KIT 3.1

Develop and implement management options to minimise the cost of effectively and sustainably managing weeds.

Impact	**Growers are able to sustainably reduce the impact of the most important weeds on farming systems and grain production.**
Summary	• Growers maintain weed populations at low, controllable levels. • Growers employ a range of diverse management tools to control priority weeds. • Growers utilise integrated weed management to maintain the effectiveness of control options.

OVERVIEW

Weeds represent a major cost to the Australian grain production. It has been estimated that weeds are costing Australian grain growers $3.3 billion per annum through the direct cost of weed control, the impact of weeds on crop yield loss due to competition and price downgrades due to contamination (Llewellyn et al. 2016). Weeds are currently an important consideration for growers in making management decisions regarding seasonal crop and variety choice. Limited options for the control of weeds in pulse crops is a significant constraint to incorporating pulses into rotations in many circumstances. Weeds also can be serious issues in the management of roadsides and irrigation channels and through competition can significantly reduce biodiversity and the abundance of native plant species.

Herbicide use remains extensive, with an average of 92 per cent of the Australian grain cropped area receiving at least one herbicide application each year. Over the past 20 years, increasing reliance on herbicides to manage weed populations has resulted in the evolution of herbicide resistance to 21 of the 25 known herbicide modes of action that comprise 148 different herbicides, worldwide. More recently, the introduction of glyphosate resistant crops and the general reliance on the use of glyphosate in no till farming situations have led to the evolution of 24 glyphosate resistant weeds in 18 countries. In Australia it is estimated that 16 per cent of farms are affected by herbicide resistant weeds (Farm Practices Survey Report, 2015). A farm practices survey conducted in 2015 revealed that 28 per cent of all grain growers stated that weeds caused a change in what crop or variety they grow.

The current weed challenges for Australian grain growers include: increasing incidence of herbicide resistance across multiple modes of action; high direct and indirect (labour) cost of control/management (estimated average of $113/ha); reduced crop yield due to competition for resources (estimated average of $33/ha); trade-offs in management decisions (e.g. the implication of residual herbicides on crop choice); and an increasingly complex and costly regulatory environment. An additional challenge is not only the evolution of herbicide resistance in weeds but the evolution of herbicide avoidance characteristics in weeds such as delayed germination. Weeds are continually adapting to changes to management practices or environmental conditions. Hence, weeds continue to be a major impediment to crop profitability.

Over the past 20 years the grains industry has made significant advancements in weed management including the evolution of harvest weed seed control and the strong adoption of double-knock control strategies. However, the impact of weeds will continue to be problematic without an integrated approach to their management. Integrated approaches combining tactics, such as mechanical, chemical and cultural farm-management techniques.

Integrated management strategies include mixing and rotating herbicides with different modes of action, harvest weed seed control, crop competition, hay making and good farm hygiene. Novel management tactics and technologies such as the application of robotics and other engineering solutions, as well as weed competitive crop types could be important weed management tools in the future.

GRDC has and will continue to invest in RD&E to deliver the most effective weed management tactics for the grains industry. RD&E is needed to inform grower decision-making and equip them with the knowledge and tools to deploy weed management strategies to increase on-farm profitability and productivity in an environment of increasing herbicide resistance.

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Transforming research outcomes into on-farm management strategies is critical to guiding and supporting grain growers in tackling this major constraint to farm business profitability. Industry-driven extension efforts will provide growers knowledge and tools to make informed decisions to effectively and sustainably manage weeds.

Key Investment Target (KIT) 3.1 is partitioned into four linked phases or scope areas. The first scope area focusses on understanding the distribution and impact of different weed species. This will assist GRDC to prioritise its investment in RD&E to deliver management solutions the highest potential impacting and risk weeds. The second scope area will focus on understanding the inherent biology of weeds and weed communities to assist in identifying potential management strategies. The third scope area will focus on identifying potential effective weed control tactics while taking into consideration the ability of weeds to resist these tactics. The fourth scope area will focus on integrating weed management tactics for priority weeds into sustainable and effective strategies suited to modern farming systems utilising knowledge of weed and crop biology and the economics of weed management and impact.

FUTURE RD&E FOCUS

SCOPE – Understanding of the distribution and impact of weeds

The current and potential distributions and impacts of weeds are quantified.

The term 'weed' when used to refer to a plant growing out of place, is a straightforward concept in cropping systems, where any plant other than the crop being grown is unwanted. However, individual weed species differ in the impact they have on the crop and farming system.

Like crop plants, weeds have preferences for areas with different climate related factors such as rainfall, temperature and day length and weeds can also have preferences for soil attributes such as texture and pH. Weeds interact with the farming system practices being used and they can adapt to growing with different crop types and adapt to cope with tillage. Some weed species have evolved to be generalists and can proliferate under many different environments. Others are adapted to very specific or localised environments even within paddocks. Understanding the potential areas of establishment of a weed species at both landscape and paddock scale is critical to determining the potential impact on grain crops and can help guide broader industry and jurisdictional management plans to prevent further spread and guide regional action or area wide management opportunities.

Most weeds do not occur discretely within a landscape and some species can disperse naturally and via assistance over considerable distances. The dispersal ability of a given weed species is dependent on its inherent biology. Weed species such as sow thistle and feathertop Rhodes grass disperse by wind, potentially moving across property boundaries and disparate land uses. Weeds such as annual ryegrass, wild radish, barley grass, doublegee, and wild oats can be dispersed by humans, livestock, machinery, contaminated grain and fodder. Therefore, actions by one land manager can influence the weed situation of others. Different crop industries such as viticulture, horticulture or cotton often share the same landscape with grains, such as in the Riverina area of southern NSW, and so one industry can impact the weed status of another.

Understanding the areas where weeds can potentially establish (areas of adaptation) and the mechanism by which individual weeds species disperse will be important in informing the identification, development and implementation of effective and sustainable weed control management strategies.

Investment Outcome 3.1.1 – Growers have access to tools and technologies to identify, quantify and map the distribution of weeds in farming systems.

Grain growers need improved tools and methods to easily identify, quantify and map weed incursions on the land that they manage. This in turn would enable the development of effective management strategies for weed populations on their land. The mapping of weeds across the land identifying localised areas that specific weeds prefer can provide growers with the basis for a tailored on-farm weed biosecurity plan embedded within the whole of farm weed management strategies. New tools for improved weed identification will need to include the capacity to discriminate resistance biotypes which could be achieved through molecular or other novel technologies.

The development of site-specific weed management technologies to allow for targeted in-crop herbicide application is a primary focus for R&D investment and technology development in the private sector. The ability to detect, discriminate

between and map weed species in-crop during each machinery pass in a paddock, or via increasingly high spatial-resolution aerial imagery, has multiple benefits, such as:

- Better inform the timing and number of herbicide applications and chemistry mixes to control weeds
- Lower the cost base of manual chipping and/or route optimised robotic platforms
- Allow for spatially guided adjustment of harvester settings for optimal harvest weed seed control (HWSC) without having to broadly compromise harvest speed, throughput or cutting height across an entire paddock
- Early detection of new weed species infestations and/or herbicide resistant biotypes.

The detection of weeds away from the in-crop setting also has distinct advantages. Quantifying the number of weed seeds in the soil would also provide considerable advantages in proactive management. Detecting weed seeds during grain handling (directly on the header or during grain transfer) allows marketing opportunities to be realised.

GRDC will consider investments that increase the speed of delivery of this technology to Australian grain growers and/or broaden the usefulness of the technology to the suite of grain crops and Australian weeds.

Investment Outcome 3.1.2 – Growers and researchers understand the current and future potential impacts of different weed species.

There are hundreds of plant species which have the potential to be cropping weeds when the definition of a weed being a plant growing out of place is used. However, weeds can be alternatively identified as plants that have negative economic, ecological and/or social impacts on farm businesses and communities. The magnitude of these impacts is an important determinant of the current or potential seriousness of a weed species.

GRDC will focus RD&E investment on those weeds which have the greatest current or future potential impact on crop production both short term and long term but also take into consideration the ecological and/or social impacts on farm businesses and communities. GRDC will consider investing in RD&E to understand the current and future impact of weeds for different situations. This combined with information from Investment Outcome 3.1.1, will enable grain growers to address those weed related factors and challenges that have the greatest current and potential impact on their farm profitability.

Weeds are defined as plants that have negative economic, ecological and/or social impacts. The magnitude of these impacts is an important determinant of the seriousness of a weed species. Whilst we have data on estimated economic impact of the most troublesome cropping weed species from the Llewellyn et al. (2016) 'Impact of weeds' report this doesn't recognise emerging weed species or the potential impact of these new or emerging species. R&D is required to develop a method to objectively quantify the risk of these weed species. This is particularly true of localised weeds which have an impact in a smaller geographical zone.

Future RD&E effort will be focussed on weeds with the greatest potential impact on the enduring profitability of Australian grain growers. Prioritisation of weed species research must be informed by a risk-based approach. GRDC will invest to determine a defined process that prioritises which weeds will be the focus of future RD&E investment. There are numerous existing models which would serve as a starting point for assessment on their suitability for this purpose

SCOPE – Understanding of the biology and ecology of priority weeds

Knowledge of the ecology and biology of weeds is improved, to support development of optimal management options.

For integrated weed management strategies to be effective the strategies need to take into account individual weed species biology and ecology. The factors relating to biology and ecology that need to be understood about a weed species to enable design of optimum management strategies include:

- The weeds preferred ecological niches (e.g. temperature, soil type, pH, level of disturbance)
- The weeds expected response to changing farming practices such as reduced tillage
- The weeds expected response to interaction with specific crop types and with other weeds.

There are currently 47 weed species which have confirmed herbicide resistance status in Australia. These are resistant to 10 different Modes of Action. Thirty of these species are known to be weeds of grain crop production. It has been estimated

that grain growers spend an extra $8.24/ha to control herbicide resistant weeds. These total $187M for Australia nationally. Weed species and populations are constantly evolving as a result of selection pressure. An ever-increasing number of species of weeds are being found to be herbicide resistant or resistant to a new Mode of Action. Of concern is the developing resistance to newer pre-emergent herbicides.

Monitoring for herbicide resistance across the Australian grain growing regions allows for early detection of emerging resistance issues, so tailored solutions can be developed. Understanding the mechanisms by which weed populations have become herbicide resistant enables the possibility of developing control tactics for resistant populations and delaying resistance in susceptible populations through appropriate management. Knowledge on the evolution of resistance and the associated mechanisms can advise the development of more effective herbicides or herbicides that weeds have a lower chance of evolving resistance to or development of other management tactics to disrupt this evolution.

Investment Outcome 3.1.3 – Growers and researchers have the knowledge and tools to better understand the biology and ecology of priority weeds and their interactions with crops and other weeds.

By having increased knowledge on the biology and ecology of weeds, grain growers will have the tools to implement the most appropriate management strategies for the weed spectrum occurring on their properties. Grain growers need to be aware of the likely weed related implications of changing farming practices such as new crops, earlier sowing, or soil amelioration. Growers need to understand how changes to farming practices impact weed populations and species, so that the benefit cost of implementing the new farming practice can be fully determined.

For many weed species, effective control strategies are relatively well known. However, for many other weed species, particularly those which are emerging in distribution and impact, knowledge is lacking. Recent investments such as UA00156 and DAW00257, have generated considerable new knowledge on the biology and ecology of a range of emerging and localised weeds in all GRDC regions. To assist growers in making more informed decisions to manage emerging weed species requires integrating this biological knowledge into control tactics and generating effective integrated weed management strategies for these weeds.

Investments that address additional knowledge on priority weeds and the ecological drivers that influence weed species in different farming systems will be considered by GRDC.

Investment Outcome 3.1.4 – Growers have the knowledge and tools to effectively monitor changes in the impact, crop interactions and herbicide resistance status of weeds.

Weeds and crops interact by competing for resources (light, water and nutrients). Understanding how weeds interact with crops as well as with other weeds within crops offers additional opportunities to exploit any weaknesses in the weed and focus on utilising the strengths of the crop. This work would include considering aspects of crop plant architecture (roots, leaves and stem), placement of nutrients, chemical interference (allelopathy), and relative time of seed shed by the weeds.

Early detection of herbicide resistance is important as it provides time for growers to adjust their management practices to reduce the incidence and extent of herbicide resistant weeds. Effective communication is important to increase industry awareness of herbicide resistance issues leading ultimately to increased resistance detection by growers and advisors. This allows optimal weed management decisions to be made. Increasing the tools that improve the activity of growers to enact weed resistance strategies through improved understanding, timeliness and accuracy, will assist in the management of resistance and will be consider as a priority for GRDC investment.

SCOPE – Tools and technologies to manage weeds

Tools and technologies are developed to assist growers to optimise management of priority weeds in farming systems.

The Australian grain industry has adopted herbicides as a primary tool to manage weeds due to their efficacy, ease of use and cost effectiveness. The increasing rise of herbicide resistance as well as increasing regulatory oversight will require the adoption and integration of a range of novel tools, technologies or tactics.

The capacity of weed populations to evolve and adapt, requires growers to continually deploy a range of different control strategies combined in an integrated weed management approach. Some of the different techniques include diversifying the herbicides used, harvest weed seed control, strategic cultivation, plant competition and farm hygiene. Research and development to create novel management tactics such as low disturbance physical control methods, weed competitive crop types and other agronomic tactics is a priority consideration for future RD&E investment by GRDC.

In addition to the traditional RD&E delivery pathway GRDC and other Australian R&D investors will consider partnering with commercial companies that have proven research, freedom-to-operate and path to market expertise to facilitate the discovery and delivery of new tools and technologies including chemistries, both traditional and novel.

Investment Outcome 3.1.5 – Growers have access to diverse biological, chemical, agronomic and physical options for the control of weeds.

Herbicides will continue to be a major tool for weed management in Australian grain production. However, these tools need to be supplemented with new or improved complementary tools and tactics, due to: the increase in herbicide resistance, ongoing increases in regulatory requirements, the decreasing number of new herbicides being developed and increased market and social influences on herbicide availability. Effective non-chemical weed control technologies could enable Australian grain growers to differentiate their grain produced in markets on the basis of free of chemical residues.

GRDC will continue to consider RD&E investment aimed at the introduction of new chemistry and more targeted application of chemistry including application methods that can avoid creating herbicide residues in grain.

With the increase in accurate identification of weeds in cropping systems as identified in Investment Outcome 3.1.1, in combination with the substantial cost savings through site-specific targeted weed management provides opportunity for the development of novel tactics which would be too expensive if applied across whole paddocks.

Biological, cultural and physical weed control options applicable to multiple farming systems and weeds could be a critical part of a sustainable weed management strategy. Relatively low disturbance physical control methods, crop competition, weed suppression and grazing are all important agronomic weed control options. Biological control agents are the most cost-effective solution for landscape scale management of weeds. GRDC will consider investing in RD&E that provides growers with additional complementary weed management tools to implement integrated weed management in grain farming systems.

R&D focussed at the breeding of crops for improved weed competition, breeding of herbicide tolerance traits, and breeding for tolerance to novel weed management tools is likely to be a consideration for future GRDC investment. For example, newer genetic tools are in their infancy in weed management, however, their impact in other agricultural disciplines indicate that they could have application in weed management tactics (e.g. weed sterility, seed dormancy) as well as weed identification.

SCOPE – Integration of weed control decision-making in farming systems

The management of weeds is optimised in a whole-of-farm business and farming system context.

Despite much excellent RD&E on Integrated Weed Management (IWM) solutions, weeds continue to remain a significant challenge for Australian grain growers. This is largely due to the ongoing evolution of biotypes of weeds with resistance to an increasing range of different chemistry or the evolution of weeds which have changed their germination characteristics and now germinate later during crop growth to avoid early crop stage chemical application. To deliver grain growers truly effective IWM strategies or options will require not just high quality and innovative research, but also enhanced awareness and communication of the R&D outcomes. IWM can be considered complex, expensive and less efficacious to implement than straight herbicide use and therefore dedicated and strategic thought into the best methods to achieve adoption of IWM strategies will be essential. Effective communication and extension of IWM strategies will be an important consideration for GRDC investment.

Weeds have a huge cost impact on agriculture, including rural community assets such as roadsides and can significantly reduce biodiversity through competition with native species in uncropped areas. Weed management is often done in an

un-coordinated manner with the sole focus on the result at the individual land unit or business level rather the landscape or community level. This fails to incorporate the dynamics of weed mobility, landscape use and human behaviour at the community level. A collaborative cross-sector area wide approach to weed management may offer a method to address these constraints and result in a decrease in overall weed abundance and impact at the individual primary producer and landscape level.

Investment Outcome 3.1.6 – Growers understand the risks and economic implications of weed management options within farming systems.

GRDC will consider investing in RD&E that delivers grain growers tools and information to enable them to implement weed management strategies not just for the current crop but for the cropping rotation, broader farming system and the greater farming landscape. The information required to achieve this includes the direct impact of the weeds, the interactions between weeds and specific crops and associated crop agronomy, changes in weed population and dynamics due to seasonal influence, the extent of weed seed carryover at the paddock level, weed seed contamination of grain, and dispersal into or re-infestation of neighbouring non-cropped areas. It is intended that grain growers would be able to utilise this information to integrate management options (IWM) to optimise the level of weed control based on the direct impact on the crop, the impact on crop price due to contamination, and the availability of weed management options in following crops and adjacent non-cropped areas.

Investment Outcome 3.1.7 – Growers have the knowledge and tools to control weeds while maximising the longevity of diverse management options.

Through the understanding of weed biology and ecology, and by having access to a range of IWM tools and tactics, grain growers can develop effective weed management strategies for the land that they manage. Short term returns on IWM are measured by the direct impact on the gross margin of the crop. However, understanding the true impact of IWM on the weed seedbank, the evolution of herbicide resistance and the impact of changing farming systems on weed populations needs to be considered over the long-term. For example, a small number of weed survivors will significantly increase the seedbank. Weed seed carryover in the soil seedbank has a huge impact on cropping returns in future years. Calculating returns over the long term (e.g. 10 years) will help determine the real value of weed management options. GRDC will consider RD&E investment to provide growers with the tools to assess the long-term impact of IWM on their farming business and local community.

Investment Outcome 3.1.8 – Growers plan and implement optimal weed management tactics and strategies.

A range of weed control tactics are required to build effective IWM strategies. These tactics need to suit a range of different environments and farming systems as well as be able to be customised for individual growers and situations. A well-adapted and customised IWM strategy will need to consist of a number and combination of cultural, physical, genetic and chemical weed control tactics. The participation of growers and advisors in local RD&E to validate, test and build confidence in a range of tactics and strategies through discussion and sharing, would potentially enhance the adoption of IWM strategies and in turn reduce the impact of weeds on the grain industry. It is also important that information is available to support growers to choose the appropriate tactics to build an IWM strategy suited to their specific situation. This could be considered a focus for future GRDC investment.

REFERENCES

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