GRDC investments relevant to "deep dive" issues and strategic reviews of investment –
Medium Rainfall Zone Southern RCSN – July 2019

Issue No. 36 - "Better access to profit and production focused precision agriculture support would increase return on investment in the low rainfall zone"

GRDC investments addressing this issue

Assessing the economic value of precision agricultural tools for grain farming businesses in the Southern Region (9175511)	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. The Society of Precision Agriculture Australia (SPAA) has been instrumental in promoting the development and adoption of PA technologies to Australian grain growers. The GRDC supported SPAA publication, PA in Practice II: Using precision agriculture technologies — a guide to getting the best results (2012), provides selected case studies, supporting trial results, technical articles and a list of available resources that demonstrate how PA is helping growers to maximise returns while controlling input costs. Despite generally high awareness of the potential benefits of PA technologies in cropping systems, adoption by growers in the Southern Region is generally low. A range of issues are believed to contribute to the relatively low adoption rates of PA including - • lack of clarity and local evidence regarding the financial benefits of available PA technologies; • the perception that PA increases the complexity of management, a deterrent for growers who prefer simple and streamlined operations; • a significant investment in time by growers and advisors is required to effectively utilise PA tools; • a limited number and geographical coverage of advisors with the skills, experience and confidence in PA exists. Typically, PA approaches involve considerable complexity and require interpretation of multiple and large spatial data sets including yield maps, NDVI measurements and different types of soil measurement and mapping (e.g. chemical analysis and EM38). Data platforms are frequently not compatible, which is a major issue for the integration, management, interpretation and use of information collected. Fortunately, many of the above challenges are being met by a range of experienced advisors and private organisations. For example, numerous specialist service providers have the capability and tools required to develop prescription maps for variable rate application of crop inputs and support the application and applied use of those maps on-farm. Also, a number of organisations now provide direct up-load of yield data from the harvester to the cloud, integration of data from a range of platforms and utilisation of NDVI data generated from satellite imagery or drones to produce production zone maps. With these barriers largely overcome, assisting growers to make economically informed decisions on the adoption and use of PA will be important. The GRDC project "The Integration of Technical Data and Profit Drivers for More Informed Decisions" examined the financial benefit associated with 20 case studies in PA adoption across Australia. Financial benefits varied considerably with the type of PA technology adopted, and the soil types and landscapes in which the technologies were employed. Hence, a "one size fits all" approach to the adoption of PA is not generally appropriate. 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 GRDC seeks 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. 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.
Future Farm phase 2: Improving farmer confidence in targeted N management through automated sensing and decision support (9176493)	The Future Farm phase 2 project aims to re-examine and improve the way in which soil and crop sensors are used to inform decisions about input management and to provide a way of automating the process from data acquisition, through analysis, to the formulation and implementation of decision options. The initial focus is on improving the efficiency and profitability of applied nitrogen (N). It will focus on the adaptive generation of site-specific management models through increased and improved use of in-season field monitored data (soil, crop, climatic), historic on-farm data, external public and private data and automation of decision rules in software that may potentially be linked to real-time application equipment. In addition to strong communications and extension component, the project has three key outputs; 1) Developing improved calibrations that enable greater value to be extracted from proximal sensing tools for nitrogen sensors, 2) developing 'back-end' analytics software that could enable growers or advisors to integrate multiple data layers from on-farm (e.g. yield maps, soil tests) and off-farm sources (satellite imagery, weather forecasts) to predict the optimum N application, and 3) a proof-of-concept multi-sensor tool that integrated multiple streams of required sensor data to predict and apply the optimum N rate in real-time. The project is entering the second year of field trials in 2020 and has core 'farmer scale' research sites (i.e. 10 to 50 ha in size) in each of the GRDC regions in addition to 10-15 satellite sites. The core research site in SA is on Mark Branson's Tarlee property, and the core research site in VIC site is in Nhill. Further information about the project is available via: GroundCover article summarising the project GRDC media release covering part of the project GRDC Updates paper by Precision Ag researcher Brett Whelan In addition to this key investment, GRDC is currently negotiating project specifications for 4 new investments in precision agriculture related to early disease detection, rapid quantification of frost damage, rapid and detailed spatial measurements of PAW and remote monitoring of crop phenology. Further information about these 'Enabling Analytics for Grain Crop Monitoring' tenders can be found here.
Application of Precision Ag Tools to a Wheat Breeding Program (GRS11009)	High-throughput phenotyping has the potential to provide great advances to the plant breeding industry, with phenotyping sensors having been proven useful in controlled environments and in small scale research. However, their implementation has yet to be realised at a large scale. This project aims to; 1) implement high-throughput phenotyping in a large scale wheat breeding programme, 2) investigate data extraction methods and statistical analysis methods of the phenotypic data collected, and 3) ultimately use this data to improve genetic gain within the breeding programme. This will be combined with environmental characterisation data to better understand variation within, and between field sites. Phenotyping sensors (primarily DSLR cameras and LIDAR sensors) will be used to characterise field trials across multiple sites in the 2016 and 2017 growing seasons, with this data being compared to manually recorded measurements. Methods for data extraction from phenotyping sensors will be developed, as well as statistical analysis methods for using this data within plant breeding programmes. Australian Grain Technologies is well situated to partner with the University of Adelaide and the PhD candidate on this project having the appropriate resources, as well as a highly capable PhD student who has already spent a year working on the project.
A platform to interpret soil attributes to support profitable farming	This innovation will deliver platforms for fine scale mapping of soil attributes to provide reliable real-time information to growers to support their decision making processes. Profitable farming systems depend on high quality data, including soil data, to manage annual agronomic decisions affecting crop performance. This good soil management will also secure soil production potential into the future, reducing long term risk. Developing this system requires soil and its related data to be measured at a finer scale than is currently

systems (US00087)	feasible for farming systems relying on data derived from traditional soil laboratory techniques. The reduced cost of generating this data will increase the growers' ability to assess variability in the field and support precision agriculture approaches to reach their full potential. While a number of sensors have been developed to measure soil properties quickly, cheaply and in situ, the current investigations have focused on a single or small number of properties, or developed calibrations that are only suitable for a given region or soil type. There has also been no explicit linkage to any interpretation of the agronomic impacts of the measured properties. This research will fill these gaps by developing calibrations for proximal soil sensor measurements and connecting sensor derived properties with the wealth of information held in pedotransfer functions through the use of a spectral inference system. Much of this work will be automated and will culminate in the production of a standardised report presenting key soil attributes in an easily interpretable way.
GRS - Optimising crop predicted and produced yield through an intuitive and cost effective decision support tool (**UOS1807-001RSX)**	Precision agriculture and the use of Site-Specific Crop Management (SSCM) can deliver higher profitability with a lower environmental cost by tailoring management actions to suit the spatially varying demands of crops. Remote sensing allows us to identify winter wheat (Triticum aestivum) and sorghum (Sorghum bicolor) crop demands over a larger area in a shorter time than traditional methods, and, when coupled with sophisticated statistical and modelling techniques, can match or exceed the robustness of their estimates. Remote sensing can detect a wide range of biophysically significant variables, such as photosynthetic efficiency, soil moisture content as well as leaf concentrations of nitrogen. Using these variables with climatic and topographical conditions can drive estimates of grain yield potential, as well as prescription maps of how much nitrogen to apply where to achieve them.
Precision Ag EXPOS (SPA1902-001AWX)	Precision agriculture conference support
GRS (Andrew Longmire)- Hyperspectral remote sensing of wheat crops for rapid assessment of effective nutrient status and improved crop growth model performance (**UOM1903-001RSX)**	The overarching objectives of this PhD project are to apply hyperspectral image collection and processing to enable more accurate, more reliable and faster decision-making in the context of precision agriculture and to improve crop growth models by assimilation of remote sensing (RS) outputs. The project takes a multidisciplinary approach by combining state-of-the-science techniques from remote sensing, model inversion and statistics with traditional agronomic and plant science experimental approaches. These can potentially be applied to problems of global importance and real-world relevance to grain growers. Across the Australian grains industry, crop use efficiency of applied N is around 50%. The other half escapes from leaky agroecosystems, representing a very significant cost to farmers, who pay up front for fertiliser and therefore assume significant financial risk. Modern techniques in RS and image processing have the potential to improve targeting of fertiliser to crop needs, for example by assessing the actual effect of N status on plant physiological performance. Solar-induced fluorescence can be directly observed and is considered a direct proxy for electron transfer rate and therefore photosynthesis, as well as being closely linked to Vcmax. Hence it is now possible to quantify net assimilation by analysis of images captured by airborne sensors mounted on either piloted or unpiloted aircraft. Moreover, other indicators of plant function, including chlorophyll concentrations, leaf N content and canopy structure (e.g. LAI) can be derived by inverting leaf and canopy physical models, and the high spectral resolution of hyperspectral RS can also be used to derive a wide range of finely-tuned reflectance indices. These techniques are a vast advance on crop RS methods currently practiced in Australia, which rely on simple reflectance indices incapable of delivering insight into plant and crop function beyond assessments of greenness. This project is aimed at the following objectives: 1. Improved matching of nitrogen fertiliser to crop needs using RS hyperspectral imagery and processing algorithms to diagnose and map spatial variability in crop plant performance, specifically photosynthetic rate, by direct observation of solar-induced chlorophyll fluorescence. Application: In the context of precision agriculture utilising drone-mounted and aircraft-based spectral sensing equipment, this will improve farmers' capacity to target their tactical agronomy more accurately by assessing both temporal and spatial variations in crop performance. 2. Improve crop growth models and decision support tools by assimilating RS-derived knowledge of plant / crop performance, including leaf area index, chlorophyll concentration, photosynthetic rate and other aspects of leaf and crop canopy structure. Application: In the context of crop growth models currently in use in Australia, particularly APSIM / YieldProphet™, this would aim to improve the models' skill in predicting yield and grain protein.
ACT00004 - Application of CTF in	Adoption of Controlled Traffic Farming (CTF) in the low rainfall zone (LRZ) of the Southern Region is very low (e.g. SA/Vic Mallee, 4%) compared to other zones in the Region (e.g. Vic HR, 26%) (GRDC 2012 Farm

the low rainfall zone° (completed June 2019)	Practices Survey). This is believed to reflect scepticism about its benefits in many LRZ environments when weighed up against the cost of adopting the practice. The project 'Application of controlled traffic in the low rainfall zone' will evaluate whether or not this scepticism is justified. It will use a balanced combination of research and development (R&D) to answer growers' questions about CTF and provide the information they need to make informed decisions about whether to invest in adopting the system on their farms. To help LRZ growers answer the questions and uncertainties they face when thinking about CTF adoption, the project will conduct research on four sites (R sites) across Southern Australia at: • Loxton • Swan Hill • Lake Cargelligo (NSW) • Minnipa At these sites, information will be gathered on soil properties and crop growth under a range of existing compaction situations to enable comparison of crop productivity between current guidance systems and full CTF. APSIM and yield Prophet modelling will be used to help evaluate crop response to controlled traffic over a wider range of seasonal conditions. The research data from these sites will be supported by information from smaller development sites and will more broadly investigate: i. how well soil compaction effects can be reduced by self-repair or amelioration practices, ii. the power and energy benefits from CTF and iii. the system (timeliness and uniformity) benefits of CTF. The research activity will provide valuable information to help answer the important questions being asked about the relationship of CTF to grain productivity in the LRZ, especially on the characteristically light soils of the region where there is currently little information on soil compaction or its effects, or on the effectiveness of CTF systems.

Issue No. 5 - "High value pulse and legume varieties bred for a wider range of soils types and rainfall districts of the Medium Rainfall Zone will improve farm profitability on a broader scale"

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

Please also see Southern Pulse Agronomy investments below

Pulse Breeding Australia: Faba Bean Breeding (UA00163)	The development of improved varieties of faba bean will result in more reliable production with reduced inputs for disease management and enable the expansion of the crop to new areas of production. This will contribute to GRDC goal of increasing the component of pulses in cropping systems from 7 to 10% in the next 10 years Faba bean is one of the major cool season food legume crops internationally, with a global production of approximately 4 million tonnes per annum. It has been cultivated in Australia since 1980 with major areas of production in the temperate and Mediterranean-type environments in South Australia and Victoria, where it is generally grown in higher rainfall districts, and in the sub-tropical environment of northern New South Wales (NSW). There is also potential for expansion of the crop into irrigated cropping systems in northern Victoria (Vic), and southern NSW, into the Western Districts of Vic and into slightly lower rainfall areas on the fringes of the current traditional faba bean production area with the development of new, adapted varieties. Faba bean crops are grown over diverse environments therefore a range of varieties that carry traits required for adaptation to the contrasting environments, such as variation in day length, temperature, rainfall patterns, soil type and dominant diseases, is required for the Australian industry. Faba beans are susceptible to a number of fungal and viral diseases and control of these requires significant inputs in both time and money. Resistance to the major diseases has been identified and progress has been made in combining resistance to several diseases in adapted genetic backgrounds. Further breeding and evaluation is required to identify the highest yielding of these lines for release as new varieties. In recent years there has been significant research into new traits to incorporate into Australian pulse varieties, and several important traits have been identified in faba bean. These include tolerance to several herbicides, resistance to a new pathotype of Ascochyta blight and tolerance to heat. This project will commence the introduction of these traits to a range of elite breeding lines with the long-term objective of developing more robust varieties with a wider range of adaptation and improved weed management

	options. Faba bean is a high protein, staple food in many countries in the Middle East and north Africa, and Australia is one of three major suppliers to these markets, together with France and the United Kingdom. There is a limited market with strong competition among the exporting countries and it is important to produce a high quality product that will ensure continuity of supply to maintain market share. Expected outcome: This project will develop new faba bean varieties that have greater yield than current varieties, better adaptation to the major production regions in Australia and improved disease resistance. Improved germplasm incorporating new traits, such as herbicide tolerance, will be developed for the longer-term benefit to the faba bean industry. Outputs: • Identify a potential release line for the southern region with significant yield improvement over current varieties in identified regions to enhance expansion of faba bean production. The line will have a good level of resistance to Ascochyta blight and chocolate spot, good standing ability and quality suited to the Middle East food markets. • Identify a potential release line for the northern region with significant yield improvement over current varieties. The line will have a good level of resistance to rust and a manageable level of resistance to bean leaf roll virus and chocolate spot, early flowering and maturity and quality suited to the Middle East food markets. • High yielding, agronomically stable advanced germplasm with combined resistance to diseases and incorporating new traits such as herbicide tolerance. Methodology: The breeding program will be conducted as a component of Pulse Breeding Australia (PBA) and coordinated by The University of Adelaide. The major breeding and evaluation nodes will be based at the Waite Campus, University of Adelaide, and at Sydney University Plant Breeding Institute Narrabri. Significant contributions will be provided by South Australian Research and Development Institute and NSW Department of Primary Industries in the areas of disease resistance and regional evaluation. The project will build on the efforts of previous breeding programs that have developed methods for breeding faba beans and identified new sources of disease resistance and lines with good adaptation in different production regions in Australia.
Collection, phenotyping and exploitation of wild Cicer genetic resources for chickpea (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. 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 is constrained by limited genetic and adaptive diversity, and therefore the recent GRDC-funded augmentation of the depauperate world collection of diverse wild relatives, that are interfertile with domestic material, has raised unprecedented opportunities for chickpea improvement. This project will strengthen chickpea breeding efforts and act as model for the exploitation of wild genetic resources by: • Targeted collection to widen the habitat range and genetic diversity of existing collections • Extensive phenotyping of traits prioritized as limiting Mediterranean adaptation • 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.
Eliminating grain defects in chickpeas (DAN00196)	Downgrading of harvested chickpeas due to grain defects such as seed markings or pre-harvest sprouting, can cost a grower $50-80 per tonne on receival. Seed markings (commonly termed tiger striping or blotching) are known to occur in a small percentage of desi chickpea varieties under certain environmental conditions. Pre-harvest weathering, leading to sprouted grain, occurs due to rainfall on mature crops prior to harvest and commonly occurs in northern NSW and southern and central QLD. For this reason kabuli chickpeas are not widely grown in those regions.

	To date, plant breeders have no information on the genetic characteristics which predispose some chickpea varieties to either seed markings or weathering damage. This lack of knowledge is hampering efforts to breed varieties which are not susceptible to these defects.
	
	This project, led by NSW DPI and involving five other research agencies across four states, will conduct research towards eliminating these two grain defects in chickpea and will examine both desi and kabuli chickpeas in trials conducted across all the major growing regions of northern and southern Australia. In addition, this project will link into existing research projects under the umbrella of Pulse Breeding Australia (PBA).
	
	The major outcomes from the project will be:
	• A geographical map of incidence indicating the particular environmental conditions under which different susceptible varieties express these defects;
	• Identification of the nature and critical timing of weather events that lead to these defects;
	• An improved understanding of plant-related factors such as growth stage, crop architecture and genetic characteristics that favour defect occurrence;
	• Assessment of the means by which these defects affect product quality for grain processors; Preliminary identification of tools to mitigate these seed deficiencies including:
	  • agronomic practices that can reduce the risk of defects;
	  • phenotypic traits which can be used as screening tools to select resistant breeding lines;
	  • image analysis techniques for quantification of markings;
	  • identification of contrasting genotypes that could be used to develop future genetic markers for these defects.

Improving weed management in pulse crops through herbicide tolerance - Part B (DAS00131-BA)	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. Weed management in Australian pulse production will continue to rely on chemical control methods due to limited suitable agronomic management options and the inherent low competitive nature of pulses. Improved genotypic tolerance to available herbicides and new herbicides or new application timings of existing herbicides are imperative for the continued economic and sustainable production of pulses. Furthermore, the availability of pulses with multiple herbicide tolerances will reduce the risk of herbicide-resistant weeds developing and assist with sustaining intensive cropping systems. Outcomes: The provision of germplasm to Pulse Breeding Australia (PBA) with improved tolerance to registered herbicides and tolerance to new herbicides is expected to lead to generation of varieties that will assist in increasing the productivity and profitability of pulses in Australia. The development of pulse varieties with new and or multiple herbicide tolerances will enable greater variation in herbicide usage patterns and will reduce the risk of herbicide-tolerant weed development. The project will have five components: **1. Chickpea (desi and kabuli) lines with at least one novel source of herbicide tolerance, field validated and delivered to PBA** Pre-emergent herbicide options in chickpea are limited to flumetsulum, which has a limited weed control spectrum and is often damaging in chickpea. This component of the project will develop kabuli and desi chickpea bulk mutation populations using ethyl methane sulfonate (EMS) mutagenesis techniques to develop lines with tolerance to at least one novel herbicide, as decided in consultation with industry. **2. Development of herbicide-tolerant faba bean and lentil germplasm from putative tolerant lines discovered in DAS00107 and delivered to PBA.** Putative tolerant lines of faba bean (imazethapyr and metribuzin) and lentil (metribuzin) were developed in DAS00107. These lines were screened for tolerance through a preliminary progeny herbicide assay at the M4 stage in 2012. The most promising of these lines will be multiplied and validated through glasshouse and field dose-

	response experiments to discover if an agronomically useful level of tolerance exists. If so, lines with useful levels of tolerance will be handed over to PBA for inclusion into the breeding program. M3 field selections were taken from dicamba (faba bean and lentil) and carfentrazone-ethyl and isoxaflutole (lentil) mass field screens in 2012. These selections exhibited varying levels of damage symptoms and will be 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 if an agronomically useful level of improved herbicide tolerance is identified, those lines will be delivered to PBA **3. 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.** Screening methods, including the use of diagnostic markers where applicable, will be developed initially in lentil and faba bean to rapidly and non-destructively identify lines from opportunistic crosses with improved levels of herbicide tolerance, e.g. imidazolinone tolerance in metribuzin-tolerant lines. Lines found to carry tolerance to the two herbicides will be delivered to PBA for incorporation into the breeding programs'; evaluation and release cycle. **4. Identification of other potentially-useful herbicides for screening mutant populations.** In consultation with PBA, Pulse Australia (PA), agrichemical companies and industry, appropriate herbicides will be identified for future screening. The criteria used will be: • current levels of crop tolerance are narrow and insufficient • genetic variation for tolerance is known to exist • the herbicide has a wide weed spectrum, lower risk of herbicide resistance and the potential for use over a large area. **5. Contract with a GLP-accredited laboratory, if required, to establish herbicide-residue profiles of any herbicide-tolerant lentil or faba bean varieties identified for variety release by PBA in accordance with the APVMA and in collaboration with the GRDC minor-use-chemicals project to assist with any required registration process.**
Capacity building to support research and plant breeding at the I.A. Watson Grains Research Centre (US00058)	This project will build plant breeding research capacity at the I.A. Watson Grains Research Centre at Narrabri, in the GRDC Northern region. Included will be a new breeding glasshouse; and improved field phenotyping capabilities with a new bird cage. The new modern glasshouse for use by breeders will have three compartments (each 30 m2), each with separate services and entrance, and will be constructed of aluminium and polycarbonate. A large (2 ha) bird/hail cage will also be deployed, and the field area that can be irrigated by a large travelling low-pressure lateral-move irrigator will be expanded. That extension of area irrigated by the lateral-move irrigator will be enabled by relocation of a power-line that traverses the I.A. Watson Centre, and by extending the irrigation supply pipeline to provide extra hydrants. All components of the new research and breeding capacity will be located on the property of the farmer-owned NSW Wheat Research Foundation, which is on long-term lease to the University of Sydney. The breeding glasshouse will be available at cost to the expanding range of non-University of Sydney participants on the site, including those funded by GRDC and other private and public entities that are carrying out breeding and pre-breeding activities of relevance nationally and especially to the Northern Region for cereal, pulse, and brassica crops. Examples include, but are not limited to, researchers and groups from commercial companies (such as Australian Grain Technologies and Longreach Plant Breeders), CSIRO, the Queensland and NSW DPIs and other universities. The new capacity will enable all users of the site to create pre-breeding and breeding outputs of benefit to growers in the Northern Region and nationally more efficiently and to a larger extent because of increased reliability and scale of research at the Watson Centre. This capacity building will make a major contribution to goals of the National Grains Industry Research and Development Strategy and will ensure enhanced regional delivery of national research activities.
An integrated platform for rapid genetic gain in pulse crops (UWA00175)	Pulse genetic improvement has historically been constrained by the long lifecycle of the plant. In breeding, this translates as slow genetic gain. In conventional breeding systems, one to three generations can be obtained per year, with six required for fixation of favourable genes. GRDC funded research (UWA00140, UWA00159) has resulted in breakthrough technology to accelerate the traditional Single Seed Descent (SSD) system in the four major pulses (chickpea, lentil, field pea and lupin). Accelerated SSD (aSSD) enables turnover of six to eight generations per year, more than halving the current fastest route to gene fixation

	(homozygosity) in these species. Within UWA00159, we have also undertaken research toward the goal of developing an integrated breeding platform, which incorporates aSSD with hydroponic screening to discriminate breeding material with tolerance to salinity, aluminium or boron toxicity. We have modified the hydroponic screens so that they can be applied to immature seed, with robust germination and recovery of tolerant plants to flower and set seed with little time penalty within our accelerated generation turnover system. The objectives of this project are: • help address the loss of $74 million per annum in pulse yield by developing biotic screening methodologies for two of the major pulse pathogens -- Ascochyta and Botrytis - that can be applied within the aSSD platform. • To assist in the rapid integration of new herbicide tolerance traits by developing and applying herbicide selection within the aSSD platform. • To deliver the resulting comprehensive pulse aSSD platform with capacity for abiotic/ biotic and herbicide screening to the Pulse Breeding Australia (PBA) pulse improvement community. Structure of the investment: Component 1 will integrate the aSSD technology into PBA pulse breeding activities, giving Australia a unique comparative advantage in pulse breeding. Component 2 will focus on the further enhancement of the platform for pulse improvement. This will be achieved by incorporation of physical or molecular screening for biotic and abiotic production constraints within the aSSD system. The aSSD technology will enable breeding programs to develop fixed F6 material in a single year. In the case of metribuzin tolerance in lentil, incorporating this trait up to two years faster is estimated to improve on farm profits by $6 million. If we consider $6 million per trait as a benchmark value of delivering specific traits more rapidly and further assume one trait per species will be rapidly integrated using aSSD within this project, then this investment has the potential to increase on-farm profits by c. $18 million.
Managing Crop Disease - Improving chickpea pathogen resistance (PRR) (DAN00172-BA)	Pulses are a vital component of Australia's cereal-based cropping systems. They contribute to soil nitrogen and reduce the impact of cereal diseases, resulting in improved yield, quality and profitability. In addition, pulses such as chickpea can be a highly valuable cash crop. Most (>70%) of Australia's chickpeas are grown in the Northern Region, with the remainder in the Southern Region (only 1% in the Western Region). Plant diseases are estimated to cause an annual loss of $24 million or $81/ha to the Australian chickpea industry (Murray and Brennan, 2012). This represents 16% of the average annual value of the crop. Of these diseases, *Phytophthora* root rot (PRR) is by far the most important, costing Australian chickpea growers on average $8.2 million a year. This is almost twice the cost of *Ascochyta* blight, recently estimated at $4.8 million per year. Although more prevalent in the Northern Region, the PRR pathogen, *Phytophthora medicaginis* occurs throughout eastern Australia. There are two features of the disease that make *Phytophthora* particularly difficult to manage: once a plant is infected it usually dies, unlike *Ascochyta*, which is readily controlled with fungicides, once a plant/crop is infected with *Phytophthora*, there is nothing a grower can do. These features mean PRR can be managed only by pre-sowing decisions using an integrated approach based on assessing the PRR risk of the individual paddock and selecting the variety best suited to that risk. Currently, there are several chickpea varieties - e.g. Yorker - growers can use in paddocks with a low to moderate PRR risk. However, no current variety will survive realisation of high-risk PRR situations. Even Yorker will die under conditions highly favourable to the disease. Clearly, there is a need for chickpea varieties with greatly-improved resistance to PRR. The development of such varieties will, in combination with other management tools, provide growers with a resilient integrated disease management package and thus increase grower confidence and profitability. This project aims to mitigate the impact of *Phytophthora* root rot in eastern Australia by: • Identifying, in wild relatives of chickpea, novel sources of resistance to *Phytophthora* that offer robust protection against the disease. • Incorporating this resistance into new chickpea varieties using innovative breeding technology to speed up varietal development. • Expanding our knowledge of the pathogen to ensure that the breeding process matches and/or surpasses pathogen variability. • Constructing improved grower guides for managing PRR that incorporate the applied research outcomes from this project.

	This work will involve plant breeders, molecular biologists and pathologists based at Adelaide, Tamworth, Toowoomba, Wagga and Warwick. Key activities planned in the project are: • Validate PRR resistance in wild relatives of chickpea and in crosses between wild relatives and chickpea. • Sample chickpea paddocks in northern NSW, southern Queensland, southern NSW, Victoria and central Queensland to determine geographical extent of the disease and assemble a collection of pathogen isolates. • Determine variability within the pathogen population by testing isolates against a differential set of chickpea varieties and lines (genotypes). • Update relevant grower management guides in conjunction with industry. • Seed-increase recombinant inbred lines (RILs) and collect basic agronomic data. A RIL is the progeny of genetically-distant parents that have been stabilised through inbreeding (self-fertilisation). • Screen (= phenotype) mapping populations with diverse sources of PRR resistance for reaction to PRR. Mapping populations are families of RILs. • Using phenotypic data, identify superior individuals from RILs and cross into elite, locally-adapted chickpea germplasm. • Determine the genetic make-up (genotype) of PRR RIL population individuals. • Generate linkage maps (to identify the location of genes in relation to each other) and undertake quantitative trait loci (QTL) analysis to link genes to PRR screening data. QTL analysis helps identify markers. • Identify markers associated with PRR resistance. Markers are molecular 'tags' that tell breeders if they have found a source of PRR resistance or have successfully transferred it into a plant. • Identify elite RILs following QTL analysis for use in a marker-assisted backcrossing strategy. • Utilise markers in marker-assisted back-crossing strategy to incorporate, and if applicable pyramid, alternative QTL for PRR resistance. • Validate PRR marker/s in the chickpea breeding program and implement marker use as a routine breeding strategy. These activities will help fast-track new PRR-resistant chickpea varieties and thus support growers in developing resilient farming systems better placed to minimise losses from the key diseases in the region.
Application of Focused Identification of Germplasm Strategy (FIGS) in Australian environment (ICA00014)	With the looming spectre of climate change, the emergence of virulent new pests and disease biotypes, and the demand for varieties that will perform under low fertility condition plant breeders require genes that are not readily available within the current breeding genepools. Thus they must look to genetic resource collections of old farmer varieties (landraces) and wild relatives of crop plants. However the search for rare alleles within massive germplasm collections has been likened to looking for a needle in a haystack. Pre-breeders simply don't have the resources to evaluate entire germplasm collections. Thus methods are required to identify trait specific best-bet subsets of germplasm of sizes that economically feasible to evaluate. In recent years GRDC has invested in the development of a technology that uses germplasm collection site agro-climatic and edaphic information to predict for adaptive traits. The premise behind the approach is that the environment under which wild and landrace material develop will drive the evolution and selection of adaptive traits that could be of use to plant breeders. Thus FIGS seeks to determine and quantify relationships between collection site agro-climatic conditions and the presence of specific traits, such as disease resistance or heat resistance. This approach has led to the discovery of previously undiscovered genes and useful variations of known genes for resistance to serious pests and diseases. The project proposed here is to further refine the FIGS algorithms so that their predictive power is improved and deploy them to identify relatively small best-bet subsets of germplasm for cereal and pulse crops that will increase the probability of capturing rare alleles for key traits. The subsets will be drawn from global germplasm collections. Once identified the subsets will be delivered to pre-breeding and research programs in Australia and the International Centre for Agricultural Research in the Dry Areas.
Managing on-farm biosecurity risk through pre-emptive breeding: the case of rust	Lentil and field pea crops are integral components in cereal cropping rotations in Australia. Rust is a significant yield constraint in the production of lentil and field pea in various regions of the world and is the most important foliar disease of lentil in North and East Africa, South America and South Asia. Infection usually occurs at flowering, causing yield losses of 40 to 70%. Complete crop failure has occasionally been observed due to severe epidemics earlier in the season. Rust of pea is an important disease in tropical and

(CUR00020)	subtropical areas such as northern India and central China. It also has significant impact in pea production in temperate regions (e.g. Spain and Canada). In pea crops, rust causes 30 to 50% yield losses depending on the pathogen species and the cropping areas. Higher yield losses are observed in tropical and sub-tropical regions. Rust on pulses is caused by obligatory biotrophic pathogen species of the genus *Uromyces*. The most common causal agent of rust in cool season food legumes is *Uromyces viciae - fabae*. Isolates of *U. viciae - fabae* are specialised for one or more host species; for example, *U. viciae - fabae* (isolates derived from lentil) are better adapted and develop higher disease levels on lentil than on other host species. Although there are *U. viciae - fabae* strains capable of infecting pea, the disease levels are not as severe and are dependant largely on the environmental conditions. *U. viciae - fabae* infections on pea are observed in tropical and subtropical regions (e.g. India and China), but in temperate regions such as the current Australian and Spanish pea cropping areas the crop is primarily affected by *U. Pisi*, which has a narrower host range. The information on the distribution, prevalence, population structure, and host range of these species is recent, remains incomplete as it only covers certain pea-rust-prone areas and is of utmost importance to any breeding program. In Australia, the causal agents of rust on lentil and field pea are apparently absent as no rust symptoms have been observed on these crops under natural conditions. Therefore, *U. viciae - fabae* has been classified as an exotic plant pathogen (EPP) and is considered a serious threat to the lentil and pea industry. In light of recent reports by Rubiales and colleagues [6-8], we propose that *U. pisi* should be rated as posing a similar threat to pea production in Australia. Potential incursions of either of these species could be detrimental to the vulnerable lentil and field pea industries as weather conditions during the cropping season are favourable to disease development. The most effective and economic way to manage both of these diseases is through the use of resistant cultivars. They can be controlled with fungicide applications but the practice is not economically viable. High levels of resistance have been observed in lentil and pea germplasm in various international nurseries but, as in other cool-season food legumes, resistance to rust in lentil and pea is incomplete, with spores being produced in susceptible and resistant lines. While resistance in lentil is often characterised by the occurrence of hypersensitivity (i.e. infection occurs with host cell necrosis), in pea, no hypersensitivity has been observed with infections by *U. viciae - fabae* nor *U. pisi*. Most studies have shown that incomplete resistance in both crops is controlled by single loci, with dominant effect explaining a large proportion of the phenotypic variance. Information on molecular markers flanking the different resistant loci is scarce; additional markers closer to the resistance gene are needed. Outcome: The aim of this project is to provide to the Australian lentil and field pea industries with tools to mount a rapid and effective response to the incursion of *Uromyces viciae - fabae* and *U. pisi*, two exotic plant pathogens causing rust. These pre-emptive measures include: • evaluation of current elite cultivars and breeding lines in key rust host-spots • identification of novel sources of resistance and introgression of resistant loci into locally-adapted Australian elite germplasm • assessment of the pathogens' populations structure and virulence shifts to account for difference between sites. This will enhance breeding efforts through better gene deployment strategies. Identification of molecular markers linked to resistant loci will assist in the selection of resistant breeding lines in the absence of the pathogen. The expected outcome of this strategic investment is to provide growers with access to pulse varieties with genetic resistance/genes against exotic plant pathogens (EPPs) such as rusts, thereby mitigating against the potential economic impact of a high-risk EPP incursion and ensuring that pulses remain competitive rotational crops in Australian farming systems. The economic impact of a *U. viciae - fabae* and *U. pisi* incursion on the Australian lentil and pea industries under current cropping conditions could be substantial, with predicted yield losses equivalent to $12.6 million (lentil) and $7.3 million (pea) per annum. These figures are based on the potential yield losses (8%) of rust in faba bean in the southern and western Australian cropping regions, the average Australian production estimates for 2011 and 2012 of 242,400 tonnes (lentil) and 353,500 tonnes (pea) per annum (Pulse Australia, Australia Pulse Crops Forecasts) and estimated unit values of $650/t (lentil) and $260/t (pea). Outputs: New knowledge/information on the relative resistance/susceptibility to rust infection of at least 80 current lentil and field pea varieties and elite breeding lines adapted to the various Australian cropping areas (delivered by June 2015). • Current information on the pathogen population in key cropping areas of the world, its composition and distribution (delivered by June 2016). • Parental genetic stocks in elite adapted Australian backgrounds, with resistance to single and

	multiple EPPs, *U. viciae - fabae* (lentil and field pea) and/or *U. pisi* (field pea), which can be used to develop field pea and lentil varieties possessing resistance (delivered by June 2017). • Molecular markers flanking rust-resistant loci (within 2cM) in lentil and field pea (delivered by June 2018). Approach: The project builds on the most advanced, evidence-based knowledge in the field and taps into the expertise, skills and resources of current world-leading scientists in rust of pulses. Our approach is based on: • multiple-field evaluations of Australian material, local landraces and other international germplasm in rust-hot sites of high risk to the Australian industry (e.g. Spain, Ethiopia, India, China and Chile) • characterisation of the current pathogen population • assessment of cultivated and wild germplasm of *Pisum* and *Lens* spp. using highly-virulent isolates of *U. viciae-fabae* and *U. Pisi* under controlled conditions • genetic studies to identify the loci associated with rust resistance. The project is set as an international collaboration to ensure the smooth running of the experiments and exchange of germplasm.
An international collaborative effort to sequence the genome of field pea (CUR00021)	The Australian pulse industry faces substantial challenges, including the unsustainable preference for non-legumes in rotation systems and the reduction of cropping areas dedicated to legumes. In order to regain farmers' confidence on pulse crops there is a need to develop varieties that are productive with stable yields and adapted to the targeted cropping areas. Pulse breeding programs are successfully responding to the needs of the cropping systems but progress is slow. Field pea cropping is no different from other pulses in this scenario. Recent advances in sequence technologies have the potential to speed the breeding cycle and facilitate the introgression of novel traits from landraces and wild material into elite adapted germplasm. The pea genome is relatively large (c. 4.5Gb) and represents a reasonable challenge to genome sequencing due to the high proportion of repetitive DNA - estimated to be about 75% of the genome (Murray et al., 1981; Flavell et al., 1974). However, unlike other large crop genomes (e.g. the hexaploid 17Gb-long wheat genome), the pea genome is relatively simple and appears to be a true diploid, with no evidence of major gene duplications events. An international consortium was formed in 2012 with the purpose of sequencing the genome of field pea (*Pisum sativum)*. The scope of this GRDC project is to enhance the genome sequencing activities and to provide a link between the activities of the international consortium and the Australia community of pulse breeders and researchers. The GRDC funding will be used exclusively to complement the Genoscope/ CSPG funding in the acquisition of sequence data.
Pulse Breeding Australia (Chickpea) (DAN00212)	Chickpea is now a major Australian cropping industry. National crop area expanded to 675,000 ha in 2015. In addition to being a highly profitable cash crop in its own right, chickpea is also an established rotational crop in a range of cropping systems. The chickpea growing environment in Australia includes a complex mix of biotic (mainly disease) and physical (soil/climate) stresses; some of these problems are unique to Australia. Only a local breeding program has the capability of producing varieties with the necessary adaptation. Significant progress has been achieved by the Pulse Breeding Australia (PBA) Chickpea national breeding program since its inception in 2006. The first locally adapted varieties with improved resistance to *Ascochya* blight (AB), the most important production constraint, have now been released, and other releases are imminent. However, further investment is required to progress other “pipeline”; breeding material and to meet emerging production problems and marketing opportunities. The breeding program will retain a national structure. There will, however, be a concentration in north-eastern Australia where production has consolidated. Most (80%) resources will be allocated to desi types, reflecting the dominance of desis in Australian production; a continuation of the kabuli subprogram is justified by the higher value of kabuli types, their increasing share of world trade and their comparative production advantage in southern Australia. 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 features incorporated into new varieties will reflect the regional importance of the key production constraints. An increased breeding effort on chilling tolerance will be made through the early sowing and tagging of F3 populations. A site within each region will also be sown early within the optimal sowing window to identify breeding lines with improved chilling tolerance. The program will build on recent efforts to incorporate novel herbicide tolerance identified in DAS00107 within PBA Chickpea. An increased investment in selection and validation of novel herbicide tolerance by the South Australian Research and Development Institute (SARDI) group will see this develop into a significant

	component of the PBA Chickpea program. It is envisaged that a herbicide tolerant chickpea variety would have a major impact on the farming system fit of chickpeas in north, south and western GRDC regions. Germplasm will be identified in DAS00107, however if mutation events; are not found within this project, access to international germplasm and the appropriated freedom to operate will be investigated (e.g. Canada). The PBA Chickpea program will include a junior chickpea breeding position at Tamworth. This role will develop skills and capacity of a junior breeder in the area of variety development. The project will also link with a GRDC and NSW Department of Primary Industries funded capacity building position (DAN0200) in Chickpea Genetics. This role will focus on implementing traits from the germplasm enhancement programs (funded from PBA Chickpea discretionary budget). This position will build capacity and strengthen collaborations between chickpea breeding and pre-breeding projects. Germplasm with new traits and screening methodologies from germplasm enhancement projects and new technologies (e.g. molecular markers, speed breeding) will be adopted into PBA Chickpea once their effectiveness has been demonstrated. There will be two project outcomes: • directly, a more secure and profitable chickpea industry underpinned by higher, more stable yielding and better quality varieties, and • indirectly, increased profitability of other (mainly cereal) crops grown in rotation with chickpea resulting from nitrogen fixation and a reduction in cereal disease inoculum.
Diagnostic services for pulse germplasm enhancement and breeding programs (DAV00134-BA)	The Australian winter pulse industry (field peas, chickpeas, faba beans and lentils) is expected to increase substantially in the near future, driven by the need to protect farm incomes through crop diversification and because of their ability to fix atmospheric nitrogen, lowering input costs. The use of legumes as a rotation crop has also shown to dramatically reduce stubble-borne wheat diseases like crown rot. However, the increase in pulse area and production may amplify its own disease and pest problems. Viral diseases are of particular concern to pulses and, unlike most fungal diseases, legume viruses may have several legume hosts and some also have non-leguminous hosts. Currently 15 viruses have been described on winter pulse crops in Australia. All require insect vectors, mostly aphids, to move from infected to healthy plants. A limited number of pulse viruses can be seed borne, but most need living plants to survive between cropping season. The need for insect vectors and summer hosts makes virus epidemiology infinitely more complicated than that of fungal diseases with virus outbreaks depending on a wide range of environmental vectors and highly influenced by changing farming systems. Viruses are frequently a problem in the northern grain region, where summer rains provide a between cropping refuge for the viruses and their aphid vectors. However, virus induced losses are also frequently encountered in the southern regions with Mediterranean climates. Only a limited number of virus control strategies are available; delayed sowing may lower exposure to viruliferous aphid flights; crop hygiene can limit the spread of viruses that survive on weeds; persistently-transmitted viruses can be controlled by insecticides as their aphid vectors have to feed on plants both to acquire and to transmit the virus. However, most of these control strategies interfere with optimal crop management or will increase the use of pesticides. Non-persistently transmitted viruses are extremely difficult to control as many have multiple vectors and can be transmitted by short probes, although the vector loses the virus after a limited number of probes on healthy plants. Genetic resistance is the most economical and sustainable way to control viral diseases in pulses. There is mounting evidence that the threat of viruses to the Australian pulse industry has been underestimated in the past and that more efforts are needed to control virus-induced crop losses. In the past decade all four Pulse Breeding Australia (PBA) breeding programs have initiated projects to improve resistance to viruses of high priority to each specific crop. The priority viruses for each of the four crops have been determined by surveys of commercial and experimental crops in different growing regions and are as follows: • Bean leafroll virus (BLRV, persistently transmitted): High priority for faba bean, field pea, lentil and chickpea. • Beet western yellows virus (BWYV, persistently transmitted): High priority for chickpea and lentil. • Alfalfa mosaic virus (AMV, non-persistently transmitted): High priority for chickpea and lentil. Cucumber mosaic virus (CMV, non-persistently transmitted): High priority for chickpea and lentil. • Bean yellow mosaic virus (BYMV, non-persistently transmitted): High priority for faba bean .Pea • seed-borne mosaic virus (PSbMV, non-persistently transmitted): High priority for field pea. PSbMV is potentially of high priority in lentil as well, after the recent finding of lentil seed-transmissible strains in lentil germplasm. This project focuses on providing the virus diagnostic services required to screen pulse germplasm for virus resistance and to ensure freedom from seedborne viruses during the breeding and variety development processes. Tissue blot immunoassay (TBIA), has become the virus diagnostic method of choice for surveys

	and variety improvement work as it is reliable and economic and can handle the large number of individual plant samples needed for surveys or variety improvement. Screening for resistance to these viruses is largely carried out in specific screening nurseries sowed in the virus-prone environment of northern NSW. Diagnostics are extensively used in the virus screening trials to identify resistant germplasm and to distinguish between viruses, as well as in breeding trials throughout the country. Apart from the high priority viruses, tests are as well carried out for viruses that occasionally show high incidences as follows: • Soybean dwarf virus (SbDV, persistently transmitted): Regularly found in the northern grain region on faba bean with symptoms that are undistinguishable from the closely related BLRV. • Subterranean clover stunt virus (SCSV, persistently transmitted): Occasional severe infections found in faba bean with symptoms that are undistinguishable from BLRV and SbDV. Tomato spotted wilt virus (TSWV, persistently transmitted by thrips): Low level infections regularly found on faba bean in the northern grain region. A destructive virus with the potential to be of economic significance. • Clover yellow vein virus (ClYVV, non-persistently transmitted): A highly destructive virus closely related to BYMV. Generally only low levels of infection are found close to inoculum sources in white clover stands. Distinguishing between viruses is not possible based on symptoms and a well-equipped virology laboratory that can provide a fast diagnostic service is required to support the pulse improvement programs. One of the advantages of the TBIA methodology is that the initial processing of the samples can be done close to the sampling site. Blotted membranes can then be mailed to a specialised laboratory for further processing. The DEPI Victoria virology laboratory at Horsham has been providing this service to the breeding programs with over 50,000 tests made on a yearly basis. The project will enable the laboratory to continue providing this service as well as to develop and refine diagnostic techniques. The project will facilitate the screening of pulse germplasm for virus resistance to enable development of virus-resistant pulse varieties; it will support other aspects of virus research such as studies on virus / vector relations and epidemiology; and it will also undertake virus-testing during germplasm enhancement and selection in the PBA breeding programs at DEPI, Horsham to ensure new varieties are free of seedborne virus.
Cereal and Pulse cultivar resistance ratings for the Southern region (DAV00144)	In many Australian cropping soils the presence of nematodes limits field crop production. In south-eastern Australia nematodes were estimated to reduce wheat and barley production by 4.9% ($98 million) and 5.1% ($42 million) respectively, with losses in excess of 20% possible (Murray and Brennan 2009). Field studies conducted by the Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR) and South Australian Research and Development Institute (SARDI) demonstrated losses of 5 to 10% in intolerant wheat cultivars due to root lesion nematodes with losses from cereal cyst nematode (CCN) known to be higher. In south-eastern Australia the nematodes of importance are the cereal cyst nematode (*Heterodera avenae*) and two species of root lesion nematode: *Pratylenchus thornei* and *P. neglectus*. The nematode species and density present within a paddock can be efficiently determined using the DNA based diagnostic test provided by SARDI (Ophel-Keller et al. 2008). Since the yield loss caused by nematodes is related to the density of the nematodes present in a paddock and the tolerance/intolerance of the crop, growers can minimise yield loss in two ways. The first is to grow crops or cultivars that are tolerant of the nematode (that is they can still yield well in the presence of the nematode). The second is to grow crops or cultivars that are resistant to the nematode and thereby reduce nematode densities, thus reducing losses in subsequent crops. For growers to select, and breeders to develop, field crop cultivars with resistance and/or tolerance to the range of important nematodes in south-eastern Australia reliable field data is required. Using field experiments the project will provide growers and their advisors with field tolerance and resistance ratings of newly released cereal cultivars and breeding lines to the important nematodes that limit yield in south-eastern Australia. The project will also screen pulses (e.g. field peas, faba beans, chickpeas and lentils) for resistance in the field to root lesion nematodes to develop resistance ratings in these important rotational crops. The tolerance and resistance ratings developed within this project will be published within DEDJTR and SARDI' annual disease guides to enable growers to select cultivars that will minimise yield loss in the presence of root lesion and cereal cyst nematodes.
Understanding the implications of new traits on adaptation, crop physiology and management of	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 b. Disease management c. Canopy management (biomass and architecture) d. Harvest quality

pulses in the Southern Region (DAV00150)	Variety specific agronomy packages are a focus of this investment that predominately is focussed upon traditional pulse growing region of the GRDC Southern region.

The project will also deliver research and development activities, whilst maintaining flexibility to address rapidly emerging industry needs (e.g. changes in disease resistance status):

- New traits for modern farming systems – i.e. Strategic genotype x management research
- Herbicide tolerance and weed ecology
- Disease management:
  - Field pea: Blackspot
  - Faba bean and chickpea: Resistance to ascochyta blight.
- Canopy management (biomass and architecture):
  - Lentils and faba beans: Improvements in vigour, architecture and biomass development
- Harvest quality:
  - The impact of adverse weather events on mature crops
- Integrated crop management strategies:
  - Targeted agronomic research will produce data for advanced breeding lines and new pulse varieties

The research will address major pulse production zones:

- SA Mid-North/Yorke Peninsula/Lower Eyre Peninsula
- SA/VIC Bordertown/Wimmera
- SA/VIC Mallee including Upper Eyre Peninsula
- VIC High Rainfall

MRZ trials of the existing project were focussed upon the following crops and agronomic factors:

2017 TRIALS	
Crop	**Focus**
Chickpeas	Disease Management - 17 varieties x 4 fungicide treatments
Chickpeas	Sowing Time - 2 TOS x 12 early maturing varieties
Chickpeas	Sowing Time - 16 varieties 2 TOS
Chickpeas	Disease Management - 20 varieties x fungicide application timings
Chickpeas	Fungicide treatments - 2 application timings
Chickpeas	Harvest Quality - 8 varieties x 3 delayed harvest timings
Faba Beans	Disease Management - 8 varieties x 4 fungicide strategies
Faba Beans	Herbicide Tolerance - 2 varieties x 15 Group B herbicide treatments
Faba Beans	Sowing Time - 3 TOS x 9 Varieties
Faba Beans	Sowing Time - 1 variety x 6 plant densities x 3 TOS
Faba Beans	Herbicide Tolerance - 4 varieties x 9 Group B herbicide chemistries
Faba Beans	Disease Management - 4 varieties x 4 fungicide application timings
Faba Beans	Harvest Quality - 4 varieties x 3 delayed harvest timings
Field Peas	Sowing Time - 2 TOS x 2 Lines x 6 fungicide strategies
Field Peas	Sowing Time - 4 fungicides x 2 TOS x 2 fungicide application timings
Field Peas	Crop Topping 4 varieties x 3 crop topping treatments
Lentils	Sowing Time - 2 TOS x 20 early maturing varieties
Lentils	Herbicide Tolerance - 4 varieties x 12 Group C herbicide treatments
Lentils	Harvest Quality - 8 varieties x 4 harvest timings (+ Crop-topping)
Lentils	Sowing Time - 2 TOS x 20 varieties
Lentils	Canopy Management - 2 varieties x 3 PGR's x 4 application timings
Lentils	Harvest Quality - 12 varieties x 3 delayed harvest timings
Lentils	Crop Topping 12 varieties x 3 crop topping treatments

2018 TRIALS	
Crop	**Focus**
Lentils	Sowing Time - 4 x TOS (irrigation @ TOS1) x 8 varieties
Lentils	Herbicide Tolerance - 2 varieties x 25 Group C herbicide treatments (incl rates) +/- Brodal
Lentils	Herbicide Tolerance - 2 lines x 5 Group B herbicide x 4 application timings
Chickpeas	Sowing Time - 4 x TOS (irrigation @ TOS1) x 8 varieities
Chickpeas	Disease Management - 15 Varieties x 4 fungicide treatments

Chickpeas	Disease Management - 2 varieties x 10 fungicide treatments (incl 2 seed treatments)
Chickpeas	Traits - 27 lines targeting cold tolerance
Faba Beans	Disease Management - 8 varieties x 3 fungicide strategies (especially new lines)
Faba Beans	Herbicide Tolerance - 2 lines x 5 group B herbicides x 4 application timings
Lentils	Sowing Time - 2 TOS x 20 varieties
Chickpeas	Sowing Time - 2 TOS x 16 varieties
Field Peas	Disease Management - 5 fungicides x 2 fungicide application timings
Faba Beans	Herbicide Tolerance - 2 lines x 8 group b herbicide treatments incl rates and nil treatments
Lentils	Herbicide Tolerance - 1-line x 8 group b herbicide treatments incl rates and nil treatments
Chickpeas	Disease Management - 10 varieties x 4 fungicide application timings

Improving grower surveillance, management, epidemiology knowledge and tools to manage crop disease in South Australia (DAS00139-BA)	The aim of this project is to identify disease threats, including emergency issues, to inform management strategies for plant diseases that are impacting on the SA grains industry. Costs and losses to the grains industry will be reduced by improving grower management of crop diseases. Disease-surveillance reports and management advice packages for cereals, pulses and oilseeds will be developed, appropriately updated using data from active pathologist field surveillance and delivered annually. These reports and packages will include emerging pathology issues such as virus management, *Ascochyta* blight of pulses and white grain in cereals. A coordinated 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 be used to manage disease in the cropping season. An extension program will use 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 use of electronic media to deliver information on best-practice disease management in the context of cost-effective crop-protection practice.
New tools and germplasm for Australian pulse and oil seeds breeding programs to respond to changing virus threats (DAN00202)	
Pulse Breeding Australia: Field Pea Breeding (DAV00153)	Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR) and Pulse Breeding Australia (PBA) will conduct a world class field pea breeding project that will deliver superior new varieties with increased productivity and profitability for field pea growers and which will expand the crops production range in Australia. To achieve this, the breeding will focus on improving yield potential, yield reliability and general adaptation, particularly for lower rainfall climates. The project will aim to combine desirable genetic variation that will increase grain yield potential, reduce crop production costs, reduce crop risk and maintain grain market access. The specific focus on trait genetic improvement will be annually reviewed and will cover: • Grain yield and adaptation (general and regional) • High yield potential across and within the major production regions for field pea • Yield reliability particularly in low rainfall or short season climates • Plant features and suitable agronomy • Emphasis on the 'Kaspa'; ideotype which is characterised by erect and vigorous vegetative plant growth, improved harvesting efficiency (e.g. lodging resistance, suitable plant height) and reduce harvest losses caused by pod shattering (e.g. sugar pod trait). • Selection for flowering time and flowering duration that suits lower rainfall climates where peas are the preferred pulse crop. • Regional adaptation for grain yield. • Multiple disease resistance to: Ascochyta complex, Bacterial blight, Downy mildew, Powdery

	mildew, • Viruses: Bean Leaf roll Virus, Pea Seed-borne Mosaic Virus • Abiotic stress tolerance to: High soil boron and soil salinity, Herbicides, Reproductive frost damage, Drought, Grain quality. The project will move away from the traditional Dun seeds to the more spherical 'Kaspa' type seeds. Other opportunities in the yellow and blue pea markets will be pursued as dictated by breeding outcomes. The project will ensure long-term genetic improvement for growers by undertaking a targeted parent building program for the major abiotic and biotic traits where superior genetic variation has been identified. Modern molecular breeding technologies and analyses will be adopted to accelerate breeding and genetic gains.
Pulse Breeding Australia: Lentil Breeding (DAV00154)	The Pulse Breeding Australia (PBA) Lentil program aims to deliver improvements in profitability and reliability of the Australian lentil industry and expand lentil production into new growing areas. To achieve this the program is delivering higher yielding mid and early maturing disease resistant red lentils, superior imidazolinone tolerant lentils and new germplasm that provides higher botrytis grey mould (BGM) and ascochyta blight disease resistance and higher boron and salinity tolerance for growers. In the previous PBA Lentil Breeding projects, a range of red lentil varieties with improved adaptation to low rainfall (PBA Flash, PBA Bounty, PBA Blitz) and large seed (PBA Jumbo) were released to growers. Subsequent to this, the first imidazolinone tolerant lentil was released in 2011 (PBA Herald XT) to improve weed control in the crop and across rotations. PBA Ace and PBA Bolt were launched in 2012 and are now benchmark varieties, with respect to yield and adaptation. In 2013, the high yielding imidazolinone tolerant lentil PBA Hurricane XT was released. This variety was the most popular lentil variety ever released to the Australian industry, with more than 1000 tonne of seed sold in the first year. This popularity shows the value that Australian growers place in the germplasm and novel traits being developed by this breeding program. In 2014, PBA Jumbo2 a high yielding, disease resistant, large seeded red lentil was released. It is now the highest yielding commercial lentil cultivar available in Australia. The lentil breeding program has worked closely with the southern pulse agronomy project and industry to maximise the benefits of new varieties for growers. Planning, monitoring and variety release has involved members of the Lentil Release Advisory Group (LRAG) and has utilised specialist knowledge from a range of sources such as plant breeders, agronomists, pathologists, marketers, stakeholders and PB Seeds representatives. The lentil breeding program continues to make progress in pyramiding traits that increase yield potential and reliability, disease and herbicide resistance, tolerance to abiotic stresses, harvestability, improved grain quality and general adaptation to more marginal climates for lentil production across southern Australia's cropping zone. We will focus on making gains in agronomic adaptation and yield potential, alongside improvements in tolerance to imidazolinone and metribuzin herbicides. Disease resistance in lentil germplasm will continue to be a priority, with an effort to incorporate new sources of resistance to combat changes in pathogen virulence which overcome resistance genes.
Coordinator of Pulse Breeding Australia (PBA) (FWC9175826)	

Southern Pulse Agronomy, Southern Pulse Validation and Southern Pulse Extension investments

GRDC investments -

Understanding the implications of new traits on adaptation, crop physiology and management of pulses in the southern region (DAV00151)	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 and France 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. Variety specific agronomy packages will also be developed. 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.
Improving the profitability of pulse production through local validation of research outcomes in the Southern Region (DAV00150)	A targeted validation trial program of significant scale to deliver local data and knowledge for the development of pulse crops suitable to areas across the southern region where research and development is limited. In collaboration with the Southern Pulse Agronomy project (DAV00150), pulse crops and constraints will be prioritised for each agro-ecological zone to develop the focus of the validation program. For example, it is envisaged that up to four of the most important pulse crops and up to four constraints will be examined in each zone where gaps exist. Local biophysical data from the validation trials and their impact on crop management, farming systems and farm economics will be made publicly available. The validation trial data will feed back into research and development activities of the Southern Pulse Agronomy project, and new knowledge will flow into the pulse extension project (PROC 9175825). In partnership with these and other GRDC projects, this three and a half year investment, starting early 2018, will deliver greater knowledge of the pulse phenotypes suited to each agro-ecological zone and management practices to optimise their production and profitability. Expected outcome, by June 2021, grain growers, advisers and industry will have access to local trial data that address the main constraints to the production of key pulse crops in each agro-ecological zone across the southern region. These data will quantify the adaptation and performance of key pulse crops in each zone, and the benefits of traits and management practices providing adaptation to local environments and farming systems, and enduring profit. These data and supporting economic analyses will contribute to grower and advisor confidence in pulse production, and will inform optimum agronomic practices for specific pulse phenotypes through evaluation of their applicability, profitability and risk in local environments.
Building capacity, skills and knowledge for the pulse industry in the Southern Region: Supporting expansion of high value pulses into new areas and ensuring sustained profitability of all key pulse crops in existing areas. (9175825)	Pulse crops have long been recognised as providing numerous economic and farming system benefits including: biological nitrogen fixation; providing a disease break for some foliar and soil-borne pathogens; enabling increased diversity in weed management; and providing agronomic and economic diversity in enterprise mix. Whilst immediate opportunities for expansion in pulse area in the Southern Region may be apparent, and are in-fact occurring, the willingness of growers to adopt is often limited due to a range of factors including: perception of risk and complexity in production; concerns over the longer-term sustainability of pricing as Australian production increases; lack of local agronomic knowledge and support; agronomic challenges relating to disease, weed and pest management; seed-cleaning, storage and marketing issues; and required investments in plant and infrastructure. Pulses are considered by many to be complex to manage and poor agronomy subsequently poses a risk to the profitability of inexperienced growers. The present shortage of specialised knowledge and skills relating to pulse crop agronomy within industry necessitates targeted investment in capacity building within the advisory sector to build future industry leaders and provide agronomic support to growers through the multiplier effect. In building this capacity special consideration needs to be given to the demand on existing recognised experts within the pulse industry, specifically key personnel within the research community. In addition, a targeted program to directly build the skills, knowledge and confidence of growers in the production of high value pulse crops, focusing upon lentil and chickpea, is required to hasten the successful expansion in area planted to these crops in the Southern Region. It is proposed that a

	participatory approach to knowledge transfer is implemented, targeted to identified geographical areas for expansion where these crops may be well adapted. This investment involves delivery of discussion groups, training, workshops and communication materials to realise long-term farming system and financial benefits to build capacity, skills and knowledge for the pulse industry in the Southern Region.
Increasing symbiotic nitrogen fixation for the benefit of following crops (9176601)	This extension and communication investment adds value to previous and current GRDC projects improving N fixation of winter pulse crops and promoting their wider adaptation and adoption. The three year investment commenced in in 2018, working with local influencers to promote best management inoculation and pulse management practices, and raise awareness and knowledge around pulse nodulation and N fixation, and the impact of soil acidity, especially subsoil acidity.
Increasing the effectiveness of nitrogen fixation in pulse crops through improved rhizobia strains, inoculation and crop management practices (9176500)	Recent expansion of the pulse industry is seeing crops increasingly grown in new and marginal environments that are responsive to rhizobial inoculation. In these situations, the viability of the pulse crop is strongly dependant on the availability of competent inoculant strains of rhizobia and best practice application of those rhizobia. This project will improve the viability and profitability of high value pulses (bean, lentil and chickpea) through the provision of improved inoculant strains, the assessment of inoculant delivery technologies under hostile establishment conditions and improved understanding of pesticide impacts on the symbiosis. It will demonstrate where inoculation is of value and identify opportunities for future symbiotic improvement. Specifically, the program will: • Complete the evaluation and commercialisation of a new acid tolerant strain of rhizobia for bean and lentil • Isolate, test and short list improved rhizobia for chickpea • Provide an objective assessment of inoculant technologies across a range of marginal environments and sowing conditions • Quantify the impact and develop strategies that minimise the impact of crop protection and herbicide applications on pulse N fixation. Promising strains of acid tolerant rhizobia for faba bean and lentil have been identified in previous GRDC supported research. The next phase of this work will focus on commercialising one of the strains and understanding the pH boundaries where it reliably delivers benefits. The ability of the new rhizobia to survive in soils outside of the host plant, will also be tested, which is an important to understanding future inoculation requirements. Similar rhizobia strain improvement work will be initiated for chickpea. New formulations and methods of inoculant application have been developed by industry to improve the options that growers have to inoculate their crops. However, there is a lack of current objective information on how the inoculants perform especially when sown into hostile soils. This project will assess the merit of different inoculant formulations and whether they provide advantages under challenging conditions, including where they are applied under dry sowing conditions. The effectiveness of inoculation can also be reduced through mixing with additives such as herbicides, fungicides, insecticides and fertilisers. The impacts, particularly on N fixation, are easily overlooked in the field. The extent to which crop protection chemicals are impacting on N fixation will be measured and growers and industry informed about which pesticides are most damaging and avoided where possible. The work will investigate the extent to which herbicide tolerant pulse varieties overcome the detrimental impacts of some herbicides on N-fixation. The project will be delivered by applied N-fixation researchers from the South Australian Research and Development Institute and University of Adelaide, collaborating with southern pulse agronomy and farming system groups in SA and Victoria. The program will have a strong field focus. To encourage practice change, the benefits will be demonstrated in validation trials across southern region in collaboration with key influencers of the pulse industry.
Managing legume and fertiliser nitrogen in the southern region (UA00165) - completed 2018	Grain growers in the southern region have a high level of uncertainty about the amount of nitrogen (N) supply required for cereal crops and the value of legume N in their cropping systems, including the amount of N contributed by legumes and when that N is available to the following crop. A significant amount of research has been done in quantifying amounts of N fixed by different legume crop and pasture species, but this information is only a small part of what is required by growers to make rational fertiliser decisions

	for following crops, and will depend on the frequency of legumes in rotation. What growers need to know is what proportion of the legume N is made available to the following crop or crops and the timing of the N availability and how this compares with fertiliser and mineral N, in order that they can supply appropriate N to cereal and canola crops in the southern region. The project will assist advisors and growers through improved knowledge and tools to assist the prediction of N supply from legume and fertiliser in the southern region. In summary, this two year project will: • Seek advisor and grower input on issues with current N fertiliser decisions, through facilitated workshops, • Produce a preliminary report on the current knowledge of N cycling and N management in commercial grain production systems of the southern grains region. • Evaluate and develop a support tool or tools, fact sheets and, for the southern region to assist in N decision-making by growers and advisors; • Develop a comprehensive user-friendly manual to be used by advisors and growers in the southern region to inform decisions on fertiliser N and soil N management in grain cropping • Capture advisor and grower feedback on the tool/s and manual through facilitated workshops.

Issue No. 51 - "Foliar diseases and poor agronomy of oats reduce hay yields and quality"

GRDC investments addressing this issue

Tactical break crop agronomy in Western Australia (DAW00227)	The grain growing region of south-west WA is dominated by wheat and barley production. If a profitable break from wheat or barley was available most growers would choose to include such a break crop and have shown this inclination in the past –e.g. lupin in the 1980's and 90's. With the decline of the lupin industry (low commodity price and weed issue) and the reduction in the WA's sheep flock the frequency of cereal production has increased. In the void left by lupin a wide range of alternatives such as oaten hay, bare fallow, pasture fallow, short pasture phases and in particular canola has appeared. Canola is grown throughout all rainfall zones and is in an expansion phase in low to medium rainfall zones as a wider range of adapted varieties become available and canola maintains its competitive price advantage over other options. As the area sown to canola expands into new areas there is a large knowledge gap in terms of basic canola agronomy such as density, nitrogen rate and timing, seed system choice (OP vs. hybrids), and herbicide system choice. In high rainfall areas canola is being grown in very tight rotations – often canola-cereal and blackleg management and variety choice is becoming a focus of industry concern. In this project issues will be identified and prioritised by project members, GRDC regional networks and by a Reference Group. The majority of issues will be tackled by field based research trials located throughout WA. The results from these trials and other relevant information will be extended to growers via spring field days, GRDC Crop Updates, GRDC and DAFWA web sites and mass media. Key to all of the agronomic questions for canola and indeed to all break crops are the economic benefits in the year they are grown and the system benefits growers obtain. An important component of this proposal is collaboration between DAFWA researchers and agribusiness consultants to provide economic analyses of the proposed trial program to provide clear guidelines on the economic impact of potential changes and whether these changes are large enough to cover the risks involved in growing a break crop. In the last 10 years we have witnessed reduced numbers of students studying agriculture and increasing age of researchers and extension specialists. For example the youngest professional officer in DAFWA's Grain Crop Agronomy group is 30 years old and the majority are over 40. Both DAFWA and GRDC recognise the issues such a situation may lead to in 10 years' time when some of the experienced staff begin considering retirement, and the importance of bringing fresh new ideas and building up experience of people with a long career in front of them. This proposal aims to employ two new professional and one technical officer and provide them professional training and mentoring.
Improved Resistance to oat pathogens and abiotic stress management (DAS00133-BA)	The production of oat in Australia increases by about 10-15% annually due to its growing demand domestically and for export, both for milling oats and oaten hay. Human health benefits and agronomic advantages as a break crop in rotations and its frost tolerance are reasons for its increasing popularity. Increasing demand has shifted oat production from traditional high rainfall oat growing areas to regions not traditionally known for growing oat including low rainfall environments. To develop better adapted and improved varieties environmental challenges are to be addressed through pre-breeding research that can focus on the constraints that have the biggest impact on oat crop production. Resistance to Cereal Cyst

	Nematodes, to stem and crown rust, to Red Leather Leaf disease, and in Western Australia to Septoria blotch are the most important biotic stresses in oats with drought tolerance being an abiotic key priority in oat breeding. Expected outputs: 1. Oat lines carrying new sources of stem and crown rust resistance genes in an adapted background that is available to the National Oat Breeding Program. 2. Oat lines carrying diverse sources of CCN resistance combined with CCN tolerance in adapted background available to the NOBP. 3. Identification of oat lines with improved resistance to Septoria avenae. 4. A cultivation and inoculation protocol of the Red Leather Leaf fungus that allows oat breeding lines to be assessed. 5. A toolbox of closely linked, user-friendly breeder markers for marker-assisted-selection of the rust and CCN resistance genes that have been analysed in this project. 6. Generation of a knowledge base on oat performance under low rainfall conditions comprising the determination of the critical period of yield determination, the preliminary screening and determination of phenological groups and the phenotyping for drought adaptation. Approach and expertise: Aforementioned traits will be screened for by using current varieties, breeding lines as well as nationally and globally sourced oat accessions including wild relatives. Existing mapping populations will be used for investigating the inheritance of resistance to stem and crown rust as well as CCN resistance. These mapping populations form the basis of molecular marker developments that will facilitate the introgression of the resistance traits into the breeding process. The analysis of the different diseases will be carried out in growth chambers, glasshouses and disease nurseries in the field. To assess the oat germplasm for the improvement of drought tolerance, secondary plant traits that can contribute to better performance under low water availability, such as flowering time and maturity, early vigour, canopy temperature, yield components, leaf chlorophyll and water soluble carbohydrates will be evaluated in well-watered and drought-stressed conditions, latter requiring the establishment of rain-out shelters. This project is a collaborative enterprise by researchers from the South Australian Research and Development Institute and the Cereal Rust Research Centre, University of Sydney.
Investigating phenology diversity in germplasm to optimise profitability from April sown oats	Oat production area was 345,000ha in WA and 820,000ha nationally in 2016-17 (ABARES). In WA, oats are grown as grain, dual purpose and hay crops and are valued for being less susceptible to frost than other cereals. Oats have a unique farming system fit in terms of weed competitiveness and provide options to sow deep and sow early. Current milling oat varieties lack diversity in their season length. Only early to medium spring types are available (~8 days spread when sown in late May), with no late spring or winter germplasm commercially grown. Recent research indicates the potential for oats to compete with barley and wheat when sown early (Troup et al. 2017). Furthermore, the vernalisation requirement of oats can be met in most seasons and environments (pers. Comm. Biddulph, 2018). There is, however, a higher risk of grain staining when sowing current oat varieties in April (early-mid spring types). The recent changes in oat receival standards in WA have tightened for Oat2 (groats and screenings) from the 2019/20 harvest and there will be no segregation for feed grade oats. Failure to meet Oat2 standards means that there is no option to deliver to the CBH supply chain. The risk of this occurring is greater to farmers without livestock in their enterprise (i.e. medium-low rainfall region) who cannot utilise the undeliverable feed quality grain. Therefore, the potential for early sowing late spring and winter types in milling oat production systems may combat the issues of grain staining and discolouration, through avoidance of adverse weather conditions. This investment aims to: a) Screen a wide range of oat lines (including international germplasm) at two locations under controlled environment (irrigation for establishment) conditions for adaptation and suitability to WA growing conditions. b) Investigate milling oat varieties and breeding lines expected to be released, when sown early (April and May), under different nutrition strategies to determine the best-bet agronomy for growers to meet tightening milling oat quality specifications. Research will focus on the principal oat-growing region in the medium and high rainfall areas of the Western

	Region in the Albany and Kwinana Port Zones. The project extends the strong existing collaboration with the National Oat Breeding Program.
National Oat Breeding Program (**DAS1808-004RTX)**	The National Oat Breeding Program develops improved oat varieties for the southern region of Australia. Two teams located at SARDI and DAFWA are responsible for delivering outcomes to oat grain industries throughout the country. Climate variability and the expansion of oat into low rainfall areas has emphasized the need to identify germplasm for the National Oat Breeding Program with improved drought tolerance. Demand for milling oat continues to increase with the nutritional benefits of the grain and the development of new food products using oat. The project objectives are to deliver high yield potential oat varieties with improved disease resistance and enhanced grain quality. Oat is becoming synonymous as nature's functional food. The healthy benefits of the grain are an important consideration for companies producing food products from oat. The National Oat Breeding Program in collaboration with Uncle Tobys Company (UTC) will develop a healthier oat variety by increasing beta-glucan content in the grain. The outcomes from the project will be the development of high yield potential oat varieties adapted to South Australia, Western Australia, and south-eastern Australia with improved combinations of disease resistance, and enhanced grain quality; identification of superior parental lines for drought tolerance to be used in the crossing program; and identification of an advanced breeding line with higher levels of beta-glucan for potential release.