KIT 3.5

Develop technology to reduce fertiliser manufacture and/or application costs and improve fertiliser use efficiency.

Impact	**Growers generate more profit through access to cost-effective and sustainable technologies or practices that better match nutrient supply to crop demand.**
Summary	• Opportunities for growers to realise savings associated with lower fertiliser manufacture and/or supply costs are created or accelerated. • Technologies and practices that lower the cost or improve the efficiency of on-farm storage and application of nutrients are implemented. • New solutions that minimise nutrient losses or improve nutrient access, uptake and/or efficiency of use by crops are identified and developed. • Research and development informs nutrient stewardship, policy and regulation to ensure ongoing fertiliser access and flexibility of use.

OVERVIEW

The purchase, transport, storage and application of fertiliser is one of the largest input costs in Australian grain production, with fertiliser purchases typically representing 20 to 25 per cent of variable input costs (IPNI 2013). The total expenditure on fertiliser nitrogen (N) alone in Australian grain production is around $1.1 billion per annum (Fertilizer Australia 2018; Norton and Drew 2016). Grower expenditure on N and phosphorus (P) does vary considerably across businesses, farming systems, environments and years. In winter cropping systems of Southern Australia for example, N and P costs range from $20 to 55 per tonne of wheat yield (Vogt et al. 2017). In addition, the efficiency of nutrient use is sometimes sub-optimal due to reduced availability in some soils (locked up in the soil nutrient pool) or as a result of direct loss mechanisms (gaseous loss, leaching, run-off or erosion), thus presenting immediate opportunities for growers to realise significant cost savings.

Key Investment Target (KIT) 3.5 aims to address the cost lever of the profit equation through the development of technologies that reduce costs associated with the manufacture, storage, handling and/or transport of fertilisers and/or increase fertiliser use efficiency to generate greater profit from fertiliser application. A broad range of global factors influence Australian fertiliser pricing, including international pricing; exchange rates; product demand; cost of raw materials; commodity prices; cost of energy; production capacity; freight costs; and government policies. As many of these factors are beyond the influence or scope of GRDC, investment by GRDC in RD&E will need to be highly targeted and remain cognisant of the significant ongoing investment by the private sector in driving both manufacturing and supply cost efficiencies. To enable the intended impact of KIT 3.5 it is likely that more transformational or disruptive approaches will need to be explored in collaboration with commercial partners. Greater accuracy and timeliness of demand forecasting, transformational new chemistry or manufacturing approaches and strategies that better leverage domestic production capacity may be key areas that could be explored.

Four key macro-elements are predominantly used in Australian grains production, being N, P and (to a lesser extent) potassium (K) and sulphur (S). The use of P and N in winter cereal crops accounts for 53 per cent of total nutrient consumption by crops and pastures in Australia (Australian Competition and Consumer Commission 2007) and represents the major nutrient spend by grain growers in their cropping enterprises. Key fertiliser products used in broadacre grains production include mono-ammonium phosphate (MAP), di-ammonium phosphate (DAP), urea and ammonium sulphate. Whilst N and P fertilisers are manufactured in Australia, peak domestic demand far exceeds Australian production capacity, with approximately half of the total fertiliser used in Australia being imported. Phosphate rock is largely sourced from Morocco, China and Phosphate Hill in Queensland, and K fertilisers are almost exclusively imported from Canada, the United States and Europe, predominantly as potassium chloride (muriate of potash or MOP). However, some sulphate of potash is starting to be sourced from WA. Sulphur is largely provided to crops in the form of ammonium sulphate, elemental sulphur (by-products of the mining industry) and sulphate in superphosphate, although manufacturing of the later has

Grains Research and Development Corporation (GRDC)
PO BOX 5367, Kingston, ACT 2604, Australia | grdc@grdc.com.au | **www.grdc.com.au**
T +61 2 6166 4500 | **F** +61 2 6166 4599

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diminished greatly over the past four decades. Key fertiliser manufacturers in Australia include Incitec Pivot Limited, CSBP Limited and Impact Fertilisers Pty Ltd. In addition, there are several other fertiliser importers and suppliers of fertiliser products to Australian grain growers.

The relatively small size of the Australian fertiliser market, only representing approximately 1.4 per cent of global fertiliser consumption, poses challenges in fertiliser supply and pricing as well as any business case for bespoke new product development for Australian grain production and other agricultural sectors. Demand is very seasonal, requiring excellence in demand forecasting and posing challenges for suppliers to meet highly variable in-season grain grower demand. Australian grain growers typically order most of their fertiliser products four to eight months before planting based on estimated yield and crop demand predicted prior to the cropping season. The ability for growers to realise economically attainable crop yield potential in favourable seasons is subject to additional in-season fertiliser requirements being met, posing challenges considering lead times of two to five months from date of fertiliser order to distribution within Australia. Constraints for Australian manufacturers to better utilise out-of-season domestic production capacity locally include availability of storage capacity and a decline in quality of some products while in storage.

Efficiency of N use in Australian grains production remains low for many growers, even under the best management practices currently available. Across the grains industry as a whole, approximately 50 per cent of applied N is not taken up by the crop in the year of application and can be lost entirely from the production system with little or no productive gain (Angus and Grace 2016). Much of the loss of N is through denitrification, ammonia volatilisation, and leaching (Chen et al. 2008). Over the past 30 years, soil organic matter levels under cropping systems have declined. In addition, the amount of synthetic N fertiliser used in Australian grain production has increased four-fold (Fertilizer Australia 2018). Without major innovation and intervention, losses of N from Australian cropping systems may increase even further as the industry continues to strive for higher productivity via increased use of fertiliser N whilst minimising any potential environmental impacts related to greenhouse gas emissions and reduced water quality.

Similarly, very small proportions of P applied in fertilisers are taken up by the crop in the year of application. Apart from the very sandy soils, P is bound tightly to clay particles in the soil and is largely unavailable to crops. Highly calcareous soils, pH >8.0 in CaCl2 and containing 30–90 per cent free lime, pose major implications for crop nutrition. Calcium carbonates make phosphate (P) and many trace elements (Zinc, Manganese, Copper and Iron) highly unavailable to plants, resulting in poor crop growth and yield even when these elements are abundant in the soil. Although P can leach on very sandy soils, losses of P on other soil types are largely limited to soil erosion into waterways. While nutrient losses from the grains industry are thought to be relatively small, environmental concerns influence fertiliser stewardship, policy and regulation.

The manufacture of fertiliser products for cropping is a well-established, competitive, high volume, generally low margin industry. For GRDC to invest in research, development and extension (RD&E) to develop new, more cost-effective fertiliser product innovations engagement, collaboration and partnerships with the private sector will be required to ensure a pathway to market. Investment would, where possible, leverage extensive historic and ongoing R&D investment and intellectual property generated by the fertiliser industry aimed at reducing the costs or increasing fertiliser efficiency. GRDC investment in RD&E to develop technologies that improve nutrient access, uptake or efficiency of use by crops or inform policy may increase grower profitability directly and/or support the long-term sustainability of fertiliser use. GRDC investment in this area would need to ensure equitable value share between growers, co-investment partners and other beneficiaries and realise grower benefit through associated cost savings, improvements in grain yield and quality and/or flexibility in fertiliser use.

Australian grain production is highly mechanised and uses fertiliser products at scale in bulk storage, handling and application systems. Even though Australian grain production currently benefits from economies of scale and efficiencies from mechanisation of operations, opportunities to further reduce cost or improve the efficiency of on-farm nutrient storage and application may be further explored through targeted RD&E investment.

The aspirational outcome associated with KIT 3.5 is to generate more profit for grain growers through access to cost-effective and sustainable technologies or practices that better match nutrient supply to crop demand. This will be achieved through investment under three areas of scope:

1. Reduced costs associated with fertiliser manufacture and supply;
2. Reduced costs and/or improved efficiency of on-farm nutrient storage and application;
3. New solutions to improve the efficiency and sustainability of nutrient supply, uptake and use by crops.

In summary, the strategy aims to ensure:

- Opportunities for growers to realise savings associated with lower fertiliser manufacture and/or supply costs are created or accelerated;
- Technologies and practices that reduce the cost or improve the efficiency of on-farm storage and application of nutrients are implemented;
- New solutions that minimise nutrient losses or improve nutrient access, uptake and/or efficiency of use by crops are identified and developed;
- Research and development that informs nutrient stewardship, policy and regulation to ensure ongoing fertiliser access and flexibility of use.

FUTURE RD&E FOCUS

Opportunities to increase Australian grain grower profit are significant should GRDC investment in RD&E identify and realise costs savings associated with the purchase, storage, handling and application of fertilisers. GRDC may also deliver impact through RD&E into new and innovative solutions that increase the efficiency of nutrient supply, uptake and use by crops to maximise the $/T return from fertiliser spend and ensure long-term sustainability of use. The strategic focus of KIT 3.5 will be on maximising return from applied N and P. The focus on N and P is based upon the fact that these two macro-elements make up by far the highest proportionate spend on nutrients by Australian grain growers. Recognising the critical importance of balanced crop nutrition to yield and return on expenditure on N and P, K and S are secondary priorities whilst investment in RD&E to develop technology to reduce costs associated with the manufacture, application or fertiliser use efficiency of other nutrients, including trace elements is proposed as a lower priority.

SCOPE – Reduced costs associated with fertiliser manufacture and supply

Growers have access to cost-effective fertilisers through savings associated with the manufacture, transport, storage and handling of fertiliser pre-farm gate.

The highly competitive nature of the fertiliser industry and ongoing advances in manufacture, transport, supply and handling technologies means opportunities for GRDC to invest to further reduce fertiliser cost to growers are likely to be limited and challenging. Investment in RD&E by the fertiliser industry within Australia and globally continues to explore opportunities to drive efficiency in fertiliser manufacture and supply costs to gain a competitive edge and maintain or improve sales margins. Despite this, GRDC will consider targeted investment to reduce costs associated with the manufacture of fertiliser products and/or logistical costs of supply of fertiliser from manufacture site to farm, provided investment can demonstrate a clear pathway to adoption, equitable and demonstratable value to grain growers and in doing so does not create any form of market failure.

Recognising the existing intellectual property, expertise and investment of fertiliser manufacturers in R&D to reduce fertiliser costs, as well as the need to ensure a pathway to market for any related new technologies developed, investment by GRDC in RD&E aligned to this area of scope will likely be through public/private partnerships. The requirement to collaborate with commercial fertiliser companies in the development of new fertiliser manufacturing and/or logistics technologies is further justified through the need to validate these at scale to ensure regulatory, production and supply chain factors are considered and appropriately addressed. An example includes the significant investment in pilot production activities that would warrant commercial implementation and subsequent realisation of any GRDC investment in RD&E. Co-investment by GRDC with the fertiliser industry should aim to stimulate investment in the development of technologies that would not otherwise occur, i.e. where market failure is identified or potentially transformational opportunities are prohibited by high technical or commercial risk.

Investment in this scope area by GRDC may not be limited to process improvement only, but could also include RD&E to inform policy that may assist in reducing the costs of raw material supply or sea and land freight (e.g. port costs, infrastructure, and transport options and regulation).

Investment Outcome 3.5.1 – New solutions to lower the cost of manufacture of fertiliser products, including by reducing energy and operating costs, are identified, developed and implemented.

GRDC will consider targeted investment to reduce the key elements of fertiliser manufacture, being raw materials (including gas or rock phosphate), energy and operations. This will require active consultation with the fertiliser industry to identify and explore the technical and commercial feasibility of potential new approaches to ensure complementarity of

RD&E investment and a pathway to market for any related outputs.

Urea, the most widely used and concentrated form of N available in Australia is manufactured through combining ammonia and carbon dioxide under high pressure, and hence, the price of energy is reflected in the cost of this fertiliser. Considering the energy intensive nature of N fertiliser manufacture and an evolving global energy market, an opportunity exists to undertake RD&E to reduce energy costs, greenhouse gas emissions, and proactively address future policy changes or competing energy demand. Labour costs associated with fertiliser manufacture have already undergone significant downward pressure through automation of manufacturing processes as standard practice. This means that required innovations are likely to come from other industries or completely new approaches to reducing the cost of manufacturing fertiliser. In all cases, reducing costs will likely influence broader manufacturing processes and this must be considered as part of any innovation to ensure the benefits of investment in RD&E are realised by both growers and co-investment partners.

GRDC, in collaboration with fertiliser manufacturers and others, may invest in RD&E to facilitate a reduction in fertiliser manufacturing costs through the identification, development and implementation of alternative technologies or processes that lower energy and other operating costs. Given the likely benefits to other agricultural industries, opportunities for co-investment with other Research and Development Corporations may be explored.

Investment in RD&E to achieve this outcome should leverage related investment in the following KIT strategies:

- KIT 4.1: Support research to advise policy and investment decisions that lead to reduced post-farm-gate-costs
- KIT 4.2: Invest in R&D that informs industry and government approaches to trade and market access for Australian grain into export markets.

Investment Outcome 3.5.2 – New solutions to lower the logistical costs of supply of fertiliser from manufacture site to farm are identified, developed and implemented.

The fertiliser supply chain generally comprises manufacturers, distributors and retailers before reaching the grower. Although this represents the basic flow of product, in many cases functional levels are bypassed or organisations vertically integrated e.g. product is sometimes supplied direct from manufacturer to grower (Australian Competition and Consumer Commission 2007).

Changes to Australian domestic freight and supply chain logistics are complex and largely beyond the scope of influence of GRDC. GRDC may, however, consider RD&E investment targeted to understand the variables that drive supply chain costs and inform policy, or to identify, develop and support the effective implementation of new technologies or business models that lower costs associated with freight, pre-farm gate storage and handling, and other logistics from manufacture site to farm. This could include new supply and demand forecasting approaches, pricing intelligence, and freight and storage strategies and technologies.

Investment in RD&E to achieve this outcome should leverage related investment in the following KIT strategies:

- KIT 4.4: Improve automation of transport and handling activities and/or alternative logistics and distribution models to realise greater value capture by growers.

SCOPE – Reduced costs and/or improved efficiency of on-farm nutrient storage and application

Technologies and practices that lower costs associated with on-farm nutrient storage and application are implemented.

Small advances in efficiency of on-farm storage, handling and application of fertilisers may be possible through further technological advances in plant and equipment, operational scheduling, automation, data collection and analysis. Such efficiencies may reduce costs directly through lower costs of storage, decreased plant and equipment purchase and/or running costs, and increased labour use efficiency, and may also result in benefits associated with improved operational timeliness, reduced operator fatigue and greater ease of management.

Investment in RD&E to achieve the outcomes aligned to this area of scope should leverage related investment in the following KIT strategies:

- KIT 3.7: Identify engineering solutions to reduce labour costs and/or improve the efficiency of repetitive tasks (including automation and robotics)

- KIT 3.8: Identify engineering and novel business solutions to reduce capital costs and running costs
- KIT 4.3: Improve the reliability and cost effectiveness of on-farm grain storage to reduce handling costs and capture market opportunities
- KIT 4.4 Improve automation of transport and handling activities and/or alternative logistics and distribution models to realise greater value capture by growers.

Investment Outcome 3.5.3 – Lower cost or more efficient nutrient application and handling solutions are identified, developed and implemented on farm.

GRDC will consider investment in RD&E to identify and develop technologies or practices that lower the cost, improve the efficiency, and reduce the complexity of fertiliser handling and application on-farm. This may include advancements in operational practices and scheduling; or data, automation or engineering solutions involved in loading, unloading, blending, transport, drilling or spreading of fertilisers on-farm. GRDC may also consider investing in validating or extending existing information and knowledge regarding efficiency of application or handling of different product forms, methods and application timings. Examples of this include knowledge or information on variable rate technology; liquid versus granular forms of fertiliser pre-drilled pre-plant, drilled at planting or in-crop; or fertiliser broadcast by air or ground application. Efficiencies in combining operational tasks or any other RD&E to improve the efficiency of fertiliser logistics on-farm or between farms (excluding storage) may also be considered. An example is RD&E that results in opportunities for reducing the number of operational passes across a paddock.

Investment Outcome 3.5.4 – Lower cost or more efficient nutrient storage solutions are identified, developed and implemented on farm.

Investment by Australian grain growers in sheds, tanks and other storage solutions for plant and equipment, fertiliser, grain and other crop inputs is significant. Grain growers require cost-effective nutrient storage solutions to maximise return on investments in infrastructure, plant and equipment and farm labour. Enhanced grain grower profitability could be achieved through storage solutions that enable operational efficiency, maintain quality and longevity of fertiliser products, reduce waste, minimise repair and maintenance costs of machinery, and ensure operator health and safety. Some fertiliser products are hydroscopic, corrosive and have a limited shelf life. Residual or excess stock of fertiliser products, particularly in solid form, often cannot be easily retained on-farm for use in subsequent years. Therefore, synthetic fertilisers and other nutrient sources are generally managed on-farm and within supply chains over short time periods.

GRDC will consider investment in RD&E to identify, develop and facilitate adoption of practical and cost-effective on-farm nutrient storage practices or technologies. GRDC investment in outcomes associated with KIT 4.3 (improve the reliability and cost-effectiveness of on-farm grain storage to reduce handling costs and capture market opportunities) and KIT 3.8 (identify engineering and novel business model solutions to reduce capital and running costs) may also deliver towards this outcome.

SCOPE – New solutions to improve the efficiency and sustainability of nutrient supply, uptake and use by crops

Growers have a range of new products or technologies available to them to minimise nutrient losses and/or improve nutrient access, uptake or efficiency of use by crops.

Regardless of nutrient source, it is important that growers maximise the return on fertiliser investment through nutrient applications that are targeted to crop demand to maximise yield and profit. Initiatives aimed at maximising return on fertiliser spend through improved crop uptake of nutrients simultaneously support both grower profitability and environmental outcomes by minimising nutrient losses from farming systems.

Key challenges limiting the development of new fertiliser products that require consideration include:

- The high nutrient density of most current synthetic fertilisers and the fundamentals of chemistry and physics that limit the opportunity for further advances;
- The generally high suitability of current products to low cost, bulk handling, transport and application;
- The commodity nature of most fertiliser products and the competitive pricing driven by wide availability and difficulties in differentiation within the fertiliser market;
- A focus upon reducing logistical costs as opposed to new product development due to market competition.

GRDC will consider investment in RD&E to facilitate grower access to new fertiliser sources or products, practices or technologies, including plant-based, biological or engineering solutions, that minimise nutrient losses and/or improve nutrient access, uptake or efficiency of use by crops.

Investment Outcome 3.5.5 – Growers have access to nutrient sources, products or other technologies that match supply to crop demand while minimising losses and/or mitigating effects on the community or environment.

GRDC will consider investment in RD&E to support the development of products or technologies aimed at reducing losses or better matching nutrient supply to crop demand. Any investment by GRDC in this outcome will need to be highly considerate of the costs and benefits of new versus existing products, the pathway to market, and the opportunity for grain growers to capture value.

Numerous products or technologies are currently available or in development that aim to increase nutrient use efficiency, reduce nutrient losses, unlock nutrients bound by chemical interactions in the soil, and/or slow or control the release of nutrients to better match nutrient supply to crop demand. These products or technologies include various inhibitors of nutrient loss processes, for example urease and nitrification inhibitors to prevent N losses, and different fertiliser formulation and coating technologies. Field trial results in Australia to evaluate inhibitors of losses or control-release nitrogen fertilisers have to date been highly variable and rarely cost-effective in the grains industry as a result of the episodic and unpredictable nature of nutrient loss events (Drew and Norton 2019 unpublished).

Any investment by GRDC to develop or validate enhanced efficiency fertiliser products or inhibitors will need to target areas considered to be at high risk of nutrient losses and hence most likely to demonstrate a consistent economic or environmental benefit to grain growers. An example of this is denitrification losses under waterlogged conditions. This will require assessment of the likely frequency and timing of nutrient loss events based on soil type and historical climate data at regional or sub-regional scales.

In addition to prevention of irrecoverable nutrient losses through inhibition of associated loss processes, opportunities for RD&E to assist in unlocking nutrients from the soil nutrient pool may be explored. An example of this is phosphorous that is currently unavailable due to nutrient tie-up in the soil. Opportunities for co-investment and leverage may be explored, including development or validation of products targeted at other sectors, for example sugar and pastures, and/or international markets.

Internationally, government policy relating to water quality and gas emissions has affected growers' freedom-to-operate through legislation relating to fertiliser product type and application practice. This includes the mandatory use of nitrification inhibitors with urea in some European countries as well as limitations around product rates in nitrate sensitive zones. Investment by GRDC in RD&E to address Investment Outcome 3.5.5 will need to consider effects of fertiliser use on the community and environment, including related sustainability and social licence issues. Future changes in public policy relating to nitrous oxide emissions and/or nitrate leaching into waterways may significantly change the economics of inhibitors and controlled release N fertilisers for the Australian grains industry. GRDC may invest in RD&E to inform science-based policy decisions relating to the long-term sustainable and profitable use of fertilisers in Australian grain production.

Investment Outcome 3.5.6 – Growers have access to new technologies that improve nutrient access, uptake or efficiency of use by crops.

Whilst RD&E investment opportunities aligned to Investment Outcome 3.5.5 are likely to primarily focus on innovation to deliver new or improved fertiliser products, further opportunities exist to discover and develop technologies that improve nutrient access, uptake or efficiency of use by plants once applied to the plant or soil. GRDC will consider Investment in RD&E aligned to Investment Outcome 3.5.6 that explores plant-based, biological or engineering solutions to improve fertiliser use efficiency and return on nutrient spend.

RD&E investment opportunities that may be explored include, but are not limited to, plant mediated nutrient release from fertilisers, plants with enhanced efficiency of nutrient uptake and/or internal utilisation, mediating nutrient release from fertilisers in response to the soil environment (e.g. soil water, soil temperature or nutrient concentration in solution) or novel engineering or fertiliser placement technologies. Exploiting the soil microbiome to improve nutrient availability and uptake is addressed in KIT 3.6 – Improve N and P availability by greater capture of value from soil biota, optimisation of nitrogen-fixing, soil amelioration.

REFERENCES

1. Angus. J. and Grace, P. (2016). Proceedings of the 2016 International Initiative Conference. www.ini2016.com
2. Australian Competition and Consumer Commission (2007). ACCC examination of fertiliser prices, 31 July 2008.
3. Chen, D., Suter, H., Islam, A., Edis, R., Freney, J. R. and Walker, C.N. (2008). Australian Journal of Soils Research 46, 289-301
4. Fertilizer Australia 2018. www.fertilizer.org.au.
5. IPNI (2013). Fertilizer Expenditure in the Australian Grains Industry: Summary from ABARES Farm Input Surveys. http://anz.ipni.net/article/ANZ-3133.
6. Norton, R. and Drew, N. (2016). Proceedings of 7th China International Fertilizer Show, Shanghai
7. Vogt, S., Hillcoat, J. and Craddock, T. (2017). Learning from the Top 20% operators. Grains Research & Development Corporation Update Papers, September 2017.

Grains Research and Development Corporation (GRDC)
PO BOX 5367, Kingston, ACT 2604, Australia | grdc@grdc.com.au | **www.grdc.com.au**
T +61 2 6166 4500 | **F** +61 2 6166 4599