GRDC INVESTMENTS ADDRESSING A SELECTION OF ISSUES – MEDIUM RAINFALL ZONE RCSN – December 2017

Issue No. 1 - Nitrogen decision-making is difficult – technology to measure nitrogen in real-time and improved nitrogen budgeting tools, better rules of thumb for nitrogen (N) mineralisation, N budgeting and management, improve N use efficiency

This issue emerges each year as a high priority concern and was again raised at the 2017 open meetings. Growers and advisors find making in season N management decisions difficult because there is uncertainty around the amount if N available in the soil (mainly due to low uptake of deep soil N testing), the amount of N required by the crop (yield potential) and the financial risk associated with meet crop N demand if there is a dry spring or a frost or heat stress event.

GRDC investments addressing this issue –

Real time evaluation of soil nitrate using ion exchange technology (EPF00002-A) and (UA00165)	This project seeks to better assess N supply to cereal crops and canola in the southern region, based on an improved estimation of mineralisation of soil N and the supply of N from legume crops and pastures. The project will undertake a number of activities that aim to assist and inform advisors and growers in understanding N dynamics in cropping systems to improve N supply to crops.
Soil spectroscopy capability (CSO00045)	The overall objective is to strengthen capability in soil spectroscopy in Australia and provide grain growers and advisers with access to information and new spectroscopic technologies to reducing soil analysis costs and improving speed of data acquisition. For that purpose, this project will examine the performance of field spectrometers for the rapid and inexpensive assessment of key soil properties important in controlling production of grain crops in Australia. The study will focus on the application of the spectrometers as handheld devices, or in applications where the instrumentation can be integrated into current commercial soil sampling equipment (e.g. core drill equipment)
Proximal Soil Sensing for Profitable and Sustainable Farming (CSA00048)	The development of new soil testing methods, which are rapid, cheap, accurate and spatial, is needed for the implementation of sustainable farming practices in the grains industry in Australia. The main objectives are to: • Review currently available proximal soil sensors that may be used in the management of

	Australian grain-growing soil • Assess the feasibility of commercialising a selected set of sensors—operating alone or as part of an ensemble.
Managing legume and fertiliser nitrogen in the Southern Region (UA00165)	The project will construct and economic model that can evaluate the role of fixed and residue nitrogen in modern farming systems. This tool will help farmers evaluate the profitability or otherwise of growing grain or pasture legumes as commodity prices vary, as fertiliser prices vary and as attitudes to risk change. A new biophysical economic framework that values commodity prices, left over nitrogen and fertiliser prices will be constructed to deliver a tool to farmers that help them evaluate the role legumes can play in their farming system. The calculator will also evaluate risk, as the decision to grow a legume may alter the risk profile for the subsequent cereal crop.
Reassessing the value and use of fixed nitrogen (CSA00037)	The project will construct and economic model that can evaluate the role of fixed and residue nitrogen in modern farming systems. This tool will help farmers evaluate the profitability or otherwise of growing grain or pasture legumes as commodity prices vary, as fertiliser prices vary and as attitudes to risk change.
Optimising nitrogen fixation of grain legumes - southern region (DAS00128)	This project will improve the amount of fixed nitrogen (N) contributed to cropping systems in southern Australia (South Australia & Victoria) from pulse legumes. This project will quantify the symbiotic potential of different pulse cultivars and lines, so N fixation indices can be developed and used by pulse development programs and growers.
More Profit from Crop Nutrition Initiative – Phase II (MPCN II) Re-assessing the value and use of fixed nitrogen (CSA00037)	The project will construct and economic model that can evaluate the role of fixed and residue nitrogen in modern farming systems. This tool will help farmers evaluate the profitability or otherwise of growing grain or pasture legumes as commodity prices vary, as fertiliser prices vary and as attitudes to risk change A new biophysical economic framework that values commodity prices, left over nitrogen and fertiliser prices will be constructed to deliver a tool to farmers that help them evaluate the role legumes can play in their farming system. The calculator will also evaluate risk, as the decision to grow a legume may alter the risk profile for the subsequent cereal crop.
More Profit from Crop Nutrition Initiative – Phase II (MPCN II) Benchmarking wheat yield against nitrogen use (DAS00147)	To create a robust benchmark for the nitrogen status of current wheat varieties. This will allow growers to better match nitrogen inputs to meet crop demand. We will develop a so called 'nitrogen dilution curve'. This curve shows the minimal concentration of nitrogen in shoots that is required to achieve maximum growth. Crop nitrogen status can then be assessed by dividing the actual nitrogen concentration of the crop at a given biomass, by the critical nitrogen concentration derived from the nitrogen dilution curve at that same biomass. The outcome is a Nitrogen Nutrition Index.
Nitrogen inputs by free living nitrogen fixing bacteria – Grower messages (CSP00191)	This project is mainly to develop user friendly information based on the scientific research outputs from the recently completed project CSP00138. To develop extension messages based on the findings from the project CSP00138 and GRDC Soil Biology Initiative II Theme based projects to identify areas that this is likely to produce agronomically significant amounts of N inputs and to help growers and agronomists incorporate contribution from FL-N fixation in their N management decisions.
More Profit from Crop Nutrition (MPCN) II – Regional soil testing guidelines for the southern region (DAN00168)Proximal Soil Sensing for Profitable and Sustainable Farming (CSA00048)	To better match NPKS fertiliser inputs to crop demand and hence meet the twin goals of maximising economic response to fertiliser yet minimising potential loss of nutrients to the environment.
Updated nutrient	Review and synthesise the currently available macro-nutrient response curve data to identify and

response curves in the northern and southern regions (UQ00082)	prioritise gaps that will constrain growers and advisors ability to identify likely nutrient limitations and therefore fertilizer responsiveness for key crops in their rotations; Sow trials to further create a critical soil test to determine accurately the nutrient requirement x crop type (What, Barley, Oats, Canola, Legumes)
Improving nitrous oxide abatement in higher rainfall cropping systems and developing nitrogen response curves (DAV00125)	The challenge will be to develop practical management strategies so that grain growers can simultaneously reduce excessively high levels of soil mineral nitrogen and labile carbon (which lead to high N2O emissions) following pasture conversion whilst maintaining sufficient N to supply the demand of large yielding grain crops in an environment characterised by high rainfall and/or often water logging. Growers and advisers in the Southern Region will have access to N response curves for representative sites (soils varying in organic matter and N content) and seasons, leading to better predictions of how much fertiliser N growers need to apply to different crops.
Nutrient performance indicators (IPN00003)	There are many ways to define nutrient use efficiency, but meaningful metric needs to be universal and applicable at a range of scales. At a field or farm scale, it is not possible to assess agronomic efficiency as growers are not likely to have nil fertilizer treatments which are required to make that derivation. The objective of this bench marking project is to dis aggregate fertilizer use data by crop and region to get mean values for each, and then compare these mean values to on-farm nutrient balances taken from a sample of farms across the one of the three GRDC regions.
Strategies to better synchronise nutrient supply and crop demand (UM00023)	2007 project: This project will improve the efficiency of nutrient use by identifying factors affecting spatial and temporal supply of N and P, matching them to crop demand. This knowledge when matched with estimates of the size and dynamics (storage and rates of loss) of soil nutrient pools will be used to develop management guidelines to improve the efficiency of nutrient use in complex farming systems in 3 agro-ecological zones of south-eastern Australia.
Nitrogen and water interactions (DAS00157)	Objective of this investment is to understand the interaction between soil moisture, seasonal forecast and soil nitrogen and its impact on nitrogen fertiliser decision-making.
Understanding how waterlogging affects water and nitrogen use by wheat (DAV00151)	This project will use a combination of field measurements and modelling to: 1. Enhance understanding of the effects of waterlogging on crop growth and water and nitrogen uptake and the consequences for grain yield and quality and 2. Identify management practices that may increase crop production on waterlogging-prone soils.
MPCN II – Managing micronutrient deficiencies in cropping systems of eastern Australia (DAS00146)	Objectives of this project are: To assess the effect on crop yield of multiple rates and application strategies of micronutrient fertilizers in soils deficient in the target micronutrients (copper, zinc, manganese, boron and molybdenum
Understanding Biological Farming Inputs (CSO00044)	The objectives of this project are 1) characterise the chemical variability of a range of biological amendments (including biostimulants, biochars, composts, manures, humates, fulvates etc.) and assess biological impacts (soil microbial diversity and function); 2) understand how this chemical diversity leads to similarities or differences in crop responses as a result of different soil constraints in 8 field experiments; and 3) use the generated knowledge to guide grower groups and the wider land sector in the testing of biological inputs in their specific scenario.
Increasing the effectiveness of nitrogen fixation in pulse crops through development of improved rhizobial strains, inoculation and crop management practices (to be contracted)	As well as generating useful income, pulses provide significant benefits to following crops, including nitrogen (N) fixation boosting N supplies to following crops. Pulses are estimated to fix about 120 kg N/ha or more than 220,000 tonnes N across Australia, worth about $220 M each year. However, not all pulses are well nodulated and fix N to their potential, especially on acidic soils. It was recently estimated that N fixation could be increased by 25%. The aim of this investment is to enhance nitrogen (N) fixation of winter pulse crops through improved rhizobial strains for hostile soils and enhanced inoculation practices that minimise the potential impact of fertiliser and crop protection applications, and maximise rhizobial survival,

	nodulation and nodule function. These improvements will broaden the adaptation of pulses onto soil types and areas where they are currently not widely cultivated. This three year R&D investment, starting early 2018, will be supported by a separate extension and communication investment to promote awareness of nodulation and N fixation in pulses, and adoption of best inoculation practices. Expected outcome - by June 2022, growers in the southern region have access to improved rhizobial strains compared to the current commercial inoculums for winter pulse crops, plus best management practices for optimising nodulation and nitrogen (N) fixation, including minimising the impact of fertiliser and crop protection applications. These innovations will enhance N fixation and production of pulse crops with flow on benefits to following crops, and enable expansion of pulses onto soil types and in agro-ecological zones where they are currently not widely grown.

Issue No. 4 - Level of knowledge and skill of advisers is critical to the profitability, risk management and/or compliance of farm businesses.

Growers depend on the skills, knowledge and recommendations of advisers which guide their decisions and contribute to the management of their farm businesses. Hence, the knowledge and abilities of advisers and agronomists may inadvertently be limiting the profitability, risk management and/or compliance of farm businesses.

GRDC investments addressing this issue

GRDC Farm Business Updates – Southern Region (ORM00015)	The GRDC Farm Business Updates (FBU) for advisers and growers provides a unique forum to learn from and network with leading growers and industry professionals. The program has a broad range of topics delivered by an outstanding selection of expert speakers. It provides topical and practical advice and information on the key issues facing grain growers and their advisers, including managing risk and business resilience. This three-year project provides: • FBU for Advisers (One day program; four per annum): to be held in strategic locations to maximise accessibility by advisers; • FBU for Growers (One day program; four per annum): at locations maximising accessibility of events to growers, to be reviewed annually with assistance of the Update Planning Committees and local grower groups; • Adviser FBU Newsletter (Four page – A4; six per annum): Targeted and distributed directly to advisers; • Farm Business Management Fact Sheets (four per annum); • FBM Ground Cover Articles (One page; six per annum); • Coordination and facilitation of the production of crop enterprise gross margin guide for the GRDC southern region by relevant agriculture agencies in each State; Activities/products accessible via the GRDC website to extend the impact of the Updates across the entire year include event planning; schedules; registration (via link to ORM website); papers as included in proceedings; presentation slides; integrated presentations (video + slides; social media and direct e-mail to event attendees (past and current).
GRDC Research Updates – Southern Region (ORM00014)	This project delivers cutting edge research, development and extension information to growers and adviser both through GRDC branded, face to face events (i.e. Updates) delivered by researchers and GRDC and supporting activities/products. This is achieved through: • Regular provision of a dynamic, engaging and interactive learning environment for participants to maximise adoption of new technologies and practices. • Showcasing GRDC and partners' RD&E outputs and responsiveness to emerging industry issues and trends; • Use of a wide range of keynote speakers that provide timely, relevant and quality information

	on RD&E. • Targeted adviser update programs for differing skill sets, catering for both experienced and less experienced advisers; • Emphasis of practical take home messages focussed on supporting adoption on-farm of R&D outputs and delivering benefits to growers; • Increasing the footprint of the Updates by: - Striving to maintain (and wherever possible increase) the accessibility and attendance at Update events by ensuring appropriate timing and location of events and - Providing a diverse range of supporting activities/products pre and post Update events to deliver timely and relevant information to growers and advisers through the entire year. - In summary, the investment provides research updates for advisers (2 day program; 3 per annum): NSW, VIC and SA, in strategic locations to maximise accessibility by advisers. Research updates (1 day program; 14 per annum) for growers are held in various locations across the southern region to maximise accessibility to growers). A research update newsletter is produced for advisers (4 page – A4; 6 per annum) and activities/products are accessible via the GRDC website to extend the impact of the updates including event planning, schedules, registration, papers as included in Update proceedings, presentation slides, integrated presentations of all presentations at all two day Updates, social media and direct e-mail to event attendees.
GRDC Grower and Adviser Development Program	Grower Leadership and Development - GRDC encourages growers to register their interest for support in accessing opportunities for developing their technical knowledge base, professional and leadership skills. Growers may nominate a specific opportunity they have identified, or a general expression of interest. Specific opportunities generally take the form of short course training, related to technical aspects of crop production, business management or personal development. The GRDC also supports several events run by other organisations that provide value to the industry. These include industry, agronomic and scientific conferences, ranging from regional topic-focussed gatherings to national and international gatherings. Where the GRDC has an opportunity for registrations through sponsorship, growers in the general interest pool may be invited to attend. The GRDC will accept expressions of interest from individual growers to: 1. Undertake identified short course training in technical aspects of grain production, farm business management or professional/personal development, 2. Be included in a general expression of interest pool to attend grains industry training organised by the GRDC, 3. Be included in the general expression of interest pool for registration for GRDC supported conferences, where these opportunities exist. Grower and Adviser Development (Study Tours) – this program is targeted at groups of Australian grain growers (and accompanying advisers, or groups of advisers) seeking to arrange and undertake study and professional development, requiring travel to access these opportunities. Support will be provided on a competitive basis for arranging visits to GRDC-supported research and development projects, or other relevant research projects, centres of excellence, farming systems groups and similar; or to support the travel of an expert in a specific scientific field to visit a community to share their knowledge and experience. The aim is to assist grain growers to gain new knowledge, develop new skills, build relationships, and acquire new information that will enable grain producing businesses to be productive, enduring and profitable. Funding opportunities are offered twice each year, where applications will be received for GRDC support for: • up to one international development support program per region in the following six months, not exceeding $30,000 per application and • up to six domestic development support programs per region in the following six months, not exceeding $15,000 per application. Preference will be given to applications from groups of growers (a group being 5 or more growers),

	that demonstrate clearly identified area/s of study, a hypothesis linking the area of study to local grain production, learning goals and proposed outcomes.
Stubble Initiative – Yeruga Crop Research – Output No. 3	Surveys of famer experience with different harvest machinery will be implemented and case studies will be developed to determine base line information about harvest machinery. A simple decision support tool will be developed to assist grower and advisor learning about the various aspects of the decision to consider machinery investments that deal with stubble post-harvest. Stubble removal costs will be considered here as well, considering time, nutrient removal and carbon influence. It is important to develop simple decision support tools to support decision making in relation to stubble management. Multiple inputs using data inputs that users lack confidence in will result in poor adoption of the tool and subsequently will have no impact on practice change. Simple, single issue tools relating to specific questions on the relative advantage of changing a practice are likely to be more successful. Furthermore, simple tools reduce the need for extensive training for time poor consultants. They must provide simple outputs that relay a simple message that can be used to provide learning for the growers they are aimed at via the advisor conduit.
Assessing the economic value of precision agricultural tools for grain farming businesses in the Southern Region (to be contracted)	Precision Agriculture (PA) has considerable potential to increase the efficiency and profitability of grain production systems in the Southern Region, in particular to better target crop inputs to productive capacity and likely return on investment. Despite a generally high awareness of the potential benefits of PA technologies in cropping systems, adoption by growers in the Southern Region is generally low. Given the net impact on profitability is highly variable based on individual circumstance, it is essential that the application and adoption of a PA technology is carefully considered prior to any investment. It is suggested that building knowledge, skills and capacity would assist growers to objectively assess the operational, farming system and economic impact of the adoption of specific PA technologies to individual farm businesses. Access to robust and practical guidelines and decision support tools to assess the impact of PA technologies on the profitability of individual farm businesses is needed. The aim of this investment is to provide growers and advisers in the southern region with enhanced capacity and skills to assess the economic impact of the adoption of various precision agriculture (PA) technologies in order to make informed business decisions. This will be achieved by identifying key technologies and situations where PA has been proven to consistently improve the profitability of cropping systems; developing a simple decision matrix and related tools to support PA decision making; producing relevant high impact communications and extension activities to promote awareness and build the skills, knowledge and confidence to motivate growers and advisers to realise the profitability opportunities presented by the broader adoption of PA in the GRDC Southern region. Expected outcome - by December 2019, growers and advisers will have enhanced knowledge, capacity, skills and confidence to make informed and objective economic decisions relating to the adoption of PA technologies aimed to increase the profitability of grain growers in the GRDC Southern Region.
Supporting the sustainable use of insecticides and local on-farm implementation of integrated pest management strategies in the GRDC Southern region (to be contracted)	The cost of insect damage to crops and implementation of management strategies targeted at control have potential to cause major impacts on the profits of grain growers in the GRDC Southern Region. The historic reliance upon insecticides for control has contributed to the development of insecticide resistance in several important pests including green peach aphid, diamondback moth, and red-legged earth mite. An increase in the number of cases and extent of insecticide resistance in the future poses a threat to the future ability of growers to cost-effectively manage these important pests. Fortunately, attitudes are shifting and growers and advisors recognise the need to change insecticide use to minimise impact on beneficial insects, and manage the risk and impact of insecticide resistance development. There is increasing recognition that the integration of a range of non-chemical control strategies is required to encourage natural enemies and beneficial insects to assist in suppressing pest populations. Industry stewardship which utilises the practical

	knowledge of specialists in the industry will continue to be essential in driving on-farm practice change. Activities designed to further raise awareness and build knowledge relating to the relative risk and impact of insecticide resistance and broader principles and applied implementation of integrated pest management (IPM) based on local farming systems, pest complex and environment are required. There is an identified need to motivate growers and advisors to reduce prophylactic insecticide application through more strategic and targeted use. The development of locally relevant best management guidelines and extension activities will help up-skill growers and advisors to abate the impacts of resistance, ensure responsible and sustainable insecticide use, minimise potential impacts on off-target species and delay future increases in the cost of control associated with the availability of fewer higher costs control options. Agronomists and advisors are often key influencers of insecticide use, and hence, are key target audiences. Regionally adapted, science-based recommendations and decision making tools fit to farming system should be delivered through relevant local communication and extension activities. The aim of this investment is to develop, promote and deliver a number of high impact communication products and extension activities to raise awareness and build knowledge relating to the risk, occurrence, impact and management of insecticide resistance. This investment should support practice change required to increase the incidence and extent of adoption of sustainable and cost-effective integrated pest management strategies tailored to local farming systems and environment for key insect pests of grain crops in the GRDC Southern Region. Activities must address the current attitudes of growers, advisors and agribusiness and aim to motivate them to implement best practice IPM strategies on-farm.
Extension of knowledge and resources to manage risk and exploit opportunities to improve whole farm profit through successful integration of cropping and livestock enterprises in the GRDC Southern Region (to be contracted)	The aim of this investment is to provide growers and advisers across the GRDC Southern Region with information and tools to identify opportunities and strategies to better integrate cropping and livestock enterprises and increase the profitability and resilience of the whole farm business. This will be achieved by conducting extension and communication activities to increase awareness and further extend the research outcomes, tools and information previously generated by the G&G program to build grower and advisor skills and knowledge, and drive adoption of improved management practices. The investment will also include strategic update and improvement of existing tools and resources as detailed in the project outputs.
Grain and Graze III – Extension and deliver on mixed farm benefits in the Southern Region (SFS00028)	Grain and Graze 3 is the third phase of mixed farming investment by the GRDC. While farming systems and enterprise mixes vary across the low, medium and high rainfall zones, there are common issues addressed by this investment. They are: 1. <u>Smarter grazing of crops and stubbles to optimise business and production risk and increase profit -</u> The Grazing Cropped Land booklet has drawn together all results funded through the Grain and Graze program since 2003 and provides the most up to date material on grazing crops. Results from the many grazing crop demonstrations conducted in 2015 are supported by findings in the booklet. 2. <u>Better manage crop and pastures (within) a rotation to improve crop and livestock production -</u> Trialling and demonstrations have shown the potential to sow canola and wheat with strong vernalisation requirements as a fodder and grain crop. The practice involves spring or opportunistic summer sowing of the crop, using the early growth for grazing and then taking the crop through for grain. A second area is around the best choice of a fodder rotation option to manage emerging issues of weeds, nitrogen depletion and soil conditions through continuous cropping. The project has shown there are options around what can be sown, with varying benefits for weed control, nitrogen and soil however the complexity of the decision means many growers and advisors avoid trying something different. While the project is extending this knowledge, we are recognising an emerging need to develop a support tool to help work though the complexity of the rotation decision. 3. <u>Farmers making informed decisions about farm business mix that best meets their needs -</u> The Farm Decision Making booklet has provided an extremely valuable resource to discuss farm

	decision making. A facilitation guide has also been created to assist people who wish to try the exercises with their clients or in a discussion group or workshop. Aspects of risk assessment have also been advanced, with @risk training of 25 consultants and the development of the agprice guide. Other tools have been developed to assist in this area. The whole farm decision model provides an excellent resource to discuss decision making and the materials on farm boards is being sought by growers and advisors. The focus of risk and decision making has made many growers and advisors more aware of what influences their decisions and how this can be improved. Facets of the decision making theme are being used in other GRDC projects e.g. WA frost initiative. Risk analysis developed in the Grain and Graze program is now being used by private consultants throughout the country.
Grain and Graze II – Farm business logic application (NR00009)	The desired outcome of this project was to enable Australian grain growers to manage farming systems that are able to respond and adapt to changing environmental and market conditions to optimise risk and deliver an increase in profitability. This was achieved through: 1. Knowing the important business drivers - an improved understanding by growers and advisors of the risks within key farming practices in each agro-ecological zone. 2. Managing systems risk - Increased business profit (above the five year rolling average) by managing risk across seasons, between enterprises and major crops within the farming system 3. Managing individual crop agronomy - Optimise profit from the major crops grown in each agro-ecological zone by managing risk within crops. Three practice changes were identified to achieve the outcomes. 1. Identify and quantify the current risk in the business, the farmer's position on risk and the key risky business drivers. 2. Application of the knowledge about the risk position of the business and the farmer to shape the business direction both in the long term and short term. 3. Make/advise on tactical (operational) decisions that take into account the risk profile of the business, farmer, markets and the season.

Issue No. 6 - Stubble retention has increased the risk of economic damage from pests including but not limited to insects (lucerne flea, slaters, earwigs, millipedes), slugs, snails and mice.

Crop establishment is increasingly being affected by a range of pests that proliferate in retained stubble farming systems. The pest spectrum has shifted and not only includes traditional stubble loving foes such as lucerne flea, snails and mice, but includes slaters, millipedes and earwigs and slugs. There are few products registered for use on the emerging pests and limited knowledge on successful management strategies.

GRDC investments addressing this issue –

Current invertebrate pest management options (ICN00020).	Desktop research to develop a matrix of invertebrate pest x crop and supplemented by additional interviews undertaken with leading R&D chemical companies operating in the insecticide segment, entomology researchers, Pathways to Registration project personnel and industry bodies, to understand 'Where there is need for additional solutions due to registration gaps or potential loss of existing solutions to deregistration or resistance. It is envisioned that the report would contain: • Crop x growth stage x pest matrix • APVMA priority list for re-registration and potential impacts • Impact of global re-registration I reviews • Insecticide resistance and potential impact • Beneficial selectivity and value of this to stakeholders • Researchers & lndustry Bodies -Where are the big gaps?

	• Ag Chem Companies -What are they placing resources? • Need for late season applications (close to harvest) and potential MRL impacts/ risks?
Management of invertebrate pests on farms (CSE00059)	Grain crops are home to a diversity of invertebrate pest species, but each year only a few species will reach high enough densities to cause significant damage and yield loss. The diversity of beneficial species, such as predators, parasitic wasps and flies, in certain contexts can suppress pest population gr□h thus stopping pest outbreaks. We are currently limited in our ability to predict when and where pest outbreaks will occur. This is partly due to a lack of fundamental ecological knowledge around where pest and beneficial species are found and the factors that facilitate pest outbreaks. This means that growers are dependent upon reactive chemical control with limited scope for alternatives such as cultural or biological control options. Growers and consultants need to know what factors increase outbreak risk, when to monitor for pests, when to intervene with insecticides, and how to conserve important beneficials in-field during the season, and in the landscape across the year. This project will generate new knowledge about the life cycle and biology of a range of pest and beneficial species across southern and western regions, which will enable pathways for better spray decision-making and the proactive management of pests. Our focus is on delivering information to growers and consultants to help with pest control decision-making on farms. Specifically we will provide answers to these questions commonly posed by growers: 1. When do I need to watch out for that pest species? 2. When do I need to control that pest species? 3. What can I do on my farm to protect and support beneficials? By the end of this project we will deliver to growers and consultants general principles applicable across groups of species regarding the timing of management activities. For a sub-set of species we will be able to provide specific recommendations around timing of monitoring and management interventions such as timing and choice of insecticide applications. Furthermore, the information generated will lead to recommendations for how to ensure management activities at the farm-level conserve beneficials and allow them to be integrated into decision-making.
Improved management of snails and slugs (DAS00134)	The Research component will focus on four key areas. 1. To optimize the timing of bait and other chemical treatments, we will quantify the rainfall/moisture (amount, duration)/temperatures required to stimulate effective breeding and recruitment. 2. To improve baiting efficacy and resultant crop protection, we will compare the performance of a range of proprietary bait products and rates (pellet density) on different pest species, age classes (including juveniles) and infestation densities, to deliver targeted bait recommendations to growers specifically for the main pest species. Field persistence of baits under the influence of UV and moisture, and the effect of targeted spatial placement of baits, phagostimulants and bait mixtures on bait efficacy will be determined. 3. Based on a meta-review of the published literature on other molluscicide undertaken In DAS00127, we will select and trial a number of candidate molluscicide against the major pest species 4. We will survey growers to determine current harvest practices used to limit snail contamination of grain and summer cultural control practices, and use these findings to identify new potential engineering solutions. Also, preliminary research suggests that the faeces or mucus of *T. pisana* may contain a substance inhibitory to other snails; hence we will initiate a 'blue sky' pilot study of this 'toxin', and if identified, will investigate its potential as a biological or chemical control. The Extension component will integrate the new research outcomes with the existing chemical and cultural management guidelines to produce a decision tool aimed at informing management choices for cost-effective snail and slug control. The decision tool will include selection guides for chemical treatment options (based on product cost (per unit area), efficacy, special conditions/limitations and off-target impact/environmental fate) and cultural management options (based on factors such as temperature requirements. soil type. fire-risk factors. etc.). and which takes account of region. Pest species. etc. If feasible, an alert service (e.g. to optimize bait timing) may be included. This package of newly-developed pest biology and management information will be promoted through comprehensive regionally focused fact-sheets and at annual workshops in the high mollusc-risk areas of all regions.
GRDC Stubble Initiative — Maintaining profitable farming systems with retained stubble in the South East and KI regions	In the South-East region, the biggest inhibitor to retention of stubbles is pest control (and in particular snails). This problem once isolated to the more alkaline coastal regions, is now a widespread issue across the region. Ways to try and manage the stubbles in a way that will provide adequate snail control with stubble retention over a medium- long-term (3 - 5 year) period will be the biggest challenge in stubble retention systems. Livestock (hoof activity) may have a role to play

(MFM00006)	in the management of snails; due to the nature of the farming systems, this may also be investigated. These activities will be carried out at 2 main focus sites across the South-East region at Conmurra (650mm rainfall; black calcareous clay/loam soil located near Lucindale) and Frances (525mm duplex soil), where replicated sub-treatments will be overlaid on different stubble management treatments. The areas will be EM38 surveyed to try and reduce the soil variability of the site, as the stubble treatments will be carried out using farmer equipment (and not plot equipment). The pests will only be investigated in the site at Conmurra where an exclusion zone will be created around an area specifically set up to look at snail control. This will be done so that the remainder of the site can be 'protected' from damage, and other outcomes can be successfully achieved. AgKI will focus on those issues that are specific to the Kl region; demonstration and extension work around snail and slug management with retained stubbles, the effects of stubble loads on canola establishment, nutrition issues with retained stubble management, and the long-term disease issues with different stubble retention methods in a wheat/canola rotation (a common rotation on the Island).
GRDC Stubble Initiative — Research component – CSIRO *et al*	Milestones 18 and 19 - . Knowledge stock-take of pest issues in retained stubble systems. A review of the "grey literature" unpublished and published scientific articles in Australia and overseas for a selection of pests (snails, slugs, earwigs, millipedes, slaters, wireworms) including recently completed IPM demonstration project (UWA00134). We will focus on research relating to management interventions, thresholds, predictive forecasting, and economic estimates of crop losses for these pests that assist in understanding risk for pests specific to retained stubble farming systems. As a result of feedback from this review discuss how best to fill knowledge gaps throughout the course of the project, or development of new research-focussed project proposal to be considered by GRDC. Milestone 20 - Develop and communicate protocols for snail and slug monitoring based on existing knowledge and extension material. Develop a draft monitoring protocol for emerging pests (earwigs, millipedes, slaters and wireworms) that can be road-tested by the teams.
Supporting the sustainable use of insecticides and local on-farm implementation of integrated pest management strategies in the GRDC Southern region (to be contracted)	The cost of insect damage to crops and implementation of management strategies targeted at control have potential to cause major impacts on the profits of grain growers in the GRDC Southern Region. The historic reliance upon insecticides for control has contributed to the development of insecticide resistance in several important pests including green peach aphid, diamondback moth, and red-legged earth mite. An increase in the number of cases and extent of insecticide resistance in the future poses a threat to the future ability of growers to cost-effectively manage these important pests. Fortunately, attitudes are shifting and growers and advisors recognise the need to change insecticide use to minimise impact on beneficial insects, and manage the risk and impact of insecticide resistance development. There is increasing recognition that the integration of a range of non-chemical control strategies is required to encourage natural enemies and beneficial insects to assist in suppressing pest populations. Industry stewardship which utilises the practical knowledge of specialists in the industry will continue to be essential in driving on-farm practice change. Activities designed to further raise awareness and build knowledge relating to the relative risk and impact of insecticide resistance and broader principles and applied implementation of integrated pest management (IPM) based on local farming systems, pest complex and environment are required. There is an identified need to motivate growers and advisors to reduce prophylactic insecticide application through more strategic and targeted use. The development of locally relevant best management guidelines and extension activities will help up-skill growers and advisors to abate the impacts of resistance, ensure responsible and sustainable insecticide use, minimise potential impacts on off-target species and delay future increases in the cost of control associated with the availability of fewer higher costs control options. Agronomists and advisors are

	often key influencers of insecticide use, and hence, are key target audiences. Regionally adapted, science-based recommendations and decision making tools fit to farming system should be delivered through relevant local communication and extension activities. The aim of this investment is to develop, promote and deliver a number of high impact communication products and extension activities to raise awareness and build knowledge relating to the risk, occurrence, impact and management of insecticide resistance. This investment should support practice change required to increase the incidence and extent of adoption of sustainable and cost-effective integrated pest management strategies tailored to local farming systems and environment for key insect pests of grain crops in the GRDC Southern Region. Activities must address the current attitudes of growers, advisors and agribusiness and aim to motivate them to implement best practice IPM strategies on-farm.
National co-ordination of invertebrate pest research and insecticide resistance management (UM00048)	This project will establish the Grains Pest Advisory Committee (GPAC), which will deliver strategic information to GROG on invertebrate pest management. The committee will facilitate communication and coordination between researchers, advisors, growers and industry representatives, with a focus on sustainable, but practical solutions. GPAC will act as a think-tank and will be sufficiently resourced through the appointment of an Executive Officer at the University of Melbourne so that issues around resistance management, knowledge gaps and control opportunities are tackled in a rigorous manner rather than as a reaction to issues that arise within a particular season. GPAC will make recommendations about prioritising research as well as considering entomological training and capacity building (e.g. postgraduate student projects, cadetships etc.). Additionally, this project will improve the management of insecticide resistance in the grains industry by establishing a National Insecticide Resistance Management (NIRM) working group, which will feed into GPAC. This working group will undertake risk analyses of grains pests and develop resistance management strategies for key invertebrate pests that will be publicised through various channels including Croplife Australia. We will explore resistance development overseas and management approaches presently used to control invertebrate pests in Australia, as this will directly impact the likelihood of resistance developing and the rate at which resistance will spread. Collaboration across all Australian states and key research organisations will be critical to the success of these activities. To ensure resistance management plans are applicable for farming systems that combine grain production with other enterprises, this group will consult widely within the grains industry but also with the cotton, horticultural and livestock sectors.
Improved surveillance and management options for mice in Australian grain crops (commencing January 2018)	Monitoring of mouse populations in typical grains farming systems across the grain growing regions of WA, SA, Vic, and NSW. The monitoring provided data on the size (abundance) of mouse populations, their breeding status and overall activity. This information was used in models that have been developed progressively over the last 20-30 years to predict mouse outbreaks. Investment *Understanding mouse biology and ecology in zero- and no-till cropping systems to inform best practice crop production and mouse management practices* endorsed by Southern Panel, proposal to be reviewed by other panels and finer detail to be determined in consultation with researchers. Will be looking at quantifying the impact of management tactics (strategic ploughing, sowing implements, food and habitat reduction) on mouse numbers; improving knowledge of when and which mouse management tactic to use through new mouse biology and ecology studies on mice movement within paddocks and population immigration, emigration and fecundity of mouse populations in no-till and stubble retention farming systems; new information on the location, structure, utilisation and longevity of mouse burrows under no-till stubble retained farming systems being delivered to growers as optimal regional management tactics for mouse management.
MouseAlert	'MouseAlert' is a new interactive website and mobile app that allows grain growers to record and view mouse activity in their local area in real time. It has been developed by the Invasive Animals CRC in partnership with GRDC, Landcare Research and CSIRO Sustainable Ecosystems. It provides farmers and landholders with a new way of keeping a close eye on changes in mouse populations. Data entered will help with early-warning of increases in mouse activity and better forecasts for plagues. Rapid response by growers can then minimise mouse damage.

	MouseAlert can be used to record - (1) Sighting and evidence of mouse activity around your property. (2) Damage caused by mice, such as crop damage. (3) Control activities you have undertaken, such as baiting. A community group facility also allows growers to come together online to keep each other informed about mouse activity across properties. A notification system has also be developed so members of a group can be alerted to changes in mouse activity in their local area as soon as it happens, enabling a co-ordinated rapid response. MouseAlert posts updates about changes in mouse numbers and report information from current monitoring programs where researchers and farmers are working together to measure mouse numbers and trends.
Surveillance of mouse populations across the grain-belt of Australia (IAC00002)	The project is a collaboration between Landcare Research (New Zealand), CSIRO Agriculture and the Invasive Animals Cooperative Research Centre. Monitoring of mouse populations in typical grains farming systems across the grain growing regions of WA, SA, Vic, and NSW. The monitoring provided data on the size (abundance) of mouse populations, their breeding status and overall activity. This information was used in models that have been developed progressively over the last 20-30 years to predict mouse outbreaks. **Benchmark sites:** live trapping data collected for use in models in Adelaide Plains (SA), Walpeup (Vic) and the Darling Downs (Qld). **Quantitative rapid-assessment sites:** using mouse chew cards and active mouse burrows assessments on 86 transects across 11 sites. **Qualitative monitoring networks:** using data from farmers and agronomists in 11 sites.
Investments – mice impact and control e.g. • Zinc phosphide bait technology development • Biological control projects • Mouse sterilization • Numerous communication and extension programs that include information to growers and modelling populations • Zinc phosphide OH&S Package • Mouse Immuno-contraception projects	Over the last several decades mouse plagues have been increasing in frequency compared to the previous 50 years and innovations in farming practices e.g. no-till, stubble retention, may contribute to this trend. There is a need to monitor mouse populations better, and improve methods for their management. Mouse monitoring: Current methods are time and resource intensive and information is largely gathered from a small number of locations which may not be representative of a broader region. Technologies are advancing, and communication technologies are being developed and are readily available to make it feasible to develop cheap, simple and reliable methods to monitor mouse activity and abundance. The system could be designed to gather information from a wide range of locations for a regional-scale monitoring system. The regional monitoring would be designed to provide relevant monitoring data to suit the regional mouse models being developed for forecasts. Improved baiting efficiency: Zinc phosphide (ZnP) treated wheat grain is the only registered in-crop mouse control solution available to grain growers. There is an increasing number is situations where ZnP baits are not effective in reducing mouse populations, and growers are applying ZnP baits above the label use rate or spreading baits multiple times within short periods of time. There are a range of questions about the effectiveness, timing, palatability and aversion to ZnP that need to be resolved. Bait shyness is a significant issue, and there are indications that barley may be a more palatable bait base than wheat. If this is the case, it may prove to be a better option worth pursuing for registration. Farm management practices to reduce mouse impact: How can farm management practices be used to reduce the impact of mice? Various farm management strategies have been used in the past to reduce the impact of mice (e.g. cultivation), but are these still relevant now, or are other options available that could be tested? How can

	multiple, integrated strategies be implemented, in combination with effective baiting? See IAC00001, IAC00002.

Issue No. 6 - Using soil moisture information to make better tactical management decisions to optimise the use of plant available water

Plant available soil water drives crop yield and the risk associated with crop choice and management decisions. Real time knowledge of soil water status including spatial variability across the farm creates an opportunity to more effectively monitor yield potential as the season evolves and then make better decisions including crop choice at sowing time, nitrogen and disease management.

GRDC investments addressing this issue –

Measuring and managing soil water in Australian agriculture (CSP00170)	This project expand upon the soil characterisation and monitoring activity in the western, southern and northern cropping regions, and further enhanced the knowledge and skills of growers and agri-consultants in characterising the plant available water capacity (PAWC) of their soils to inform soil water management. This was achieved through discussion of soil properties, including sub-soil constraints and exploration of farming system options using decision support tools informed by locally relevant soil water and climate information.
New tools to measure and monitor soil moisture (USQ00014)	Soil Water App (SWApp)uses a tested water balance model and inputs from- • weather data from a nearby Bureau of Meteorology; • rainfall from your local rain gauge; • rainfall from a Bluetooth enabled rain gauge (10m range); • soil descriptions suited to local conditions; and • soil and crop cover conditions for each paddock. This input will estimate infiltration, runoff, evaporation, transpiration and deep drainage to estimate soil water on a daily basis. SWApp uses long-term weather data to provide a forward-looking estimate of outcomes. Data is securely stored in the cloud and can be accessed from multiple devices.

Issue No. 9 - Variability in seed supply and limited choice in canola varieties, particularly high yielding open pollinated varieties with durable disease resistance, increases production risk, compromises weed control and herbicide residue management and thus reduces profitability

The relatively low cost of open pollinated (OP) varieties and the opportunity to retain seed compared to hybrid varieties reduces the production cost and financial risk of growing canola. Seed supplies of OP varieties have been unreliable. Added to this is the dominance of hybrid canola systems and the unreliable seed supply and high cost structure. Currently there is only a single company breeding OP varieties for Australia. Growers require continued access to a range of OP canola varieties for a range of environments with a range of robust blackleg and sclerotinia resistance a range of herbicide tolerance systems.

Identified traits of new and improved canola varieties for the medium rainfall zone include –

- Physiology and phenology
    - long season spring types
    - range of flowering times
    - winter types
    - early vigour
    - lodging resistance
    - yield
    - specialty oils
    - shattering resistance
    - pollen abortion resistance

- Herbicide tolerance
    - Imi + triazine Herbicide tolerance
    - Imi herbicide tolerance
    - Triazine + glyphosate herbicide tolerance
    - Glyphosate + imi Herbicide tolerance
    - Imi + triazine + glyphosate Herbicide tolerance
    - Clethodim tolerance
- Pest resistance
    - RLEM, Lucerne Flea, Green peach aphid, false wireworm, slaters and slugs
    - Diamondback moth, Native budworm
- Disease resistance
    - Blackleg
    - Sclerotinia
    - White leaf spot
    - Viruses – Beet Western Yellow Virus and Turnip Mosaic Virus
    - Abiotic stresses
    - Heat, frost, drought
- Sub-soil constraints
    - acidity, salinity and sodicity

GRDC investments addressing this issue

National Brassica Germplasm Improvement Program	The National Brassica Germplasm Improvement Program (NBGIP) has defined priority traits for germplasm enhancement to support and improve the Australian canola industry. These are alternative sources of blackleg resistance, drought and heat tolerance, pod shatter resistance and improved oil content and stability. This project provides Australian Canola breeders with new or improved sources of open-pollinated germplasm, an improved understanding of the genetics underlying these key priority traits together with appropriate breeding tools. Research undertaken within the NBGIP will focus on: Blackleg The genetics underlying blackleg resistance, especially for adult plant resistance, are poorly understood. Moreover, no new sources of seedling resistance are available for breeding use. As the pathogen has the ability to overcome resistance in canola varieties, several seedling resistance genes present in the current Australian canola varieties have become ineffective in providing resistance under field conditions. Therefore, new sources of resistance are constantly required. NBGIP will identify new sources of resistance in diverse canola germplasm accessed from overseas as well as in relatives of canola such as turnips and cabbages. Quantitative (adult plant) resistance conferred by a number of minor genes is likely to be a more sustainable approach to maintaining resistance and prolonging the effectiveness of major genes. Therefore, this project will optimise methods to readily screen for the presence of minor genes. Drought and Heat These are the major environmental stresses limiting canola plant growth and productivity in Australia. Extended period of drought and high temperatures especially at flowering and pod-filling stages can lead to significant crop losses. The NBGIP project will investigate genetic variation for various component traits implicated in drought and heat tolerance such as grain yield, above-ground biomass production, early seedling vigour, pollen abortion and physiological traits. Shattering Despite extensive breeding by canola breeding programs, high levels of pod shattering still occur and significantly impact grower profitability. This project will evaluate diverse canola germplasm accessed from overseas including turnips and Ethiopian mustard and develop genetic solutions to reduce yield losses due to pod shattering. Oil yield Canola has the potential to deliver farming systems benefits in the Northern region (as a break

	crop for controlling take-all, crown rot and nematodes). However, it is not widely grown since many growers regularly have problems meeting minimum oil content (42%) with currently available cultivars. NBGIP will evaluate diverse germplasm accessed from Germany and elite varieties from Australia for improved oil content and stability attributes for target environments across Northern NSW.

Issue No. 10 – Cost-effective non-chemical weed control systems such as robotic weeders in broadacre crops will prolong the life of important herbicide chemistry such as glyphosate and minimise the economic impact of difficult to control weed species such as fleabane.

The over-use and reliance on herbicide strategies increases the rate at which resistance develops and reduces the efficacy of herbicides. This has resulted in an increase in the number and distribution of "hard to kill" weeds. Adoption of integrated weed management packages which include non-chemical strategies may be re-energised by developing novel technologies and tools such as robotic weeders to identify and implement targeted control of hard to kill weeds.

GRDC investments addressing this issue -

Development of new non-chemical weed control technologies – microwave control of weeds (UM00053)	This project has revealed that understanding the potential of microwave weed and soil treatment is not trivial. Clearly, microwave energy can kill weed plants. It can also kill weed seeds in the soil; however, this requires much more energy than is needed to kill plants. Therefore, the question of "commercial viability" for the technology does not have a simple answer. Increasing available power will proportionally decrease treatment time; however, there is a design challenge to make very powerful microwave systems portable. Therefore, should this technology become commercially available, it will probably rely on more powerful microwave generators than have been used in the current research programme. High power microwave generators, up to 100 kW, are commercially available, so this is a viable consideration. During the course of this project, a novel microwave applicator that restricts the volume of plant and soil matter being heated during treatment has been developed. This novel applicator significantly reduces the total energy requirements for weed plant treatment and has some influence in the very top layers of soil, if it is placed on direct contact with the soil. The engineering trade-off for reducing the overall energy requirements for treatment is a spatially restricted field distribution from the applicator, compared to the more traditional horn antenna. This field restriction is a very favourable feature with regard to: health and safety; and reduction of interference with other systems. However, it requires the applicator to be in close proximity to the soil surface for it to be effective against weeds and their seeds in the very surface layer of the soil. Irrespective of the final choice of applicator, the final prototype designs and specifications should be subjected to appropriate auditing procedures to fully determine the system's status according to the Defence and Strategic Goods List. Currently microwave heating is listed as a dual application technology and should not be restricted in terms of development and export; however, this should be evaluated when a semi-commercial prototype has been fabricated and tested. Negotiations are being continued for future investment and commercialisation including use in robotic applications.
Improving IWM practice of emerging weeds in the southern and western regions (UA00149)	This project will provide new tools that will allow better understanding and control of summer weeds: fleabane, windmill grass, feathertop Rhodes grass, tar vine, button grass and sow thistle/milk thistle, in the Southern and Western Regions. It will also provide new tactics for the control of herbicide-resistant wild radish, barley grass, brome grass and Indian hedge mustard in the Southern and Western Regions. Research seeking to understand the incidence, density and emergence patterns of emerging summer weeds (fleabane, sowthistle, windmill grass, feathertop Rhodes grass, button grass and tar vine) has shown that these species are becoming widespread across the grain growing regions. They prefer to germinate from the soil surface, meaning they become more common in no-till systems. Most species have a wide temperature range for germination, meaning they can emerge at any time of the year when conditions are favourable. However, in Mediterranean environments they tend to emerge during spring and persist into summer. Generally, these species have low levels of seed persistence in the seed bank and seed banks can be exhausted within 12 months,

	provided effective control occurs. Control studies have shown that common summer fallow herbicide applications are generally not effective. Double knock applications are more effective. Pot studies and field trials show that residual herbicides applied during winter can reduce emergence of these weeds in spring and where registered may prove more effective than relying on summer sprays. Crop competition in the cereal phase is also helpful at reducing population numbers in summer. Control of herbicide resistant wild radish requires a 2 spray approach to be effective. One spray needs to be applied early, either as a pre-emergent or an early post-emergent application. Due to its persistent seed bank, at least 3 years of effective control are required to run down seed banks. Control of herbicide resistant barley grass requires the use of effective pre-emergent herbicides along with crop competition in cereals and crop-topping in pulse crops and pastures. Glyphosate resistance in some species, such as fleabane, windmill grass and feathertop Rhodes grass, is occurring on roadsides and may move from there into cropped fields. The results of the research are being delivered to growers through field days, fact sheets, GRDC Updates and other avenues.
Surveillance of herbicide resistant weeds in Australian grain cropping (UCS00024)	Between this project and UCS00020 all grain regions are being surveyed once every 5 years for HR status of major winter weeds.US00070 is starting on summer weeds and fallows. Glyphosate resistance weeds form fallows is being identified through UWA00171 (AHRI) and UA00158 as well as recorded in ARN0001 (AGSWG). This research will seek to understand the incidence of herbicide resistance across the cropping region of Australia. This will occur through surveys in which randomly selected cropping paddocks will be visited and seed of common grass or broadleaf weeds collected. Grass weed species will include annual ryegrass, wild oats, brome grass and barley grass. Broadleaf weeds will include wild radish, Indian hedge mustard, wild turnip, fleabane and sowthistle. Other weeds present at high frequencies will also be collected. The weeds collected in the three regions (Northern, Western and Southern) may vary between regions due to differences in cropping programs, climatic conditions and weed diversity. These weeds will then be screened for resistance to a wide range of herbicides commonly used for their control. Southern region starts in 2018.
Weed management in the southern region mixed farming systems - strategies to combat herbicide resistance (UCS00020)	To perform extensive surveys to assess herbicide resistance in cropping regions across NSW, VIC, SA and TAS. To perform field and greenhouse experimentation to evaluate management factors that influence weed epidemiology or presence in southern region mixed cropping zone. To determine novel chemical and non-chemical approaches for management of weeds in cereal and pulse crops and report these findings to APVMA to assist in registration or labelling of new products/strategies for improved weed management of winter annual weeds. Surveys for screening of key herbicide resistant weeds, including annual ryegrass, bromegrass, wild radish, Indian hedge mustard, sowthistle, windmill grass, fleabane and barley grass have been conducted across 3 of 5 regions to be screened in 2013, 2014 and 2015 as outlined in project methods across NSW, VIC, TAS and SA, using standard seed collection protocols. Upon completion of random survey transects used for seed and plant collection, seed was properly cleaned and prepared for herbicide resistance testing. Herbicide resistance testing was performed for all samples collected. To date, results have shown that resistance levels to annual ryegrass and in some cases bromegrass and wild oats have increased in the past 5 years across NSW, VIC, TAS and SA. Levels of resistance to selected herbicide families were typically higher in SA and western VIC in contrast to TAS, NSW and eastern VIC. Field research sites were identified in NSW and SA for research outlined in outputs 2 and 3 (weed epidemiology of key weeds in the southern region, and use of new chemical and novel strategies for weed management) as outlined in project methods. Research has been performed on management strategies for annual ryegrass, bromegrass, fleabane, and witchgrass spp. in particular, using both chemical and non-chemical strategies. Rotational strategies that included lucerne, phalaris/clover, or canola in a two year rotation resulted in reduced weed infestations in 2 locations across NSW. In SA, rotations that included lupins or TT canola over a 2 year period resulted in reduced bromegrass seedset. Competitive crop cultivar experiments were performed

	over 2 years with diverse cultivars of canola (NSW, SA) as well as barley and wheat (NSW locations). Canola GT50 and newly released cultivars proved highly suppressive in crop and post-harvest. Selected barley and wheat cultivars (Condo, Espada, Federation, Hindmarsh) proved particularly suppressive in crop. Weed suppression was associated with early crop vigour and reduced light penetration at the soil surface due to canopy architectural traits. Canola and certain grazing wheat cultivars showed potential for weed suppression associated with crop residues post-harvest, potentially due to allelopathic activity associated with production of bioactive metabolites in the soil rhizosphere. Herbicide resistant pulse crops are under investigation at CSU and UA for their ability to suppress difficult to manage weeds using a variety of herbicide tools, in both glasshouse and field experiments.
New uses for existing chemistry (UQ00080)	The overall objective of the project is to identify new uses for existing registered pre- and post-emergent herbicides for the site-specific management of feathertop Rhodes grass (FTR), awnless barnyard grass (ABYG), fleabane, sowthistle, brome grass, barley grass, and wild radish present in crop and fallow situations. Pot and field trials were conducted to explore the potential for the use of older herbicides either alone or in mixtures for the control of feathertop Rhodes grass (FTR), awnless barnyard grass (BYG), fleabane, common sowthistle, barley grass, brome grass, and wild radish in different regions. The mixture of Product A plus Avadex Xtra provided suppression of brome grass in barley. Sakura plus trifluralin and high rates of Product B were the most effective herbicide for pre-emergent control of barley grass. A number of mixtures and sequential applications were found effective in controlling common sowthistle and flaxleaf fleabane. Three tank-mix treatments effectively controlled awnless barnyard grass; however, sequential applications exhibited higher levels of control. Herbicide tank mixtures and sequential applications were not effective on mature feathertop Rhodes grass under field conditions. Fluridone (Group F) showed promising results for wild radish control.
Emerging weeds (UA00156)	Document current knowledge on seed dormancy, life cycles and longevity, assess the relevance of this data to contemporary farming systems, and identify knowledge gaps for the major emerging weed species and identify knowledge gaps and RD&E needs. Research undertaken in 2016 has confirmed presence of large variation in seed dormancy between weed populations in some weed species such as barley grass and brome grass from the southern region. Barley grass and brome populations from cropping fields had greater seed dormancy and were much slower to emerge than populations from non-crop areas. Many other weed species displayed a much smaller variation in seed dormancy. There were large differences between weed species in the pattern of recruitment and the level of exhaustion of the seedbank. However, site rainfall during the study did not have a significant effect on the persistence of seedbank of most of the weed species. Generally weed seeds present on the soil surface had a greater rate of decay than buried seeds. Weed species with rapid germination and greater early vigour were more competitive with crops and produced more seeds. There were also major differences between weed species in the rate of seed shedding/dispersal until harvest time. This trait of weed species will have a major effect on the success of harvest seed collection.
Australian Herbicide Resistance Initiative - Phase V (UWA00171)	Sub Project investigating targeted tillage and also focussing on low seed bank farming systems and corresponding ecological weeds changes Australian grain growers, like their counterparts in other industrialised nations continue to rely on herbicides as the most important component of their weed management strategy. In the foreseeable future there are no alternative technologies in world cropping that will achieve the results that herbicides obtain. It is now understood that novel mechanisms of resistance to different herbicide modes of action exist and will continue to evolve under global herbicide selection - a better understanding of the factors and dynamics of herbicide resistance selection will delay the evolution of herbicide resistance in weeds. Evolutionary biology and Darwinian evolutionary theory provide a very powerful framework to interpret and understand how weeds can respond to herbicide use and other pressures in modern cropping systems. Improved crop/weed management strategies evolving from increased knowledge and understanding of the herbicide resistance phenomenon will ultimately benefit the Australian

	grains industry and represents a significant contribution towards achieving sustainable cropping systems. In AHRI, the 2015-2020 project encompasses three research programs; Resistance Evolution, Resistance Mechanisms and Resistance Management, plus a Communications program. All programs have a high level of engagement in delivering activities in all three GRDC regions. **1 - Resistance evolution:** Essential for monitoring on-going herbicide sustainability, field survey work will quantify herbicide efficacy and herbicide resistance evolution in key cropping weeds. Resistance surveys have been conducted for Ryegrass, Wild oats, Barley grass, Brome grass, Wild radish and Fleabane and testing for resistance has commenced. Ongoing research to highlight the importance of maintaining optimum herbicide efficacy (rates) has commenced together with evolution studies to predict the onset of resistance to new herbicides, ways to delay resistance onset and resistance management techniques. This information will be captured in the PERTH and RIM models for use in Australian cropping and disseminated widely. **2 - Resistance mechanisms:** Understanding how Australian crop weeds achieve resistance to powerful herbicides is of benefit to the nation and globally. AHRI is the international leader in this research area and attracts considerable ARC grant funding and industry support AHRI is working to establish the biochemical and molecular genetic basis of novel herbicide resistance in Australian major crop weeds and to ensure this information is widely disseminated and, when relevant, incorporated into management strategies. This fundamental AHRI biochemical/molecular research underpins an understanding of how to sustainably manage herbicides and minimise resistance. **3 - Resistance management**: The focus of this program is aimed at maximising crop production/sustainability while minimising crop-weed and herbicide resistance problems in Australian grain crops. This program has a national focus with the development of weed control solutions to fit cropping systems in each of the Western, Southern and Northern production regions. Harvest weed seed control (HWSC) systems have been developed as a major AHRI activity in response to the escalation in herbicide resistance and because of an identified opportunity to target weed seed production during grain crop harvest. The major annual weeds infesting Australian cropping; annual ryegrass, wild radish, brome grass and wild oats, all retain high proportions of their seed production at maturity. This attribute (biological weakness) is taken advantage of by targeting this seed for collection (harvested) during commercial grain crop harvest (Walsh and Powles 2007). **4 - Communication:** AHRI is committed to delivering AHRI's and other relevant research to the Australian broadacre cropping industry in an engaging manner, promoting greater awareness of herbicide resistance and educating industry stakeholders on strategies to increase crop yields and sustain herbicides. Tools to communicate AHRI messages include delivery of website, online courses, live webinars, face-to-face presentations, social media and targeted events.
WeedSmart (UWA00172)	WeedSmart is established by industry to ensure herbicide options are available for future generations. WeedSmart provides a consistent, single voice for the herbicide industry, linking stakeholders to world renowned herbicide resistance and agronomic research. WeedSmart Phase 3 builds on the strong and effective brand established in Phases 1 and 2 by continuing to work with growers and industry to increase awareness and to provide solutions to keep herbicides working.
Genetically improving wheat's ability to outcompete weeds (CSP00182)	To develop germplasm and methodologies aimed at delivery of wheats with improved weed competitiveness. Research here is advanced with regular communication in engaging breeders in identifying suitable commercial varieties, and testing/developing sources of improved early vigour for use in crossing and population development. Crosses using alternative dwarfing gene sources and deployment of molecular markers have facilitated large numbers of lines to be advanced. Phenotyping methods aimed at improved and robust high-throughput selection are being developed with the aim to deliver to commercial breeding programs targeting improved weed competitiveness.

	Note: weed competitive traits is a low priority for breeders.
Mechanisms of Weed Suppression By Early Vigour and Other Novel Wheat Genotypes (USC00022)	In conjunction with GRS100926 1. Assess the competitive traits of selected superior Australian winter wheat genotypes which are well adapted for the southern taming region 2. Assess the impact of environmental factors such as moisture and temperature on weed suppressive ability of wheat 3. Assess and measure wheat metabolites involved in weed suppression and 4. Measure weed suppression by wheat stubble post-harvest
Cultural Weed Management (being contracted)	Project to ascertain best bet combinations of cultural and chemical weed control tactics for each agro-ecological sub region. Herbicides remain the primary method of weed control in cereal crops because they are very cost effective, hence why farmers are reluctant to adopt integrated weed management (IWM) until they have a serious herbicide resistance problem. When resistance exists, farmers generally change to other modes of herbicide action (including herbicide-resistant crops); however, when resistance to multiple modes of action exists, farmers are forced to adopt more radical nonchemical or cultural control options. Crop competition is widely accepted as an important tactic for suppressing weed growth and maintaining crop yield. Agronomic choices influence crop competition, including crop species and cultivar, row spacing, crop density and row orientation. All these tactics have been shown to impact on the control of in-crop weeds. For wheat, while cultural factors such as row spacing, seeding rate, row orientation, nutrient placement, time of sowing and swathing/time of harvest are known to contribute to effective weed management, these management tactics have not been studied extensively in factorial combinations in different environments to demonstrate their relative contributions in a farming system. While significant effort has been focused on competitive agronomy in wheat and other cereals, much less effort has gone into crops such as canola. To advance this research, it is expected that more data will be needed on existing genetic variability of competitive ability in canola x agronomic region x agronomic practice. Using a limited number of diverse canola genotypes validation data could be collected on the existing genetic variability of competitive ability x agronomic region x agronomic practice. Adopting a holistic systems approach should deliver more practical information to growers on likely outcomes of specific agronomic IWM strategies. Growers can then make informed investment decisions.
Locally important weeds (DAW00257)	This project will undertake research to quantify the biology and ecology of eight (8) locally important weed species, 4 in the western region and 4 in the southern region. The weed species have been selected following a consultation process with the Regional Cropping Solutions Network (RCSN) and major Grower groups, with the final input and decision coming from GRDC. Weed species include matricaria (Oncosiphon spp.), marshmallow (Malva parviflora), stinking lovegrass (Eragrostis cilianensis) and Feathertop Rhodes grass (Chloris virgata) in the western region and Lincoln weed (Diplotaxis tenuifolia), wild vetch (Vicia sativa), caltrop (Tribulis terrestris), and Lake Boga poppy (Hypercoum pendulum) in the southern region. These weeds are of local importance but have not been the subject of major prior research projects.
Grains Industry Research Scholarship - David Hall (QUT) Automated Weed and Plant Recognition for Agricultural Applications (GRS10926)	The expected outcome of this project is a robust, plant recognition system which can be applied within an agricultural setting. This outcome corresponds to the "Protecting your crop" investment theme outlined in GRDC's Strategic Research & Development Plan 2012-17 as it can be used for in crop weed detection and management systems. Research expects to develop new plant detection and classification technologies which can be used as part of either an automated weed destruction system or an automated surveying system on a mobile ground platform. This system is expected to overcome the problems involved with applying such a system, such as the need to work in real-time, dealing with challenging conditions, and being adaptable to new crops and introduced weed species.

Issue No. 13 - Cereal diseases - genetic solutions and integrated management of Yellow Leaf Spot (YLS), Eyespot, Septoria tritici blotch and Leaf Rust.

GRDC investments addressing this issue -

Improving grower surveillance, management, epidemiology knowledge and tools to manage crop disease in Victoria (DAV00129)	This project operates under three broad objectives, i) generation of knowledge, tools and technology which improve disease management and incorporation of research results from research trials and demonstrations into disease management packages, ii) systematic surveillance, monitoring and disease diagnostics, and iii) services to growers and agronomists through provision of extension information and disease identification and IDM training relevant to the local environment and farming systems. Research focuses on integrated disease management of yellow spot in wheat, scald and net form of net blotch in barley, viruses in cereals and pulse crops and fungal diseases of pulses in the Southern Region.
Improving grower surveillance, management, epidemiology knowledge and tools to manage crop disease in South Australia (DAS00139)	The aim of this project is to identify disease threats, including emergency issues, and inform on management strategies for plant diseases that are impacting on the South Australian grains industry. Costs and losses to the grains industry will be reduced through improving grower management of crop diseases. Disease surveillance reports and management advice packages from active pathologist field surveillance will be developed and appropriately updated for cereals, pulses and oilseeds, and delivered annually. This includes emerging pathology issues such as virus management, ascochyta blight of pulses and white grain in cereals. A co-ordinated regional pathology strategy document will be updated and delivered annually to ensure that all stakeholders (growers, advisors, researchers, chemical companies and plant breeders) share this information as part of a nationally consistent extension effort. Seasonally appropriate, timely plant pathology capability and capacity in disease diagnostic support and appropriate rapid response to significant outbreaks of new and emerging diseases will be delivered as required. Pathotype changes, including virulences and fungicide resistances, will be monitored in coordination with centres of excellence, and information relayed to growers, advisors and breeding programs to enable improved crop type, variety, and fungicide selection to manage disease in the cropping season. An extension program will consist of timely electronic reports delivered in response to disease development dependent upon seasonal conditions. Annual technical support to deliver grower and advisor training in disease management will include publications and electronic media for best practice disease management in the context of cost-effective crop protection practice.
Improving grower surveillance, management, epidemiology knowledge and tools to manage crop disease in New South Wales (DAN00177)	Objectives of this investment – 1. characterisation of the frequency of insensitivity in Septoria tritici blotch populations to azole fungicides, and develop and communicate information to sustain the effectiveness of fungicides against this pathogen; 2. survey of high risk regions; 3. annual monitoring of STB monitor for further evolution of mutations in response to changed fungicide use patterns and determine geographical distribution patterns of phenotype sensitivity groups against key fungicides; 4. phenotype isolates to define sensitivity baselines for STB across a range of fungicide dose rates against a minimum of two registered modes of action; 5. sequence genes known to be implicated with fungicide resistance in STB; 6. measure efficacy of currently registered fungicides and new actives for the treatment of Septoria tritici blotch against known mutations using glasshouse pot assays; 7. deliver up-to-date knowledge on fungicide resistance management strategies and molecular tools for each disease; 8. develop a rapid molecular assay for the known fungicide resistance mutations
Germplasm enhancement for yellow leaf spot resistance in wheat (DAW00206)	Yellow spot (YS) (syn. tan spot) Is an important foliar disease of wheat in Australia and can cause losses exceeding 50% when conditions are favourable for disease development. The primary objective of this research is to identify opportunities to enhance resistance to YS through the development of genetic knowledge genetic resources and selection methodologies that can be applied by commercial breeding entities. Although good progress has been made internationally to

understand YS resistance, relatively few resistance genes have been Identified and mapped in Australian germplasm and only one (tsn1) is In general and known use in Australian breeding programs. There is a significant opportunity to enhance expression of YS resistance through identification of resistance factors other than tsn1 on chromosome 5BL.

The project aims to provide improved genetic solutions to VS management by -

1. Demonstrating robust phenotyping in different environments and key plant growth stages, for use In genetics studies that can be adapted for selection in breeding and are validated with appropriate field testing. This component will be delivered by DEEDI in conjunction with DAFWA, ACNFP and DPI Vic and will address aspects of evaluation of resistance including screening methodologies that provide the most precise, cost effective and timely means of evaluating resistance. A rapid adult plant assay will be developed under controlled environment conditions. Further demonstration of robust phenotyping will be undertaken through a 'ring test' using targeted resistant material which will be evaluated at both seeding and adult stages in Queensland, Vitoria and Western Australia. In addition robustness of phenotyping will be evaluated through multi-site screening of genetic mapping populations among the collaborators.

2. Assaying the current pathogen population for variation in virulence/aggressiveness on a range of genetic wheat stocks difference in response to the pathogen, to determine the potential for pathotype co-evolution associated with resistance gene deployment. ACNFP will develop a current national collection of isolates of the pathogen which will be assayed for variation in virulence on a range of targeted wheat lines. The purpose of this work is to determine the existence of pathogen variation that may have a potential for pathotype co-evolution associated with resistance gene deployment.

3. Improving the understanding genetics of resistance in current and future donors, and the genetic relationship and interaction with the 5BL toxin insensitivity locus. that can improve breeding outcomes. A major effort will be made to elucidate the genetic relationship and interaction of novel resistance loci and will address aspects of resistance including:
   - What genes other than tsn1 (5BL) are contributing resistance in Australian resistance sources?
   - How do these putative genes relate to current knowledge of international germplasm and can this knowledge accelerate access to breeding tools and strategies?
   - Are genetic determinants of resistance response in seedlings different from determinants of response in adult plants?
   - To what extent does combining novel resistance loci with the 5BL toxin insensitivity locus improve resistance expression?
   - Can non-adapted bread wheat introductions and synthetic hexaploid (or derived) material provides additional diversity for resistance breeding?

   An Initial consideration of the genetic materials available or to be developed In this project include ten existing mapping populations and three new proposed populations. In addition, effort will be made to combine genetic variability within the Australian germplasm by developing large single seed descent F2·5 populations from complex crosses involving genotypes with different sources of yellow spot resistance. This will maximise genetic recombination, generate potential parental stocks enriched for resistance and create opportunities for fine mapping.

4. Providing phenotypic disease data through phenotyping of mapping populations for QTL development and validation in different genetic backgrounds, including potential for pyramid10g through multi-locus MAS and closer linkage of QTL markers. DAFWA DEEDI and DPI Vic will phenotype at least two populations every year both 1n the glasshouse and field.
5. Providing elite resistant lines (validated through field and glasshouse testing) from doubled haploid populations, derived research populations and genetic resources worldwide to enhance resistance expression and diversity when used in Australian wheat breeding programs. A national set of candidate resistance donors (including durums) will be sourced from overseas and developed for use by project collaborators. Resistant germplasm identified from the above sources and from existing research populations will be validated over multiple

	years and field environments Effort will be made to introgress resistance genes individually and in pairs, into elite Australian background, in order to develop fixed lines that breeders can use as parents.
Yield loss response curves for host resistance to leaf, crown and root diseases in wheat and barley' (DAW00245)	This project has been designed to develop more accurate yield loss information for the major diseases of wheat and barley, including crown rot, yellow spot, septoria nodorum blotch, septoria tritici blotch, net blotch, scald, barley leaf rust and powdery mildew and nematodes. The five-year project, from 2014/15 to 2018/19, will generate yield responses to regional priority pathogens and nematodes for a range of varietal resistances and disease pressures from negligible to severe. This is being be done by conducting field trials across a range of cropping regions where the diseases occur. The project is developing information to support crop agronomic decision-making, considering crop sequence, varietal selection, stubble management, seasonal climate, for disease risk considerations. By gaining improved understanding of the actual impacts of disease, more growers and advisers will make improved agri-chemical and plant variety decisions, which will result in improved profitability and sustainability. This project has been designed to develop, collate and deliver quantitative information on wheat and barley variety response to disease that is comprehensive, comparative and reliable in terms of yield and other system-relevant indicators of the impacts of resistance. It will achieve this by generating yield responses to a representative range of varietal resistances for regional priority pathogens and nematodes and under a range of disease pressures. The Australian grains industry access a suite of crop management, agri-chemical and plant varietal options to deliver improved profitability and sustainable management of important disease threats. Crop agronomy is optimised within a range of crop sequence, stubble management, seasonal climate. sowing practice. soil type and disease risk situations. The industry has broadened its use of pesticides, particularly fungicides, as a means of seasonal disease risk management or as a tactical requirement. Resistant varieties continue to underpin the breadth of industry's approach to disease risk management including industry-wide regional benefits of epidemic mitigation and individual farm business benefits of profitability and sustainability. Optimising the mix of crop management, agri-chemical and plant variety options require a suite of information that can be integrated by individuals to make rational management decisions. To this end industry develop comprehensive, comparative and consistent qualitative information on varietal response to disease, supported directly by GRDC investment of around $1.5M p.a. in varietal disease response ratings for wheat and barley. This significant national effort effectively ranks varieties according to their likelihood of experiencing yield impacts (among varieties but within diseases) but does not quantify this risk in directly interpretable agronomic and economic terms that provide a more well-informed decision of how to optimise risk and profitability for a recognised suite of disease threats in a specific environment (both among varieties and between diseases). In providing growers with quantitative information about disease resistance, a significant national effort is required to develop comparative and consistent quantitatively based decision support rather than the broadly qualitative approaches currently available. In particular, the development of disease response curves indicating the potential yield losses associated with the selection of varieties with low levels (MS, S, VS) of varietal resistance has been identified by GRDC as a priority. This will assist in variety adoption strategies and also ensure growers are well prepared for situations requiring intervention with fungicide. The project will focus on regional disease priorities for the northern, southern and western regions including crown rot, root lesion nematodes, yellow spot of wheat and net blotch of barley, other foliar fungal diseases including rusts and mildew.
Centre for Crop and Disease Management (CUR00023)	CCDM Program 1 - Project A - Early detection and management strategies for fungal diseases CCDM Program 1 - Project B - Best management practices for fungal disease control CCDM Program 1 - Project C - Economics of disease management and capacity development. CCDM Program 2 - Extension and engagement CCDM Program 3 - Septoria nodorum blotch biology CCDM Program 4 - Tan (yellow) spot CCDM Program 5 - Net form of Net Blotch Functional Genomics

	CCDM Program 6 - Sclerotinia Stem Rot of Canola and lupins CCDM Program 6 - Ascochyta blight of pulses CCDM Program 8 - Durable Resistance to Powdery Mildew CCDM Program 9 – Fungicide resistance
National pathogen management modelling and delivery of decision-support (DAW00228)	Improving crop yield in Australian farming systems is hindered by a number of factors; crop disease is one of them. Recent reports commissioned by GRDC indicate that the annualised costs of diseases of cereals, and oilseeds and pulses is over $1.2 billion and $210 million, respectively. Managing diseases at the right time with the right control techniques can and will substantially reduce the costs of diseases and thereby increase farm income. However, such management needs to be economically viable. This project aims to provide the grains industry with tools and processed information in order to aid decisions on economically feasible crop disease management.
Benchmarking resistance and managing Septoria tritici Blotch and Leaf Rust (FAR00004A)	The research will combine field research on fungicide performance with laboratory testing of the fungal populations pre and post fungicide application in the regions where these diseases are most problematic. It will also give an early warning system across the prevalent regions for detection of resistant mutants following SDHI and strobilurin application.
Septoria Resistance	Effective genetic control of Septoria tritici blotch (DAN00203)
Rust Resistance – a range of investments	1. ACRCP- CIMMYT delivery of resistant germplasm and surveillance for resistance in Australian cultivars (CIM00017) 2. Triple Rust Resistance Project – ACRCP (CSP00161) 3. ACRCP- Molecular marker program CSIRO/University of Sydney/CIMMYT collaborative project (CSP00164) 4. Advancement of new genes for stem and leaf rust resistance from uncultivated relatives of wheat -continuation (UA00141) 5. Australian Cereal Rust Control Program - Durable genes (US00063) 6. Australian Cereal Rust Control Program - National breeding support (US00064) 7. Accelerating the utilisation and deployment of durable adult plant resistance to leaf rust in barley (US00070) 8. Development of genetic tools for Australian barley crops against leaf rust (US00074)
Regional Agronomy SA - Improving disease management through improved agronomic practices (DAS00167-BA)	Guided by a literature review, this project will identify at least three field crop diseases where improvements in management are possible and then instigate a range of field experiments and paddock surveys to produce a range of integrated disease management strategies aimed at improving the efficacy of current best management practice. Diseases of field crops in the Southern Region currently cause growers considerably in terms of loss of yields and grain quality as well as the expenses associated with controlling disease. Murray and Brennon (2012 a,b,c & d) estimated that diseases of wheat currently costs growers in the Southern region $62 .10/ha, disease in barley costs $53 .27 /ha, disease in oilseed crops costs $63/ha and disease in pulse crops costs $37/ha. Disease control can be provided through genetic resistance, cultural methods and through the application of fungicides. An understanding of agronomy and farming systems, can be used to improve the performance of disease management by incorporating genetic resistance, cultural controls and fungicides to provide sustainable, cost effective strategies to match the risk of disease to various agro-ecological environments.
National improved molecular diagnostics for disease management. (DAS00137)	This project will reduce the costs and losses through Improving grower management of crop soilborne diseases. This will be achieved by industry increasing cost effective adoption of fungicide resistance management plans to 50% and increasing cultural management strategies as a key control strategy to 40% of growers surveyed by GRDC. This will be achieved through the delivery of the following objectives: 1. New knowledge, tools and technologies that provide an effective balance of genetic, cultural and chemical options for control and that support the integrated management of crop disease and impacts on yield, quality and crop returns. 2. Manage and prioritise emerging pathogen risk by improving knowledge of epidemiology for current and emerging diseases through systematic survey and modelling.

	3. An Increased focus on emerging diseases affecting grain quality and production, and improved molecular diagnostic field monitoring, early warning tools and models which will reduce costs and losses for growers. 4. Increased grower and advisor use of an integrated approach using resistant varieties, cultural management and fungicide use options to support crop planning and in-a-op disease minimisation. 5. Advisors will have targeted plant disease training so that growers can have access to independent information to manage crop disease appropriate to their geographic circumstances and crop rotations.
Australian Cereal Rust Control Program - Towards 2019 and a century of monitoring cereal rust pathogens in Australia (US00067)	Rusts are among the most damaging of all cereal diseases, and are of high biosecurity concerns because of their abilities to spread rapidly over huge distances and develop explosively in susceptible crops once established. A graphic reminder of this was documented in 2014-15, when a new exotic leaf rust pathotype was found in SA and then spread to all Australian wheat growing regions in only 13 months. In 2009, rust diseases of wheat and barley alone were estimated to have the potential to cause $1.8 billion in damage if left unchecked. Rusts can and have been successfully controlled by resistance, with annual savings from this approach in wheat and barley estimated at over $1 billion. This project tangibly contributed to these savings by providing early warning to growers on the occurrence of new rust pathotypes, and changes in the rust responses of cultivars as a result of these new rusts. It also provided guidance to resistance breeding efforts by identifying the most important rust pathotypes to be used in breeding nurseries, and also in the genetics program that has identified and incorporated many new resistance genes that have saved growers from yield losses due to rust infection. For example, the resistance genes Lr24/Sr24, and Lr37/Sr38/Yr17, which were introduced and incorporated into locally adapted germplasm by ACRCP staff at the University of Sydney's Plant Breeding Institute, were identified using select rust pathotypes identified in the national surveillance program. These resistances have been incorporated into at least 126 wheat cultivars (e.g. Bremer, Cutlass, Elmore CL Plus, Gazelle, Hatchet CL Plus, Impala, Mace, Scenario, Scepter, Scout, Sunlamb). Due to their airborne nature, the ability of the pathogens to change, and because of their sporadic occurrence, a nationally coordinated approach to rust control is essential if genetics is to continue to deliver the savings it has done in the past, and to reduce the current cost to industry, which is in the order of $177 million in losses and $187 million in fungicides. New rust pathotypes with the ability to overcome 4 resistances in wheat (e.g. Lr13+Lr24, Lr13+Lr37, Lr13+Lr12) and 2 in oat (Pc91, PcDrover), and an incursion of an exotic leaf rust pathotype in 2014, underscore the need for ongoing R&D to ensure industry-wide rust protection.
Improved fungicide use for cereal rust control (FAR00002)	This project has been set up as new component of the Australian Cereal Rust Control Programme (ACRCP) research programme lead by Sydney University Plant Breeding Institute (PBI) at Cobbitty, near Sydney. The project entitled "Integrated Fungicide Management - Improved fungicide use for cereal rust control' will be established to contribute to, enhance the genetic protection of Australian cereal crops from breeders to control cereal rusts. By integrating fungicide management with more diverse sources of genetic resistance the project aims to reduce overall dependency on fungicides for rust susceptible cultivars and reduce both the impact of disease in high risk situations and the overall inoculum loading in the environment. The Integrated Fungicide Management Project led by the Foundation for Arable Research, has three distinct objectives: 1. To increase the understanding of how new fungicides, with new modes of action, can be used to enhance the effectiveness of adult plant resistance (APR) for the control of cereal rusts in new cultivars. 2. To optimise the timing of new fungicide actives and formulations for the control of cereal rusts In commercially available wheat cultivars. 3. To provide stewardship information on fungicide management on known genetic backgrounds to breeders. Integrating the use of newer fungicide active ingredients with recently released cultivars will be done in collaboration with both agrichemical manufacturers and breeders. The controlled environment studies would be targeted at improving our understanding of curative and protectant properties of new fungicides In relation to the control of cereal rusts. This information would then be ground truthed under field conditions with a view to formulating

	improved fungicide management strategies. It is proposed that this study will focus on different rust species and different rust resistance sources in individual years of the project. , The field studies will establish the optimum rates and timings for newer fungicides when applied to regional cultivars with Intermediate disease resistance to cereal rusts. The same trials will also look to verify whether the new strobilurins and succinate dehydrogenase Inhibitors (SDHI) fungicides enhance green leaf retention during grain fill to a greater extent than currently available fungicides (a feature of these products observed overseas).
Hyperparasites for the control of cereal rusts in Australia (UHS11004)	Undergraduate Honours Scholarship Existing control of rusts on cereal crops in Australia predominantly consists of planting resistant cultivars [Ellis et al. 2014, Park 2008], along with fungicide use and preventative agronomic practices such as tillage, crop rotation, and green bridge destruction. Use of rust-resistant cereal crops has generally been effective, however, the evolution and spread of virulent rusts strains that can infect previously resistant cultivars are having significant impacts on effective control [Lemma et al. 2015, Olivera et al. 2015, Singh et al. 2015]. Rust fungi evolve rapidly [Hulbert & Pumphrey 2014] and cultivars with race-specific rust resistance genes can become susceptible after a few years of use due to the development of strains with matching virulence [Kolmer 2013]. Because of the negative impact on the environment due to increases in fungicide use [Woo et al. 2014], and emerging fungicide resistance [Singh et al. 2016], there is demand for environmentally responsible techniques of disease control. In addition, there is increasing interest in natural biocontrol methods for organic food production, due to public concern about health effects of fungicides and their impact on the environment. The use of biocontrol may be an environmentally sensitive alternative, or simply a further line of defence against increasingly more virulent strains of rust. The experiments in this project were designed to investigate the effects of hyperparasite isolates on rust pathogen development, growth and sporulation during colonization of plant hosts. Susceptible cereal plant cultivars were grown and infected with host plant specific rust pathogen and treated with each hyperparasite conidial inoculum. This was conducted on sections of cut leaves plated on water agar. The cut-leaf assay involved treatment with hyperparasite inoculum prior to rust infection. Using microscopy at 16-40 x magnifications, the numbers of rust pustules were counted per 2 cm leaf section. Results showed all treatments, on all three rust species tested displayed significant ($P < 0.01$) reductions in the average number of rust pustules that developed compared to controls. Microscopic observations showed fungal colonization of rust. Other observations included erratic pustule growth in most treatments, reductions in pustule size, aborted rust lesions and low sporulation of urediniospores produced from lesions that were present in each treatment type. Necrotic patches in the leaf surface were present in some treatments. In some cases, heavy fungal colonization created complex networks of mycelium over pustules, physically containing urediniospores. Fungal growth appeared to be present on rust uredinia, and absent on healthy leaf surfaces. The results may indicate that hyperparasites can be species-specific antagonists to different species of rust. Mechanisms of action include direct parasitism in some cases, results indicating the production of antifungal compounds and not simply a plant defence response, and combinations of these actions that produce anti-fungal compounds, but also appear to be directly hyperparasitic. Some cultures may have prevented rust entry and/or induced plant recognition of pathogen. Some hyperparsites may additionally have a beneficial effect on host plant growth. The results of this study confirmed the potential of hyperparasites to minimize disease due to rust pathogens on cereal plants and therefore support the original hypothesis