throughput genotyping (e.g., Single Nucleotide Polymorphism (SNP) arrays).
  - Field-based phenomics to capture key traits.

- Statistical models to link genotype with phenotype and predict genetic potential (e.g., Genomic Estimated Breeding Values (GEBV)).
- Selection of top candidates for advancement or crossing.

Alternative species and multispecies swards may have potential

- No single forage species meets all production requirements and mixed swards, multispecies swards, and alternative species (see Definitions on page 15-16) are tools to deal with challenges – rather than an end in themselves.
- There is a need to clearly identify what potential improvements could be made in investigating alternative forage species. The currently low seed sales of these alternatives to ryegrass suggest there is little strong evidence that they provide significant benefits. If clear advantages existed, farmers would likely have adopted them more widely, as they tend to quickly change their feedbase when a better option is proven – such as the widespread uptake of nitrogen fertiliser.

Multispecies mixtures should be chosen with a clear understanding of the problem that is trying to be solved, and therefore what traits are required. That is, a bespoke approach, rather than combinations based on 'feel good' factors.

- Any future investment in multispecies swards should be guided by recent studies, which conclude that there is currently insufficient evidence to support their widespread use, especially regarding improvements in agronomic performance or animal productivity compared to mixed swards (e.g., perennial ryegrass and white clover). However, some research suggests multispecies swards may offer environmental benefits, particularly in reducing nitrogen losses. Therefore, further research may be warranted, focusing specifically on accurately measuring these environmental impacts and exploring whether similar benefits can be achieved with simpler mixtures.
- Multispecies sward research questions should be addressed by integrated multi-environment, multi-year R&D programs, rather than the current approach of funding relatively small, disconnected, within-region projects.

No single forage species meets all production requirements and mixed swards, multispecies swards, and alternative species are tools to deal with challenges – rather than an end in themselves.

4.1.4 R&D focus areas – productivity

Future forage R&D focus areas related to productivity improvements identified and ranked through the strategy process are summarised in table 7 below.

Table 7: Productivity R&D focus areas, potential impact, and ease of implementation

Forage R&D focus areas	Potential impact of future R&D score – NBT	Potential Impact Score of Future R&D – conventional breeding	Ease of implementation
Higher digestibility and energy content	7.6 [H]	6.9 [M]	6.2 [M]
Pest or disease resistance	7.1 [H]	7.4 [H]	4.4 [D]
Improved nutrient use efficiency	7.6 [H]	6.8 [M]	4.4 [D]
Improved water use efficiency	7.4 [H]	6.6 [M]	4.4 [D]
Improved drought tolerance	6.7 [M]	6.9 [M]	4.4 [D]
Improved forage yields	6.7 [M]	6.6 [M]	5.2 [M]
Reduced environmental impact	6.4 [M]	–	7.0 [E]
Improved animal health	6.3 [M]	–	7.0 [E]
Identifying optimal annual and perennial pasture plant phenotypes for balancing yield and resilience by region: National Breeding Objectives		7.1 [H]	3.5 [D]
Systematically screening forage species for environmentally beneficial traits		6.5 [M]	7.0 [E]
Use of endophytes and seed treatments		4.5 [L]	8.2 [E]

4.2 Profitability

4.2.1 Expected R&D outcome

Improved competitiveness and reduced cost of production of forage systems.

4.2.2 Issue

Failing to match competitors in production costs will weaken Australia's position in dairy export markets. Likewise, if dairy underperforms other land uses in returns on assets and investment, capital, skills, and infrastructure may shift to other industries. Strong market performance and access to capital are essential for long-term industry success.

Forage performance directly influences both, as higher use of grazed and homegrown forage lowers the cost of milk production.

Therefore, ongoing R&D to boost forage yields and utilisation must remain central to the national forage strategy – while also addressing why past investments have had such limited industry-wide impact, and ensuring future programs are designed to deliver better outcomes.

4.2.3 Context

Forage performance negatively impacting profitability

- Many contributors to the strategy noted the dairy industry has 'lost its way' on the fundamentals of profitable forage systems. While some regional shifts were unavoidable, key messages around the interaction of cow genotype, forage base, and stocking rate in achieving low-cost, grazed feed need to be renewed and widely shared.
- Efficient production and utilisation of grazed forages is key to profitability in temperate dairy systems. Key profit drivers in pasture-based systems are:
  - The amount of pasture harvested directly by grazing per hectare which is a function of the amount grown and the efficiency with which it is utilised for animal feeding.
  - Matching stocking rates to feed supply.
  - Selecting farm systems that result in a high proportion of the total diet being supplied by grazed pasture and homegrown forage leading to lower costs and greater system resilience.
- Dairy Farm Monitor Project (DFMP) data indicate that, since 2011, pasture harvest has increased 60-90 kg DM/ha annually in southern regions (due to increased nitrogen and stocking rates).
- Despite yield gains, the proportion of grazed pasture in the diet is decreasing – except in Tasmania and Gippsland.
- Many farmers believe they are achieving the best possible utilisation (in tonnes DM/ha consumed) for their system, yet research data (e.g., Garcia et al, 2023[12]) show substantial room for improvement. Addressing paddock-level limiting factors can significantly increase yields.
- Access to different forage genetics and the impacts of climate have changed in recent years, but management practices have not. Best management practices for achieving high and sustainable levels of pasture harvest need to be revisited.

Lack of credible forage performance data limits progress

- There is currently no detailed, comprehensive physical and economic analysis of forage performance across regions and systems in Australian dairying.

As a result, we lack confidence in understanding:

- Whether top-performing farms (e.g., top 5%) are nearing the limits of pasture and home-grown forage utilisation under current environmental and management conditions, or if further gains are possible. Top performers often lead industry trends – if they've plateaued, it signals an urgent need for new technologies and practices.
- The size of the gap between actual and potential performance for the broader industry. While it's generally assumed to be large, it remains poorly defined.
- Key constraints on forage performance such as grazing management, feeding, and soil fertility management appear to be major limiting factors. For example, DairyUP research shows that optimising grazing can boost kikuyu-based pasture utilisation by up to 6 t DM/ha/year within the same farm.

- This kind of independent, credible data is invaluable – but resource-intensive to collect. Committing long-term investment to such strategic analysis is essential.

12. Garcia, S.C., Clark, C.E.F., Kerrisk, K.L., Islam, M.R., Farina, S.R., Evans, J. 2013. Gaps and variability in pasture utilisation in Australian pasture-based dairy systems. Proceedings of the 22nd International Grassland Congress, 1709-1716.

Farm systems change driving costs

- In many regions, climate change and water scarcity have required many dairy farmers to shift away from direct-grazed perennial pastures as their primary feedbase. This has led to:
  - Greater reliance on annual crops and pastures.
  - Increased use of feed supplements.
  - The growing shift toward housed systems (and other feeding infrastructure such as feedpads) and the use of TMR systems.
- Even in less-affected regions (except Tasmania), supplementary feeding has risen, and perennial pasture use has declined.
- This shift has likely increased pasture substitution – where supplements displace rather than complement grazed pasture. Unless managed carefully, this can result in 0.3–0.6 kg of pasture loss for every 1 kg of supplement fed. For example, 2 t DM/ha/year of supplement could lead to 0.6–1.2 t DM/ha of wasted pasture and the associated costs of growing it.
- Similarly, higher nitrogen fertiliser use likely reduces legume content in pastures, replacing free biological nitrogen fixation with costly inputs. While nitrogen fertiliser is often highly profitable, its true return may be overstated due to these hidden substitution effects.

Widespread resistance to technology adoption

- Precision technologies and decision-support tools can enhance pasture and forage management.
- However, adoption is low – most farmers rely on experience (61%) or intuition (12%). Few use objective pasture measurement tools.
- Data alone is insufficient; farmers need training and support to interpret and to make more informed decisions when applying the information.
- Around two-thirds of dairy farmers are unwilling to invest in data-based grazing and feeding management tools such as regular monitoring of pasture cover, use of feed wedges, and rotation planners for critical transition periods.
- Previous industry investments in technology and decision support tools have had limited impact due to low uptake and unclear farmer benefits.
- A strategic rethink is needed by DMF regarding how to effectively encourage adoption, improve decision making, and deliver value to farmers from precision technologies and decision-support tools – including a co-ordinated and collaborative program (with commercial technology developers) to demonstrate proof of practice, ease of use and size of the benefit from their adoption.

4.2.4 R&D focus areas – profitability

Future forage R&D focus areas related to profitability improvements identified and ranked through the strategy process are summarised in Table 8 below:

Table 8: Profitability R&D focus areas, potential impact, and ease of implementation

Forage R&D focus areas	Potential impact of future R&D score	Ease of implementation
Increasing pasture and homegrown forage harvest	8.3 [H]	7.0 [E]
Better utilising DM and ME grown for animal feeding, especially via direct grazing	7.6 [H]	7.8 [E]
Adopting and utilising 'next generation' technology and management systems	6.4 [M]	7.0 [E]
Using sensor-based precision pasture and forage management tools	6.1 [M]	7.0 [E]
Identifying poorer-performing paddocks and addressing growth limitations	6.0 [M]	7.6 [E]
Optimising timing of grazing and regrowth intervals in grass-based systems	5.9 [M]	7.2 [E]
Using formal measurement and decision-support tools for grazing rotations, feed budgeting, and pasture allocation	5.4 [M]	7.0 [E]
Enhancing pasture renewal to capture genetic gain	4.9 [L]	7.7 [E]

Note: While the adoption of formal management decision tools is rated relatively low in Table 7 above, the "size of the prize" nationally is significant so this opportunity should be actively progressed despite historically low uptake.

4.3 Resilience

4.3.1 Expected R&D outcome

Improved stability and consistency of forage yields.

4.3.2 Issue

Climate variability is increasing, with more frequent and intense extreme events – such as heatwaves, droughts, frosts and floods. When these extremes are considered, the long-term outlook for forage growth emerging from climate change modelling studies shifts from neutral (or slightly negative) to clearly negative without adaptation.

Failing to prepare and manage these extremes leads to higher costs and greater risk of environmental harm. Perennial forages, which offer greater resilience, are highly desirable – but their presence in Australia's dairy systems has diminished substantially over recent decades.

4.3.3 Context

Rising pressure, costs, and risks in systems change

- Intensification in the grazing sector (e.g., higher stocking rates, use of Holstein-Friesian genetics, year-round calving, increased cow liveweight and intake, more imported feed, and increased use of synthetic nitrogen) has moved farm systems away from the core principle of matching home-grown feed supply with animal demand, which has supported industry productivity and profitability for decades.
- Feed demand has risen, but home-grown feed supply has not kept pace. Expectations of pastures and home-grown forages are unrealistic, as they face increased management pressure and more frequent climate extremes. This may explain the shortened productive lifespan of perennial pastures, with 20-30% of farm areas being renewed every three to five years.
- The shift to short-term grasses, while addressing feed supply, may increase costs and risks such as soil degradation, loss of soil carbon, and nutrient losses, particularly nitrogen.
- Farm systems are now more vulnerable to fluctuations in input availability and costs.
- There is a need to refocus on farm systems for low-cost, low-environmental-impact production and key messages about the interactions between cow genotype, forage base, and stocking rate for low-cost, low-environmental-impact production must be refreshed and communicated across the industry.

Climate shifts reshaping forage performance

- Climate change brings two key challenges: greater variability and extreme weather events; and gradual shifts in temperatures and rainfall patterns.
- Moderate warming may slightly increase pasture production in some temperate and Mediterranean regions.
- Changes in climate patterns could advance seasonal break by one to two months and shift pasture growth patterns significantly.
- Extreme events already have a stronger, more immediate impact on farm performance than gradual climate trends.

Tactical adaptation needed for extreme weather events

- Climate variability is increasing with more frequent heatwaves, droughts, frosts and floods.
- Traditional adaptation strategies (e.g., irrigation, forage species selection, supplementary feeding) are becoming less effective.
- Agricultural systems models often underestimate the severity of extreme events – and projected outcomes are expected to worsen without adaptation.
- Immediate responses may include shifting from perennial to annual forage species.
- RD&E should prioritise scalable, practical solutions to boost climate resilience and advances in plant breeding, agronomy, and adoption of industry best practices.

Strategic adaptation required for long-term climate change

- Rising temperatures and declining rainfall are projected to reduce total forage production, shorten perennial ryegrass growing seasons, and increase the need for heat-tolerant and water-efficient forage species, especially during summer.
- Irrigated systems face added pressure from reduced water availability and lower growing season rainfall.

- Long-term resilience will require:
  - NBTs focused on water use efficiency and heat tolerance with eight to 10-year development timeline to market.
  - High-performance soils and integrated soil health strategies.
  - Precision nutrient management to maintain productivity.

Soil and plant microbiome holds promise

- Genomic selection and other technologies are providing new insights into the role of the microbiome (bacteria, fungi, and archaea) in plant function and plant-soil interactions.
- The dairy industry already benefits from microbial associations in grassland agriculture, such as rhizobia in legumes and Epichloe endophytes in grasses.
- Emerging evidence suggests the soil microbiome influences key plant growth processes, including nutrient uptake, disease resistance, insect protection, and tolerance to drought or salinity.
- However, the dairy industry currently knows little about the identity and function of soil microbes in grazed pastures and crops, or how microbiome interactions change when pastures are replaced by crops.
- New research may eventually fill this knowledge gap, leading to technologies that can be applied on farms.
- Despite rapid developments, practical, beneficial outcomes remain uncertain and are likely still far off.

4.3.4 R&D focus areas – resilience

Future forage R&D focus areas related to resilience identified and ranked through the strategy process are summarised in Table 9 below:

Table 9: Resilience R&D focus areas, potential impact, and ease of implementation

Forage R&D focus area	Potential impact of future R&D score	Ease of implementation
Species choices (beyond ryegrass) to better match plant and environment	8.1 [H]	4.8 [D]
More informed decisions when selecting pasture and crop options	7.0 [H]	7.4 [E]
Expanding forage-cropping	6.4 [M]	6.8 [M]
Using forages and/or management practices to prevent and/or support recovery from pugging damage to soils and pastures.	5.0 [M]	8.8 [E]
Shifting towards annual pastures and crops	4.6 [L]	8.6 [E]
Deferring grazing of perennial pastures	3.2 [L]	6.6 [M]

4.4 Sustainability imperatives

4.4.1 Expected R&D outcome

Forage production systems with low environmental footprints – and that avoid or minimise the impacts of current and future environmental regulations.

4.4.2 Issue

Global dairy supply chains are increasingly requiring on-farm certification to prove compliance with greenhouse gas emission standards as a condition for market access. At the national and state levels, regulations targeting dairying's impact on freshwater, biodiversity, and contaminants are tightening, increasing compliance costs and community scrutiny. Forages may offer lower-cost solutions to some of these environmental challenges.

4.4.3 Context

Balancing environmental and economic outcomes in sustainable forage strategy

- A sustainable forage strategy must balance environmental and economic outcomes.
- Key environmental concerns include:
  - Nutrient losses and movement into waterways and groundwater.
  - Soil degradation.
  - Greenhouse gas emissions.
  - Sediment movement.
- The Australian dairy industry's sustainability priorities are:
  - Managing physical climate risk.
  - Improving water use efficiency.
  - Reducing greenhouse gas emissions.
  - Enhancing nutrient management and biodiversity.

Addressing complex environmental challenges through integrated farm systems

- The complex challenges outlined above cannot be addressed through single interventions. Instead, they require a 'stacked' approach[13], where multiple management and technological solutions are implemented in combination. This demands integrated farm systems research that aligns species selection, strategic and tactical management, and enabling technologies (e.g., methane or nitrification inhibitors) to optimise both profitability and environmental outcomes.

The role of experimentation and modelling

- Farm systems experimentation and demonstration are essential for two key reasons:
- They allow R&D to absorb the risk of implementing multiple simultaneous changes, which individual farmers are unlikely to accept without evidence.
- They uncover interactions between interventions, many of which may reduce the net benefit due to non-additive effects and must be understood to set realistic expectations.
- Given the cost of systems trials, pre-experimental systems modelling is critical to ensure efficient and targeted design. The dairy sector is well-positioned here, with strong modelling expertise and a proven track record in farm systems innovation.

13. Bilotto, F. et al. 2025. Costs of transitioning the livestock sector to net-zero emissions under future climates. Nature Communications 16, Article number 3810. https://www.nature.com/articles/s41467-025-59203-5

4.4.4 R&D focus areas – sustainability imperatives

Future forage R&D focus areas related to sustainability imperatives identified and ranked through the strategy process are summarised below in table 10:

Table 10: Sustainability imperative R&D focus areas, potential impact, and ease of implementation

Forage R&D focus area	Potential impact of future R&D score	Ease of implementation
Better management of water, carbon and nitrogen cycles in grazing and cropping systems. (e.g. reducing farm gate nitrogen surplus, improved water use efficiency, retain soil carbon)	8.4 [H]	7.0 [E]
Increasing adoption of multi-species pastures and enhanced nutrient cycling	8.1 [H]	7.0 [E]
Re-prioritising legumes as critical components of resilient, low-footprint forage systems	7.6 [H]	7.8 [E]
Decreasing animal nutritional syndromes. (e.g. bloat, ryegrass staggers, heat stress)	4.9 [L]	7.5 [E]
Pushing towards rainfed or partially irrigated systems requiring lower inputs – de-intensification	4.2 [L]	4.6 [D]
Integrating plantain into forage base	4.1 [L]	7.6 [E]

4.5 Input volatility

4.5.1 Expected R&D outcome

Reduced dependency on key inputs for forage production.

4.5.2 Issue

Volatility in input prices and supply is disrupting farm productivity, profitability, and industry stability – driven by global supply chain issues, export restrictions, and dependence on imports. Regulatory and climate changes are also affecting irrigation water access, availability, and cost. In the southern Murray-Darling Basin, water markets have evolved to direct water towards its highest-value use.

4.5.3 Context

Forage input costs rising significantly

- Forage costs per hectare have risen 66% in real terms over the past decade.
- Forage now makes up 25–35% of farm variable costs and about 20% of total production costs.
- Key cost increases (since 2014):
  - Fertiliser: Up 62% to $311 per hectare (2023), driven by global supply issues and nitrogen price volatility.
  - Seed: Up 72%, now averaging $45 per hectare, reflecting increased import costs.
  - Fuel: Increased 21%, impacting irrigation and fodder conservation.
  - Pesticides: Averaged $28 per hectare in 2023, with access issues due to import reliance and regulation.

Difficulty in access to irrigation water

- The Murray Darling Basin (MDB) accounts for 25% of dairy's gross value of agricultural production (GVAP), with 78% of MDB dairy farms in Victoria.
- Over half of dairy farms rely on irrigation, covering 64% of milking platforms.
- Water markets in the southern MDB favour high-value alternate crop use, raising allocation prices.
- Farmers are avoiding irrigation when prices exceed $200/ML, shifting to water-efficient forage crops, or in some cases, exiting dairy altogether due to economic related water pressures.

Dairy land prices soaring

- Dairy land prices rose by an average of 5.6% annually over 30 years – but surged 28.1% from 2020–2023.
- Regional land price averages:
  - Northern Victoria: ~$20,000/ha (2.1x broadacre).
  - Gippsland: ~$42,000/ha (4.4x broadacre).
  - Tasmania: ~$46,000/ha (4.9x broadacre).
- High land costs are driving:
  - Intensification of dairy systems.
  - Greater reliance on high-yield forage crops (e.g., lucerne, maize silage).
  - Relocation to more affordable regions.
- Farmers cite access to water and land prices as major constraints and change drivers for forage systems over the next decade.

4.5.4 R&D focus areas – input volatility

Future forage R&D focus areas related to input volatility identified and ranked through the strategy process are summarised below in Table 11:

Table 11: Input volatility R&D focus areas, potential impact, and ease of implementation

Forage R&D focus area	Potential impact of future R&D score	Ease of implementation
Pushing towards more self-sufficient feed systems e.g., maximise home grown forage for total feed supply	7.5 [H]	7.2 [E]
Better utilisation of inputs to grow DM and ME	7.5 [H]	8.0 [E]
Better utilisation of inputs to match with changed growing season windows and the impact of pests and diseases	6.7 [M]	5.4 [M]
Innovative weed and pest management solutions	5.1 [M]	6.6 [M]

4.6 Enabling factors

4.6.1 Issue

While many specific forage R&D priorities have been identified, their impact will be limited without corresponding capabilities, capacity, infrastructure, and partnerships. Analysis of reports and stakeholder interviews revealed several critical unmet needs with most pressing listed below.

4.6.2 Context

Farm systems capability diminishing

- There has been a reduction in professionals skilled in whole-of-farm systems thinking – limiting the ability to assess interactions between forages, animals, economics, and environment.
- A shift toward siloed, discipline-specific work has weakened the development of practical, systems-based solutions for farmers.
- Retirement or movement of senior farm systems researchers and advisors has not been matched by new capability.
- Funding tends to prioritise component-level research, leading to gaps in system-level understanding and innovation.
- Practical, farm-scale testing and learning opportunities for systems integration have declined, reducing farmer engagement and trust.

Concerns about development processes

- Generally, forage R&D projects are not reviewed and tested in a structured format with farmers and other users of the project outputs early enough in the planning phase.
- There does not appear to be high levels of genuine co-design with stakeholders (e.g., farmers, commercial sector) at the project initiation and planning phases.
- Project teams are not engaging with a diverse range of farmers, including those who will challenge scientific thinking across a range of areas.
- Broadening stakeholder engagement, including input from the commercial sector and technology providers, and other end-users is required to enhance the relevance and impact of forage R&D projects.
- Some stakeholders, including project teams, are concerned about insufficient resourcing and capability in the Development and Extension (D&E) part of the innovation chain.

Strengthened leadership and collaboration needed

- Recent mid-term reviews of Dairy Australia-funded feedbase projects show:
  - Research teams often list collaborators in proposals, but follow-through is weak.
  - Collaboration typically stalls due to time constraints and limited staffing.
  - Some Australian forage researchers have declined or ignored opportunities to work with local or international peers.
- Currently, there are no joint forage projects between Australian and New Zealand (e.g., between Dairy Australia and DairyNZ), despite clear synergies and shared challenges. This represents a missed opportunity for deeper trans-Tasman collaboration in a strategically important domain. Also, collaboration between Australia and Ireland (e.g., Irish Agriculture and Food Development Authority (Teagasc)) remains undeveloped.
- Similarly, there is a lack of tangible collaboration in forage R&D between Australia and countries with strong exposure to TMR-based forage systems.
- Current fragmentation between plant breeders, agronomists, and animal nutritionists is limiting the value and impact of forage innovation. Unlike the grains industry – where breeding is driven by clear end-use requirements and aligned stakeholder input – the dairy forage sector operates in silos, with minimal communication across disciplines.
- Stronger cross-sector linkages with Meat & Livestock Australia (MLA), the Grains Research & Development Corporation (GRDC), and others would provide broader benefits and access to more forage phenotypic data and research capability and capacity than exists in dairy alone.

5

Strategic R&D priorities

5.1 Areas to increase effort, funding, or attention

Set National Breeding Objectives and implement evaluation systems to drive progress on regional benchmarks:

Develop industry-endorsed National Forage Breeding Objectives for perennial grasses, short-term grasses, legumes, and forage crops (see Section 6). This exciting initiative will foster structured collaboration across diverse stakeholders and technical experts – including farmers, systems researchers, plant breeders and geneticists, agronomists, economists, plant physiologists and animal nutritionists – unlocking the full potential of the dairy forage sector.

Implement robust evaluation systems that enable objective, quantitative assessments of all elements within the NBO objective statements. These systems will establish comprehensive baseline data on forage performance by region, empowering ongoing monitoring of progress and providing a solid foundation to measure genetic and management improvements. Long-term stakeholder commitment will be vital, with a collaborative partnership between DMF and plant breeding companies, supported by levy funding to build the necessary infrastructure.

Identify and address barriers to realising genetic gains, including evaluating whether current potential improvements in yield and other traits are fully achieved on-farm. This essential insight will build confidence that the NBOs are delivering meaningful benefits and positive change throughout the industry.

Recognise that this work extends beyond plant breeding alone, embracing adaptive management of new phenotypes to ensure innovations translate into practical success on farms.

Implementation is realistically rated as 'Difficult' due to data and capability gaps, but this can be addressed by adopting successful models from animal and cropping sectors. There is clear opportunity for collaboration with New Zealand in this area.

Ownership of NBOs must rest with DMF. While Dairy Australia or DMF could contract a technical provider (e.g., AbacusBio, DataGene, etc.) to develop and maintain the NBOs, DMF and Dairy Australia must retain strategic oversight.

In the short term, DMF should lead the initiative. Longer term, if Dairy Australia or DMF re-establishes a cross-sector body (similar to Pastures Australia), governance of NBOs could transition there to reflect the relevance of forages across dairy, beef, and sheep sectors. This model would mirror the successful Grains Australia structure, where crop-specific NBOs are managed under a unified industry umbrella.

Design integrated forage systems for low-emissions dairying that deliver productivity, profitability, and sustainability:

- Develop innovative farm systems that combine multiple mitigation practices appropriate for regional soils, climates and systems to significantly reduce nutrient and greenhouse gas footprints, while maintaining strong productivity and profitability.
- Enhance nitrogen management by refining species-specific strategies:
  - Improve the system-wide efficiency of nitrogen fertiliser inputs (kg dry matter utilised per kg nitrogen applied) to open opportunities for reducing total synthetic nitrogen inputs, sustain higher legume contributions and biological nitrogen fixation, and reduce farm gate nitrogen surpluses which eventually flow into the wider environment. Both management practices and fertiliser product technologies are applicable here.
  - Precisely measure dry matter yield and quality responses to nitrogen for short-term grasses like annual, Italian, and hybrid ryegrass, compared to perennial grasses and new cultivars.
- Explore forage species and new breeding technologies (NBTs) that offer environmental benefits, such as biological nitrification inhibition or methane-reducing compounds. Collaborative efforts with New Zealand and Ireland on trait discovery create exciting opportunities to further reduce dairy's environmental footprint.
- Assess the environmental sustainability of systems relying more on short-term pastures, including their overall net carbon balance, to guide future farm design and practices.

R&D into balanced forage systems must include both greenhouse gas emissions and soil carbon sequestration and balance – which necessitates long-term trials in key regions, which can be adapted as knowledge accumulates.

Implementation is rated 'Easy' but is critically reliant on excellent leadership by DMF members, and in particular Dairy Australia, including strategic vision, stakeholder engagement and influence, and credibility and technical depth.

Refresh forage management practices to maximise genetic potential and adapt to changing conditions:

- Update best-practice guidelines for ryegrass-based pastures to reflect advances in plant breeding (e.g., tetraploid varieties, larger leaves, etc.) and increased nitrogen use that alter the interactions between plant phenotype, grazing frequency and severity, and rates of plant recovery following grazing. This will help ensure an optimal balance between animal performance, pasture feed supply and pasture resilience is retained.
- Build a stronger evidence base to support the effective management of emerging forage genetics (new cultivars) under increasingly variable climate conditions, while minimising environmental impacts.
- With new, more palatable varieties becoming available, reinvigorate best-practice recommendations for species such as tall fescue and cocksfoot, opening up broader and more resilient forage options.

- Enhance the data underpinning forage species selection to more precisely match plant characteristics with seasonal feed demand and regional climate patterns, supporting both productivity and sustainability.

Implementation is rated 'Easy' for updating agronomic knowledge and best-management guidelines, but species choices (beyond ryegrass) to better match plant and environment is rated 'Difficult' mainly due to data gaps.

Harness next-generation technologies to transform forage management:

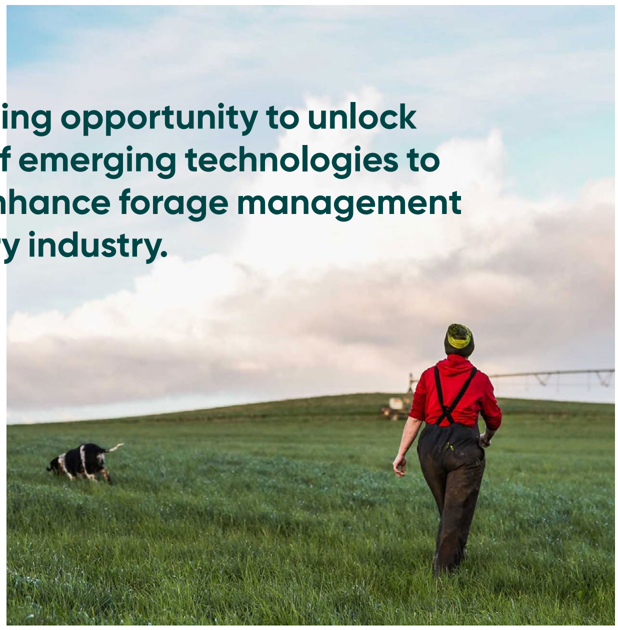
- There is a growing opportunity to unlock the potential of emerging technologies to significantly enhance forage management across the dairy industry. While adoption of formal decision-support tools for grazing and feeding has traditionally been limited, continued efforts by Dairy Australia and DMF to demonstrate their value remain essential. The advent of advanced remote sensing and data technologies presents an exciting frontier that could redefine how forage decisions are made on-farm.
- Strategic investment by DMF in this space offers the chance to bring together sensors, decision-support systems (including seasonal forecasting), robust databases, and artificial intelligence to create a new generation of tools. Clearly, these innovations should be designed for high usability and convenience, ensuring strong uptake and real-world impact for farmers.
- As a foundation, a comprehensive review of advanced, forage-specific technologies should be undertaken to assess their practical benefits for forage utilisation and farm profitability.
- In parallel, early-stage efforts could include working closely with technology developers to establish standardised data protocols, initiating the development of a national forage performance database, and supporting the refinement of algorithms that deliver measurable, sector-wide improvements. Together, these steps pave the way for a smarter, more sustainable future for forage management in the Australian dairy industry.
- Providing comprehensive foundational training for new users of forage management technologies is essential to maximise the impact of future investments in this area. Ensuring that users can confidently and effectively apply these tools will support adoption, drive productivity gains, and enhance long-term sustainability.

Implementation of adopting and utilising 'next generation' technology and management systems is rated 'Easy' but is fundamentally tied to involvement of the commercial technology sector and leading farmers. A project in this area requires a national multidisciplinary approach combining technology skills, farm systems experience, and modelling and data science expertise.

Much of the work required under this priority would be described as development of existing knowledge, though some further research will be required. Critically, new technology alone will not lead to better outcomes. Users must have a very clear understanding of the key factors that lead to highly efficient use of forage through grazing management (e.g., rotation lengths, pre-and post-graze pasture covers, average farm cover, etc.), how to recognise when these factors are moving out of balance, and what management levers to pull to retain the balance. The new technologies are simply tools to help manage decision-making: if users don't know what decisions they should be making and when, then they will quickly lose confidence in the value of technologies.

In this context, Dairy Australia and other DMF members must clarify their respective roles regarding remote sensing and data technologies – including how they will interact with digital technology providers and whether system evaluation or system development is appropriate and the translation of the technologies to on-farm adoption.

There is a growing opportunity to unlock the potential of emerging technologies to significantly enhance forage management across the dairy industry.



Optimise yield, quality, and system performance of mechanically harvested forages:

It is recommended that future investment into mechanically harvested forage systems directly address current limitations to both forage yield and nutritive value and align with the strategies in the focus area of forage production described in the dairy Industry Action Panel (IAP) on Intensification Final Report.

Traits identified as priorities by animal nutritionists – such as digestibility, fibre quality, or specific nutrient profiles – may not always align with traditional agronomic goals like maximising biomass or harvesting efficiency. In some cases, there may be biological trade-offs between yield and nutritional quality.

To ensure that future forage systems deliver optimal whole-farm value, rather than just maximising single performance traits, a deliberate balance must be sought between agronomic productivity and animal nutritional requirements. This may require redefining breeding targets, harvesting practices, and system management protocols based on integrated agronomy-nutrition modelling and evidence.

Final specification of target traits and R&D directions should take account of:

- Establishing minimum standards for forage quality traits (e.g., neutral detergent fibre (NDF), neutral detergent fibre digestibility (NDFd)) in National Breeding Objectives (NBOs), similar to approaches used in the US and Canada.
- Focusing TMR-related R&D on maize and lucerne, as these are the foundational components of most rations, with other forages playing a supplementary role.
- Explicitly including Brown Midrib (BMR) maize and sorghum and high-tannin lucerne germplasm in strategic priorities due to their proven impact on feed digestibility and livestock performance.
- Fully utilising existing genomic selection and speed breeding platforms for forage development, rather than duplicating or overlooking these capabilities.
- Addressing weed control as a critical constraint in TMR forage production systems, particularly due to quality loss and limited herbicide options in fodder crops.

Track emerging insights into soil-plant microbiomes to guide future innovation:

- Staying attuned to advances in soil and plant microbiome research offers exciting potential to strengthen the resilience and productivity of both crop and pasture systems. By actively monitoring developments – such as new findings in microbial interactions, breakthroughs in microbial inoculants, or changes in microbial communities resulting from shifts between perennial pastures and cropping – dairy industry stakeholders can stay ahead of the curve.
- This includes regularly reviewing scientific literature, engaging with key research institutions, and participating in relevant forums or networks to identify trends and discoveries with practical relevance. Insights gained through this process can help shape strategic research investments and highlight opportunities to harness microbiome science in ways that support sustainable farming systems.
- By maintaining a focused and informed watch on this rapidly evolving field, the dairy industry can position itself to leverage soil-plant microbiome innovations that drive long-term environmental and economic benefits as the science evolves.

Unlock impact through collaboration:

- DMF members, and in particular Dairy Australia, must take much stronger leadership roles in initiating and enabling forage R&D collaboration.
- Key actions for DMF members in genuinely improving collaboration are:
  - Identify and facilitate strategic collaborations across projects.
  - Ensuring that research duplication and replication is avoided.
  - Provide necessary support, funding, and resources to enable collaboration success.
  - Strengthen evaluation of proposed projects for collaborative purpose and value.
  - Enhance alignment across projects by synchronising milestones for better coordination and impact.

5.2 Areas to refocus or reduce efforts

Refocus new breeding technologies to overcoming limitations to yield potential (NUE, WUE, and drought recovery) and increasing nutritive value in targeted species:

- To maximise impact and ensure focus, pre-breeding efforts using NBTs should prioritise key traits with the greatest potential to enhance resilience and productivity—namely, Nutrient Use Efficiency (NUE), Water Use Efficiency (WUE), and drought recovery in priority forage species. These foundational efforts will pave the way for future trait selection to be guided by well-defined NBOs once established.
- As NBTs continue to advance forage improvement, it is timely to shift focus from yield as a primary target trait. Despite extensive past efforts, consistent yield gains have proven difficult to achieve due to its complexity and variability in real-world farming conditions. While yield is de-emphasised as a breeding target, maintaining performance on par with the top 10% of current cultivars remains essential. This balanced approach enables innovation in areas of highest potential while ensuring continued productivity and reliability for farmers.
- Cutting-edge NBTs such as gene editing, controlled environment systems, and speed breeding offer powerful tools to fast-track improvements in these critical traits, particularly during periods of active plant growth and recovery following environmental stress.
- In parallel, enhancing the nutritive value of forages remains a compelling breeding goal to boost farm profitability. For example, reducing lignin content in grasses holds significant promise for improving feed quality and animal performance. This is especially relevant as climate change drives increased heat and water stress, placing greater demands on pasture resilience and persistence. By strategically leveraging NBTs, the industry can accelerate the development of forage systems that are more productive, sustainable, and future-ready.

Reduce emphasis on further agronomic research into multispecies swards:

- Future investment in multispecies swards should be approached with caution and guided by the latest knowledge, which indicates limited evidence for their superiority in agronomic performance or animal productivity over conventional mixed swards. However, given emerging indications of potential environmental benefits – particularly in reducing nitrogen losses – any future research should focus on accurately quantifying environmental outcomes and evaluating whether similar benefits can be achieved through simpler, more adoptable mixed swards.
- If further R&D is justified, it should be founded on:
  - Clear definition of the purpose of a multispecies sward, i.e., the problem to be solved, or opportunity to be exploited.
  - Improved environmental outcomes while maintaining forage supply and nutritional value.
  - Clear specification of the management practices needed to sustain an optimal multispecies sward.

Refocus R&D investment to maximise impact through strategic pre-breeding:

- To ensure the greatest return on investment and long-term industry benefit, levy and public R&D funding should transition away from direct involvement in plant breeding and commercialisation. Instead, efforts should be concentrated on high-impact, NBO-guided pre-breeding research that underpins innovation across priority forage species and supports the broader success of commercial breeding programs.
- Investment in pre-breeding for lower-priority or alternative species should be paused unless there is a clearly defined and viable pathway to market and on-farm adoption. This targeted approach enables more effective use of resources, accelerates genetic gains in the traits that matter most, and positions the industry to deliver greater value through stronger partnerships with plant breeding companies.

Cutting-edge NBTs such as gene editing, controlled environment systems, and speed breeding offer powerful tools to fast-track improvements.

To ensure the greatest return on investment and long-term industry benefit, levy and public R&D funding should be concentrated on high-impact, NBO-guided pre-breeding research that underpins innovation across priority forage species and supports the broader success of commercial breeding programs.

6

National breeding objectives

6.1 Background

The development of agreed National Breeding Objectives (NBOs) for forage species is critical to guide genetic improvement programs supporting Australia's dairy industry. Similar frameworks have successfully driven genetic gains in both animal breeding and major crop industries, demonstrating the importance of clear breeding targets for industry advancement.

Examples of successful breeding objective frameworks include:

- **Australian Dairy Cattle Breeding** – Three national indices – the Balanced Performance Index (BPI), Health Weighted Index (HWI), and Sustainability Index (SI) – guide dairy cattle breeding by balancing traits for lifetime contribution, including production, health, fertility, feed efficiency, and environmental outcomes.
- **Australian Wheat Industry** – Breeding objectives focus on stable high yields, quality traits (such as bread-making performance and protein content), disease and pest resistance, stress tolerance, straw strength, and end-use market requirements.
- **Canadian Soybean Industry** – Objectives include high yield potential, resistance to major diseases and pests, adaptation to diverse growing conditions, maturity group suitability for different regions, and targeted end-use qualities. Genomic tools are increasingly used to accelerate progress.

In the Australian wheat industry, NBOs are led by Grains Australia, with their Wheat Commodity Group responsible for developing and guiding the NBOs. In Canada, the NBOs are 'owned' by Soy Canada.

6.2 Importance of forage NBOs for the dairy industry

Establishing forage NBOs will provide a clear framework for aligning public and private breeding efforts with the dairy industry's long-term goals. They act as a 'genetic business plan' for the industry, shaping breeding priorities and investments for maximum impact. Key benefits include:

Alignment with industry goals

- Focus breeding efforts on traits that directly influence profitability, such as stress tolerance, and nutrient and water use efficiency.
- Support better alignment between forage characteristics and livestock nutritional needs, improving farm system performance.
- Enable stronger partnerships between industry and commercial breeding companies, driving demand for improved genetics and supporting viable private sector investment.

Better research prioritisation and investment efficiency

- Provide clear direction for species and trait priorities.
- Enable use of new breeding tools (e.g., genomic selection, gene editing) to efficiently quantify and deliver valuable genetic gains.
- Guide strategic investment in capability, capacity, and infrastructure.

Balancing profitability with sustainability

- Maximise economic returns while also targeting traits that reduce environmental impacts (e.g., lower nutrient losses and greenhouse gas emissions).
- Use economic modelling to quantify the value of sustainability traits, supporting balanced breeding goals for long-term viability.
- The FVI, used for ryegrass cultivar selection, demonstrates how Economic Values (EVs) can guide cultivar choice by region. A similar modelling approach will be required to establish forage breeding indices across multiple species.

Adaptability and resilience

- Allow breeding programs to adjust rapidly to changing conditions such as climate variability, new technologies, and emerging production challenges.
- Facilitate regular updates to maintain relevance and effectiveness.

Improved communication and collaboration

- Present objectives in clear, actionable formats (e.g., SMART[14] goals) to enhance communication across breeders, seed companies, researchers, and investors.
- Promote accountability and alignment across the sector, supporting better teamwork and cross-sector collaboration.

Sustained genetic progress

- Ensure breeding decisions made today drive genetic gains that benefit future generations of dairy forage systems.

Enhanced market competitiveness

- Deliver forages that better meet farmer needs for yield, quality, and resilience, improving farm profitability and competitiveness across the dairy supply chain.

Focus breeding efforts on traits that directly influence profitability, such as stress tolerance, and nutrient and water use efficiency.

14. Specific, measurable, achievable, relevant and time-based

6.3 Establishing NBOs for dairy forages

Developing NBOs for the Australian dairy industry will require the following steps:

- **Trait and technology prioritisation** – In consultation with industry stakeholders, identify and prioritise key breeding traits, along with associated management practices, inputs, and technologies, that will drive on-farm outcomes and industry value.
- **Development of forage-specific breeding indices** – Use rigorous economic modelling to create breeding indices that recognise the diverse roles of different forage species. While feed supply is a common function, species also differ in traits such as seasonality, persistence, and biological nitrogen fixation (for legumes).
- NBOs should be developed for five forage categories:
  - Perennial grasses.
  - Short-term grasses (annual, biennial).
  - Legumes.
  - Forage crops.
  - Mechanically harvested/ Total Mixed Ration (TMR) crops.
- **Leadership and cross-sector collaboration** – It is recommended that DMF lead the initiation of a project to develop and implement NBOs across these categories. NBOs must be treated as a 'living framework,' subject to regular review to ensure they remain relevant to evolving forage system needs. The establishment of breeding indices will require collaboration between economists, farm systems modellers, plant breeders, researchers, agronomists, and nutritionists across both public and private sectors.
- **Supporting tools and frameworks** – To assist prioritisation, a table of possible considerations for future National Breeding Objectives has been developed based on extensive consultation with dairy stakeholders (see Table 12). While recognising regional differences, these areas focus on the Tier 1 and 2 forage species expected to underpin Australia's dairy systems by 2040.

NBOs must be treated as a 'living framework,' subject to regular review to ensure they remain relevant to evolving forage system needs.

Table 12: Possible considerations for future National Breeding Objectives

		Gippsland/ South Coast NSW	South West VIC/ South East SA	Northern VIC/ Riverina/ Inland NSW/SA	Tasmania	Queensland/ North Coast NSW	South West WA
Contribution to National Milk Production (2024)		26%	25%	25%	11%	8%	4%
Tier 1 & 2 priority species (2040)							
Annual and perennial mixes		****	****	***	****	***	***
Annual ryegrass		***	***	****	**	****	*****
Italian ryegrass		***	***	****	**	***	***
Maize		***	***	****	**	****	***
Perennial ryegrass		****	****	**	*****	*	**
Other clovers		***	***	***	**	**	***
Herbs (chicory, plantain)		****	***	**	***	**	**
White clover		****	***	**	****	**	**
Lucerne		**	***	****	**	***	**
Brassicas		***	****	**	***	**	**
Driver	**R&D strategy target**						
PRODUCTIVITY	Breeding for higher digestibility and energy content.	****	****	****	****	****	****
	Breeding for pest or disease resistance.	****	****	****	****	****	****
	Breeding for improved nutrient use efficiency	****	****	****	****	****	****
	National Breeding Objectives	****	****	****	****	****	****
	Breeding for improved water use efficiency	****	****	****	*	*	****
	Breeding for improved drought tolerance	****	****	****	*	*	****
	Breeding to improve forage yields.	****	****	****	****	****	****
	Screening forage species for environmentally beneficial traits	****	****	****	****	****	****
	Breeding for reduced environmental impact	****	****	****	****	****	****
	Breeding for improved animal health	***	***	***	***	***	***
	Use of endophytes and seed treatments.	***	***	***	***	***	***

		Gippsland/ South Coast NSW	South West VIC/ South East SA	Northern VIC/ Riverina/ Inland NSW/SA	Tasmania	Queensland/ North Coast NSW	South West WA
PROFITABILITY	Increasing pasture and homegrown forage harvest	*****	*****	*****	*****	*****	*****
	Better utilising DM and ME grown, especially via direct grazing	****	****	****	****	****	****
	Adopting and utilising 'next generation' technology and management systems	****	****	****	****	****	****
	Using sensor-based precision pasture and forage management tools	***	***	***	***	***	***
	Identifying poorer-performing paddocks and addressing growth limitations	***	***	***	***	***	***
	Optimising timing of grazing and regrowth intervals in grass-based systems	***	***	***	***	***	***
	Using formal measurement and decision-support tools for forage management	***	***	***	***	***	***
	Enhancing pasture renewal to capture genetic gain	***	***	***	***	***	***
RESILIENCE	Species choices (beyond ryegrass) to better match plant and environment	***	***	****	*	****	****
	More informed decisions when selecting forage and crop options	****	****	****	****	****	****
	Expanding forage-cropping	***	***	****	*	**	****
	Using forages and/or management practices to prevent and/or support recovery from pugging damage to soils and pastures.	***	***	***	***	***	***
	Shifting towards annual pastures and crops	***	**	***	*	***	***
	Deferring grazing of perennial pastures	**	**	**	**	**	**

		Gippsland/ South Coast NSW	South West VIC/ South East SA	Northern VIC/ Riverina/ Inland NSW/SA	Tasmania	Queensland/ North Coast NSW	South West WA
SUSTAINABILITY	Better management of water, carbon and nitrogen cycles in grazing and cropping systems.	*****	*****	*****	*****	*****	*****
	Increasing adoption of multi-species pastures and enhanced nutrient cycling	****	****	****	****	****	****
	Re-prioritising legumes as critical components of resilient, low-footprint forage systems	****	****	****	****	****	****
	Decreasing animal nutritional syndromes. (e.g. bloat, ryegrass staggers, heat stress)	***	***	***	***	***	***
	Pushing towards rainfed or partially irrigated systems r equiring lower inputs – de-intensification	**	**	**	**	**	**
INPUT VOLATILITY	Integrating plantain into forage base	**	**	**	**	**	**
	Pushing towards more self-sufficient feed systems e.g., maximise home grown forage for total feed supply	***	***	****	**	***	****
	Better utilisation of inputs to grow DM and ME	****	****	****	****	****	****
	Better utilisation of inputs to match with changed growing season windows and the impact of pests and diseases	****	****	****	****	****	****
	Innovative weed and pest management solutions	***	***	***	***	***	***

Once R&D strategies, breeding traits, management practices, inputs, technologies, and associated breeding indices are identified and prioritised, NBOs can be established for dairy forages. The following provides 'strawman' examples of NBOs across the four nominated forages categories:

6.3.1 Perennial grass species:

Forage perennial grass varieties and associated management practices that sustain clear advantages in DM yield and nutritive value (principally ME content) over baseline (genetic base) cultivars of the same species for at least six years post-sowing under commercial-level grazing and pasture management practices appropriate for key regions of use. While incorporating traits for increased persistence through increased tolerance to abiotic and biotic stress. This objective considers DM yield (moderate priority), feed quality (high priority), persistence (high priority) and adaptability to grazing systems (high priority).

Key Regions:
Gippsland/South Coast NSW, South West VIC/South East SA, Tasmania, Queensland/North Coast NSW

6.3.2 Short-term forage species:

Forage varieties and associated management practices that generate stable increases in DM yield, nutritive value (principally ME content) and digestibility over baseline (genetic base) cultivars of the same species. Lower inputs (e.g. nutrient and water use efficiency). While considering compatibility and performance of annual multi-species mixes and incorporating traits for increased tolerance to abiotic and biotic stress. This objective considers DM yield (moderate priority), feed quality (high priority), multi-species compatibility (high priority) and adaptability to grazing systems (high priority).

Key Regions:
Gippsland/South Coast NSW, South West VIC/South East SA, Tasmania, Northern VIC/Riverina/Inland NSW/Riverland of SA, Queensland/North Coast NSW, South West WA

6.3.3 Legume species:

Forage legume varieties and management practices that generate stable increases in DM yield, nutritive value (principally Protein content) and digestibility over baseline (genetic base) cultivars of the same species. While considering compatibility and performance of annual multi-species mixes and incorporating traits for increased persistence namely tolerance to abiotic and biotic stress. While also considering soil factors (i.e. soil/plant microbiome associations) and impact on animal health (e.g. bloat). This objective considers feed quality (high priority), multi-species compatibility (high priority), persistence (high priority) and adaptability to grazing systems (high priority).

Key Regions:
Gippsland/South Coast NSW, Tasmania

6.3.4 Forage Crops:

Forage crop varieties and management practices that generate stable increases in DM yield, nutritive value (principally Protein content) and digestibility over baseline (genetic base) cultivars of the same species. While incorporating traits for increased tolerance to abiotic/biotic stress and lowering water and nutrient inputs. This objective considers feed quality (high priority), abiotic/biotic stress (high priority), lowering of inputs (high priority) and adaptability to harvesting systems (high priority).

Key Regions:
South West VIC/South East SA

6.3.5 TMR crops:

Crop varieties and management practices that generate stable increases in DM yield and digestibility over baseline (genetic base) cultivars of the same species. While incorporating traits for increased tolerance to abiotic/biotic stress and lowering water and nutrient inputs. This objective considers feed quality (high priority), abiotic/biotic stress (high priority), lowering of inputs (high priority) and adaptability to harvesting systems (high priority).

Key Regions:
Northern VIC/Riverina/Inland NSW/Riverland of SA, Queensland/North Coast NSW, South West WA

7

Pathway to market for plant breeding R&D

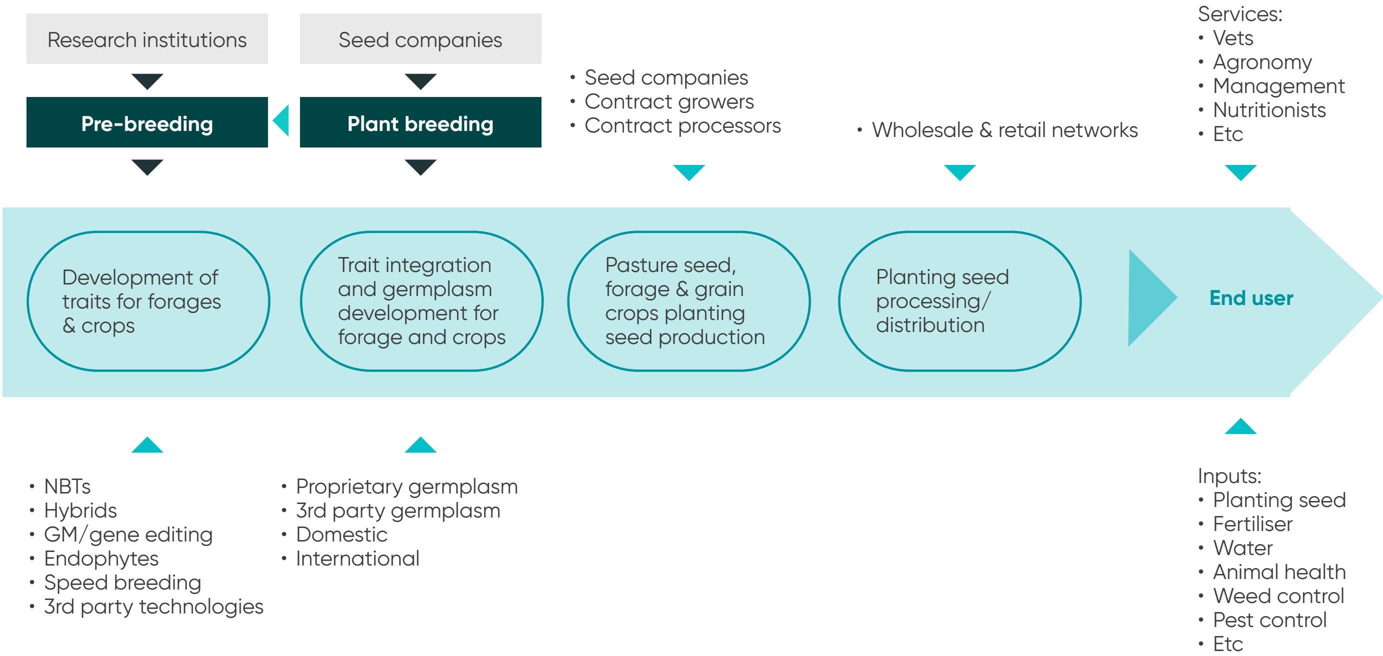
The pathway to market for forage plant breeding research refers to the framework through which stakeholders – such as researchers, input suppliers, distributors, processors, manufacturers, and marketers – deliver products and services to end users, primarily dairy farmers.

Traditionally, this concept focused on post-farm gate activities like storage, transport, processing, and marketing. However, in modern agricultural systems, it also encompasses pre-farm gate elements, including inputs and services that directly support on-farm production.

Figure 2 outlines this expanded pathway, highlighting the key roles of various stakeholders in delivering technologies, inputs, and services that enhance forage productivity, sustainability, and profitability.

The pathway to market for forage research, including new varieties, has become increasingly complex and volatile. This is driven by industry consolidation, international acquisitions – particularly with major seed companies based in Europe – and the reliance on overseas sources for the supply of planting seed for key forage species. Compounding this, farmers now access seed through a wide range of channels, including commercial companies, traders, other farmers, and saved seed.

Figure 2: Dairy forage pathway to market – pre-farm gate



7.1 Translating forage R&D to on-farm outcomes

Translating innovative forage research into on-farm adoption has been widely studied over the past 50 years, resulting in numerous publications and frameworks on farmer adoption. As shown in Figure 2, a wide range of stakeholders – both within Australia and globally – are involved in moving forage research from concept to on-farm use.

A key feature of this process is the diversity of stakeholder roles across the pathway to market. While some, like research institutions, have specialised functions, others, such as seed companies, operate across multiple stages – from research and breeding to production, processing, and distribution. Similarly, some retail outlets are also engaged in wholesaling and breeding.

In Australia, major investment in forage trait development and species evaluation for the dairy industry has come from Dairy Australia, the Gardiner Foundation, and State Governments, with additional contributions from seed companies.

From a plant breeding perspective, research efforts have included:

- Applying genomic selection to improve yield and quality.
- Using genetic modification and gene editing for stress tolerance.
- Developing novel endophytes for established species.
- Evaluating new species such as plantain.

While some research has led to successful adoption (e.g., endophytes, plantain), others – despite significant investment in NBTs – have not (e.g., high fructan ryegrass, low lignin tall fescue), with detailed reasons outlined in separate Dairy Australia reports.

Given that future forage R&D will likely focus on NBTs for traits like water and nutrient use efficiency and stress tolerance, two critical questions must be addressed:

- **What role should Dairy Moving Forward members play in future forage plant breeding R&D?**
- **What is the role of technology providers and seed companies in translating this research into practical on-farm outcomes?**

7.2 Role of DMF in forage pre-breeding R&D

Anecdotal feedback from dairy industry stakeholders revealed confusion about specific DMF member's roles in forage plant breeding research. While some DMF members are perceived as investing across pre-breeding, breeding, and commercialisation, many stakeholders view this broad involvement as blurring boundaries – creating potential conflicts of interest and a lack of alignment with end-user needs.

A common sentiment shared by interview participants was: "DMF members should step back from plant breeding and commercialisation and focus on pre-breeding – where all breeding programs across key forage species could benefit. Plant breeding should be left to commercial companies."

This view aligns with the model used by the Grains Research and Development Corporation (GRDC), which focuses on strategic pre-breeding investments to support commercial breeding across multiple crops. GRDC's work helps breeders develop varieties that better withstand environmental stresses and meet market demands.

In a similar way, DMF's focus on pre-breeding could play a foundational role in accelerating innovation and improving the relevance of research outcomes for dairy farmers. Under the guidance of the National Forage Breeding Objectives, DMF's roles in pre-breeding should include:

- Strategic trait development: invest in traits that improve forage resilience, yield stability, and climate adaptability.
- Enhancing genetic resources: facilitate access to diverse germplasm through strategic partnerships.
- Targeted forage improvements: Focus on traits and forages most important to Australian dairy systems.
- Accelerating genetic gains: Support step-change improvements through advanced technologies, including artificial intelligence tools to enhance breeding strategies and projects linking physiological traits with breeding outcomes.
- Research partnerships: collaborate with universities, industry experts, and growers to ensure practical outcomes.
- Responding to industry needs: prioritise investment areas based on farmer-identified challenges.
- Measurable outcomes: ensure pre-breeding investments lead to:
  - Faster development of improved cultivars.
  - Greater environmental resilience.
  - More efficient integration of valuable traits into breeding programs.

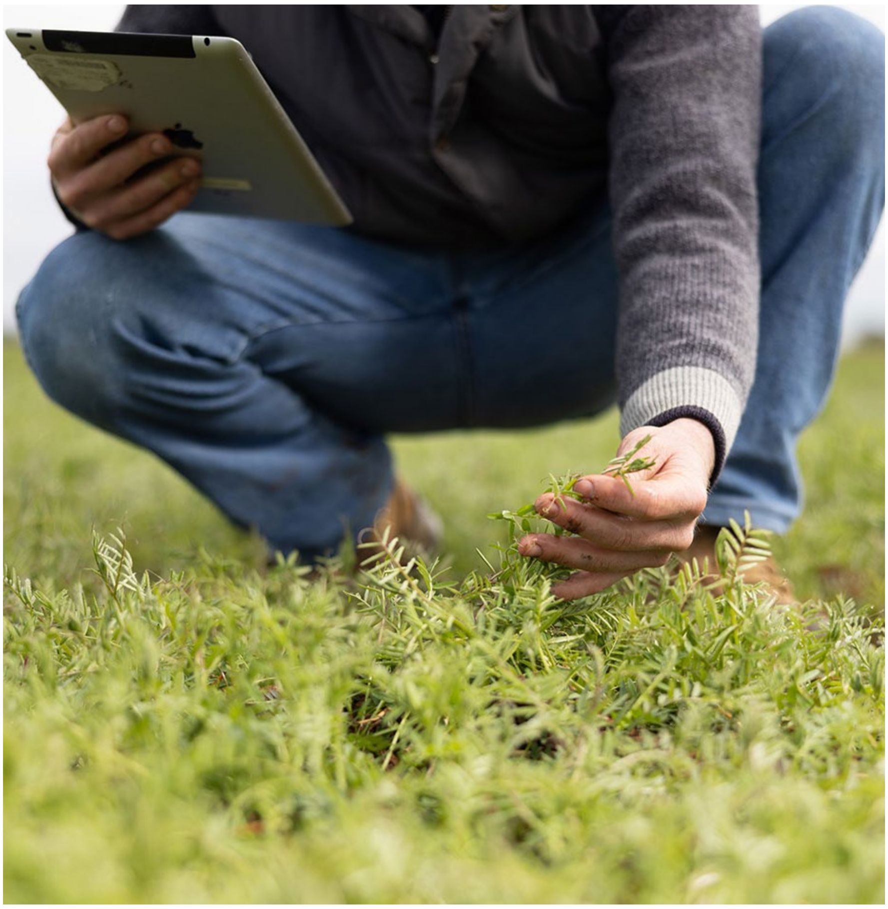
In summary, by focusing on pre-breeding, DMF members can bridge the gap between research and on-farm adoption – delivering productivity, profitability, and sustainability gains for the Australian dairy industry.

7.3 Role of technology providers

The successful adoption of forage research on-farm depends heavily on two key players: technology providers, who develop target traits, and seed companies, who incorporate those traits into commercial varieties. However, past failures – such as the limited adoption of NBTs – highlight a disconnect in roles and responsibilities among technology providers, seed companies, and research investors.

To improve future outcomes, it's essential to clarify these roles. While responsibilities may vary by case and can involve partnerships or role transfers (e.g., for deregulation), the following outlines the key functions of technology providers:

- Innovation and trait development – technology providers lead R&D efforts to develop traits that address production challenges such as pest resistance, drought tolerance, and nutrient efficiency. They apply advanced tools like genomic selection, speed breeding, and gene editing (e.g., CRISPR) to improve yield, resilience, and environmental sustainability.
- Regulatory navigation – for traits developed using GM or gene editing technologies, providers manage complex regulatory approvals – covering environmental safety, food safety, and trade compliance. They may also help establish coexistence protocols for GM and non-GM systems.
- Intellectual Property (IP) management – technology providers hold patents on novel traits and breeding methods, licensing them to seed companies and other stakeholders. This protects their R&D investments and controls how innovations enter the market.



- Stewardship programs – to ensure responsible use of new technologies (e.g. endophytes, GM or GE forages), providers offer stewardship guidelines on grazing, seed use, resistance management, and gene flow mitigation. These programs support product integrity and compliance along the supply chain.
- Partnerships with seed companies – providers work closely with seed companies to integrate new traits into regionally adapted varieties, ensuring the innovations are viable for local conditions and meet market needs.
- Advocacy and education – technology providers promote industry and public acceptance through engagement with farmers, policymakers, and consumers. Transparent communication and education campaigns help build trust and address concerns about safety and benefits.
- Supply chain support – providers help design and implement systems for identity preservation, traceability, and market compliance. This facilitates the coexistence of NBT-derived and conventional forages in both domestic and international markets.

In summary, technology providers are critical to bridging the gap between research and adoption. Through innovation, regulation, IP management, partnerships, stewardship, advocacy, and supply chain support, they ensure new forage technologies – such as endophytes and traits developed using NBTs – are adopted effectively, responsibly, and sustainably.

Seed companies are vital to bringing forage innovation to farms. Through breeding, regulatory expertise, seed supply, farmer engagement, and value sharing, they turn research into real-world impact across the dairy industry.

7.4 Role of seed companies

Seed companies play a central role in turning forage research – both conventional and NBT-derived – into on-farm solutions. Their involvement spans the full commercialisation pathway, from R&D to farmer engagement. Key roles include:

- Research and development – some seed companies invest directly in pre-breeding, including endophyte discovery, trait identification, proof-of-concept, and field trials. These efforts target key challenges such as persistence, pest resistance, drought tolerance, and nutritional quality. Patents on traits and endophytes help protect their investments and enable value capture through royalties or licensing.
- Plant breeding – a core function of seed companies is breeding new forage varieties suited to local environments and farming systems. This involves combining parent lines to enhance traits like yield, stress tolerance, and nutritional value, while incorporating innovations such as endophytes or NBT-derived traits into breeding pipelines.
- Seed production, processing, and marketing – once new cultivars are developed, seed companies – or their contractors – manage commercial seed production, processing (cleaning, grading, treating), packaging, and distribution through wholesale and retail networks to reach dairy farmers.
- Regulatory compliance – seed companies compile data on safety and performance to secure regulatory approvals for NBT-derived forages. This includes navigating national biosafety protocols and conducting performance trials where required.
- Local partnerships – to ensure adoption, seed companies collaborate with local entities to adapt traits into regionally preferred cultivars and facilitate knowledge transfer between researchers, providers, and farmers.
- Farmer engagement and support – in summary, seed companies connect research to the farm gate by supplying seed and offering technical support. They educate farmers on best practices, trait benefits, and management strategies, while addressing concerns around cost, safety, or complexity.
- Value capture and allocation – working with technology providers, seed companies define value capture models – such as royalties based on seed, area sown, or end-products – to fairly distribute returns across the supply chain and back to farmers.
- Advocacy and education – seed companies also play a role in building trust and acceptance of endophytes and NBT-derived forages. They conduct field days, workshops, and campaigns to promote benefits and counter misinformation.

Seed companies are vital to bringing forage innovation to farms. Through breeding, regulatory expertise, seed supply, farmer engagement, and value sharing, they turn research into real-world impact across the dairy industry.

8

Current research assessment

8.1 Alignment with future research priorities

Analysis of current levy and public investment in forage R&D reveals a misalignment between existing project funding and identified future research priorities (see Table 13).

During the strategy development process, future R&D focus areas were assessed and prioritised by the panel and a broader group of stakeholders to guide more targeted investment decisions.

Estimates of current levy and public forage R&D allocations were drawn from Dairy Moving Forward (DMF) project documentation.

The key implication is that there is a clear opportunity to rebalance investment to better support high-priority research areas critical to the future of the dairy industry.

There is a clear opportunity to rebalance investment to better support high-priority research areas critical to the future of the dairy industry.

Table 13: Level of current project funding against forage R&D focus areas

	Forage R&D focus area	Potential impact score	Estimated proportion of levy and public forage R&D funding
PRODUCTIVITY	Application of new breeding technologies (NBTs) and/or greater emphasis in conventional breeding for:		
	• Higher digestibility and energy content	7.3	18.1%
	• Pest or disease resistance	7.2	0.2%
	• Improved nutrient use efficiency	7.2	2.6%
	• Improved water use efficiency	7.0	2.6%
	• Improved drought tolerance	6.8	-
	• Improved forage yields•	6.6	30.2%
	• Reduced environmental impact	6.4	-
	• Improved animal health	6.3	-
	Identifying optimal annual and perennial pasture plant phenotypes for balancing yield and resilience by region	7.1	-
	Systematically screening forage species for environmentally beneficial traits	6.5	-
	Use of endophytes and seed treatments	4.5	-

	Forage R&D focus area	Potential impact score	Estimated proportion of levy and public forage R&D funding
PROFITABILITY	Increasing pasture and homegrown forage harvest	8.3	0.7%
	Better utilisation of DM and ME grown for animal feeding, especially via direct grazing	7.6	1.0%
	Adoption and utilisation of 'next generation' technology and management systems	6.4	-
	Sensor-based precision pasture and forage management	6.1	11.7%
	Identifying poorer-performing paddocks and addressing growth limitations	6.0	-
	Optimising timing of grazing and regrowth intervals in grass-based systems	5.9	0.8%
	Use of formal measurement and decision-support tools for grazing rotations, feed budgeting, and pasture allocation	5.4	0.9%
	Enhancing pasture renewal to capture genetic gain	4.9	-
RESILIENCE	Species choices (beyond ryegrass) to better match plant and environment	8.1	2.8%
	More informed decisions when selecting forage and crop options	7.0	4.1%
	Expanding forage-cropping	6.4	2.5%
	Using forages and/or management practices to prevent and/or support recovery from pugging damage to soils and pastures.	5.0	-
	Shifting towards annual pastures and crops	4.6	-
	Deferring grazing of perennial pastures	3.2	-
SUSTAINABILITY	Better management of water, carbon and nitrogen cycles in grazing and cropping systems. (e.g. reducing farm gate nitrogen use, improved water use efficiency, retain soil carbon)	8.4	5.6%
	Increasing adoption of multi-species pastures and enhanced nutrient cycling	8.1	10.8%
	Re-prioritising legumes as critical components of resilient, low-footprint forage systems	7.6	2.4%
	Decreasing animal nutritional syndromes. (e.g. bloat, ryegrass staggers, heat stress)	4.9	1.0%
	Pushing towards rainfed or partially irrigated systems requiring lower inputs – de-intensification	4.2	-
	Integrating plantain into forage base	4.1	-
INPUTS	Pushing towards more self-sufficient feed systems e.g., maximise home grown forage for total feed supply	7.5	-
	Better utilisation of inputs to grow DM and ME	7.5	1.9%
	Better utilisation of inputs to match with changed growing season windows and the impact of pests and diseases	6.7	-
	Innovative weed and pest management solutions	5.1	-

In summary, current R&D project funding relative to overall importance of forage R&D focus areas is shown in Table 14.

Table 14: Level of current project funding against potential impact of forage R&D focus areas – summary

Potential impact of forage R&D focus areas	Estimated proportion of levy and public forage R&D funding
Very High	-
High	52.8%
Moderate	46.1%
Low	1.1%
Very Low	-

8.2 Alignment with future forage importance

Species importance was rated on a 10-point scale (1 = Not at All Important; 10 = Extremely Important) by sector experts (see Tables 15 and 16), helping to identify critical gaps where high-priority species may be underfunded, and lower-priority species may be receiving disproportionate investment.

A review of current levy and public funding for forage R&D shows how existing investment aligns – or misaligns – with the anticipated importance of different forage species by 2040 (see Table 17).

The key implication is that strategic adjustments to investment are needed to ensure R&D efforts are focused on the species most critical to the future competitiveness and resilience of the dairy industry.

Table 15: Future importance of forage species by 2040 – grazed forages (1 = not at all important; 10 = extremely important)

	Gippsland/ South East NSW	South West Victoria/ South East SA	Northern VIC/ Riverina/ Inland NSW/ Rest of SA	Tasmania	Queensland/ North Coast NSW	South West WA	Weighted average
Annual and perennial mixes	8.1	7.6	6.4	7.7	5.9	6.5	**7.3**
Annual ryegrass	6.6	6.8	8.6	4.6	8.4	9.3	**7.2**
Italian ryegrass	6.9	6.4	7.3	4.9	5.6	6.0	**6.5**
Perennial ryegrass	8.0	7.5	4.1	9.0	1.7	3.5	**6.3**
Other clovers	5.6	6.1	6.6	4.9	4.6	5.0	**5.8**
Herbs (chicory, plantain)	7.0	6.1	4.5	5.9	4.9	4.0	**5.7**
White clover	7.3	5.5	4.5	7.1	2.0	2.3	**5.5**
Lucerne	4.8	5.6	6.3	3.9	6.6	2.7	**5.3**
Brassicas	6.0	8.0	3.0	5.5	2.0	1.0	**5.2**
Oats	3.3	3.9	6.5	3.1	6.4	5.5	**4.5**
Forage sorghum	3.6	4.0	6.5	2.1	5.0	3.2	**4.3**
Tall fescue	5.0	4.0	4.1	3.7	2.1	3.3	**4.1**
Millet	3.9	3.8	4.8	2.1	5.1	3.0	**3.9**
Cocksfoot	4.5	3.9	3.8	4.2	1.4	3.0	**3.8**
Barley	2.3	3.6	5.3	2.2	3.7	4.2	**3.5**
Kikuyu	4.3	2.3	3.6	1.9	7.1	4.5	**3.5**
Wheat	3.1	2.8	5.3	1.6	2.7	2.7	**3.3**
Vetch	2.9	3.4	4.0	2.0	2.1	2.0	**3.1**
Brachiaria	2.4	2.0	4.3	1.6	6.7	2.5	**3.0**
Rhodes grass	1.9	1.6	2.9	1.4	5.4	2.5	**2.3**
Setaria	1.6	1.6	2.6	1.4	4.7	2.2	**2.1**
Other species	2.1	1.6	2.0	1.8	2.7	1.7	**1.9**
Soybean	1.1	1.0	2.3	0.9	4.1	1.0	**1.6**
Tropical legumes	1.0	1.0	1.0	1.0	5.0	1.0	**1.3**

Table 16: Future importance of forage species by 2040 – mechanically harvested forages (1 = not at all important; 10 = extremely important)

	Gippsland/ South East NSW	South West Victoria/ South East SA	Northern VIC/ Riverina/ Inland NSW/ Rest of SA	Tasmania	Queensland/ North Coast NSW	South West WA	Weighted average
Maize	6.6	5.3	8.6	4.6	7.6	5.6	**6.5**
Lucerne	4.9	5.0	7.3	3.8	6.4	2.4	**5.4**
Sorghum	2.8	3.9	5.9	1.7	6.0	3.0	**4.0**
Oats	3.6	3.3	4.9	2.1	5.3	4.2	**3.8**
Vetch	2.6	3.6	5.5	1.6	3.1	3.2	**3.5**
Wheat	2.5	3.0	4.9	2.0	4.0	3.2	**3.3**
Millet	2.8	2.4	3.9	1.2	5.7	3.0	**3.0**
Barley	2.5	2.8	3.4	2.0	4.1	3.4	**2.9**
Mixed cropping	2.0	2.8	3.5	1.8	3.3	2.4	**2.7**
Other species – mixed/multispecies swards	2.6	2.8	2.8	2.2	1.6	2.0	**2.5**
Triticale	1.4	2.5	3.0	1.8	4.0	2.4	**2.4**
Fabaceae	1.5	1.8	1.9	1.0	3.7	1.2	**1.8**
Soybean	1.0	1.1	2.6	1.0	4.9	1.2	**1.7**

Table 17: Future importance of forage species by 2040

Forage species	Weighted average importance score		Estimated proportion of levy and public forage R&D funding
	Direct grazed forages	Mechanically harvested forages	
Annual and perennial mixes	7.3		8.4%
Annual ryegrass	7.2		7.3%
Italian ryegrass	6.5		–
Maize		6.5	0.9%
Perennial ryegrass	6.3		28.9%
Other clovers	5.8		1.5%
Herbs (chicory, plantain)	5.7		1.0%
White clover	5.5		1.5%
Lucerne	5.3	5.4	20.5%
Brassicas	5.2		–
Oats	4.5	3.8	0.6%
Forage sorghum	4.3	4.0	0.5%
Tall fescue	4.1		0.5%
Cocksfoot	3.8		11.8%
Kikuyu	3.5		9.2%
Millet	3.9	3.0	–
Wheat	3.3	3.3	0.6%
Vetch	3.1	3.5	0.9%
Barley	3.5	2.9	1.1%
Brachiaria	3.0		0.3%
Mixed cropping		2.7	–
Triticale		2.4	–
Rhodes grass	2.3		2.8%
Other species	1.9	2.5	–
Setaria	2.1		–
Fabaceae		1.8	–
Soybean	1.6	1.7	–
Tropical legumes	1.3		–
Gatton panic	–	–	0.3%
Canola	–	–	0.4%

Additional commentary:

- The 'other clover' category comprises a wide range of clovers including Balansa, Berseem, Persian, red, subterranean, etc. – as well as less well-known species such as Alsike and Caucasian clovers.
- Prairie grass was not nominated as an important future forage species. Its main attribute is winter growth, but short-term ryegrasses are comparable and perhaps easier to manage with fast rotations.
- Phalaris and paspalum were also not nominated as important future forage species.

In summary, current R&D project funding relative to overall importance of groups of forage species is shown in Table 18.

Table 18: Level of current project funding against future importance of forage species – summary

Future importance of forage species	Estimated proportion of levy and public forage R&D funding
Very High[15]	-
High or Moderately High	15.7%
Above Average or Medium	55.3%
Low or Moderately Low	25.5%
Very Low or Not at All Important	3.5%

15. No species fall into this category at a national level

9

Funding and collaboration Opportunities

9.1 Background

The success of the National Dairy Forages R&D Strategy depends on the ability of the entire dairy supply chain to translate research outcomes into practical, on-farm benefits. These benefits must generate value not only for farmers but also for stakeholders both pre- and post-farm gate, including research investors.

Achieving meaningful outcomes will require strong collaboration among research investors, providers, and seed companies. As the industry adopts more innovative technologies and practices (e.g., new breeding technologies), broader engagement from the full supply chain will become essential.

Currently, dairy forage research in Australia is concentrated among a small number of providers with the required capability and infrastructure. In contrast, the grains industry – both domestically and internationally – has seen growth in the number, capability, and capacity of research providers.

To meet future demands for forage and milk production, the dairy sector must broaden its R&D and extension partnerships. This includes fostering collaboration within the sector (public and private), across sectors (e.g., grains, horticulture), and internationally (e.g., New Zealand, Ireland, the Americas) to access the innovation needed to deliver next-generation forages.

9.2 Future forage R&D collaborations

Successful collaborations in dairy forage research have led to valuable outcomes, such as the development of endophytes in perennial ryegrass and tall fescue, and the application of genomic selection in ryegrass. In the animal domain, for example, breeding indexes developed through extensive industry collaboration have been widely adopted for sire selection.

Despite these successes, collaboration failures are common. Globally, 50–75% of inter-organisational collaborations fail. In Australian dairy forage research, examples include the inability to translate breeding technologies into improved cultivars like high-fructan ryegrass and low-lignin tall fescue.

Interviews with stakeholders identified four common reasons for collaboration failure:

- Misalignment in roles and responsibilities.
- Lack of a shared value proposition and research goals.
- Poor communication.
- Weak commitment and relationship breakdowns.

These challenges typically relate to issues of people, process, structure, and context (see Table 19).

Table 19: Common causes of dairy R&D collaboration failure

Cause	Description
Communication breakdown	Unclear roles, lack of dialogue
Misaligned goals	No shared vision or objectives
Inequitable credit	Disputes over recognition or workload
Cultural clashes	Conflicting values or systems
Lack of commitment	Passive engagement or short-term focus
Resource issues	Unequal or insufficient resources
Administrative hurdles	Complex approvals or delays
Relationship breakdown	Loss of trust or unsustainable partnerships

To improve future forage research collaboration, particularly those involving Dairy Australia and other DMF partners, several critical success factors must be in place:

- Trust and transparency – stakeholders must foster open and honest relationships.
- Commitment to shared goals – alignment around a common vision and objectives is essential.
- Decision synchronisation – all decisions should be timely, coordinated, and communicated across stakeholders.
- Aligned value propositions – value must be defined, shared fairly, and clearly linked to the collaboration's purpose.
- Effective information sharing – data must be relevant, standardised, and accessible.
- Clear communication – frequent, open communication prevents misunderstandings and unlocks value.

To reduce risk and increase the likelihood of success, Dairy Australia and other DMF partners should apply a structured process when assessing new collaborative opportunities with research providers or supply chain stakeholders (see Figure 3).

If a proposed collaboration proceeds, partners should adopt the AgriFutures Value Chain Collaboration Guide[16], which provides a practical framework and checklists to support successful collaboration design and execution. A key output is the Collaboration Agreement, which defines the governance and operational foundations of the partnership.

Figure 3: Forage research collaboration evaluation process guide

1 Opportunity identification

Industry/producers identify potential opportunity for revenue generation:

- Product
- Market
- Value adding
- Vertical or horizontal integration.

Requires mapping of the value chain and will vary with the level of industry maturity.

2 Strategy identification

Undertake assessment of opportunity and identify strategy for capitalising on the opportunity.

Is collaboration a strategy to either leverage the opportunity or address barriers/pinch points?

3 Potential for collaboration

If yes, identify:

- Role that a collaboration could play
- Identify where along the value/supply chain the collaboration fits
- Identify the potential partners for the collaboration.

Once have established where a collaboration could assist in delivering producer revenue opportunities, the collaboration model can be applied to assist in building a successful collaboration.

4 Apply the collaboration model

If applicable, the collaboration model and supporting tools can be used to fully assess and implement the collaboration.

Note this would be done in parallel to business planning/business case activities that would be undertaken by any business/industry development activity.

16. Hudson D, McLean B, Richards R. (2024) Value Chain Collaboration Guide for AgriFutures Australia Levied and Emerging Industries. AgriFutures Report. Project no. PRO-019136. AgriFutures Australia publication no. 24-207.

9.3 Future forage R&D investment

Funding forage research in Australia – particularly within the dairy sector – remains a persistent challenge. This is largely because pastures and forages are viewed as a subcomponent of various livestock industries, rather than a distinct sector with its own strategic focus.

As a result, public sector investment has fluctuated across states depending on the relative priority of the dairy, beef, and sheep industries. Over time, this has led to a decline in capability, capacity, and infrastructure for forage R&D (and increasingly extension). Simultaneously, private sector investment has also contracted, driven by shrinking livestock numbers, higher input costs, lower margins, and increased global competition.

This gap has placed greater reliance on funding from RDCs like Dairy Australia and philanthropic groups such as the Gardiner Foundation. Meanwhile, global consolidation of the seed industry—with major R&D companies now headquartered overseas (e.g., RAGT in France, DLF in Denmark, Barenbrug in the Netherlands) – has shifted investment priorities toward international rather than Australian needs.

Given limited prospects for entirely new funding sources, future strategies must focus on maximising return on existing investment and expanding access to co-investment opportunities. Key approaches include:

Target national funding programs

- Align research with national priorities to tap into broader funding pools such as the Future Drought Fund, Australia's Economic Accelerator, and the CRC for Net Zero Emissions in Agriculture. These offer opportunities for projects related to drought resilience, climate-smart agriculture, and new forage development.

Build international collaborations

- Partner with researchers in New Zealand and Ireland on grazed forage systems, and with the US and Europe on forages for TMR systems. Shared priorities across dairy regions offer a strong foundation for impactful cross-border collaborations.

Future strategies must focus on maximising return on existing investment and expanding access to co-investment opportunities.

Leverage cross-industry expertise

- Collaborate with research providers from other plant industries – especially in advanced breeding technologies like gene editing and GMOs – to apply their expertise to forage traits such as drought tolerance and nutrient efficiency. This reduces duplication and speeds up delivery to market.

Support spin-out companies

- Evaluate opportunities to commercialise early-stage research through startups. Spin-outs can attract private capital, enable agility, reward researchers, and allow industry funders to manage innovation risks more flexibly.

Establish a dedicated forage R&D investment consortium

- Establish a consortium of investors focused on delivering critical outcomes for the future of Australian dairy, such as improved forage systems. For example, a consortium (including governments and major agribusinesses) could target the development of dairy forage systems to boost productivity, resilience and profitability.

Revive a national pasture collaboration platform

- Re-establish an initiative similar to Pastures Australia or the Pasture Improvement Initiative to coordinate national efforts. These platforms united rural R&D Corporations, improved extension and communication, and fostered joint investment in non-competitive, high-impact research.

Pastures Australia was a joint venture between five RDCs (Australian Wool Innovation (AWI), Dairy Australia, GRDC, MLA, and AgriFutures) that aimed to centralise investment and coordination in pasture genetic improvement, agronomy, and extension. It enabled cross-sector alignment and efficiency.

The Pasture Improvement Initiative focused on promoting pasture adoption through advisor training, extension, and demonstration sites. It served as a clearing house for information and increased industry-wide knowledge of pasture tools and practices.

Beyond identifying opportunities, a critical step for securing future forage R&D investment is for DMF members to focus on aligning supply and value chain stakeholders. This will help remove barriers to translating forage research into on-farm outcomes and establish a seamless pathway to market for future forage innovations.

A critical step for securing future forage R&D investment is for DMF members to focus on aligning supply and value chain stakeholders.

Appendix 1: Glossary

Acronym	Description
AWI	Australian Wool Innovation
BMR	Brown midrib
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D&E	Development and Extension
DFMP	Dairy Farm Monitor Project
DMF	Dairy Moving Forward
ERA	Excellence in Research for Australia
EV	Economic value
FTE	Fulltime equivalent
FVI	Forage Value Index
GEBV	Genomic Estimated Breeding Values
GM	Genetically modified
GMO	Genetically modified organism
GRDC	Grains Research & Development Corporation
GVAP	Gross value of agricultural production
MDB	Murray Darling Basin
MET	Multi-environment trials
MLA	Meat & Livestock Australia
NBO	National Breeding Objective
NBT	New breeding technologies
NDF	Neutral Detergent Fibre
NFVT	National Forage Variety Trial
NSW DPI	New South Wales Department of Primary Industries
OECD	Organisation for Economic Co-operation and Development
OGTR	Office of the Gene Technology Regulator
PBI	PastureBase Ireland
PTN	Pasture Trials Network
QDPI	Queensland Department of Primary Industries
R&D	Research & Development
SARDI	South Australian Research and Development Institute
SDN	Site-directed nuclease
SIR	SCImago Institutions Rankings
SNP	Single Nucleotide Polymorphism
TMR	Total mixed ration

Appendix 2: Future research investment criteria

The tables below provide a clear set of criteria for prioritising future forage R&D investments:

Table 20: Assessment criteria definitions

Criteria	Summary question	Definition
Potential impact	**What difference will the option/solution make?**	The measurable and lasting improvements in productivity, profitability, and sustainability expected as a direct result of R&D investments and activities.
Potential effect on cost of production	**What effect could the option/solution have on cost of production?**	The effect on all the expenses incurred in production of forage including fertiliser, irrigation water, fuel and oil, fodder conservation, and pasture improvement and/or cropping costs.
Co-benefits	**Will the option have any adverse or positive co-benefits?**	The potential spill-over benefits for other aspects of dairy production systems that might arise from an innovation.
Scale	**Does the option address challenges or opportunities relevant to a broad segment of the industry, or a narrower sub-section?**	An innovation's capacity to expand its impact, adoption, and reach across the industry. The applicability and transferability of the solution or innovation across the different regions and farm systems that comprise the national industry.
Timeframe	**How long will it take for an innovation to move through R&D to adoption and/or commercialisation?**	The period required to achieve meaningful outcomes and impacts across the industry.
Path to market	**Is there a clear pathway to adoption and/or commercialisation?**	The structured process through which an innovation, technology, or process moves from initial research and development to commercialisation and/or widespread adoption. It encompasses all the steps required to bring an idea from the development phase to a viable product, service, or process that end-users can adopt.
Adoptability	**How easily could industry players adopt the outcomes?**	The ease with which a new technology, process, or innovation can be accepted, integrated, and utilised by its intended users or market. For forage options/solutions, this encompasses factors such as: • Relative advantage • Trialability • Observability • Complexity • Compatibility
Market acceptance	**Is the option aligned with supply chain expectations and regulations?**	The willingness of farmers, consumers, regulatory bodies, industry organisations, and other supply chain stakeholders to embrace an innovation based on perceived benefits, safety, and regulatory factors.
Risk profile	**What is the overall risk profile of an option?**	The potential risks associated with execution, outcomes, and its broader implications for the industry – and the ability to mitigate these risks. This includes the technical scientific risk associated with successfully creating the new technology or management practice.
Established capability, capacity & infrastructure	**How well does the option align with exiting core competencies and infrastructure?**	The resources, skills, systems, and physical assets required to execute the option successfully. This includes CCI in both the public (Universities, State Departments etc.) and private (e.g. plant breeding companies) sectors.

Table 21: Assessment criteria scoring

	Criteria	1-2	3-4	5-6	7-8	9-10
		VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
IMPACT	Potential impact	Insignificant impact	Minor impact	Some impact	Moderate impact	Major impact
IMPACT	Potential effect on cost of production	Major impact	Moderate impact	Some impact	Minor impact	Insignificant impact
IMPACT	Co-benefits	No expected/ likely co-benefits	Minor expected/ likely co-benefits	Some expected/ likely co-benefits	Moderate expected/ likely co-benefits	Good prospects that co-benefits for other drivers will emerge
IMPACT	Scale	Affects very small number of farms (<500), small volume of milk or small number of regions	Affects small number of farms or volume of milk	Affects reasonable number of farms or volume of milk	Affects majority of farms and/or majority of milk supply	Affects all farms – or is an industry 'must have'
IMPACT	Timeframe	Long time delay (> 20 years) before meaningful outcomes and impact emerge	15-20 years	Medium timeframe (10-15 years)	5-10 years	Short timeframe (<5 years)
EASE OF IMPLEMENTATION	Path to market	No pathway to adoption and/or commercialisation	Unproven or ineffective pathway to adoption and/or commercialisation	Moderately effective pathway to adoption and/or commercialisation	Strong, proven and effective pathway to adoption and/or commercialisation	Very strong, proven and effective pathway to adoption and/or commercialisation
EASE OF IMPLEMENTATION	Adoptability	Meets one or none of the factors of adoptability		Meets at least three factors of adoptability		Meets all five factors of adoptability
EASE OF IMPLEMENTATION	Market acceptance	Significant barriers to consumer /customer acceptance exist, unlikely to be removed within the next 30 years.	Slightly aligned with supply chain expectations and regulations	Barriers exist but are softening and/or prospects of their removal are emerging.	Strongly aligned with supply chain expectations and regulations	No barriers exist. The market is agnostic to the option/solution.
EASE OF IMPLEMENTATION	Risk profile	Very high after mitigation or risk treatment	High after mitigation or risk treatment	Medium after mitigation or risk treatment	Low after mitigation or risk treatment	Negligible risk
EASE OF IMPLEMENTATION	Established capability, capacity & infrastructure	No infrastructure or people with appropriate skills or experience	Acknowledged shortfall in infrastructure and key skill areas		Infrastructure and appropriate people are available but in demand	Infrastructure and people with appropriate skills immediately available

Appendix 3: Australian dairy forage market

The Australian Seed Federation (ASF) Pasture Seed Database (2020) lists 143 ryegrass varieties, including 61 perennial ryegrasses and 85 short-term ryegrasses (annuals to hybrids), though some are outdated and no longer sold. A DairyBio scan of breeding company listings in 2023 identified 39 perennial ryegrasses and 65 short-term ryegrasses, totalling 104 ryegrass varieties currently available.

The ASF database also lists 99 forage species (including brassicas) and 616 cultivars marketed by roughly 25 companies, though not all species are relevant to dairy. The 2023 DairyBio scan identified 267 cultivars across all species.

Table 22: Estimated annual dairy forage planting area (ha) x region

Forage system planted	South West Victoria/South East SA	Gippsland/ South Coast NSW	Northern VIC/ Riverina/ Inland NSW/ Rest of SA	Tasmania	Queensland/ North Coast NSW	South West WA	Total
Perennial							
Perennial ryegrass/white clover	11,160	9,150	9,350	6,580		1,680	**37,920**
Perennial ryegrass/white clover/herbs	1,260	5,170		1,240			**7,670**
Perennial ryegrass/white clover/sub. clover	7,510						**7,510**
Perennial ryegrass (pure sward)				3,100			**3,100**

Forage system planted	South West Victoria/South East SA	Gippsland/ South Coast NSW	Northern VIC/ Riverina/ Inland NSW/ Rest of SA	Tasmania	Queensland/ North Coast NSW	South West WA	Total
Short-term							
Annual ryegrass (pure sward)	7,880	2,150	26,400		21,870	22,870	**81,170**
Annual ryegrass/Persian clover			44,000		2,190		**46,190**
Italian ryegrass/Persian clover			35,200				**35,200**
Italian ryegrass (pure sward)	10,510	4,310	11,000		6,560	1,970	**34,350**
Annual ryegrass/sub. clover			16,500			1,970	**18,470**
Hybrid ryegrass/white clover		5,490		1,320			**6,810**
Annual ryegrass/Italian ryegrass		1,290			4,920	470	**6,680**
Annual ryegrass/Italian ryegrass/sub. clover			5,500				**5,500**
Italian ryegrass/leafy turnip/chicory					4,160		**4,160**
Annual ryegrass/leafy turnip/chicory					2,600	1,120	**3,720**
Annual ryegrass/Persian clover/Balansa clover						3,150	**3,150**
Hybrid ryegrass (pure sward)		2,150					**2,150**
Annual ryegrass/leafy turnip						1,910	**1,910**
Herbs							
Chicory/plantain	7,880	10,760		1,030	550		**20,220**
Forage crops							
Brassicas	21,010	10,760		8,260			**40,030**
Millet	5,250	4,310	13,750		550	990	**24,850**
Forage sorghum	2.630	2,150	5,500		1,640		**11,920**
Maize	1,310	1,080	550	80	110	80	**3,210**

Table 23: Australian commercial seed companies breeding and/or marketing pasture and fodder crop varieties to the dairy industry

2020 – marketer	Temperate annual & perennial grasses		Annual & perennial legumes		Forage brassicas & herbs		Tropical grasses & legumes			
Breeding and marketing	**Breeding**	**Marketing**	**Breeding**	**Marketing**	**Breeding**	**Marketing**	**Breeding**	**Marketing**	**Market access**	**Species breeding**
Barenbrug Australia	Yes	Yes	Yes	Yes	Yes	Yes		Yes	National	ryegrass, tall fescue, cocksfoot, white clover, red clover, brassicas, herbs
Cropmark Seeds	Yes	Yes	Yes	Yes	Yes	Yes			National	ryegrass, cocksfoot, white clover, red clover, brassicas, herbs
DLF Seeds	Yes	Yes	Yes	Yes	Yes	Yes		Yes	National	ryegrass, tall fescue, cocksfoot, phalaris, white clover, red clover, brassicas, herbs
RAGT	Yes	Yes	Yes	Yes	Yes	Yes			National	ryegrass, tall fescue, cocksfoot, white clover, red clover, brassicas, herbs
S & W		Yes	Yes	Yes		Yes		Yes	National	lucerne
Tasglobal Seeds	Yes	Yes	Yes	Yes		Yes			Regional	ryegrass, cocksfoot, annual and perennial clovers
Upper Murray Seeds		Yes		Yes		Yes		Yes	National	ryegrass, tall fescue, cocksfoot, phalaris
Valley Seeds		Yes		Yes		Yes			National	ryegrass, cocksfoot, phalaris, white clover
JH Williams & Sons		Yes		Yes		Yes	Yes	Yes	Regional	tropical grasses and legumes
Progressive Seeds							Yes	Yes	Regional	tropical grasses and legumes
Selected Seeds Pty Ltd							Yes	Yes	Regional	tropical grasses and legumes
Marketing only										
AGF Seeds		Yes		Yes		Yes			National	
IH Seeds		Yes		Yes		Yes		Yes	Regional	
Naracoorte Seeds		Yes		Yes		Yes			Regional	
Notman Seeds		Yes		Yes		Yes			Regional	
Synergy Seeds				Yes					Regional	

Table 24: Number of pasture and forage varieties marketed by seed companies to the dairy industry

Pasture and fodder species	Annual ryegrass (annual, Italian, hybrid)	Perennial ryegrass	Tropical grasses (multi species)	Sub-clover	Other annual clover medic	Vetch	Lucerne	White clover	Tropical legumes (multi species)	Forage brassica (multi species)	Herbs (multi species)
Breeding and Marketing											
Barenbrug Australia	10	9	16	8	8	2	5	3	6	5	5
Cropmark Seeds	7	5						2		7	2
DLF Seeds	13	10	3	3	2		5	5	2	19	3
RAGT	8	3	1	8			3	1		3	2
Upper Murray Seeds	11	7			1		4	2		1	1
Valley Seeds	10	4								1	1
Williams Seeds			2								
Selected Seeds Pty Ltd			3						1		
AlfaGen Seeds	7	3	7	4	7	4	9	1	2	8	2
Marketing Only											
AGF Seeds	11	3				1				4	
IH Seeds			1		5		3				
Naracoorte Seeds											
Notman Seeds		2									
Synergy Seeds				9	3	4	7	1			

Table 25: Number of forage varieties marketed by seed companies

Forage species	Maize – silage	Sorghum hybrids/ summer forage	Millet	Grazing/ forage oats	Forage ryecorn	Forage wheat	Forage barley	Forage triticale	Barley	Wheat	Canola
AGF Seeds				5	1	1					
AlfaGen Seeds		5	1	2			1				
Barenbrug		4		1			1	1			
DLF Seeds	6	3		5	1						
HSR Seeds	14										
Notman Seeds		2	1	2			1				
Pacific Seeds	6	6		4						14	9
Pioneer	11	5									14
RAGT Seeds		2		2					2	9	6
Upper Murray Seeds		1		2			1				

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