GRDC
Grains Research & Development Corporation

Australian Government
Grains Research and Development Corporation

2 October 2015

Committee Secretary
House of Representatives Standing Committee on Agriculture and Industry
PO Box 6021
Parliament House
Canberra ACT 2600

By e-mail: AgInd.reps@aph.gov.au

Dear Committee Secretary

The role of technology in increasing agricultural productivity in Australia

The Grains Research and Development Corporation (GRDC) is pleased to make a submission to the Committee's inquiry into the role of technology in increasing agricultural productivity in Australia.

The GRDC is a statutory authority and resides in the Australian Government's Agriculture portfolio. The GRDC is one of the world's leading grains research organisations, responsible for planning, investing in and overseeing research (R), development (D) and extension (E) to deliver improvements in production, sustainability and profitability across the Australian grains industry. This wide ranging portfolio encompasses temperate and tropical cereals, coarse grains, pulses and oilseeds.

The GRDC currently invests more than $190m per annum on research, development and extension to improve the productivity of the grains industry and, importantly, contribute to increasing the profitability of its grower funders. GRDC funding consists of compulsory levies paid by growers on production of 25 crops, and government matched funding. Whilst this varies from year to year, it roughly equates to 60 per cent from growers and 40 per cent from government.

The development of new technology and its effective adoption on farm is a key driver to Australian grain production businesses. Our submission will explore some of the ways of delivering greater productivity and profitability to grain businesses, the impact of technology and barriers to adoption, the role of the GRDC in supporting the requisite R, D & E required; and what the GRDC is doing to ensure its investments are the right ones to deliver results for growers.

Key programs the GRDC currently funds, or has historically funded, that have delivered or are now delivering noteworthy productivity gains through technological breakthroughs are also outlined. However, the challenge for an R&D investor such as the GRDC in funding innovative research is identifying those ideas most likely to overcome the technological risks associated with R&D, and are easily adopted by growers, therefore providing the best return to

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Your GRDC working with you

growers for the investment required. Examples of investments in emerging technologies that the GRDC has recently committed to, covered in detail in the submission, are:

- Unmanned Vehicles and Robotics
- International Wheat Yield Platform
- Herbicide Discovery

In short, the GRDC is working with our traditional partners domestically as well as with new international partners to ensure that:

- The most pressing issues and opportunities are accurately identified by growers and agronomists at the local level,
- Appropriate investigation into what is already known is undertaken,
- Gaps in current knowledge are identified,
- Assessment of the potential return to growers by addressing knowledge gaps is performed,
- Relevant R&D is secured to develop appropriate technology and knowledge, and,
- Information flows seamlessly from strategic (8+ years) research at the international and national levels to applied R&D at the national and regional levels and is always being designed to minimise the complexity and maximise adoption at the local level.

The GRDC welcomes the opportunity to contribute to this Inquiry. The point of contact for this submission is: Dr Steve Thomas

Yours sincerely

John Harvey
Managing Director

THE ROLE OF TECHNOLOGY IN INCREASING PRODUCTIVITY IN AUSTRALIA

ABSTRACT
The development of new technology and its effective adoption on farm is a key driver to Australian grain production businesses. This submission explores some of the ways of delivering greater productivity and profitability to grain businesses, the impact of technology and role of the GRDC in supporting the requisite research, development and extension.

GRAINS RESEARCH AND DEVELOPMENT CORPORATION

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Inquiry Terms of Reference

The Committee will inquire into and report on the role of technology in increasing agricultural productivity in Australia. The inquiry will have particular regard to:

- improvements in the efficiency of agricultural practices due to new technology, and the scope for further improvements;
- emerging technology relevant to the agricultural sector, in areas including but not limited to telecommunications, remote monitoring and drones, plant genomics, and agricultural chemicals; and
- barriers to the adoption of emerging technology.

The Grains Industry and the Grains Research and Development Corporation

The grains industry is a significant generator of agricultural wealth in Australia and a major contributor to the Australian Gross Domestic Product. The value of production of grains and oilseeds in Australia has increased from $8,852 million in 2005/06 to $13, 695 million in 2012/13 with a commensurate increase in the value of grain and oilseed exports (not including rice or cotton) from $5,088 million in 2005/06 to $11,760 in 2012/13 (ABARES, 2013). In 2014, the value of production of just four major grain crops (wheat, barley, oats and sorghum) in Australia was $11,103 million (Australian Bureau of Statistics, 2015).

The grains industry in Australia has an enviable record of productivity gains over many decades (ABARES, 2009) that have led to the observed significant increases in the value of production and exports. While much of the increase in productivity has been generated through intuitive improvements in management by growers, innovation and technology underpinned by Research and Development (R&D) has been a major contributor to Australia's success in improving grains productivity and the profitability of growers (Sheng, Gray, & Mullen, 2011).

The Grains Research and Development Corporation (GRDC) was established in 1989 under *the Primary Industries and Energy Research and Development Act* and currently invests approximately $190m to $200m per annum on R&D and extension (E) to improve the productivity of the grains industry and importantly, contribute to increasing the profitability of its grower funders. GRDC funding consists of compulsory levies paid by growers on production of 25 different crops (approximately 60%) and capped government matching funding (approximately 40%). In addition to investment by the GRDC, State Government agencies, Universities and CSIRO remain the significant funders of agricultural R, D &E in Australia but the relative contribution of these agencies has been declining in recent years. More recent declines in the rate of productivity gains in the agriculture sector has been linked to underinvestment by public agencies in R,D&E (Mullen, 2010). As such, the importance of the GRDC as the major investor in supporting the R,D&E critical for the development of technology and its adoption by growers continues to grow.

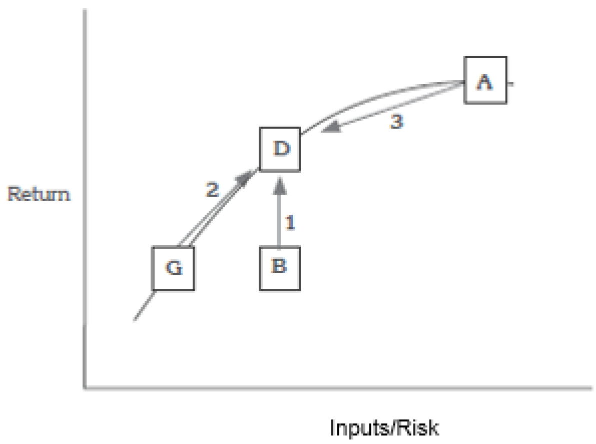
As the reliance on GRDC as the major investor in supporting R,D&E continues to grow, there are greater demands on the limited funds available. It is therefore critical that GRDC invests in the most appropriate balance of strategic research, applied research, development and validation, and extension across long, medium and short term horizons taking into account exposures to different levels of technical and adoption risk. The recent restructure of GRDC has sought to align group activities with this investment balance (Table 1).

Group	Time (Yrs)	Type	Activity	Risk
Commercial Research	8+	Strategic Research	New Genetic Traits New Varieties New Chemistry Robotics	High
Research Programs	3-8	Applied Research & Development	Farming Systems Agronomy Soils Nutrition Weeds Pests Diseases	
Grower Services	1-3	Validation and Extension	Local validation and adoption of research findings through development extension and communication	Low

Table 1: Alignment of GRDC structure with investment type, time to delivery and risk

Pathways to Productivity & PROFITABILITY Gains

The allocation of resources to R,D&E activities always involves trade-offs and judgement calls based on experience. Not all worthwhile activities can be funded and not all R&D groups can be supported. Recently, GRDC has undertaken joint efforts with CSIRO to better understand the pathways that lead to greater productivity and profitability, the technology drivers underpinning productivity and profitability improvements, and how resources can most efficiently be allocated. Crop production is a balancing act matching inputs to maximise outputs without becoming over exposed to downside risk as shown below (Keating, Carberry, Thomas, & Clark, 2012).



As inputs are increased so is the potential yield and return up to a maximum (A) determined by environmental factors such as soil type or, more typically in Australia, water availability. The very best growers do not aim to achieve maximum yield as the risk of increased input costs is not commensurate to the potential return (yield or $). The best growers therefore aim for a lower yield (about 80% of maximum environmental yield) to address risk (pathway 3) but are still efficient in that they generate the maximum yield for the inputs applied (D). More risk averse growers (G) can also be efficient but could afford to take more risk by increasing inputs to generate more returns especially in good years (pathway 2).

There are also a range of inefficiencies in grain production. A grower at point B is applying the inputs to maximise outputs but failing to meet the desired return (D) generally because of an inability to adopt available technology improvements. Current estimates of the annual losses associated with a failure to achieve outputs commensurate with inputs range from $1,698 million in the Northern cropping region to $3,075 million in the West with a National average loss of $6,467 million (Table 2).

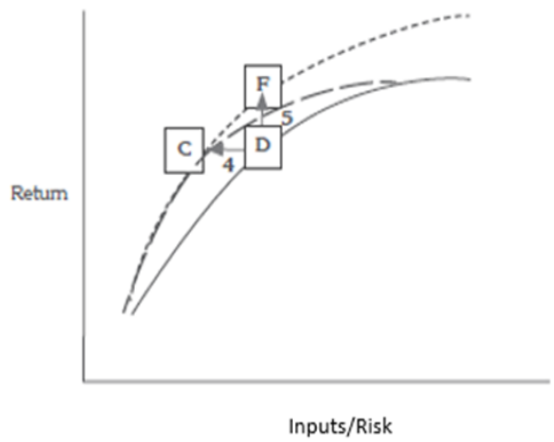
	Western Region	Southern Region	Northern Region	National Mean
Average Yield (t/ha) - B	1.65	1.83	1.67	1.74
Environmental Yield (t/ha) – A (modelled)	2.98	3.52	3.58	3.35
Best growers Yield (t/ha) = 80% of Env. Yield - D	2.39	2.82	2.87	2.68
Exploitable Yield (t/ha) = D-B	0.74	0.99	1.2	0.94
Value ($/ha/yr @ 250 $/t)	183	248	298	235
Crop Area in Region (ha)	9,388,279	12,425,171	5,706,126	27,519,576
Annual Value Lost (Million $)	1,713	3,075	1,698	6,467

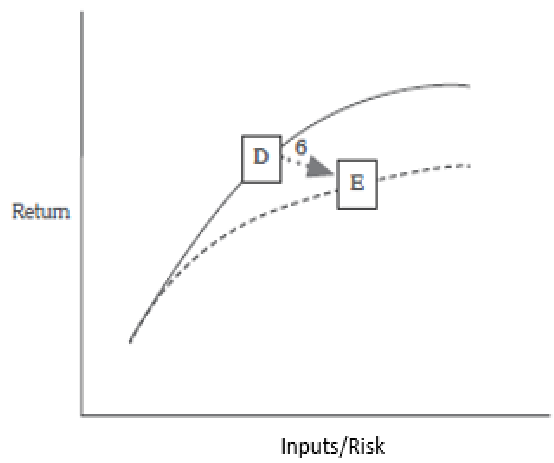
Table 2 – Estimated losses associated with a failure to recognised expected outputs for a given level of inputs.

The barriers to technology adoption are discussed later in this submission. However, it is pertinent to note at this point that GRDC currently commits at least 20% of its investments through the Grower Services program assisting growers to adopt technology and improve efficiency (pathway 1).

While significant, improvements in productivity and profit through adoption of current technologies to match inputs with expected outputs (pathway 1) tend to be incremental in nature. Break-through technologies can potentially fundamentally shift the production efficiency curve as follows:

1. Technologies that increase yield for any given level of input (D-F, pathway 5)
2. Technologies that maintain yield while reducing the cost of inputs or minimising risk (D-C, pathway 4)
3. Preventative technologies that address threats to current levels of productivity such as disease outbreaks and herbicide resistance (Preventing the movement of D-E, pathway 6).





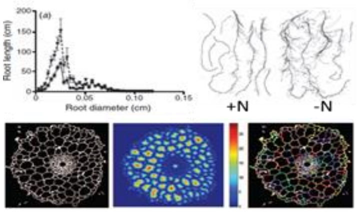
Examples of technologies that have contributed to production efficiencies across each of these pathways in Australia have been further explored by CSIRO and ABARES (Carberry, Keating, Bruce, & Walcott, 2010) and include breakthroughs in fallow management (pathway 4), conventional breeding and conservation agriculture (pathway 5).

Improvements in the efficiency of agricultural practices due to new technology.

In addition to the breakthrough technologies identified by Carberry et al. (Carberry, Keating, Bruce, & Walcott, 2010) that GRDC currently or has historically funded, there are a number of other R,D&E programs worthy of note delivering technology improvements now (TOR1).

Nitrogen Use Efficiency – Pathway 4.

Nutrition is, and has for the most part always been, one of the most significant costs associated with grain production systems. In grain production, the macro elements Nitrogen, Phosphorous and Potassium are particularly important. A failure to apply enough fertiliser results in losses of yield while the application of too much fertiliser is a waste of cash and can also result in leaching and nutrification of adjacent water sources. While recent advances have been made in modelling crop nitrogen requirements and the splitting of applications of nitrogen to minimise the risk of not matching inputs to expected yield, the rising cost of nitrogenous fertiliser means that breakthroughs in plant genetics to better utilise nitrogen (pathway 4) are keenly observed.



http://www.acpfg.com.au/index.php?id=14

GRDC has funded a number of programs in Nitrogen use efficiency both directly and indirectly. GRDC recently invested approximately $1.6m over five years with the University of Western Australia looking for natural genetic diversity for nitrogen use efficiency in wheat and barley. GRDC is also a major shareholder and funder of the Australian Centre for Plant Functional Genomics (ACPFG). The ACPFG has a substantial R&D program in Nitrogen use efficiency including both conventional and transgenic approaches and have recently made the technology available to an international breeding and life science company with interests in Australia.

Pulse Breeding Australia – Pathway 5.

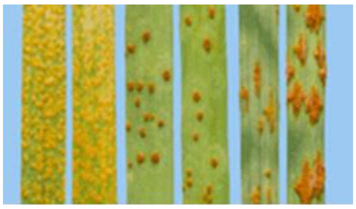
Pulses, including lupins, lentils, field peas, faba beans and chickpeas have historically been important crops in Australian dryland farming systems. They provide a level of fertilisation through the fixation of atmospheric nitrogen and importantly, act as a break for disease and weed control in following crops including wheat, barley and canola. The area planted to pulses in Australia is currently limited especially when compared with Canada and a higher area of pulse production is desirable from a sustainability view. Recent prices of lentils ($950/t) and chickpeas ($680/t) are expected to see areas of these pulses increase as they are planted as a cash crop in their own right rather than a break for a following cereal.

http://www.grdc.com.au/Research-and-Development/Major-Initiatives/~/~/media/4127CD326D834B4EBBE7B772E20A2736.pdf

Given the importance of pulses to Australian farming systems both as a rotation and increasingly as a cash crop, GRDC has made significant investments to increase the yield of pulses through conventional breeding programs (pathway 5). In the five years 2011-2016 the GRDC will invest $20.5m in field pea, lentil, chickpea and faba bean breeding programs with further significant co investment from our partners in the State Departments of Agriculture and Universities. Recent economic assessments of the lentil (AgTrans-Research, 2013) and chickpea (AgTrans-Research, 2012) breeding programs indicate an internal rate of return of 21% and 15% respectively.

Australian Cereal Rust Control Program – Pathway 6.

Cereal rust diseases (stem, leaf and stripe rust in wheat and barley) can cause devastating losses if not managed with a combination of resistance in new varieties and fungicide applications. While rusts are relatively well controlled with current technologies, estimates of annual losses if current control methods failed (e.g. a new rust race overcame varietal resistance and fungicide applications) exceed $994 million for stripe rust, $478 million for stem rust and $197 million for leaf rust in wheat alone (Brennan & Murray, 2009). The potential loss of current controls, particularly genetic resistance in new varieties is very real given the capacity of most pathogens to mutate to overcome resistances. For example, the new Ug99 stem rust race overcomes a number of current resistance genes including a major resistance gene. Approximately 80-90% of current wheat varieties globally are susceptible and without new genetics and fungicides for control, Ug99 is estimated to have the potential to cause more than 70% yield losses under favourable conditions (FAO, 2015).



http://sydney.edu.au/agriculture/plant_breeding_institute/cereal_rust/index.shtml

The Australian Cereal Rust Control Program (ACRCP) is one of GRDC's longest running R,D&E projects. The ACRCP is housed at the University of Sydney and has a national mandate to;

- undertake ongoing monitoring of rust populations across Australia to detect new strains that may cause disease,
- screen current wheat and barley varieties against rusts strains to provide information on their level of genetic resistance, and
- search for new sources of resistance that may be used by Australian breeding companies in new varieties.

The ACRCP is focussed at ensuring that rusts diseases do not limit grower efficiency (pathway 6) and given the potential losses involved GRDC has made, and continues to make, significant investments in the program. The current round of GRDC investment in ACRCP (2012-17) totals more than $25 million over five years with significant funding also coming from our collaborators at the University of Sydney, CSIRO and State Departments.

Emerging Technology relevant to the Agriculture Sector

The challenge for an R&D investor such as GRDC in funding innovative research is generally not one of a lack of options. There are many good, innovative ideas both in Australia and internationally worthy of investment. The challenge is identifying those most likely to overcome technological risks associated with the R&D, are adoptable by growers and therefore provide the best return to growers for the investment required. Below are examples of a number of investments in emerging technologies that GRDC has recently committed to.

Unmanned Vehicles and Robotics – Pathway 4.

Autonomous and semi-autonomous vehicles are attracting significant attention from broad acre farming businesses in Australia and overseas as the cost and availability of labour impacts on production efficiency. The precursors to autonomous systems, GPS guidance and auto-steer have already seen wide scale adoption with a recent GRDC grower survey indicating 83% of growers utilise auto steer for at least one part of the farming operation (GRDC, 2014). However, production efficiency gains from robotics and even simpler opportunities associated with variable rate technologies are largely still to be realised.

The continued emphasis on robotics and autonomous system is largely being driven by a lack of suitable labour (especially as the mining boom impacted) or desire to decrease labour costs, particularly in more intensive industries (pathway 4).

https://www.usq.edu.au/research/research-at-usq/institutes-centres/ncea/our-projects/about-automation-robotics-machine-vision

GRDC recently commissioned an analysis of potential opportunities for robotics and autonomous systems to underpin its bid to the Rural R&D for profit program (Rainbow, 2014). While the bid was not successful, the report has highlighted a number of areas where GRDC investment can facilitate the interaction between multi-national machinery manufacturers and national research providers particularly in the University sector and with CSIRO. The report highlights that there is a significant amount of incubated autonomous agricultural technology already developed by multi-national machinery manufacturers with near commercialisation potential. Australia has clearly been considered a significant part of these incubation programs and is thought to be 10-15 years in front of North America and Europe in both development and practical application of precision agriculture technologies.

While Australia has been used for agricultural automation technology incubation, it is unlikely that these technologies would be commercialised only for the small Australian market. GRDC has therefore committed to a large autonomous vehicle and robotics program, $8 million over the next four years, with partners from both the public and private R&D sectors to ensure the Australian growers have access to these technologies and that they meet grower needs.

International Wheat Yield Platform – Pathway 5

The International Wheat Yield Partnership (IWYP) IWYP represents a long-term, global endeavour that utilises a collaborative approach to bring together investment from public and private research organisations internationally searching for breakthrough technologies to increase the potential yield of wheat (pathway 5). The partners aims to invest up to US$100M over five years, attracting significant funding from the private sector. The current partners and members are:

Partners

- Agriculture and Agri-Food Canada (AAFC)
- BBSRC
- CIMMYT
- GRDC
- Institut National de la Recherche Agronomique (INRA)
- SAGARPA
- Syngenta Foundation for Sustainable Agriculture (SFSA)
- USAID and
- United States Department of Agriculture – Agricultural Research Service (USDA – ARS).

Membership

- Bayer CropScience
- Syngenta
- Limagrain
- DuPont-Pioneer
- KWS Desprez
- Mahyco

With ongoing discussions continuing with Monsanto, Dow AgroSciences, RAGT, SW Seeds, Secobra, Saate-Union Recherches/Biotech, LongReach, InterGrain, AGT, Arcadia, Evogene and Cibus.

IWYP is seeking breakthroughs in genetic yield potential beyond what is expected to occur in ongoing breeding programs. Therefore, new or different approaches and/or novel techniques are envisaged.

At the fundamental level this will be achieved by improving wheat's ability to capture and process the sun's energy, through photosynthesis, and making sure that the captured carbon ends up in the wheat grain. For example, wheat uses only about 1% of sunlight to produce the parts that we eat, compared to maize's 4% efficiency and sugarcane's 8% efficiency. Even increasing wheat's photosynthetic efficiency from 1% to 1.5% would allow growers to increase their yields on the same amount of land, using no more water, fertiliser or other inputs (pathway 5).

To deliver increased wheat yield, a combination of fundamental bioscience and applied research is required. IWYP targets six key research areas:

- Uncovering genetic variation that creates the differences in carbon fixation and partitioning between wheat lines
- Harnessing genes from wheat and other species through genetic modification to boost carbon capture and fixation to increase biomass production
- Optimising wheat development and growth to improve grain yields and harvest index
- Developing elite wheat lines for use in other breeding programs
- Building on discoveries in wheat relatives and other species
- Fostering breakthrough technology development that can transform wheat breeding.

GRDC will invest over $4 million over the next three years with additional funding exceeding from the other international partners targeted at the six key research areas above with results made available to Australian breeding programs for delivery to Australian growers.

Herbicide Discovery – Pathway 6.

One of the biggest threats to maintaining increases in yield in Australian is the impact of weeds in minimum tillage cropping systems and in particular the growing issue of herbicide resistant weeds. Current estimates of the in-crop cost of weeds to Australian grain producers are between $103/ha and $211/ha with a total cost of $3.27 billion per annum including $2.56 billion control costs and $708M of revenue losses due to decreased yields and quality penalties (Llewelyn, et al., 2015).

While many innovative weed control methods are being explored by GRDC, any integrated weed management system will remain reliant on herbicides for the foreseeable future. Australian grain growers therefore need access to new herbicides but are limited by the slow pace and extremely high cost of herbicide discovery, the limited number of companies undertaking new herbicide development globally and the lack of focus on the Australian farming system and unique weeds.

GRDC has recently entered into a unique innovative collaboration with Bayer Crop Science (BCS) that has not been undertaken anywhere before world-wide. Under the project, GRDC has committed to $45M funding over 5 years and BCS will increase its herbicide discovery and optimisation program with a focus on Australian cereal farming systems, Australian weeds and early testing of promising new chemistries in Australian field trials. It is expected that the collaboration will yield new chemistries for Australian conditions and released in Australia at least at the same time as our international competitors. Given the extremely high cost of weed control in

http://www.grdc.com.au/

Australian cropping systems, any new chemistry delivered even one or two years earlier to Australia will have significant production efficiency outcomes for Australian growers.

Big Data – A special mention

There is a wide expectation that the next wave of increased agricultural production will depend heavily on the capture and interrogation of data on a range of production variables. This will include capture of data not just on yield but also environmental variables such as water availability and soil constraints as well as a host of input variables such as variety, nutrition regime and pest control costs, particularly the cost of herbicides and fungicides. Monsanto's recent acquisition of Climate Corporation for approximately $1 billion, the roll out of its Field Scripts program, and the efforts of other multinationals to also dominate this area with their own proprietary offerings demonstrates that most believe that Big Data will play an implicit function in the design and implementation of future farming systems. However, despite the undoubted enthusiasm, it remains unclear as to how data is best collected, interrogated and provided back to growers to maximise their production efficiency. GRDC is in the fortunate position of having funded over 20 years of production research generating vast quantities of quality data on Australian production systems. The challenge now is to work with the private sector (not just multinationals) to leverage the value of that data in generating systems and approaches that deliver the greatest benefit to Australian growers.

Barriers to Adoption

Even when opportunities are identified to increase the efficiency of production through new technologies, adoption risk remains. There are a range of factors that contribute to the successful adoption of new technology most of which are associated with complexity and cost or lack of commercial path to market.

Complexity and Cost

In theory moving from a point on one efficiency curve to another (or even from a point below the curve to on the curve) is a straight line as depicted above (pathways 1-6). In reality, moving from the current state to a new efficiency via adoption of new technology has a cost related to complexity. Therefore, in adopting new technologies efficiency losses are often encountered before the new technology is fully implemented and increased efficiency gains realised. Complexity consumes management time, attention and labour and simplicity, ease of use and convenience are highly valued by modern farmers. As a result, the complexity of innovation and the demands on management time and attention will increasingly determine peak adoption rates, not just the time to adoption (Llewelyn, 2011).

Llewelyn (2011) further notes that the complexity of adoption impacts not only extension activities but also the fundamental establishment of R&D programs to focus on ways of internalising additional stages of innovation development, facilitate the active role of advisors and generate innovation with greater embodied knowledge and reduced management demands as being likely of increasing both value and impact.

Complexity and cost considerations equally apply to large life-science companies seeking to register either new chemistries or gene technologies. The costs associated with R&D and studies required for registration for a new crop protection chemistry have risen from $US152 in 1996 exceeding $US250M in 2008 (Figure 1.). It is clear that most of the cost increase is associated with activities required to generate data for registration of new chemistries rather than early discovery costs (Phillips-McDougall, 2010). In an environment where budgets are constrained it is clear that any increase in the costs of studies required for registration must be offset elsewhere including reductions in the early discovery research and development budgets. Such tightening of the research budget most certainly restrains the capacity of LifeScience companies to identify potential new crop protection chemistries.

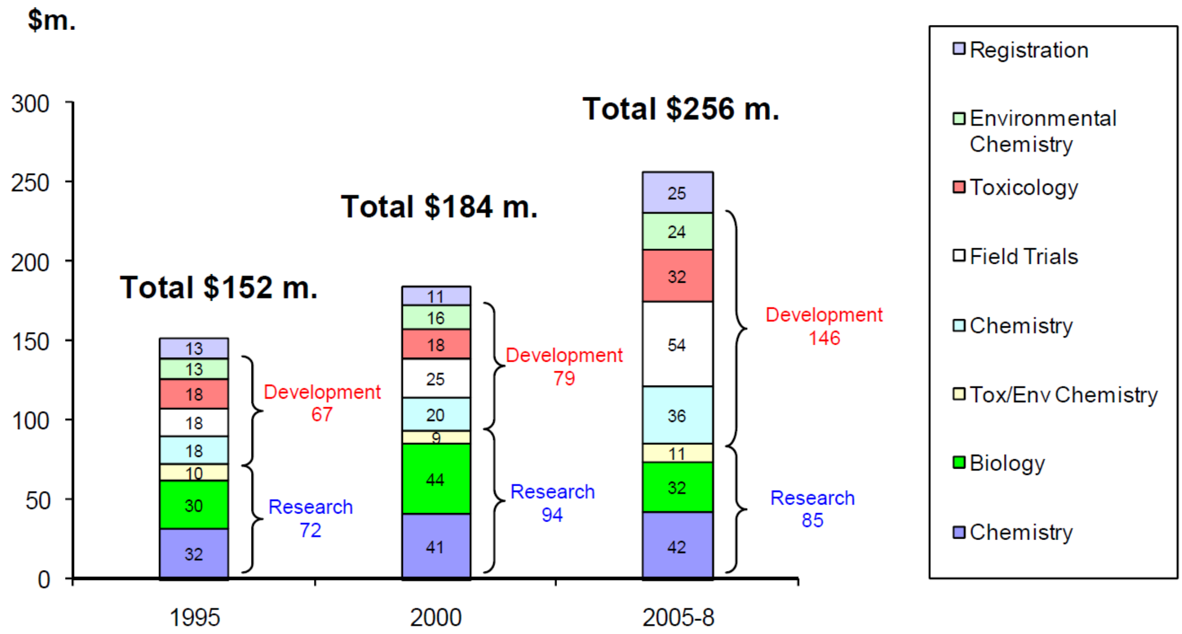


Figure 1. Discovery and development costs of a new crop protection product undertaken for Crop Life (Phillips-McDougall, 2010)**.**

Such regulatory costs equally apply to gene technology approaches. While there is little GRDC can do to offset such large costs, collaborative efforts such as the herbicide identification program with Bayer CropScience do persuade major companies to provide a focus on Australia in addition to the major markets in the North America and Europe where such large regulatory costs may be recouped more easily

Grower Participatory Approaches

One of the options to reduce the complexity and cost of adopting new innovation by growers identified by Llewelyn and others is the active involvement of advisors and leading growers in participatory approaches to R&D investment.

The old agricultural extension paradigm previously employed by GRDC amongst others centred on the theories of technology transfer and diffusion (Rogers, 1983) (Black, 2000). In practical terms research was undertaken to generate new information and technology, mostly by State and Federal agencies or universities. The information or technology was road tested in State agency research trials followed by targeted extension to so called "early adopting" farmers in a unidirectional manner with the assumption that other growers would observe the changes made by early adopters and therefore adopt the technology themselves. This top-down approach has been widely criticised by extension practitioners (Ashby, 1987) (Vanclay & Lawrence, 1995) (Farrington, 1997) (Snapp, Blackie, & Donovan, 2003) as it;

- Fails to take into account growers resource constraints and risk profiles.
- Assumes that "early adopters" of one technology will be "early adopters" of all technologies
- Fails to take into account social and cultural determinants of adoption.
- Assumes that researchers generate information of greater value than current and that failures in adoption are because of uninformed grower resistance or a failure in extension.
- Ignores the unequal distribution of impacts of change
- Marginalises the value of local knowledge
- Disempowers growers while focussing on the needs and desires of the expert.

- Ignores the difficulties in simulating all the variables that impinge on farmer decision making.

Of particular concern to the GRDC was the focus on expert researchers' opinions and desires and a lack of recognition of farmer knowledge. Russell and co-workers (Russell, Ison, Gamble, & Williams, 1989) conclude that "farmers have almost universally been sold short as both competent scientific thinkers and researchers. In particular, GRDC has recognised that the decision of growers to adopt a new technology is a carefully considered one based on quantification of benefits and comparison to costs. Adoption of new technology in Australia remains hampered by the fact that we only truly understand benefits and costs at the regional level whereas growers require data and exposure to technology at the sub-regional and local levels to make an informed decision on adoption. In response to these and other observations, GRDC adopted a participatory approach to R&D and extension in 2012 based around Regional Cropping Solution Networks (RCSNs).

Regional Cropping Solution Networks

The GRDC has established networks of more than 100 grain growers, consultants and researchers across nine separate areas in southern and western Australia to provide on-the-ground insights into priority issues requiring research and development attention. The RCSNs (Figures 2 & 3) together with the Northern Region Grower Solutions Groups (GSG) (Figure 4) ensure that the GRDC is actively listening to and engaging with growers to identify and articulate local cropping issues and help determine how best to tackle those issues.

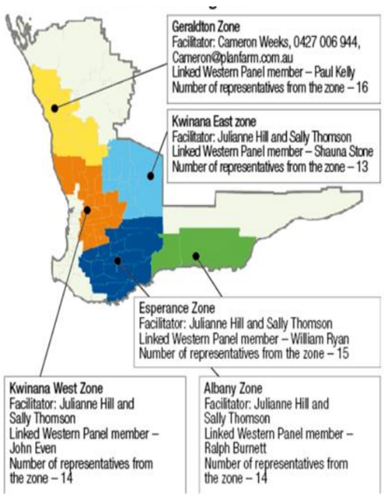


Figure 2. RCSNs in the Western Region

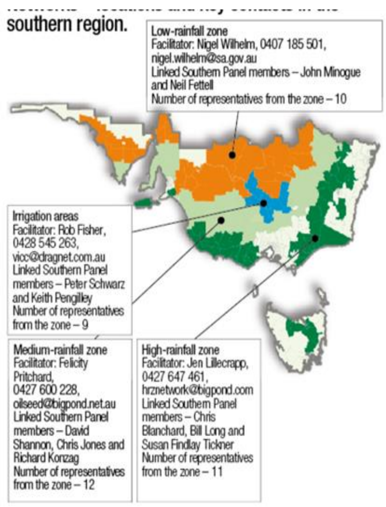


Figure 3. RCSNs in the Southern Region

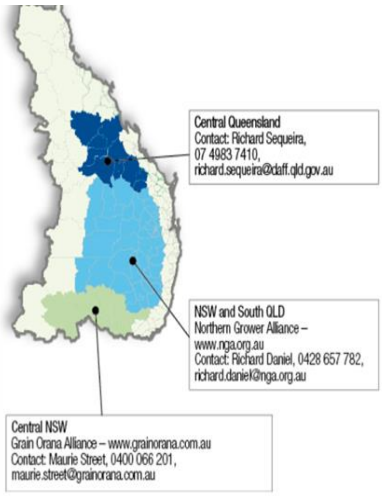


Figure 4. GSGs in the Northern Region

The involvement of landowners in the setting of outcomes and in deciding on actions in any is particularly important when one considers adoption in complex systems for different purposes (production, environmental or social outcomes) and by different people. Pannell and co-workers (Pannell, et al., 2006) report on a wide range of personal goals that can impact adoption by growers including:

- Desire for material wealth and financial stability
- Environmental protection and enhancement
- Social outcomes
- Personal integrity traits
- Work/life balance.

Overlay these goals with the complexity of undertaking R,D&E to address farming system, environmental and social issues and it quickly becomes apparent that trying to simulate such a setting is impossible. By increasing the GRDC's ability to capture information at the front line of grain production, it will be in a much better position to invest in RD&E where and when it is most needed. The networks also play an influential role in the GRDC's thrust to fast-track investments (1-3 year time to delivery) for RD&E projects aimed at improving adoption of technology to support grain growers' profitability and sustainability. Typically, this sees field trial work tackling some of the most pressing issues faced by growers in the region where relatively small amounts of investment applied quickly and flexibly can have a dramatic impact of production efficiency.

Improvements in Water Use Efficiency Program.

Water Use Efficiency (WUE) is defined as the efficiency with which rainfall is converted through a farming system into grain. The WUE program was funded from 2008 to 2013 by the GRDC and consisted of a participatory R&D approach with 16 groups of growers

coordinated by the CSIRO. The aim of the $17.5 million program was to increase WUE by 10% across Australia's southern and western cropping regions. Each group put forward ideas to increase WUE and undertook the necessary R&D to validate their idea in a participatory approach under the scientific guidance of the CSIRO but providing ownership and relevance to the groups involved. Concepts included the management of summer fallows (weed control and stubble retention) to maximize available water from summer rainfall, use of rotation crops, crop nutrition and planting of longer season varieties in higher rainfall zones. Importantly, the initiative allowed groups to interact and share ideas and results such that innovative approaches in one group were readily adopted by others. Results from the program indicate the capacity to increase WUE much more than the 10% target (16-140%) and increase yield at the farm scale by 11-47% (Kirkegaard, et al., 2014). An economic assessment of the program indicates an internal rate of return of 18.5% and the success of the initiative has been widely acknowledged. This culminated in the initiative receiving the 2014 Eureka award for Sustainable Agriculture.

What is GRDC Doing?

The recent restructure allows GRDC to more clearly focus its investment resources on the R&D most likely to deliver innovation and technological change while also supporting the adoption of new technologies to minimize the cost and maximize returns to growers. However, it is clear that GRDC cannot do this alone. GRDC must partner with our traditional collaborators (Universities, CSIRO and State Government, Grower Groups) in new and innovative ways (such as greater exploration of participatory approaches). In particular, GRDC will focus on developing and maintaining strong linkages with public and private sector R&D companies internationally especially in the areas of new traits, chemistries and robotics that are both expensive and higher risk. This will need to be achieved in an environment that is not particularly conducive. According to the OECD survey of firms collaborating on innovation with higher education or public research institutions, Australia ranks last of 33 nations for R&D collaboration between public and private sector entities (Figure 5.) (OECD, 2013).

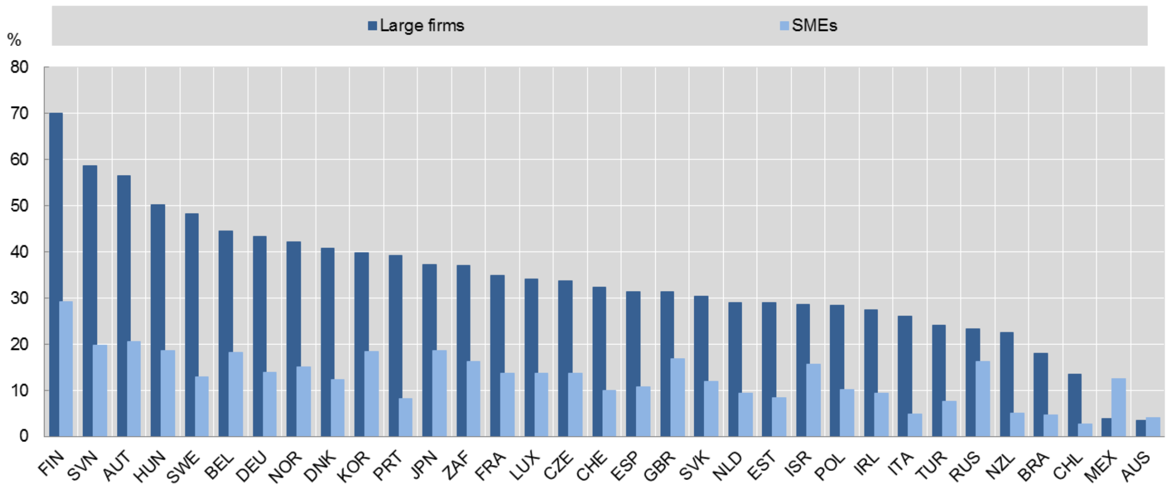


Figure 5. Collaborative innovation efforts between private and public institutions for 33 OECD nations

The future balanced investment portfolio of GRDC can best be described as an updated version of Table 1 (Table 1a.). GRDC's new approach to investment planning uses the variables of productivity pathway, time to delivery, risk, scope and region to balance the portfolio and more importantly ensure that GRDC is investing in the most appropriate R, D&E activities to maximize the return to growers through the discovery of new technology and its rapid and cost effective adoption.

Production Pathway	Activity	Time (Yrs)	Scope	Potential Partners	Example
1	Local validation and adoption of new knowledge & technology	1-3	Local Regional	Grower Groups Cropping Solution Groups Agronomists	WUE Initiative
2/3	Risk Management	1-3	Local	Grower Groups Cropping Solution Groups Agronomists	Farm Business Management Updates
4	Practices to Minimise Inputs Farming Systems Agronomy Nutrition	3-8	Regional National	CSIRO State Departments	Precision Ag VRT

	Traits and Robotics to Minimise Inputs	8+	National International	CSIRO Universities Life Science Companies	NUE genes Drones UAVs
5	Practices to maximise outputs Farming Systems Agronomy Soils	3-8	National Regional	CSIRO Universities State Departments	Soil amelioration
	New Varieties and Traits to maximise outputs	8+	National International	CSIRO Universities Life Science Companies	New crop varieties with increased yield IWYP etc. Drought tolerance
6	Practices to minimise losses Weeds Pests Diseases	3-8	National Regional	CSIRO Universities State Departments	IWM/IPM/IDM Minor use chemistry registration
	New Varieties, Traits and Chemistries to minimise losses	8+	National International	CSIRO Universities Life Science Companies	ACRCP Bayer deal

Table 1a: Re-alignment of GRDC structure with investment type, time to delivery and risk

In short GRDC is working with our traditional partners domestically as well as with new international partners to ensure that;

- the most pressing issues and opportunities are accurately identified by growers and agronomists at the local level,
- appropriate investigation into what is already known is undertaken,
- gaps in current knowledge are identified,
- assessment of the potential return to growers by addressing knowledge gaps is performed,
- relevant R&D is secured to develop appropriate technology and knowledge, and
- information flows seamlessly from strategic (8+) research at the international and national levels to applied R&D at the national and regional levels and is always being designed to minimize the complexity of adoption at the local level.

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