GRDC INVESTMENTS ADDRESS MEDIUM RAINFALL RCSN – June 2017

Issue No. 1 - Profit focused cost and productivity management can increase profit.

This issue was a combination of three issues relating to profit and costs. As growers reach water limited yield potential, assuming that maximum grain price is also being achieved, there is a need to look for other opportunities to increase profit. Obviously, there will be businesses where extracting more grain yield and achieving higher grain prices remain sources for improved profits.

Growers are concerned about the increasing cost structures of businesses as they increase scale and intensity and take on more debt. A continuation of this trend will erode profits.

It is suggested that a better understanding of business costs and strategies to more effectively manage costs is required to further improve profit. It is recognised that farm businesses with upper quartile returns display business acumen and are focussed on profitability.

<u>GRDC investments addressing this issue</u>

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).
The integration of technical data and profit drivers for more informed decisions (RDP00013)	This national project is being delivered across the 14 major grain zones in Australia through the collection of more than 300 benchmarking datasets in collaboration with five consulting organisations. These benchmarking datasets have been analysed to identify the key management affected profit drivers by agro-ecological zone. The quantitative benchmarking analysis has also been complemented by a qualitative survey process with grain growers across each region. A consistent message from the results is that there is a large gap in financial performance between the top 20% businesses and the average business in each zone and there is abundant opportunity to increase profit from the resources that growers have available to them. Adapting to manage key production and business risks is an important characteristic of successful and sustainable farm businesses. To quantify differences in risk profile between the top 20% producer and the average business in each dataset the project undertook some modelling using @Risk software. This quantified that the top 20% businesses have a lower risk profile and a lower probability of incurring operational losses in comparison to average businesses. There are a range of management affected profit drivers that can be influenced to increase profit in cropping businesses across both the SA Mid North, Lower Yorke Eyre and the SA – Vic Mallee agro-ecological zones. Most of these profit drivers are within the control of the farm manager providing significant opportunity for increased productivity. Proactively influencing the identified profit drivers will enable businesses to increase financial performance and reduce risk.
Practical financial figures for farm business management – aka Ag Profit (APR00001)	Continuing increases in volatility in key areas of the farm business sector exposes farmers to greater challenges in managing the financial risk to their business. Currently there are limited resources available to both farmers and Industry to assist farmers in improving their farm business management capability. The objectives of this project are to: 1. Increase awareness of the need for sound farm business management practices; 2. Facilitate the integration of business advisers (including regional accountants) into the development of industry farm business management strategies and initiatives; 3. Maintain innovative data analysis reporting outputs through input from well-regarded contributors from diverse geographic, rainfall and irrigation areas; 4. Provide a farm business data collection, storage, analysis, reporting and training service at a commercially accepted quality so that accountants are sufficiently enthused about 'partnering' with Ag Profit to promote this service to their clients; 5. Increase the number of growers participating in the project database application so that data analysis reporting can be of an increasing statistical quality; and 6. Securely manage all business data so as to avoid any breach of privacy.
National Paddock Survey Initiative (BWD00025)	Consultants and grower groups are working with grain producers in all grain growing regions to quantify the yield gap between actual and water-limited potential yield. Detailed monitoring of 250 paddocks over a four year rotation will identify the main yield constraints and develop amelioration practices to profitably close the yield gap. Annual paddock monitoring includes: • Soil water and soil chemistry at sowing and harvest • Soil borne disease monitoring using PredictaB • Paddock history (crop types, inputs, yield)

	• In-crop monitoring of crop growth, weeds, insects and diseases • Paddock management – sowing date, cultivar, inputs, in paddock temperature during flowering/grain filling • Yield mapping to identify low and higher yielding parts of the paddock CSIRO are responsible for analysing monitoring data and undertake the yield gap analysis. Results will increase the understanding of interactions between different constraints limiting yield and help optimise agronomic decisions to assess production potential and manage risk.
Rural R&D for Profit — Seasonal forecasting	The purpose of the program is to bridge the gap between seasonal climate forecasts and farm business decisions, and to improve productivity and profitability. The program will: • define the critical seasonal climate risk information needed by Australian farmers • improve understanding of the usefulness of seasonal climate forecasts and how to incorporate these into business decision making • provide seasonal climate information which can be tailored to individual needs • improve seasonal climate forecast skill in agricultural areas. The program plan addresses the following three priorities: Valuing the forecast. It is very difficult to assess how to use a forecast in a meaningful way if a person doesn't know how useful (valuable) a forecast is for a certain region at a given time. This is particularly true because forecasts are usually presented in probabilities, which are difficult to understand, especially for on-farm decision-making. Using the forecast. We know that farmers have higher profits if they better understand what a forecast actually means, and how to use that forecast to manage risk. This is achieved when farmers minimise losses in bad years and maximise returns in good years. Improve the ACCESS-S forecasting model. It's fundamental that any improved use of forecasts must be accompanied by improved forecasts. This area of the project aims to correct biases within Australia's seasonal forecasting model, ACCESS-S, in relation to atmospheric convection. Fixing the biases will deliver forecasting benefits across Australia, particularly in regional areas.

Issue No. 2 - High value pulse crop varieties (lentils and chickpeas) bred for a wide range of soil types and rainfall zones will improve farm profitability on a broader scale.

There is an opportunity to expand and intensify the production of high value (>$600/t) lentil and chickpea crops and increase the profitability of farm businesses. The development and adoption of improved varieties and agronomic packages are essential to capitalise on this opportunity.

GRDC investments addressing this issue –

Pulse Breeding Australia – Lentil Breeding Program (DAV00119)	Project outputs are: 1. One broadly adapted medium to large-seeded IMI tolerant red lentil variety with the following characteristics: - Yield higher than PBA Hurricane XT - Ascochyta resistance rating of R - Shattering, pod drop and lodging resistance of at least MR - Flowering and maturity equivalent to PBA Hurricane XT 2. At least one other IMI tolerant variety with the following characteristics: - Moderate salt tolerance (at least equivalent to Nipper) - Early maturity equivalent to PBA Blitz - Yield higher than PBA Hurricane XT - Ascochyta resistance rating of at least MR - Shattering, pod drop and lodging resistance of at least MR

	3. A conventional red lentil variety with the following characteristics: - Tolerance to boron equivalent or superior to best PBA lentil varieties - Yield superior to PBA Bolt - Moderate salt tolerance (at least equivalent to Nipper) - Ascochyta resistance rating of at least MR - BGM resistance superior to PBA Bolt - Shattering, pod drop and lodging resistance of at least MR - Maturity equivalent to PBA Bolt 4. Lines with novel herbicide tolerance from project (DAS00107) evaluated in the field.
Pulse Breeding Australia – Chickpea Breeding (DAN00212)	Project outputs will be new varieties with increased yield potential and improved seed quality. The project will concentrate on a restricted set of breeding objectives: resistance to disease (AB, Phytophthora root rot (PRR); appropriate phenology (allied to chilling tolerance); salt tolerance; improved harvestability; and improved seed quality. The mix of adaptive features incorporated into new varieties will reflect the regional importance of the key production constraints. Breeding target traits for medium rainfall zones (Wimmera (Vic), south eastern (NSW), Yorke Peninsula, Mid-North, Lower Eyre Peninsula) are: **Desi traits:** • maintain AB resistance equivalent to PBA Slasher • improved adaptation and farming system fit through phenology, particularly chilling tolerance and earlier maturity • improved harvestability through plant type, increased pod height and improved lodging resistance • improved seed colour and size (equivalent to PBA HatTrick) • improved salinity tolerance as identified in controlled environment screening • improved registered herbicide tolerance and/or novel herbicide tolerance if identified in the herbicide tolerance project (DAS00107). **Kabuli traits:** • increased AB resistance with 9 mm seed size • increased adaptation through phenology, particularly chilling tolerance • improved salinity tolerance as identified in controlled environment screening • improved registered herbicide tolerance
Understanding the implications of new traits on adaptation, crop physiology and management of pulses in the southern region (DAV00151)	1. New traits for modern farming systems - Strategic genotype x management research will be conducted that provides information on understanding and maximising the benefits of new traits/genes recognised in the breeding program through improved crop management - a. Herbicide tolerance and weed ecology - Understanding the agronomic importance and viability of traits linked with weed management and herbicide tolerance in lentil and faba bean (metribuzin and Group B tolerance) and chickpea (potentially Group B and Group I). Implications for weed management and ecology will also be considered, including early maturing varieties for crop topping. b. Disease management – In field pea, blackspot continues to be a major limitation to production. Recent work in SA by the SPA and in France by INRA suggest there are opportunities to minimise the risk of blackspot by combining novel fungicide applications, with improvements in genetic resistance enhanced by plant morphological and architectural differences. In faba bean and chickpea, resistance to ascochyta blight has recently broken down and implications for management packages need to be elucidated. c. Canopy management (biomass and architecture) – In lentils and faba beans improvements in vigour, architecture and biomass development combined with improved disease resistance, may require reduction in seeding rates, particularly when combined with early sowing dates to secure yields in dry years. There are also opportunities to better manage bulky canopies and maximise pod set through a combination of crop management and genetic practices including the use of PGR's. d. Harvest quality – Little is understood about the impact of adverse weather events on mature crops, yet major quality and industry issues have arisen when they have occurred in the past. Genetic and

	agronomic differences have been reported as being important in reducing quality losses. Opportunistic research through trials assessing delayed harvest and weather events on a range of genotypes under the same conditions will add to this knowledge both for producers and breeders. 2. Variety specific agronomy packages (VSAP) - Targeted agronomic research will produce data for new pulse varieties which will be synthesised into management packages for the southern Australian cropping regions in collaboration with PBA or other pulse breeding organisations. This will deliver maximum benefits of new varieties to growers immediately after they are released. The pulse industry views the delivery of VSAP's and the matching of genotypes to optimum farming systems as an essential link in the development of new varieties by PBA.
Improving weed management in pulse crops through herbicide tolerance (DAS00131)	A lack of herbicide options in pulse crops limits weed control, production and area sown. This inability to adequately control weeds in pulses affects their adoption and role in farming systems, particularly given that the prevention of weed seed set in these crops is a vital tool in weed management. Suitable and safe herbicides are limited in pulses, especially for the post emergent control of broadleaf weeds, with many registered herbicides having a narrow crop safety margin. This project will develop and supply to PBA, germplasm with improved tolerance to registered herbicides and tolerance to new herbicides leading to the generation of varieties that will assist in increasing the productivity and profitability of pulses in Australia. Project Outputs: 1. Chickpea (desi and kabuli) lines with at least 1 novel source of herbicide tolerance, field validated and delivered to PBA. The novel herbicide target decided in consultation with industry. 2. Development of herbicide tolerant lentil germplasm from putative tolerant lines (metribuzin) developed in a previous project. Lines screened for tolerance and the most promising of these lines will be multiplied and validated through glasshouse and field dose response experiments to identify agronomically useful level of tolerance for use by the PBA lentil breeder. 3. Selections showing low levels of damage from dicamba (faba bean and lentil) and carfentrazone-ethyl and isoxaflutole (lentil) mass field screens multiplied and assayed for tolerance under controlled conditions. Lines showing useful levels of improved tolerance will be multiplied and validated in dose response and field experiments and those with agronomically useful levels of improved herbicide tolerance delivered to PBA breeders. 4. Development of cost effective, repeatable and non-destructive screening methods for stacking of herbicide tolerances in pulses and the subsequent development of lentil and faba bean germplasm with multiple herbicide tolerances. 5. Screening methods, including the use of diagnostic markers where applicable, developed to rapidly and non-destructively identify lines from opportunistic crosses aimed to specifically improve levels of herbicide tolerance. 6. Identification of other potentially useful herbicides for screening in pulse mutant populations. 7. In consultation with industry, appropriate herbicides will be identified for future screening.
Collection, phenotyping and exploitation of wild Cicer genetic resources for chickpea improvement (CSP00185)	While chickpea production has expanded dramatically over the last decade to become Australia's most valuable pulse export, the Mediterranean regions in the south and west have not recovered their earlier position as the dominant production areas for this crop. In addition to Ascochyta, Mediterranean production regions pose specific adaptive challenges such as terminal drought, low temperatures during flower and podset, salinity and low pH (particularly in WA). Genetic solutions to these constraints will accelerate the spread of chickpea throughout Mediterranean Australia and address grower demands for more diverse rotations incorporating a profitable grain legume. Chickpea improvement is constrained by limited genetic and adaptive diversity, and there is a need to increase the pool of germplasm that breeders can draw on in order to develop improved varieties adapted to Southern and Western cropping regions. This project seeks to strengthen chickpea breeding efforts and act as model for the exploitation of wild genetic resources by: 1. Targeted collection to widen the habitat range and genetic diversity of existing collections 2. Extensive phenotyping of traits prioritized as limiting Mediterranean adaptation 3. Coordinating wild Cicer-based phenotyping and population development projects in

	Australia and Turkey, linking these with international collaborations involving the USA, Canada, Ethiopia and India.

Issue No. 3 - No-till cropping farms do not have the infrastructure, tools/technologies, and knowledge/skills to integrate livestock into the business.

Many no-till grain growers recognise the advantages of integrating livestock into their farming system to provide income diversity, reduce input costs and increase profits. Paddock size, fencing, water points are often inadequate to manage grazing without causing damage to the soil resource. A range of new and modern tools may offer potential solutions which would allow growers to capture this opportunity.

GRDC investments addressing this issue -

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. Smarter grazing of crops and stubbles to optimise business and production risk and increase profit - 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. Better manage crop and pastures (within) a rotation to improve crop and livestock production - 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. Farmers making informed decisions about farm business mix that best meets their needs - 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. 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.

Issue No. 5 - Efficacy of glyphosate is declining due to over-use and increased incidence of glyphosate resistant weeds.

Glyphosate has multiple and ever increasing use patterns- knockdowns, fence-line hygiene summer weed control, in-crop weed control in Round Up Ready Crops and spray-topping. The extent and number of weed species developing glyphosate resistance is also rapidly increasing. The efficacy of glyphosate is quickly declining. Glyphosate resistance threatens the viability of no-till systems. It is the key non-selective tool used to manage weeds during fallow periods. Hence, the urgent need to develop alternative tools and systems to manage weed without glyphosate.

GRDC investments addressing this issue

GRDC Australian Glyphosate Sustainability Working Group (ARN0001)	Produce the latest information on the status of non-selective herbicide resistance and effective management strategies relevant to their farming systems through a nationally coordinated extension program that includes a specific web site, media releases and extension materials. Integrated weed management training programs will be modified to incorporate the latest developments. A consistent message on the management of glyphosate, paraquat and Group I resistance is extended across Australia. Web site - http://www.glyphosateresistance.org.au Facebook - https://www.facebook.com/Australian-Glyphosate-Sustainability-Working
GRDC – Bayer Crop Science Herbicide Innovation Partnership (HIP00001)	Investment in herbicide discovery. Increasing capacity of Bayer the leading cereal herbicide multinational. Australia lifted to priority 1 status in preliminary screening (equal with EU, USA and Sth America) with 10 Australian weeds in primary screening and primary field screening of molecules occurring in Australia.
Australian Herbicide Resistance Initiative (AHRI) – Phase V (UWA00171)	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 (UWA001724)	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. The WeedSmart campaign ensures that the latest information and practical solutions reach grain growers as quickly as possible. WeedSmart continues to promote practice change on farm by providing growers and advisers with well researched management strategies to curb the impact of resistance and, therefore, increase the sustainability of available chemicals.
Benchmarking and managing soil herbicide residues for improved crop production (DAN00180)	To benchmark the risk of soilborne herbicide residues to crop production, including indirect effects on soil function and direct plant-back risks. To develop models and monitoring tools to assist farmers and agronomists in managing herbicide residues in soils. Anecdotal evidence also suggests that plant-back damage in rotational crops due to herbicide residues is a growing concern amongst growers, but the scale and cost to the Australian Grains industry remains unknown. This project will benchmark level of herbicide residues in cropping soils and generate new knowledge about the fate, behaviour and risk of herbicides to productivity. This will enable the Australian grains industry to better understand the risks and implement changes in management for more productive and resilient farming systems. A review of over 340 peer-reviewed articles found that there is little evidence for consistent, long-term impacts to soil (microbially mediated) functions caused by herbicides when used at

	registered label rates. Some site-specific exceptions include the interaction of sulfonylurea herbicides with certain pathogens (e.g. Rhizoctonia) on alkaline soils to increase disease risks and inhibit N-cycling processes. Controlled laboratory experiments screened the impacts of 6 different herbicides on soil enzyme activities and N-cycling in 5 different soil types and confirmed that effects are minimal at up to 5 times label rate application. Metsulfuron-methyl had significant but minor impacts (<25% of control level) on nitrification in 3 of the 5 soils tested (impact on 2 alkaline soils and 1 low OM soil). Two nationwide field surveys across in 2015 and 2016 determined baseline levels of herbicide residues in Australian grain growing soils prior to sowing. The dominant residues in both surveys (in terms of detection frequency and residue load) were the herbicide glyphosate and its breakdown product AMPA, plus the herbicides trifluralin and diflufenican. Relatively high levels of triasulfuron and diuron were also found in some regions. Plant bioassays have been conducted to determine the risk of these herbicide residues on crop growth and symbiotic associations (rhizobia in legumes for biological N2-fixation). A new model to predict herbicide persistence in soil has been developed and validated in conjunction with a rapid, inexpensive Quicktest™ to quantify atrazine residues.
Mechanisms, evolution and inheritance of resistance (UA00158)	The objective of this project is to develop new understanding of the mechanisms, inheritance and evolutionary dynamics of resistance to key herbicides in Australian agriculture. The project will concentrate on understanding glyphosate resistance in brome grass, barnyard grass, Sowthistle, windmill grass, fleabane and feathertop Rhodes grass; 2,4-D and diflufenican resistance in Indian hedge mustard; 2,4-D resistance in common sowthistle; clethodim resistance in annual ryegrass; and resistance to the pre-emergent herbicides trifluralin, propyzamide, triallate and prosulfocarb in annual ryegrass.
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.

Issue No. 6 - 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 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.

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:

	1. 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. 2. 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. 3. 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. 4. 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. 7 - 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 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 sowthistle/milkthistle, 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.

Harvest weed seed control for the southern region (SFS00032)	Develop and validate harvest weed seed control techniques for the higher rainfall and irrigation areas of the southern grain cropping region of Australia. The project Harvest weed seed control (HWSC) for the Southern high rainfall zone was implemented to evaluate the efficacy and reliability of HWSC practices in that region. Seven small plot trials have been implemented over 2015 and 2016 with the main focus being on annual ryegrass (ARG). In 2015 three trials were conducted investigating the impact of varietal phenology, time of sowing (TOS) and harvest height. three wheat varieties, early, mid and late maturity were sown a three different TOS, (early, mid & late). Each treatment was harvested at 15cm high or 30cm high to impersonate HWSC harvest technique (15cm) or the more traditional harvest heights of 30cm. All harvest trash was captured in bags and removed to prevent any ARG weed seed that entered the plot harvester being placed back on to the plots. Weed seed shedding prior to harvest was collected in two trays per plot to determine numbers of weed seeds escaping the HWSC system. In 2016, as a result of no significance of any treatments in 2015 on ARG soil seed bank numbers, trials were sown to one variety at one TOS and harvested at the same height as used in 2015. This would provide large numbers of replications to smooth out impacts of ARG weed density variation. Native populations of ARG across all sites were highly variable as evidenced in 2015. Four on farm trials were also implemented in in 2015 and another 4 on farm demonstrations in 2016. Two were at existing sites from 2015 and two were new sites in 2016.
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.

Issue No. 8 - The current processes for pesticide legislation and governance within APVMA restrict timely access to pesticides and negatively impact on crop production and profit.

The current regulatory process for the registration of new and/or an extension of chemical use patterns is lengthy which limits access to tools that growers require to cost-effectively manage risks. A lack of registered products and timely permit renewals impacts on product supply, the management of weeds, pests and

disease and resistance. Growers perceive that regulators do not fully comprehend the financial impact of restricted or delayed access to chemicals e.g. fungicides.

GRDC investments addressing this issue

Not within the GRDC mandate as this is a policy matter dealt with through both the APMVA and legislation which is managed by the Dept. of Agriculture and Water. Policy issues need to be through grain grower representative groups such as GPA and GGL.

However please note that APMVA legislative time frames are shorter than its counterparts in Canada, USA, EU, NZ and UK

GRDC may provide scientific comments on APMVA documents and does so in regard to where there are documents for public comment such as registration public release summaries (PRS), chemical review and trade advice notices (TANs).

Pathways to registration (PHA00012)	Gathering and Prioritisation of crop x pest x solutions, followed by data generation for registration submission
Minor Use applications (AKC00006)	Maintenance of current permits and submission of new permits for minor use including data generation where required.
AgVet Access grants	The programme will provide funding to assist with data generation to support an application to the Australian Pesticides and Veterinary Medicines Authority (APVMA) that seeks to gain, maintain or broaden access to priority uses of agvet chemicals identified by the collaborative forum.
Ag chemical priority forum (cross RDC project)	Annual forum where crop by biotic threat is provided to the ag chemical industry for them to nominate possible solutions

Issue No. 9 - Increased seasonal climate variability creates extremely contrasting growing seasons and requires adaptive, agile and flexible management options to optimise yield and maximise profit including but not limited to a "menu" of crop species and cultivars.

The changing climate has increased the extremes and variability of seasons, e.g. an extreme dry followed by an extreme wet in the 2015/16 and 2016/17 seasons. Growers require a greater range of knowledge and management skills to optimise profit from such contrasting seasons, i.e. management complexity is increased.

GRDC investments addressing this issue

Improving forecast accuracy, especially with improved Indian Ocean Initialisation (MCV00008)	Overview Sea surface temperature (SST) variations in the tropical Indian Ocean are a prominent source of climate variability for Western Australia through to south-eastern Australia. Much of the climate anomalies that develop over south-eastern Australia during El Nino Southern Oscillation (ENSO) events are a result of the co-variance with SST in the Indian Ocean. The forecast skill of tropical Indian Ocean SST with the POAMA1.5 and POAMA2 seasonal forecast systems is much less than for that in the Pacific Ocean. The main purpose of this project was to investigate the reasons for the lower skill in the Indian Ocean, to what extent this has improved in POAMA-2 which utilises a new ocean data assimilation scheme and to what extent further improvements in the ocean initialisation can lead to increased skill. During the project there were two upgrades to the operational version of POAMA. POAMA- 2P replaced POAMA-1.5 as the Bureau's seasonal prediction system. POAMA-2P included the new ocean data assimilation system called PEODAS. Evaluation of the impact of PEODAS was carried out as part of this project. There was also a second upgrade to POAMA-2M, a version more suitable for multi-week prediction. POAMA-2M included some enhancements developed as part of the MCV-Multiweek project. In May 2013 the Bureau decided to start using POAMA forecasts for its official seasonal climate outlook, the first

	time that dynamical based forecasts have been used at the Bureau for regional temperature and rainfall. This is a major step for the Bureau as it shifts from basing its climate outlooks on statistical models to basing the outlooks on a dynamical model, POAMA. The main outputs of this project were threefold: a. Increased understanding of the use of ocean observations by the POAMA model, the performance of the assimilation technique, and the impact of the systems on the forecast performance, including benchmarking against other international systems b. Development and evaluation of improvements to the initialisation strategy, and recommendations for which should be included in the next version of POAMA c. Science papers and research reports that document the project discoveries
Assessing and managing heat stress in cereals (MCV00006)	This project investigated the damage to wheat yield caused by hot spring days, the likelihood of these hot days and strategies to manage the risk. When the likelihood of a hot day is considered in the context of flowering time, flowering in October and early November in some of the high rainfall regions have similar or higher risks of a hot day than low rainfall regions flowering in September. Through discussions with grain growers and agronomists, a spread-sheet and interactive workshop has been developed which explores the trade-offs between the heat and frost risk. The most likely use of the risk management information is tactically in a season that the break is late (hence heat stress dominates over frost risk) and a grain grower is weighing up the risks on whether it is worth sowing marginal paddocks.
Impacts of climate on low rainfall and marginal areas (CSA00053)	The project gathered information relevant to all GRDC's agro-ecological zones focussing on the Low Rainfall Zone (< 250mm). It undertook a series of reviews around farm business structure and climate risk, methods for effective identification of resilient genetic traits from existing trials, and climate prediction services. A review and survey revealed that the most significant barriers to use of seasonal cropping forecasts were: • perceived lack of local or regional relevance; • perceived lack of sufficient lead time; • perceived lack of skill/accuracy during periods when critical farm level decisions and period of time during which the SCF has perceived skill; • context relevant knowledge products; and • perceived lack of application to understanding how SCF's translate to measurable improvements in farm profitability.

Issue No. 10 - Growers are not able to predict the risk of pest and disease incursions to plan and proactively manage.

Understanding and being aware of the risk of a range of pests and diseases e.g. Russian Wheat Aphid, Beet Western Aphid Virus etc. would enable growers and advisors to better plan and implement timely strategies to proactively and more effectively manage identified risks. This could be achieved by modelling and communicating climate conditions which are generally the major pre-cursers that influence the risk of disease and insects invasions. This information could be used to assess the risks and provide an early warning system to enable growers and advisors to develop and implement strategies to cost-effectively manage insect and diseases.

<u>GRDC investments addressing this issue</u>

Predicting insect pest issues in Australian grain crops (UM00054)	In order for farmers to effectively, sustainably and efficiently manage invertebrate pests in grains, predictive models that describe the interaction between local weather conditions (e.g. rainfall and temperature) throughout the season and pest population dynamics should be developed. This project will gather (and in some cases establish)

	biological parameters for multiple pests of grain crops and use them to predict outbreaks and severity. Mechanistic and phenological models will be employed to generate predictive models that will be subsequently validated using field surveys and experimentation. In addition, correlative (Ecological Distribution Models such as MaxEnt) and semi-mechanistic (Climex and DEB) models will be used to identify the environmental variables that contribute to pest species distribution. These models will be validated directly in the field across different geographic regions and across several seasons. Ultimately such models can be used to forecast pest threats and provide information on uncertainty around events such as pest outbreaks and pest severity to growers and advisors. Landscape factors and on-farm practices will be fed into models to predict pest severity in a given space and time point, thus pointing to new ways to manipulate landscapes for promoting natural enemies (beneficial insects) and aiding the implementation of IPM strategies
Improving grower surveillance, management, epidemiology knowledge and tools to manage crop disease in South Australia (DAS00139)	Epidemiology (spore trap) studies covering White Grain, Eyespot and Septoria to determine timing of inoculum release and risk periods.
Centre for Crop and Disease Management (CUR00023) – Research Program 1A– Early detection and management strategies for fungal diseases and Program 9 –Sclerotinia management	This project aims to develop bio-meteorological and physical approaches for early warning of disease risk as well as economic thresholds for major fungal diseases of wheat (Tan spot and Septoria nodorum), barley (mildew and net blotch), and field peas (ascochyta blight)., Weather stations are being set up. Spectral image initial results suggest that, in the absence of other stress factors, indices calculated from red edge and near infrared spectra can differentiate pathogen induced necrotic/chlorotic tissue from normal tissues. This work will continue in 2017. In-field testing and validation will be carried out in the 2018 growing season Sclerotinia: testing of several available sclerotinia models will be conducted in WA and possibly in NSW (NSW DPI bilateral) during 2017
Improving Plant Pest Management Through Cross Industry Deployment of Smart Sensors, Diagnostics and Forecasting (Rural R&D for Profit)	This project will develop a mobile cross-industry plant pest surveillance network, which will provide actionable information to primary producers and government on established, trade sensitive or exotic pests. It will underpin existing surveillance initiatives, and provide a foundation for a nation-wide surveillance network. Producers involved in production of grains, cotton, sugar, horticultural products, wine and forestry products will be primary beneficiaries through improved information on pest status and levels, and with the provision of improved forecasting tools. Producers will receive timely and accurate knowledge of the types of plant pests, and prevalence of these pests in their region, to give improved information to support management decisions. The network will move to respond to industries' seasonal needs, allowing greater efficiencies through a cross-industry approach that provides high quality, consistent data on plant pests that are economically relevant to multiple industries. In addition, the project will include a focus on exotic pests; their incursions have the potential to result in severe trade disruptions and production losses. The surveillance network will support claims of pest freedom and perform an important function in exotic pest detection. The project will facilitate gains in productivity, reductions in farm inputs, reduced pest resistance, and maintenance of market access. Project involves all seven plant based RDCs, SARID, AgVic, DAFWA, QDAF, NAQS,CSIRO The project is structured for controlled scale-up of hub construction and roll out. The project has five sub-projects (see below), which will be led by appropriate project partners. Data will be collated into *AUSPestCheck* and information will flow between each sub-project, allowing informed decision making within the project. *Governance:* Horticulture Innovation will ensure that the project is managed to a high quality, deadlines are met, and outputs meet project objectives. This component will undertake Monitoring and Evaluation ensure regular reporting of project progress to the Commonwealth and implement project governance arrangements.

	Extension: AUSVEG will collate regional priority pest information from producers in each industry, communicate progress to producers and other stakeholders and deliver training on the use of *AUSPestCheck* and industry surveillance data. This sub-project will support and build on existing preparedness and on-farm biosecurity initiatives and identify complimentary mechanisms to educate producers on biosecurity best-practices. *Surveillance:* SARDI will set up the flexi hub infrastructure, based on trapping technology developed by SARDI in partnership with Rothamsted Research and Burkard Manufacturing, GRDC and the Plant Biosecurity CRC. Flexi hub construction and development will be carried out as follows: Year 1 – Two flexi hubs produced and placed in Virginia-Barossa Valley and Renmark-Riverland. Years 2 and 3 – Three flexi hub produced and deployed per annum. SARDI, with support from a number of regional organisations, including DAFWA, the Department of Agriculture and Food, Queensland (DAFQ) and NAQS, will maintain and relocate these hubs to reflect seasonal industry and biosecurity needs. Samples will be collected and couriered for diagnosis. *Diagnostics:* SARDI and AgVic will diagnose hub samples using morphological identification to provide the samples for developing high throughput molecular diagnostic tests. Additional morphological identification will be undertaken through significant in-kind contributions from the forestry sector for forest pests and NAQS for northern Australia samples. Service providers will further develop molecular diagnostics for high throughput, high quality analysis of pest samples, with a key focus on reducing labour costs. Agriculture Victoria will develop next generation sequencing (NGS) technologies to screen for potential exotic incursions. SARDI will develop qPCR protocols to provide quantitative data on established priority pests. Diagnostic data will be uploaded to *AUSPestCheck* for industry and use in developing forecasts. *Forecasting:* Modelling platforms will be developed by CSIRO to simulate the timing, abundance and spread of pests. Integration of surveillance, modelling and weather forecast information will provide information to producers on four priority cross-industry pests (potentially Diamondback moth, Green peach aphid, Silverleaf whitefly and Downy mildew). Additional work on Cotton bollworm will be conducted with Rothamsted Research. This information will be used by producers to plan and execute pest scouting and management activities. Three industry specific sub-projects will also be conducted. A cotton specific project will measure BT resistance in trap samples, a sugar specific project will look at NGS diagnostics for exotic pests and a DAFWA 'Royalties for Regions' project trialling smart traps at 11 sites in the Western Australian grain belt will be used to provide data for this project.
Economic thresholds for the major pests grain crops (being contracted)	Project to provide plan to enable Australian grain growers and their advisors have access to empirically-based, reliable, and dynamic economic thresholds for the major grain pests to support decision making, reduce reliance on broad-spectrum chemistry, and increase grower profits. Project is to conduct regional information-gathering workshops to determine: • tacit knowledge used by agronomists on thresholds • priority listing of pest x crop for each region • proposed methodology to determine thresholds (e.g. field experimentation, glasshouse microcosm, field evaluation of tacit knowledge of agronomists, field validation from other regions) and why this method was chosen over other methodologies • incorporation of beneficials into the dynamic thresholds, where appropriate • consideration of crop recovery factors