

**REPORT**

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# THE ECONOMICS OF PRECISION WEED MANAGEMENT

A review of optical spot spray technologies  
with six case studies



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with six case studies

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**PHOTO:** Julia Brown, Upstream Communication

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Photo: Evan Collis/GRDC

# 01. INTRODUCTION

Weeds present one of the biggest challenges to the effective management of cropping systems. Rainfall and seasonal weather patterns, differing weed types and characteristics, along with herbicide resistance require the application of different weed management practices. The challenges posed by weeds continue to change, requiring ongoing adaptation of management practices, especially with the rise of herbicide resistance.

In 2016, the *Impact of weeds on Australian grain production* report estimated the annual cost of weeds to Australian grain growers to be \$3.3 billion. Of this, \$487 million was spent on fallow weed control through herbicide application and cultivation. Since then, herbicide resistance has become more widespread, reducing the effectiveness of some herbicide mode of action groups. This issue, coupled with the slow development of new herbicide chemistries, necessitates concerted efforts to maintain effective weed control and preserve herbicide longevity. The GRDC's *Integrated weed management in Australian cropping systems* manual reported that herbicide resistance affected 43 per cent of cropping land on average, with 64 per cent of growers identifying some herbicide resistance on their farms. To date, 49 weed species in Australia have confirmed resistance to herbicides, 17 of which are resistant to glyphosate.

# 02. INTEGRATED WEED MANAGEMENT

Precision weed management technologies offer significant potential for enhancing the efficiency and effectiveness of weed control in Australian grain production, ensuring long-term sustainability and profitability for growers. This report examines optical spot spray technology (OSST) in Australia using six case studies, exploring its use and the economic impact to a farm business operation.

For long-term weed management and to avoid chemical resistance, an integrated weed management approach is crucial. It considers personal, financial, natural resource and production goals. The *WeedSmart* Big 6 highlights six ways to manage weeds.

- 1. Rotate crops and pastures.**
- 2. Increase crop competition.**
- 3. Mix and rotate herbicides.**
- 4. Optimise spray efficacy.**
- 5. Stop weed seed-set.**
- 6. Implement harvest weed seed control.**

New herbicides and precision application technologies, such as optical spot spray technology (OSST) solutions, are enhancing the tools available to stop weed seed-set.

# 03. PRECISION WEED MANAGEMENT TECHNOLOGIES

Several precision weed management technologies are available. The technologies are classified into four groups based on how they detect weeds: sensor based, camera based, drone weed mapping, and mechanical.

OSST solutions have been used in Australia for more than a decade. Green-on-brown (GoB) technologies were the first introduced and are now widely used. GoB focuses on weeds during the fallow period, leading to significant increases in stored plant-available water and nutrients at planting that enhance crop yield and grain quality.

Green-on-green (GoG) technologies use artificial intelligence (AI) to determine if a plant in the camera's vision is a weed. Several algorithms are being developed to implement GoG technologies more widely for Australian conditions and weeds.

### Sensor-based technologies

Sensor-based technologies are a form of OSST that can be used in GoB fallow or summer spraying situations. They detect green weeds against a 'brown' (soil or dead plant matter) background and spot-spray them using near infrared (NIR) technology. These technologies emit light from the spray boom towards the soil and plants, where living chlorophyll emits a small amount of NIR light as a reaction called 'chlorophyll fluorescence'. This wavelength distinguishes a living plant from dead matter, soil and other substances.

These technologies have been operating in Australia for several years. Their simple interface design makes them easy to use and they can be retrofitted to most booms. Some sensor-based technologies can require a set boom height to ensure stability for sensor accuracy. Examples of sensor-based technologies already available in Australia include WeedSeeker® 2 and WEED-IT.

#### WeedSeeker® 2

WeedSeeker® 2 is a sensor-based technology that uses red or NIR light to detect when a weed passes underneath the sensor and then signals the linked spray nozzle to activate. The upgraded sensors in WeedSeeker® 2 take more readings per second and can recognise smaller weeds. They can also adjust to various levels of ambient light, temperatures and backgrounds.

Sensors are placed at 50-centimetre intervals and use both infrared and NIR light sources, enabling the system to target 2cm weeds while travelling at speeds of up to 20 kilometres per hour. WeedSeeker® 2 also logs and maps the areas where weeds have been sprayed, allowing for the generation of mapping records that can identify problem areas in different paddocks.

#### WEED-IT

WEED-IT is a sensor-based technology with sensors spaced one metre apart across the boom. These sensors emit a red light (previous models used a blue light) that scans the ground surface 40,000 times per second to detect chlorophyll, which absorbs the light and emits NIR light back to the sensors, activating the sprayer.

The nozzles are spaced 25cm apart, with five nozzles covering the area of one camera. Each individual spray solenoid opens in one millisecond to spray the targeted weed. This sensor-based technology is compatible with several booms and can be adapted to different tank set-ups. It can create a dual line, to apply different chemicals at different rates, or it can blanket spray with one chemical while spot spraying with another.

### Camera-based technologies

Camera-based technologies can be used in both GoB and GoG situations. They use RGB (red, green, blue) cameras and/or distance or multispectral cameras to capture video images of weeds as they pass over them. Using algorithms and machine learning, these technologies are continually evolving and improving.

The cameras scan and analyse the paddock in real time, with computing modules processing the images using AI to detect and spray weeds. As the algorithms continue to develop, the technology evolves, becoming more effective. Several algorithms are being refined at the moment for broader implementation in Australian conditions and weeds. Examples of camera-based technologies available in Australia include SenseSpray®, Bilberry and John Deere See & Spray™ Select. Summaries of these technologies are provided below.

#### SenseSpray®

SenseSpray® is a camera-based technology that triggers a solenoid to spray only the detected weed when the camera identifies it. Using a proprietary algorithm (patent pending), SenseSpray® can identify weeds at speeds up to 18km/h. Each SenseSpray® camera processes its own data, minimising lag in triggering the spray solenoid.

The system is designed to run parallel with existing farm technology and can be scaled to fit the size of the grower's boom. SenseSpray® can be retrofitted to most sprayers, with kits developed for various self-propelled and towed sprayers including Case IH Patriot®, John Deere, Hayes, JTA, Goldacres, Apache and Rogator.

## Bilberry

The Bilberry technology uses RGB high-definition video cameras spaced at 3m intervals across the boom. Using machine learning, Bilberry continuously improves its detection capabilities by identifying patterns from experience and data. A cab-mounted screen serves as the control centre, interfacing with the operator and coordinating nozzle activation.

For GoB spraying, night-vision kits can be used. GoG algorithms are available for broadleaf weeds in wheat, barley and oats. In 2022, a beta release included: blue lupins in narrow leaf lupins (white) and lupins; grasses in canola; and vetch in lentils. This camera-based technology is commercially available on Agrifac, Goldacres and Miller self-propelled sprayers, but it cannot be retrofitted to existing sprayers.

## John Deere See & Spray™ Select

The See & Spray™ Select is a camera-based technology that scans fallow ground, sending data to the sprayer's vision-processing unit. It uses RGB cameras to differentiate green plants from non-green backgrounds, allowing the vision-processing unit to identify the colour green and apply herbicide only to the weed.

The See & Spray™ Select system can switch from broadcast spraying to targeted spraying and can be used at night. It records and maps herbicide application, enabling operators to manage weeds over time using the Operations Centre. The system features a single tank with a capacity of up to 6057 litres. With 36 cameras across a 36.6m boom, it can travel up to 19km/h and apply targeted spray within 200 milliseconds of detection. However, See & Spray™ Select cannot be added to an existing boom.

## Drone weed mapping technologies

These technologies require the operator/grower to map the paddock with a drone, identifying weed locations based on their size. This mapping allows the grower to assess weed pressure and determine the most effective treatment across the paddock. Weed management decisions, such as which types of weeds to target, herbicide usage, application rate and precision of application, can be made based on these maps.

The data provided by the drone enables the grower to identify the exact volume and cost of spray required before mixing any chemicals, ensuring adherence to herbicide usage labels and preventing waste at the end of a spray run. Unlike systems with boom-mounted sensors, these technologies spray according to a prescription map developed by a drone and loaded into the tractor console.

Since a drone is required, the operator/grower needs another level of technical competency, as drone map development is the applicator's responsibility. Licensing, in the form of a remote pilot's licence, is also necessary if you are not flying over your own land and your drone weighs more than 25 kilograms but not more than 150kg.

If you choose to operate the drone for hire or reward, you will also be required to obtain a remotely piloted aircraft operator's licence. Examples of drone weed mapping technologies available in Australia include Single Shot (now WeedMapper), HARDI GeoSelect and InFarm. Summaries of these technologies are provided below.

## Single Shot

Single Shot is a drone-based weed mapping technology that operates at an altitude of 80m, covering more than 200 hectares per hour. The drone is equipped with optical cameras that map the weeds, allowing for mapping operations under less-than-ideal conditions, such as when the paddock is too wet or the weather too hot.

These maps are downloaded from the drone and used to create spray maps that can be transferred to the tractor console, providing growers with the ability to specifically target several types of weeds.

Weeds are identified based on a minimum size of 3cm, with a small buffer around each weed, helping growers understand the types of weeds present in their paddock. This information facilitates informed weed management decisions. Compatible systems include John Deere, Trimble, Raven and Ag Leader.

In late 2024, Single Ag released a new product called WeedMapper. (The case studies presented in this document were analysed in mid-2024. At time of analysis, Single Shot was used by growers; this technology has now been superseded by WeedMapper.)

## HARDI GeoSelect

HARDI GeoSelect is a drone weed mapping technology that enables users to map weeds before spraying using either a manned aircraft or a drone. Once the mapping is complete, the data is transferred to the spray computer for processing, with software calculating the precise amount of chemicals needed before starting.

The system includes sensors on the boom that continuously measure boom height and deflection, adjusting nozzles to accurately target each weed at speeds up to 30km/h and achieving a 99.7 per cent accuracy rate. This system is designed to operate under any lighting conditions and includes adjustments for boom sway to ensure precise herbicide placement.

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## InFarm

InFarm uses drones to capture high-definition images of paddocks. These images are uploaded to InFarm's processing platform, where a specialised weed-identifying algorithm is applied. The processed data is converted into a tractor-ready file, which can be uploaded into a standard variable-rate console via USB.

This file controls the sprayer nozzles, activating or deactivating them based on the detected presence of weeds. The system integrates with existing spraying machinery. This technology also has the capacity to map farm catchments for management of water flow, erosion and storage in the landscape.

## Other precision weed control technologies

These technologies could include the use of cameras, laser and physical methods to control weeds. Many of these are still in development, with further testing and trials required to meet Australian broadacre conditions. Some examples of these technologies include:

- LaserWeeder by Carbon Robotics (US) – autonomous laser weed management being field-tested in large-scale horticulture
- DataFarming (Australia) – low-orbit satellite weed detection, agronomy
- Electrical weeding – examples include Azaneo (Australian), Zasso (Swiss), RootWave (UK) and Weed Zapper (US), which are being developed for broadacre use
- 'Weed Seed Destroyer' conceptual product by Global Neighbor Inc – a harvester-mounted system that uses high-intensity blue light and mid-wave infrared heating to kill weeds in chaff
- RIPPA™ – Robot for Intelligent Perception and Precision Application developed by the Australian Centre for Field Robotics at the University of Sydney and under field trial in horticulture.

With technological advancements and ongoing innovation, the precision weed management landscape is constantly evolving. Table 1 summarises some of the weed management technologies available in Australia. Mechanical weed technologies are not yet widely available.

**Table 1: Summary of the different precision weed management technologies available in Australia.**

Technology	Available	Green-on-brown (GoB)	Green-on-green (GoG)
<b>Sensor-based technologies</b>			
WeedSeeker® and WeedSeeker® 2 (owned by Trimble)	✓	✓	
WEED-IT and WEED-IT Quadro	✓	✓	
<b>Camera-based technologies</b>			
Sense Spray	✓	✓	
Bilberry	✓	✓	✓
John Deere See & Spray™ Select	✓	✓	See & Spray™ Ultimate limited US release
<b>Drone weed mapping technologies</b>			
Single Shot	✓	✓	
HARDI GeoSelect	✓	✓	✓
InFarm	✓	✓	



Croplands Sonic WEED-IT system, Warakirri Cropping in Donald, Victoria  
Photo: GRDC

### A note on spray application

GoB and GoG technologies require an understanding of mode of action chemistry and sprayer output accuracy to ensure efficacy. Growers should review their sprayer configuration to ensure best practices for all spray operations. The GRDC GrowNotes publication *Spray application manual for grain growers* is a valuable resource for maximising sprayer output accuracy and efficacy.

In response to the increased use of optical spraying, APVMA has issued a minor use permit for new optical spot sprayer herbicide rates for another 15 herbicides from Corteva, Sipcam, Arysta, Nufarm, Shandong Rainbow, Syngenta, Sumitomo, Nutrien Ag Solutions and FMC Australasia. This permit (PER90223) is for various herbicides applied using OSST such as WeedSeeker®, WEED-IT, John Deere See & Spray™ Select, Bilberry and other emerging GoB optical spray systems that enhance weed management in fallow situations. The permit is in place until 31 December 2026. All registered products can be applied at broadcast rates through an optical sprayer if there is no specified OSST rate on the label.

## 04. ECONOMIC ANALYSIS

This economic framework provides a systematic approach to evaluating the viability and financial benefits of adopting precision weed management technologies, to add to the information available to growers when making investment decisions.

The case studies in section 5 primarily focus on GoB technologies, which target weed control during fallow and summer periods to produce efficiency gains by reducing inputs while maintaining or enhancing outcomes. Additionally, one case study involving GoG technology captures yield quality benefits and productivity changes.

### Productivity and efficiency

Productivity in this context refers to increasing output or yield using existing inputs more effectively; generating more with the same resources. Efficiency, on the other hand, is about using fewer resources to maintain yields. The economic analysis assessed these technologies' efficiency gains by considering the reduction in chemical application and costs relative to the capital cost of the technology.

### Two-stage economic analysis

A two-stage economic analysis was undertaken for each case study.

- 1. Partial budget analysis.** This first stage estimated the marginal effects of implementing a weed management technology within a farming system. It focused on the savings and overall efficiency gains, excluding fixed and overhead costs that were typically unrelated.
- 2. Investment analysis.** The second stage evaluated whether the initial capital investment yielded a positive return over a five-year period. The net present value (NPV) was calculated considering the present value of cashflows over a five-year period, discounted at 7 per cent. The chosen five-year timeframe reflected the average sprayer replacement interval and rapid evolution of technology within this space.

### Partial budget analysis

To ensure that the technology was assessed accurately, several costs were collated to consider the previous approach to weed management and compare it to the new application-of-technology approach. As it is a partial budget, the costs of the previous approach were calculated along with the new application of technology.

### Standardisation and costs

When analysing the economics of precision weed management technologies, it is essential to consider the cost of the technology – the purchase price, the cost of operation (including fuel and labour) and ongoing maintenance expenses. These costs must be subtracted from the benefits gained from the technology, such as reductions in chemical usage, improved application precision, and potentially lower labour costs due to increased efficiency and effectiveness in field operations.

To ensure consistency across case studies, costs were standardised. The variables standardised were:

- labour costs, set at \$40 per hour and encompassing all associated costs;
- chemical costs, as shown in Appendix A. Each case study also has an appendix that relates directly to the chemical costs for its specific application; and
- capital costs, which were recorded based on the purchase prices at the time by respective growers. It is important to note that some costs may have varied over time. These figures should serve as a guide and a full quotation and costing should be obtained before any purchase.

### Labour cost

A labour cost of \$40 per hour was used. The basis for calculating this rate was the [MA000035 Pastoral Award 2020](#). Here is a detailed breakdown of the calculation.

- 1. Base wage.** The gross pay rate for the award wage ranges from \$26.95 to \$32.47.
- 2. Superannuation.** Superannuation at 12 per cent is calculated on the base wage:  
Superannuation per hour =  $0.12 \times 32.47 = \$3.90$  per hour.
- 3. Leave loading.** Leave loading is 17.5 per cent for four weeks of leave a year. To find the additional cost per hour:  
Leave loading per hour =  $0.175 \times 32.47 / 38 = \$0.15$  per hour.
- 4. Total cost per hour.** Adding the base wage, superannuation and leave loading gives:  
Total cost per hour =  $32.47 + 3.90 + 0.15 = \$36.52$  rounded to \$40.

The rounding up to \$40 per hour allows for possible additional costs and contingencies. When growers pay themselves they might set a higher wage, but often they work more than the standard 38 hours a week. This can complicate wage calculations as it may not directly align with the standard wage calculations provided in the award.

## FORM

The term 'FORM' stands for fuel, oil, repairs and maintenance. The calculation of FORM was based on the assumptions made with the case study grower on their specific machinery and farm layout. The FORM costs were focused on the in-paddock use, not total costs of owning machinery; therefore, depreciation and insurances were not captured.

The FORM costs considered machinery, horsepower, maximum fuel use, percentage of full load used when used, and the number of years of expected life of the tractor and implement. This was then used to calculate the requirements for the oil and air filter changes, seal replacements, tyres and nozzle changes over its life.

*Repairs and maintenance per hour for implement and tractor or self-propelled sprayer = Total life R&M / tractor life (yrs) / hours of use per year (hrs)*

*FORM (\$/hr) = fuel and oil (\$/hr) x % load of implement or operation  
+ repairs and maintenance per hour for implement and tractor or SP sprayer.*

## Diesel cost

A diesel cost of \$1.58 per litre was used, based on the cost being \$2.06 and the rebate being 47.7 cents per litre.

## Field efficiency

Field efficiency refers to the effectiveness of using resources in a field operation, in this case spraying. It is a measure of how well the equipment and labour are used to achieve the desired output.

To calculate field efficiency, the following formula was used:

*Field efficiency = effective field time / total time × 100.*

Here is a breakdown of the terms.

- **Effective field time** – the actual time spent in the paddock performing the operation productively.
- **Total time** – the total time spent on the operation, including refilling and travel required to refill.

For example, if a sprayer operates in the field for six hours working effectively and takes two hours to travel back to refill, the field efficiency would be:

*Field efficiency (%) = 6 hours / 8 hours × 100 = 75%*

A higher field efficiency indicates better utilisation of resources and lower labour costs.

## Work rate

The work rate captures the speed (km) x width of pass of implement (m) and the field efficiency (%) to assess how many hectares can be covered in an hour.

*Work rate (ha/hr) = (Speed (km) x width of pass of implement (m)) x field efficiency (%) / 1000*

## Efficiency benefits

The benefits varied between case studies. They were captured as savings in chemicals (less used) and FORM costs along with changes to the work rate due to speed or width of pass changes caused by the adoption of the new technology.

## Production system variables

Each case study provides detailed estimates of various production system variables specific to each grower including machinery details, herbicide control strategies and fallow management practices. These variables are tailored to the unique circumstances of each grower, considering factors such as soil type, scale of operation and overall production system.

Given the case-specific nature of these variables and the potential variability in economic impact, it is recommended that any grower looking to adopt similar changes in practices should seek independent financial advice. This approach helps ensure that the decisions made are well-informed and aligned with each grower's specific operational conditions and financial objectives.

## Investment analysis

Four economic indicators were calculated for each case study to understand the viability of the investment in the capital technology: net present value, annual annuity, return on investment and payback period.

## Net present value

Investment decisions about equipment for precision weed management typically involve one large investment at the beginning of the assessment period with multiple returns spread over the remaining lifetime of the asset or evaluation period.

Net present value (NPV) is a critical indicator for the profitability of this investment as it assesses all investment costs and changes in expenses and revenues in the cashflow relative to the previous farming system approach.

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It also discounts the cashflows over time for two main reasons: to adjust for the risk and to account for the time value of money. This means that a dollar today will not have the same purchasing ability as a dollar in the future due to inflation and opportunity costs.

Essentially, NPV is the value of all future cashflows (positive and negative) over the entire life of an investment discounted to the present. For this evaluation, we assessed the investment over five years.

$$NPV = (\text{new technologies partial budget result} - \text{previous weed management approach partial budget result}) / (1 + \text{discount rate of } 7\%)^5 - \text{initial capital investment}$$

### Annual annuity

An annual annuity smooths out all cashflows and generates a single average cashflow for per annum. It allows businesses to make more informed decisions when comparing projects with different lifespans or different investment options. This is particularly useful in industries where technology evolves rapidly, such as precision weed management, and equipment may become obsolete quickly.

$$\text{Annual annuity} = (\text{discount rate } 7\% \times NPV) / (1 - (1 + \text{discount rate } 7\%)^{-5\text{years}})$$

### Return on investment

Return on investment (ROI) is a ratio that measures the profitability of a technology investment by comparing the gain or loss to its cost.

$$ROI = \text{benefits over 5 years} / \text{capital cost technology}$$

### Payback period

Payback period is the number of years it takes for the benefits to accrue to cover the capital cost of the technology.

$$\text{Payback period (yrs)} = \text{capital cost} / \text{annual net benefit}$$



# 05. CASE STUDIES

Photo: GRDC

## THE ECONOMICS OF PRECISION WEED MANAGEMENT

Six case studies on precision weed management were developed, with one applying GoG technologies, four applying GoB and one drone mapping service. They explore users' adoption of the technology and their experience. Different users including growers, contractors and developers participated in the case study interviews so that a range of perspectives could be gathered.

Case studies were selected across GRDC growing regions (Figure 1). The diversity of location and soil and varying weed pressures provided unique insights. Each grower had previously operated different spray management systems and had varied reasons for adopting their current approaches. Common weeds in fallow management across the eastern seaboard case studies included flaxleaf fleabane (*Conyza bonariensis*) and sow thistle (*Sonchus oleraceus*).

The technologies examined included WEED-IT, Bilberry and Single Shot. The scale of operations among the growers also varied. One grower implemented the Bilberry system, two case studies involved corporate farm enterprises using the WEED-IT OSST, one grower developed and implemented the Single Shot technology, one grower transitioned from WEED-IT OSST to Single Shot and another contracted out Single Shot as an agronomist (Table 2).

This diversity of users provided a wide range of perspectives, motivations, benefits and challenges encountered. It is important for growers to consider how well any modern technology acquisition integrates into their existing farming system. Implementing these technologies may necessitate updates and further modifications. The case studies highlighted various combinations of machinery and software used with the technologies, underscoring the importance of compatibility and integration within each unique farming set-up.

Case studies were researched in early to mid-2024. They represent the weed management technologies that the interviewed growers were using at that time. The economic analysis is based on the technology specified in the analysis. Growers researching technologies should understand that the precision weed management technologies presented in this publication may have enhanced their capabilities and specifications since that time.

Figure 1: Location of case studies.



To explore technology uptake in different regions, the following GRDC regions were covered:

- **southern region** – Wimmera, Donald and Horsham;
- **western region** – Kwinana East Port Zone, Merredin; and
- **northern region** – south-west Queensland, Goondiwindi; south-east Queensland, Warra; and central east NSW, Coonamble.

Table 2: Precision weed management technologies case studies summary.

Case study and technology	Name and location	Problem weeds
<b>CASE STUDY 1 – Next-level spray precision (Bilberry technology)</b>	Tim Rethus, Horsham, Victoria	Whip thistle ( <i>Lactuca serriola</i> L.), sow thistle ( <i>Sonchus oleraceus</i> ), marshmallow ( <i>Malva parviflora</i> ), annual ryegrass ( <i>Lolium rigidum</i> ), heliotrope ( <i>Heliotropium europaeum</i> L.), volunteer pulses and cereals
<b>CASE STUDY 2 – WEED-IT's role in sustainability</b>	Warakirri Cropping, Donald, Victoria	Flaxleaf fleabane ( <i>Conyza bonariensis</i> ), sow thistle ( <i>Sonchus oleraceus</i> ), marshmallow ( <i>Malva parviflora</i> ), heliotrope ( <i>Heliotropium europaeum</i> L.)
<b>CASE STUDY 3 – Scale efficiencies delivered in Merredin (WEED-IT technology)</b>	Warakirri Cropping, Merredin, WA	Caltrop ( <i>Tribulus terrestris</i> ), Afghan melon ( <i>Citrullus lanatus</i> ) and paddy melon ( <i>Cucumis myriocarpus</i> )
<b>CASE STUDY 4 – Single Shot reduces costs and controls herbicide resistance</b>	Single family, Coonamble, NSW	Flaxleaf fleabane ( <i>Conyza bonariensis</i> ), barnyard grass ( <i>Echinochloa crus-galli</i> ), feathertop Rhodes grass ( <i>Chloris virgata</i> Sw.) and annual ryegrass ( <i>Lolium rigidum</i> )
<b>CASE STUDY 5 – Herbicide reduction a winner in Warra (Single Shot technology)</b>	Wade Bidstrup, Warra, Queensland	Sow thistle ( <i>Sonchus oleraceus</i> ), flaxleaf fleabane ( <i>Conyza bonariensis</i> ) and feathertop Rhodes grass ( <i>Chloris virgata</i> Sw.)
<b>CASE STUDY 6 – Contracting weed management solutions using Single Shot</b>	Jordan Billsborough, MCA, Goondiwindi, Queensland	Sow thistle ( <i>Sonchus oleraceus</i> ), flaxleaf fleabane ( <i>Conyza bonariensis</i> ) and feathertop Rhodes grass ( <i>Chloris virgata</i> Sw.)



Photo: GRDC

# CASE STUDY 1: Next-level spray precision

Tim Rethus, Horsham, Victoria



## Snapshot

**Name:** Tim Rethus

**Location:** Horsham, Victoria

**Hectares:** 4000

**Rainfall:** 420mm

**Crops grown:** wheat, canola, barley, hay and pulses

**Problem weeds:** summer fallow – volunteers, sow and whip thistle, annual ryegrass, marshmallow, heliotrope. Lentils crop – vetch

**Precision weed management investment:** \$250,000  
Bilberry system integrated with \$900,000 Agrifac sprayer

**Return on investment:** 2.19

**Net present value:** \$918,714

**Payback period:** 3 years

Left: Grower Tim Rethus, Horsham, Victoria.  
Photo: GRDC

Tim Rethus operates a zero-till cropping business in Horsham, western Victoria, where he produces wheat, canola, barley, oaten hay and pulses. After more than 20 years with a self-propelled (SP) sprayer, Tim now uses an Agrifac SP sprayer that is equipped with a Bilberry camera system for green-on-brown (GoB) and green-on-green (GoG) spraying.

Tim's crop rotation is flexible, adapting to the specific features of each paddock. He typically produces 34 per cent pulses, 20 per cent canola and 10 per cent hay, with the remainder consisting of durum wheat and barley.

During the fallow period, Tim targets weeds such as volunteer cereals, sow and whip thistle, annual ryegrass, marshmallow and heliotrope. He also uses the GoG system to identify vetch in lentils.

Tim is enthusiastic about integrating technology into his farming practices and actively contributes to the Agrifac and Bilberry collaboration to develop GoG algorithms. While the creation of new algorithms is a time-consuming process for Bilberry, initial efforts resolve about 80 per cent of issues within the first few years. More complex challenges may require the development of additional algorithms. Tim has also worked on an algorithm for spraying wild oats out of wheat, although its application has been delayed by a dry spring.

## Precision weed technology in use

Tim uses an Agrifac 49m SP sprayer (see photo on page 17). This system features pulse width frequency modulated nozzles spaced every 25cm, an 8000L tank and a 750L rinse tank. It is equipped with a Bilberry camera system for GoB and GoG spraying.

The system has cameras spaced 3m apart, each covering 1.5m on either side, with a total of 16 cameras across the boom. Tim has observed that the cameras perform better under overcast conditions or when light levels result in less shadow from the boomspray itself and stubble.

He explains that standard spray overlap patterns require at least two overlapping nozzles to deliver the full chemical rate to the target. For spot spraying, operating in 'side safety' mode is optimal. This mode activates nozzles adjacent to a weed-detecting nozzle to ensure the full chemical rate is applied, increasing the lethal hit percentage. Typical chemical savings range from 60 to 90 per cent. Tim notes that when coverage is less than 10 per cent, few weeds are visible and without a camera system an agronomist would not recommend such areas for spraying.



Tim Rethus's 49m Agrifac boom, which is equipped with a Bilberry camera system.  
Photo: GRDC

The primary benefit Tim sees in spot spraying is reducing the weed seedbank, which allows more flexibility in crop rotation and the choice of the most economical crop. Tim points out that studies such as those by the Birchip Cropping Group show the value of effective summer weed control in maximising moisture savings in summer fallow, leading to higher yields in water-limited environments.

Tim uses the vetch algorithm for lentils with the GoG system, which specifically detects purple vetch flowers. He applies this algorithm when the vetch is in full bloom, maximising detection as multiple flowers are present, usually in a patch.

Tim also uses the technology in other ways. For instance, two years ago, during wet conditions, *Ascochyta* blight affected his faba beans. He used the Bilberry system to apply a fungicide combination (fludioxonil and pydiflumetofen) only to the healthy plants, while treating dead plants as dirt on the GoB system. Tim believes that such opportunistic uses highlight the significant benefits of the technology.

When considering improvements, Tim would like the capability to run a dual line that could apply both fungicide and herbicide with GoG. This would enhance time management and support multi-weed detection and better mapping over time.

The Bilberry subscription costs \$2.50 per hectare for GoB and \$8.50 per hectare for GoG for access to all weed algorithms. These subscriptions allow for multiple passes over the same areas throughout the year and can be used with existing consoles.

Algorithms for broadleaf weeds in cereals include most weeds with a diameter greater than 5cm, such as: wild radish (*Raphanus raphanistrum*); volunteer canola (*Brassica napus*); capeweed (*Arctotheca calendula*); double gees (*Rumex hypogaeus*); mallows (*Malva* sp.); and clover (*Trifolium* sp.).

There are also algorithms for grasses in broadleaf crops (canola, soybeans, sunflowers, chickpeas, faba beans, mungbeans), especially windmill grass (*Chloris*), feathertop Rhodes grass (*Chloris virgata* Sw.), button grass (*Gymnoschoenus sphaerocephalus*), vetch in lentils, grass in lupins, and blue lupins in narrow-leaf (white) lupins. Algorithms for grasses in cereals are in the large-scale testing phase.

### Green-on-brown

Tim typically performs a blanket spray after harvest to eliminate any volunteer plants, followed by a second pass using Bilberry technology. This second pass targets larger, persistent weeds that may have survived the initial blanket spray. By combining a cost-effective blanket spray with a more precise and expensive targeted spray for difficult-to-control weeds, Tim optimises his approach. To manage resistance, he changes the chemistry used in the subsequent passes.

During periods of scattered summer showers, Tim has used the technology extensively to address emerging volunteer weed populations. He maps this activity through his John Deere Operations Centre account.

## Green-on-green

Tim grows lentils in rotation with oaten hay, canola and wheat. Lentils are a key part of his crop rotation and if vetch sets seed there is a seven-year window of viable vetch seed to be managed before lentils can be grown again. Lentil delivery standards have a strict requirement of two seeds of vetch per sample of 200 grams before he incurs a seed cleaning fee of \$30 per tonne. Therefore, the management of vetch in-crop for Tim is critical. Tim has worked with Bilberry to develop the algorithm for treating vetch at flowering.

## Weed management strategy

Tim's summer fallow weed management strategy involves an initial comprehensive blanket spray followed by targeted spot treatments using a specific mix, typically containing glyphosate and tiafenacil. Depending on the emergence of new weed sets post-rainfall, a follow-up spot treatment with glufosinate-ammonium might be necessary. Occasionally, the sequence of treatments is adjusted, with the blanket spray applied last, depending on the timing of the rainfall during the summer.

Tim finds the greatest benefit of using his GoG system is being able to incorporate a lentil crop into his rotation, thanks to effective weed control, rather than having to switch to lower-margin crops such as faba beans. The GoG algorithm for vetch specifically detects its purple flowers. To maximise detection and control, Tim sprays when vetch is in full flower as they are generally found in patches within the lentil crop.

Tim notes the flowering window is critical, with past trials finding that 82 per cent of the vetch weeds are hit. Another spray is required to ensure the remaining 18 per cent are killed. Tim uses glyphosate to spray the vetch at flowering. The surrounding lentil plants in the spray pattern are also killed, but Tim finds the loss is acceptable given the overall economic gain obtained by not having to remove vetch from the lentil sample at harvest and breaking the seven-year seedbank cycle.

## Economic implications

The initial capital investment was for both the Agrifac SP boom and the Bilberry technology. The Bilberry technology required an upfront capital investment of \$250,000 for the integration, in addition to an ongoing annual subscription fee. The Agrifac SP boom was \$900,000. This economic assessment focuses on the capital investment in the new technology compared with his original boomspray system, the performance of GoB during the summer fallow period and GoG for managing vetch in lentils (Table 3).

Tim has gained several benefits by shifting to precision weed technology. These include the ability to have lentils in his crop rotation through use of GoG, increased machinery work rate, and subsequent decreased chemical costs.

Previously, Tim's operational norm consisted of one hour dedicated to spraying and an additional 30 minutes for travel and refill. With the new technology in place, the time to spraying has increased slightly to one hour and 15 minutes, with the same 30 minutes allocated for travel and refilling. Despite this increase in time, the new system allows him to cover 33 per cent more area than before. This enhancement in paddock coverage has significantly boosted his field efficiency, improving from 50 per cent to 75 per cent (Table 3). This heightened efficiency, coupled with the wider boom, has led to the work rate increasing from 43.2ha per hour to 88.2ha per hour (Table 4).

**Table 3: Technology benefits comparison between 36m conventional boomspray and Agrifac SP 49m boomspray and Bilberry system.**

Key benefits	Previous system with boomspray operation	Current Agrifac SP 49m boomspray with Bilberry system
Increased machinery work rate	36m (Case Patriot) 50% field efficiency Work rate of 43.20ha/hr	49m boom width 75% field efficiency Work rate of 88.20ha/hr
Capacity for targeted spot spraying with GoB and GoG	Blanket spray	AI precision weed spraying in fallow (GoB) and control of vetch in lentil crop (GoG)
Increased efficacy of weed management allowing retained soil moisture to increase flexibility in crop rotation	Rotation fairly set over five years: cereal/pulse/canola/cereal/pulse	Potential to modify crop rotation based on increased moisture from weed control and be more flexible, including higher profit margin crops such as lentils and canola

These savings and efficiencies reflect the tangible benefits derived from the Agrifac with Bilberry system. In terms of operational efficiency and cost-effectiveness, they underscore the economic justification for the integration of precision weed technology into Tim's farming operations.

**Table 4: Machinery costs comparison between conventional boom and Agrifac SP sprayer.**

Characteristic	Previous conventional boom	Agrifac SP sprayer with Bilberry system
Horsepower (PTO)	220	288
R&M tractor and implement (\$/hr)	9.85	31.85
FORM (\$/hr)	44.61	61.33
Pass width (S)	36m	49m
Speed (km/h) (R)	24	24
Field efficiency (%) (T)	50	75
Work rate (WR) (ha/hr) $((R*S)*T)/1000$	43.20	88.20
FORM (FORM/WR) \$/ha	0.97	0.70
Labour (hrs/ha) $(1/WR)$ (L)	0.02	0.01
Labour cost (\$/ha) $(L*40)$	0.80	0.40
<b>Total FORM (FORM/WR) + labour cost <math>(L*40)</math> (\$/ha)</b>	<b>1.83</b>	<b>1.15</b>

## THE ECONOMICS OF PRECISION WEED MANAGEMENT

When managing vetch in his lentil crops, the algorithm Tim uses requires the vetch to be flowering. This targeted approach allows Tim to significantly reduce herbicide use, with only 10 per cent of his 1000ha lentil program requiring treatment.

Tim's involvement in developing the algorithm for vetch technology gives him a profound understanding of the operational coverage and the efficiencies gained from past applications. Two passes in the Agrifac are required to initially get 82 per cent coverage and then to remove the late flowing seed. The larger benefit, which is more critical to the overall operation, is the addition of lentils to the crop rotation. If Tim was to clean 100 per cent of his crop due to the presence of two seeds or more of vetch, he would incur a total cost of \$75,000.

The chemical savings and enhanced field efficiency Tim gains with the Bilberry system significantly contribute to the financial outcomes of his investment. The integration of this technology not only reduces chemical usage but also improves operational efficiency, leading to substantial cost reductions over the operational area. These efficiencies are a key factor in achieving a positive net present value of \$918,714, indicating that the expected benefits of the investment outweigh the costs over its lifetime (Table 6).

His return on investment (ROI) calculates as 2.19. This underscores the profitability of his investment, demonstrating that for every dollar spent, Tim gains approximately \$2.19 in return. This strong ROI further validates the economic viability of incorporating advanced technologies such as the GoG system into Tim's farm business. Novel applications – such as when Tim used the GoB system to treat *Ascochyta* blight in his faba beans – that have not been accounted for in this analysis increase the economic outcomes.

**Table 5: Green-on-green benefit.**

Lentil area (ha)	1000
Average yield (t/ha)	2.5
Cleaning fee for vetch in lentils (\$/t)	30
Bilberry application % of paddock	10
Cost of cleaning if vetch not treated (assuming 100% of lentil seed is required to be cleaned) (\$) (1000ha x 2.5 x 30)	\$75,000
Cost of managing vetch with glyphosate across 10% x 2 passes	\$4800
Agrifac FORM + labour cost per ha \$1.15 over 1000ha x 2 passes	\$2300
Benefit in avoided cost of seed cleaning	\$67,900
Collateral lentil loss – 5% per hectare at average of \$200 gross margin per tonne (1000ha x 0.05 x 2.5 x 200)	\$25,000
<b>Total benefit</b>	<b>\$42,900</b>

**Table 6: Headline economic results, Tim Rethus, Horsham.**

Indicator	Result
Capital cost (\$)	\$1,150,000
Net present value	\$918,714
Annual annuity	\$64,309
Return on investment	2.19
Payback period (years)	3

# CASE STUDY 2: WEED-IT's role in sustainability

## Warakirri Cropping, Donald operations, Victoria



### Snapshot

**Name:** Warakirri Cropping

**Location:** Donald, Victoria

**Hectares:** 14,000

**Rainfall:** 390mm

**Crops grown:** 50% lentils, with the balance being wheat, barley and canola

**Problem weeds:** flaxleaf fleabane, sow thistle, marshmallow and heliotrope

**Precision weed management investment:** \$550,000

**Return on investment:** 3.58

**Net present value:** \$1,062,729

**Payback period:** 2 years

Left: Warakirri's assistant manager at Donald, Patrick Anderson.  
Photo: GRDC

Warakirri Cropping embraces a holistic approach to stewardship, underpinning its operations with a strong commitment to economic sustainability and responsible environmental management. Key to this strategy is the reduction of herbicide usage, where it leverages advanced technologies such as WEED-IT to achieve its goals.

Founded in 1996 and funded by the REST industry superfund, Warakirri Cropping operates across the diverse agricultural landscapes of Australia, including the Wimmera and Mallee regions of Victoria, the Riverina and north-west slopes of NSW, the Darling Downs in Queensland, and in WA. Collectively, this amounts to managing more than 130,000 hectares of rain-fed farmland across four states.

The company's sustainability framework is comprehensive, focusing on people and communities, sustainable farming systems and responsible stewardship within its farming systems. Best-in-class practices include a mix of technology and innovation alongside pest and weed management to ensure high productivity and minimal environmental impact.

In line with its commitment to sustainability, REST pledged in 2021 to achieve net zero carbon emissions by 2050, reinforcing Warakirri Cropping's environmental objectives. John Stevenson, Warakirri's southern regional manager, says that their weed management strategies are tailored to the biophysical and systemic attributes of their various farms. Technologies such as Bilberry and Weed-IT are implemented in the Riverina, while they

use a SwarmBot in Goondiwindi and have additional WEED-IT systems in use in Victoria and WA. The use of OSST is a part of Warakirri's integrated weed management strategy.

Since 2013, OSST has been integrated into fallow management, with a focus on GoB technologies. Two case studies reviews the deployment of WEED-IT technologies at two properties: Donald, in western Victoria, and Merredin, in WA. Initially, the WEED-IT systems were leased for a trial period of three years to evaluate their compatibility with the company's operational needs, culminating in their purchase at the lease's conclusion.

The Warakirri Cropping business at Donald covers 14,000 hectares. The cropping program includes 50 per cent lentils and a 50 per cent combination of wheat, barley and canola. Key challenges in summer fallow weed management include controlling flaxleaf fleabane, sow thistle and heliotrope.

### Precision weed technology in use

The property uses two WEED-IT systems.

- 1. Croplands Sonic WEED-IT.** This sprayer is fitted to a 36m boom with 40-degree nozzles spaced 25cm apart. Four nozzles activate at a 1m spacing when weeds are detected. This system includes an 11,000L capacity tank (7000L main tank and a separate 4000L hot tank) with a dual line, allowing it to cover 400ha at 16km/h on one tank fill.

# THE ECONOMICS OF PRECISION WEED MANAGEMENT

**2. Goldacres Ground Glider WEED-IT.** This sprayer is equipped with a 7000L tank and larger wheels, maintaining a consistent 1.1m off the ground across the 36m boom. It features 40-degree air-assisted nozzles spaced 25cm apart with a single line and is versatile enough for both blanket sprays and precision applications. The batching tank holds chemicals separately, allowing the main tank to be refilled with water directly in the paddock.

A recent technological advancement beneficial to Warakirri Cropping has been the integration of the WEED-IT system with the John Deere Operations Centre. This integration facilitates mapping, which not only shows where the OSST is active but also helps identify weed populations across the paddock. This mapping is invaluable for scouting, future planning and overall management. The Warakirri team appreciates the WEED-IT OSST for its robust integration with its Croplands equipment system, noting its ease and simplicity of use and readability. Safety plays an important role in the values at Warakirri; the easy-to-use system means that different staff can easily and safely operate the OSST.

## Weed management strategy

Over recent years, Warakirri's Donald team has completed an initial blanket spray post-harvest using glyphosate followed by two additional treatments. The first follow-up typically involves paraquat, with the chemistry of the third application depending on the remaining weed presence. Assistant manager Patrick Anderson says that for the second and third treatments, they budget to spray 15 per cent of the paddock using WEED-IT.

## Economic implications

Warakirri Cropping transitioned from conventional spray booms to advanced WEED-IT systems, initially opting for a three-year lease before making the purchase. This leasing arrangement allowed team members to evaluate the effectiveness and integration of the technology into their operations without the immediate, full financial commitment. This strategic decision facilitated a measured assessment of the technology's benefits and potential challenges.

For this economic analysis, the Goldacres Ground Glider WEED-IT and Croplands Sonic WEED-IT systems were used. Warakirri Cropping invested \$350,000 for the WEED-IT camera system to be added to its Goldacres Ground Glider, and \$200,000 for two Croplands Sonic booms to be fitted with cameras. The heavier Croplands Sonic boom required a 330HP tractor to operate, while the lighter Goldacres Ground Glider needed a 220HP tractor, reflecting different operational demands and associated costs (Table 8).

With the adoption of these more advanced systems, operational costs have increased due to the additional machine weight and reduced speed of operation compared with conventional booms. Costs rose from \$1.72 per hectare with the conventional system to \$2.72 and \$2.29 per hectare for the Goldacres Ground Glider WEED-IT and Croplands Sonic WEED-IT respectively. Despite these increased per-unit costs, the large scale of the property (14,000ha) allowed repair and maintenance (R&M) costs to be spread over a wider area, mitigating some of the impact.



WEED-IT tractor console. Photo: GRDC



WEED-IT tractor console. Photo: GRDC



Looking up to the Croplands Sonic boom fitted with WEED-IT sensors.  
Photo: GRDC

Table 7: Technology benefits comparison between 36m boom, Goldacres Ground Glider WEED-IT and Croplands Sonic WEED-IT.

Key benefits	Previous boomspray operation	Goldacres Ground Glider WEED-IT	Croplands Sonic WEED-IT
Boom set-up, width and tank size	36m boom, 50cm nozzle spacing, 7000L tank	36m boom, 25cm nozzle spacing, 7000L tank	36m boom, 50cm nozzle spacing – dual line, 7000L main tank, 3000L batching tank
Capacity for green-on-brown	No; blanket spray only	Yes	Yes
Increased field efficiency due to split tank, less time needed for the nursery truck to refill	70% field efficiency	70% field efficiency	90% field efficiency
Increased efficacy of weed management allowing retained soil moisture, and capacity to map and manage weeds over time	No capacity to map weeds over time	Capacity to map weeds over time	Capacity to map weeds over time

The large Donald property requires efficient logistics to maintain field efficiency. A nursery truck equipped with chemicals moves across the property and, with water accessible at each block, operations are streamlined. The larger tank size on the Sonic achieves a 90 per cent field efficiency, while the Ground Glider maintains a 70 per cent efficiency.

## THE ECONOMICS OF PRECISION WEED MANAGEMENT

**Table 8: Machinery costs comparison between conventional boom, Goldacres Ground Glider WEED-IT and Croplands Sonic WEED-IT.**

Characteristic	220HP tractor, conventional boom	220HP tractor, Goldacres Ground Glider WEED-IT	330HP tractor, Croplands Sonic WEED-IT
Horsepower (PTO)	220	220	330
R&M tractor and implement (\$/hr)	19.8	14.35	22.22
FORM (\$/hr)	55.64	57.37	72.4
Pass width (S)	36m	36m	36m
Speed (km/h) (R)	24	15	15
Field efficiency (%) (T)	70	70	90
Work rate (ha/hr) $((R*S)*T)/1000$ (WR)	60.48	37.80	48.60
FORM (FORM/WR) (\$/ha)	0.92	1.52	1.49
Labour (hrs/ha) $(1/WR)$ (L)	0.02	0.03	0.02
Labour cost $(L*40)$ (\$/ha)	0.8	1.2	0.80
<b>Total FORM (FORM/WR) + labour cost <math>(L*40)</math> (\$/ha)</b>	<b>1.72</b>	<b>2.72</b>	<b>2.29</b>

During the fallow period, the typical regimen includes an initial spray of glyphosate followed by paraquat, with a potential third spray depending on seasonal conditions. The total cost for these sprays across three applications is \$1,017,240. However, the introduction of the WEED-IT system, with its 70 per cent reduction in chemical usage during the second pass, leads to substantial savings of \$393,329 in chemical and FORM costs.

Despite the high initial capital outlay and increased operational expenses, the investment into GoB technology can be justified by significant operational efficiencies and reductions in chemical usage. Over a five-year period, this technology has yielded a total return of \$1,062,729 for Warakirri, equating to an annual return of \$74,390 (Table 9). The ROI of 3.58 indicates that every dollar invested returns 3.58 times the amount, underscoring the economic viability of these advanced systems within large-scale operations.

Beyond the economic metrics, the use of OSST with a focus on GoB aligns with Warakirri's broader sustainability goals. By facilitating precise herbicide application, the technology significantly reduces chemical run-off, residues for following crops and exposure, enhancing environmental stewardship and farm safety.

**Table 9: Headline economic results, Warakirri Cropping, Donald.**

Indicator	Result
Capital cost (\$)	\$550,000
Net present value	\$1,062,729
Annual annuity	\$74,390
Return on investment	3.58
Payback period (years)	2

# CASE STUDY 3:

## Scale efficiencies delivered in Merredin

Warakirri Cropping, Merredin operations, WA



### Snapshot

**Name:** Warakirri Cropping

**Location:** Merredin, WA

**Hectares:** 24,000

**Rainfall:** 325mm

**Crops grown:** wheat, barley, canola, lupins

**Problem weeds:** caltrop, paddy melon and Afghan melon

**Precision weed management investment:** \$750,000

**Return on investment:** 3.27

**Net present value:** \$1,258,441

**Payback period:** 2 years

Left: Warakirri's Merredin manager  
Andrew Martin and agronomist  
Wyatt Verhoogt. Photo: GRDC

The Warakirri property at Merredin in WA covers 24,000ha and incorporates a diverse agricultural practice. This property, a conglomerate of previously individual farms, grows a rotation of wheat, barley, canola and lupins. Key challenges include managing pervasive summer fallow weeds such as caltrop, paddy melon and Afghan melon. The property's typical crop rotation includes approximately 25 to 35 per cent wheat, 15 to 20 per cent barley, 25 to 30 per cent canola, and 10 to 15 per cent fallow/lupins.

### Precision weed technology in use

Initially reliant on contractors for spraying, seeding and harvesting, Warakirri shifted its strategy in 2021, phasing out contractors and implementing OSST for weed management. This transition included the lease and subsequent purchase of two Croplands Sonic WEED-IT sprayers equipped with 36m booms and 10,000L tanks, which feature standard induction spray nozzles at 50cm spacing and camera spacing at 1m, with three nozzle sections activating simultaneously.

The thickness of stubble, particularly from barley, has occasionally led to false positives in weed detection with the OSST. However, this issue is less prevalent in wheat and lupin stubbles. The initial set-up and calibration of the boom and sensors has been crucial for effective operation, with ongoing maintenance mostly managed by an on-site mechanic. Considering future improvements, the Merredin team sees potential in implementing a dual-line system that would allow simultaneous blanket and targeted spraying, providing flexibility to use different chemical mixes as needed.

### Weed management strategy

To manage the large property efficiently, a batching trailer in the paddock facilitates in-field mixing. Additionally, a nurse truck, managed by a single operator, significantly enhances logistical efficiency, especially during night spraying, by holding batches of chemicals ready for use.

## THE ECONOMICS OF PRECISION WEED MANAGEMENT



Nurse truck filling Croplands Sonic WEED-IT in Merredin, WA.  
Photo: GRDC

Andrew Martin, the manager at Merredin, now plans for three spray passes during the summer fallow period: one blanket spray and two targeted optical sprays for difficult weeds if required. The property uses an automatic rain gauge system to predict weed growth areas, supplemented by scouting to assess weed burden to tailor treatments to specific blocks. This approach has led to significant chemical savings, with some blocks achieving up to an 89 per cent reduction in chemical use.

Over the past seven years, the Merredin team has also been implementing a comprehensive program to ameliorate fallow blocks, which includes applying soil ameliorants, deep ripping, soil inversion, growing cover crops and potentially planting canola. Following two years of cereal cultivation, an assessment is made to determine the viability of another cereal crop or if long fallow is required. The introduction of legumes into the rotation is being trialled, although their profitability remains marginal.

### Economic implications

Warakirri invested in two Croplands Sonic boom sprayers and a Goldacres Ground Glider boom sprayer equipped with WEED-IT technology (Table 10). The capital costs were:

- **Croplands Sonic WEED-IT system** – modifications for OSST to two Croplands booms at a capital cost of \$200,000 each/\$400,000 total. The Sonic system, due to its additional weight, requires a 340HP tractor for operation; and
- **Goldacres Ground Glider WEED-IT system** – modifications for OSST to one boom at a capital cost of \$350,000. The Ground Glider requires a 310HP tractor for operation.

**Table 10: Technology benefits comparison between conventional boom, Goldacres Ground Glider WEED-IT and Croplands Sonic WEED-IT.**

Key benefits	Previous boom spray operation	Goldacres Ground Glider WEED-IT	Croplands Sonic WEED-IT
Boom set-up, width and tank size	36m boom, 50cm nozzle spacing, 7000L tank	36m boom, 25cm nozzle spacing, 7000L tank	36m boom, 50cm nozzle spacing – dual line, 7000L main tank, 3000L batching tank
Capacity for GoB	No; blanket spray only	GoB	GoB
Increased field efficiency due to split tank, less time needed for the nursery truck to refill	70% field efficiency	70% field efficiency	90% field efficiency
Increased efficacy of weed management allowing retained soil moisture, capacity to map and manage weeds over time	No capacity to map weeds over time	Capacity to map weeds over time	Capacity to map weeds over time

## THE ECONOMICS OF PRECISION WEED MANAGEMENT

**Table 11: Machinery costs comparison between conventional boom, Goldacres Ground Glider WEED-IT and 2 x Croplands Sonic WEED-IT.**

Characteristic	310HP tractor with conventional boom	310HP tractor Goldacres Ground Glider WEED-IT	340HP tractor Croplands Sonic WEED-IT	340HP tractor Croplands Sonic WEED-IT
Horsepower (PTO)	310	310	340	340
R&M tractor and implement (\$/hr)	14.96	11.51	14.72	14.72
FORM (\$/hr)	50.81	88.77	64.9	64.9
Pass width (S)	36m	36m	36m	36m
Speed (km/h) (R)	24	15	15	15
Field efficiency (%) (T)	70	70	90	90
Work rate (ha/hr) ((R*S)*T)/1000 (WR)	60.48	37.80	48.60	48.60
FORM (FORM/WR) (\$/ha)	0.84	2.35	1.34	1.34
Labour (hrs/ha) (1/WR) (L)	0.02	0.03	0.02	0.02
Labour cost (L*40) (\$/ha)	0.80	1.20	0.80	0.80
<b>Total FORM (FORM/WR) + labour cost (L*40) (\$/ha)</b>	<b>1.64</b>	<b>3.55</b>	<b>2.14</b>	<b>2.14</b>



Batching truck with water tanks behind increases field efficiency at Merredin. Photo: GRDC

**Table 12: Headline economic results, Warakirri Cropping, Merredin.**

Indicator	Result
Capital cost	\$750,000
Net present value	\$1,258,441
Annual annuity	\$88,089
Return on investment	3.27
Payback period (years)	2

The sheer size of Warakirri's Merredin property demands significant operational logistics and opens opportunities for scale efficiencies, particularly in repairs and maintenance. The operational logistics include maintaining a batching truck with chemicals that moves across the property, which is crucial given the extensive area covered. Having access to water at each block facilitates the spraying process and enhances field efficiency.

Previously, the practice of blanket spraying involved three passes, which incurred a total chemical cost of \$995,040. By integrating the GoB system, Warakirri reduced this cost to \$527,714. This substantial decrease in chemical use not only represents a direct cost saving but also enhances the sustainability of the operation by significantly reducing the chemical footprint.

The initial investment in the OOST technology was \$750,000. While this figure is substantial, the savings in chemical costs and the efficiencies gained through scale and enhanced field operations help to offset this initial expense. The net present value of this investment over five years is calculated at \$1,258,441, translating to an annual return of \$88,089 for the OSST technology.

Warakirri's Merredin property results highlight the importance of considering scale when evaluating the adoption of new technologies. The significant financial outlay for advanced technology systems can be justified through the efficiencies they bring to large-scale operations. The economic benefits, coupled with enhanced sustainability, underscore the value of investing in technology that aligns with business objectives and environmental stewardship.

# CASE STUDY 4: Single Shot reduces costs and controls herbicide resistance

Single family, Coonambal, NSW



## Snapshot

**Name:** Single family

**Location:** Coonamble, NSW

**Hectares:** 4500

**Rainfall:** 598mm

**Crops grown:** wheat, barley, canola, chickpeas, faba beans, sorghum and cotton

**Problem weeds:** flaxleaf fleabane, barnyard grass, feathertop Rhodes grass and Rhodes grass

**Precision weed management investment:** \$139,000

**Net present value:** OSST to Single Shot \$97,170

**Return on investment:** 2.07

**Net present value:** blanket spray to Single Shot \$423,261

**Return on investment:** 4.93

**Payback period:** 1 year

Ben and John Single, 'Narratigah', Coonamble, NSW.  
Photo: Julia Brown, Upstream Communication

At 'Narratigah', 50 kilometres south-east of Coonamble, the innovative Single family has developed a drone-based weed mapping technology called Single Shot. This initiative was driven by John Single and his sons, Ben and Tony, under their company, Single Agriculture. While John and Tony manage the farming operations, Ben leads the technological development from Brisbane.

The inspiration for Single Shot stemmed from the family's long-standing commitment to improving weed management strategies. John and Tony, who have experience in no-till agriculture, initially faced significant challenges with annual ryegrass in the early 2000s. Initial attempts using optical sprayers were hindered by prolonged spray times, dust interference and accuracy issues due to stubble shadows. This led them to seek a more effective solution, culminating in the development of Single Shot. Single Shot has been renamed WeedMapper since the time of this case study interview and further capability enhancements have been made.

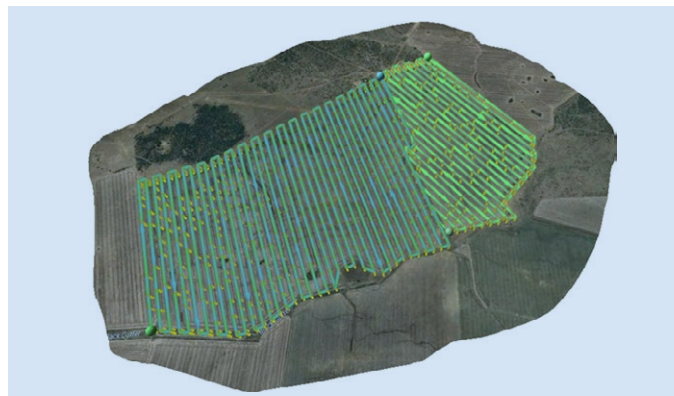
## Precision weed technology in use

The core of Single Shot technology is a high-capacity drone equipped with advanced sensors capable of mapping 1500 to 2000ha a day, even under adverse weather conditions. The drone operates at an optimal altitude of 80m, capturing imagery from various angles to minimise obstructions from stubble. It can reliably detect weeds as small as 3cm in diameter, enabling precise mapping and assessment of weed coverage in paddocks.



Single Shot drone with multiple cameras to reduce stubble shadowing.  
Photo: GRDC

Figure 2: Single Shot flight path.



The data captured by the drone can be quickly processed on-farm. Due to temperature inversions and dry conditions, there are often just four to six hours suitable for spraying during the summer in Coonamble. Quick processing allows growers to make informed decisions about weed types, coverage and the most effective spraying strategies to minimise herbicide resistance and reduce costs.

### Weed management strategy

On their property, the Singles have equipped two 36m trailing boomsprayers with air induction nozzles. The first sprayer features 18 sections with dual lines, allowing for simultaneous blanket and spot spraying with different chemistries in a single pass. This set-up cost \$40,000 for the fitting and capital expenses associated with the spot-spraying equipment.

The second sprayer, configured with a conventional seven-section blanket spray line, also serves as a spot sprayer, enabling two passes in one at the same speed as a blanket sprayer. This dual-line system enhances application timing, critical for effective weed control and seedbank management.

### Economic implications

The economic analysis of the Single Shot system, compared with previous GoB optical sprayer technology across a 4500ha fallow system, highlighted significant efficiencies. The capital investment for the Single Shot system was \$99,000, with an additional \$40,000 for modifications to enable the dual-line system on the sprayer. The drone's efficiency allows it to cover 200ha in one hour, with processing time being similarly short. This enables labour to be reallocated to other tasks, maximising its best use.

With the dual-line system in place, the Singles can effectively target both established and newly germinated weeds following rainfall, ensuring comprehensive weed control. This strategic application reduces herbicide usage significantly – up to 70 per cent in some cases – enhancing the economics and sustainability of operations. After using the Single Shot technology, the Singles have seen the weed burden on their property drop significantly.

The drone mapping system, developed by the Singles, brings a range of efficiencies and enhancements to the farming operation. Some of these extend beyond immediate quantifiable economic benefits. One such indirect advantage, especially relevant in the variable weather conditions of agricultural settings, is the system's ability to conduct drone flights for weed mapping during weather conditions that would otherwise halt spraying activities. This flexibility ensures that farm operations can continue effectively, even when traditional spraying is not feasible.

The Single Shot system enabled the following improvements, which enhanced operational efficiency.



Trimble interface used with Single Shot technology.  
Photo: GRDC

- Travel speeds were increased from 15km/h to 24km/h, allowing for quicker coverage of paddocks and reducing the time required for operations.
- Field efficiency improved from 60 per cent to 95 per cent due to the precise identification and mapping of weed densities. This precision allowed for optimal chemical usage, minimising wastage and ensuring that resources were used more effectively.
- The adjustment of nozzle spacing from 25cm to 50cm reduced the number of nozzles needed, thereby reducing maintenance and replacement costs.

These operational efficiencies translated into direct and significant economic benefits. The costs associated with flying time (200ha per hour) for the drone across the property (4500ha) amount to \$900, which covers the comprehensive mapping of weed presence. The maintenance costs for the Single Shot technology totalled \$5625 over a five-year period. Given the Singles have 4500ha, this is 25 cents per hectare per year or \$15 per hour, reflecting a sustainable investment in maintaining high operational effectiveness.

## THE ECONOMICS OF PRECISION WEED MANAGEMENT

**Table 13: Machinery costs comparison between WEED-IT and Single Shot.**

Characteristic	220HP tractor WEED-IT boom	220HP tractor Single Shot conventional boom
Horsepower (PTO)	220	220
R&M tractor and implement (\$/hr)	18.51	28.09
FORM (\$/hr)	54.35	70.22
Pass width (S)	36m	36m
Speed (km/h) (R)	15	24
Field efficiency (%) (T)	60	95
Work rate (ha/hr) $((R*S)*T)/1000$ (WR)	32.40	82.08
FORM (FORM/WR) (\$/ha)	1.68	0.86
Labour (hrs/ha) $(1/WR)$ (L)	0.03	0.01
Labour cost ( $L*40$ )	1.20	0.40
<b>Total FORM (FORM/WR) + labour cost (<math>L*40</math>) (\$/ha)</b>	<b>2.88</b>	<b>1.26</b>

Over the five years, the requirement for chemical reduced from 35 per cent of the paddock being covered using OSST to 11 per cent of the paddock using the drone, demonstrating a further reduction in chemical usage and associated costs. However, it must be noted that this is not as large as going from a blanket spray (100 per cent) to the drone (11 per cent).

Using precision drone mapping data coupled with a dual-line sprayer created a highly efficient spraying strategy for the Singles. The ability to conduct blanket and spot treatments simultaneously during a single pass enhanced the effectiveness and efficiency of spraying operations and allowed for chemical flexibility. It facilitated targeted weed management strategies that could be adapted to varying weed populations and conditions.

The financial analysis revealed strong returns from the investment in Single Shot technology. The net present value of \$97,502 indicates a substantial net gain over the investment period, factoring in the time value of money.

The annual annuity of \$6800 represented a steady yearly return that aids in financial planning and stability. The return on investment was 2.07, demonstrating the high efficiency and cost-effectiveness of the technology, with every dollar invested returning \$2.07.

The Single Shot system achieved significant operational and economic efficiencies while enhancing the sustainability of the family's farming practices. The 24 per cent reduction in chemical use, combined with improved machinery efficiency, resulted in a positive financial outcome.

**Table 14: Headline economic results, Single family, Coonamble.**

Indicator	OSST to Single Shot	Blanket to Single Shot
Capital cost (\$)	\$139,000	\$139,000
Net present value	\$97,170	\$423,261
Annual annuity	\$6800	\$29,627
Return on investment	2.07	4.93
Payback period (years)	3	1

Further analysis was undertaken to understand the impact of going from blanket spraying (100 per cent paddock coverage) to Single Shot, which was assessed at 35 per cent paddock coverage. The FORM costs aligned to the 220HP tractor Single Shot conventional boom at \$1.26 per hectare. Given the relatively low capital cost of the Single Shot drone at \$139,000, the savings in one year in chemical was \$184,016, resulting in a net present value of \$423,261 or ROI of \$4.93. These results highlight the importance of considering your weed management and the marginal benefit of adopting precision weed management – in particular the capital costs relative to the significant reduction in chemicals – and exploring options for your operation.

Note: Since the interview for this case study, Single Shot has been superseded by WeedMapper.

## CASE STUDY 5: Herbicide reduction a winner in Warra

Wade Bidstrup, Warra, Queensland



### Snapshot

**Name:** Wade Bidstrup

**Location:** Warra, Queensland

**Hectares:** 4000

**Rainfall:** 617mm

**Crops grown:** wheat, faba beans, mungbeans, barley, cotton, chickpeas, millet, field pea, corn and sorghum

**Problem weeds:** flaxleaf fleabane, sow thistle and feathertop Rhodes grass

**Precision weed management investment:** \$120,000

**Return on investment:** 3.03

**Net present value:** \$177,817

**Payback period:** 3 years

Wade Bidstrup, Warra, Queensland.

Photo: GRDC

In Warra, Queensland, Wade Bidstrup manages a diverse 4000ha mixed cropping operation on vertisol soils. Without adhering to a fixed crop rotation, Wade takes advantage of his farm's location and soil characteristics to cultivate a variety of winter and summer crops, including faba beans, mungbeans, barley, cotton, chickpeas, field peas, millet, corn, sorghum and wheat.

Wade uses a zero-till system with retained stubble, focusing on effective weed management during the fallow period to prevent yield losses in subsequent crops. Research by GRDC in nearby Dalby underscores the critical nature of fallow management, showing that 60 per cent of soil moisture at planting is derived from this period. A key aspect of Wade's strategy is maintaining his zero-till approach while managing herbicide resistance, particularly targeting flaxleaf fleabane, sow thistle and feathertop Rhodes grass.

Previously, Wade used an OSST system with a 36m pass width, operating at speeds up to 12km/h and moving between paddocks at 15km/h. However, he encountered several challenges with this system. The efficacy of the OSST was compromised by stubble shadowing, often necessitating a return to spray missed weeds. Wade said: "The optical sprayers are looking at a large angle through the stubble residues left in our zero-till system and cannot 'see' the weeds. Even when they do 'see' the weeds, the single nozzle activation over the weed often fails to hit it effectively due to stubble shading."

For taller weeds such as flaxleaf fleabane, achieving adequate coverage was difficult because the target height of the weeds was too high for effective spraying from the nozzles at the boom's operating height, which must remain constant for the sensors to function correctly.

Timeliness also became an issue, particularly when rainfall hindered access to paddocks, allowing weeds to set seed. Another significant concern was accurately measuring the necessary volume of tank mix, which often led to delays and inefficiencies, such as unnecessary trips to refill the tank or leftover spray at the end of a run.

### Precision weed technology in use

Faced with these issues, Wade sought a more suitable solution and found it in Single Shot technology. This innovative approach involves flying a drone over the fallow to map existing weeds and their sizes. Each mapping session covers 200ha and takes about an hour.

The technology uses a double overlap by default, ensuring each part of the paddock is mapped twice. If stubble partially covers a weed from one angle, the second pass provides another opportunity for detection. This dual-angle approach enhances weed identification, enabling Wade to make informed weed management decisions and precisely calculate the required herbicide before beginning to spray. The drone data is transferred to Wade's Ag Leader console in his 36m Rogator self-propelled (SP) sprayer for application.

### Weed management strategy

Single Shot's interface allows Wade to precisely target larger weeds based on size, isolating those requiring attention and avoiding the unnecessary spraying of smaller, more manageable weeds. This was not feasible with the OSST and has significantly reduced his chemical usage.

Wade invested \$120,000 in the Single Shot system, which included the drone, batteries and a computer for processing the data. He has been able to minimise ongoing costs by meticulously maintaining the drone. He stores it in a sealed container to protect it from the elements and dust, resulting in no maintenance costs incurred in the past 18 months.

Wade operates with a 6300L tank and benefits from individual nozzle control on his 36m boom, which maintains a height of 50cm over target weeds for optimal spray accuracy. This set-up allows for precise chemical application, reducing wastage and improving overall application efficiency.

Adopting Single Shot was straightforward for Wade. The system integrated easily with his existing boom on the SP sprayer, which was already equipped with an Ag Leader console. Local Ag Leader technical support was available to assist with the transition.

### Economic implications

Wade's transition from OSST to a more advanced drone mapping system has brought significant economic benefits. The Single Shot system enables faster coverage of each paddock, reducing the time spent on application and thereby enhancing overall productivity. Previously, machinery was operating at 12km/h. Using a drone mapping system, Wade has doubled the speed to 24km/h. This increase in speed directly translates to reduced time spent travelling over the same area, effectively doubling the ground coverage. Wade can also now travel at 50km/h between paddocks with his SP sprayer, up from 15km/h with a tractor-drawn sprayer, significantly reducing travel time between paddocks.

Wade has seen an average 70 per cent reduction in herbicide use across his property, coupled with considerable time savings. The detailed mapping of paddocks has also enhanced his understanding of each paddock's specific needs. Beyond weed management, Wade has used the technology for other purposes such as assessing plant populations within crops. This multifunctional use underscores the versatility and efficiency of mapping when using a drone system.

The operational repairs and maintenance (FORM) costs for Wade's farming machinery has been significantly influenced by the adoption of drone mapping technology, leading to improvements in travel efficiency and field operations. The updated parameters for FORM are detailed in Table 15, highlighting the marked enhancements brought about by this technology change.

There has been a substantial increase in field efficiency due to the precision with which the Single Shot system operates. Wade now has exact information on the amount of chemicals needed for each paddock, which not only reduces the frequency of refills but also minimises chemical wastage. Knowing the exact weeds he is targeting ahead of time enables Wade to select the correct chemical, allowing improved strategic planning and usage. This ensures that resources are allocated more effectively.

Previously, field efficiency was estimated to be 50 per cent. Wade experienced inefficiencies primarily due to slow speeds between paddocks and increased downtime associated with refilling when more weeds were detected in paddocks using the OSST. With Single Shot, efficiency has increased to 90 per cent.

The improvements in speed and efficiency have a direct impact on FORM costs. These enhancements underscore the value of integrating advanced technological solutions such as Single Shot into traditional farming operations. By streamlining processes and increasing the precision of applications, Wade has achieved significant cost savings and enhanced the overall sustainability and efficiency of his farming practice.



Weeds illustrated in white on the Single Shot map. Photo: GRDC

**Table 15: Machinery costs comparison between OSST and 36m Rogator SP with Single Shot system.**

Characteristic	Previous OSST approach	Current 36m Rogator SP coupled with Single Shot system
Horsepower (PTO)	300	315
R&M tractor and implement (\$/hr)	10.14	25.16
FORM (\$/hr)	46.18	61.00
Pass width (S)	36m	36m
Speed (km/h) (R)	12	24
Field efficiency (%) (T)	50	90
Work rate (WR) (ha/hr) $((R*S)*T)/10$	21.60	77.80
FORM (FORM/WR) (\$/ha)	2.14	0.78
Labour (hrs/ha) $(1/WR)$ (L)	0.05	0.01
Labour cost ( $L*40$ )	2.00	0.40
<b>Total FORM (FORM/WR) + labour cost (<math>L*40</math>) (\$/ha)</b>	<b>4.14</b>	<b>1.18</b>

Wade uses the drone technology extensively across summer and winter fallow periods due to his location and the nature of his crop rotations. He has optimised his spraying efficiency by not deploying a blanket spray, thereby reducing costs. The efficiency gained is calculated based on the marginal change between the original OSST usage, which had a 50 per cent efficiency rate, and the Single Shot technology, which improved efficiency to 90 per cent. The efficiency improvement resulted in increased precision at a higher speed, leading to considerable cost savings across the large area of operation.

The calculated net present value of this investment is \$177,817 over five years, resulting in a return on investment of 3.03; for every dollar spent on the Single Shot technology, Wade's operation earns back \$3.03.

Wade's strategic investment in Single Shot technology has proven to be highly beneficial for operational efficiency, reduced chemical usage/costs and improved financial returns. The significant savings on input costs coupled with enhanced field efficiency support a sustainable and profitable farming operation

**Table 16: Headline economic results, Wade Bidstrup, Warra.**

Indicator	Result
Net present value	\$177,817
Annual annuity	\$12,446
Return on investment	3.03
Payback period (years)	3

# CASE STUDY 6: Contracting weed management solutions using Single Shot

Jordan Billsborough, MCA, Goondiwindi, Queensland



## Snapshot

**Name:** Jordan Billsborough, agronomist, MCA

**Location:** Goondiwindi, Queensland

**Hectares:** 125,000

**Rainfall:** 603mm

**Crops grown:** winter plantings of wheat, barley, chickpeas and pulses, with summer plantings of sorghum

**Problem weeds:** sow thistle, flaxleaf fleabane and feathertop Rhodes grass

**Precision weed management investment:** \$120,000

Wade Bidstrup, Warra, Queensland.

Photo: GRDC

Jordan Billsborough, an agronomist at MCA based in Goondiwindi, oversees a broadacre farming system that spans approximately 125,000ha of southern Queensland and northern NSW, including Condamine, Bellata, North Star and Croppa Creek. His focus is on non-irrigated winter crops such as wheat, barley and chickpeas, along with summer crops such as sorghum.

MCA has used Single Shot technology for the past three years, initially purchasing it for use on its own farm holdings. Leveraging both the technology and its in-house expertise, MCA has expanded to offer contracting services using the drone weed mapping technology. The service is particularly valuable for targeting scattered or resilient weeds such as sow thistle, flaxleaf fleabane and feathertop Rhodes grass, which Jordan finds challenging to manage with traditional methods.

As Jordan flies the Single Shot drone outside MCA properties, he holds a remote pilot's licence (RePL) as required by the Civil Aviation Safety Authority. He is also required to hold a remotely piloted aircraft operator's certificate (ReOC), which enables him to operate commercially as a drone service provider. RePL training courses include a theory component and five hours of practical flying time.

While the drone technology has streamlined operations for many, there are nuances to consider. For instance, properties without a global positioning system base station require a calibration flight for accuracy to ensure the drone mapping aligns in the tractor console, and in some instances a blanket spray may be required.

## How the contract service works

The contracting service begins with Jordan conducting a visual assessment of weed pressure in a paddock. If deemed suitable, the drone is flown over the paddock to map the weeds. The data is then processed and the maps are sent to the client for use with their own spray rigs. Although some older screens struggle to import prescription maps, newer screens manage the data easily.

MCA charges \$8 per hectare for the drone flying, mapping and data processing. This does not include fees for agronomic advice, which is billed separately and only available to clients. After mapping, Jordan processes the data and provides clients with three key files along with an information sheet explaining how to integrate this data into their spraying systems.

## Weed management strategy

Jordan's approach involves using a residual treatment post-harvest, followed by a broadacre knockdown after rain, and then employing the drone to pinpoint and manage any remaining stubborn weeds. This technique proves especially effective in February, when managing grass is critical due to plant-back restrictions and the need to reduce seed-set while preserving soil moisture.

Many MCA clients use consoles with single-line sprayers equipped with precision weed management (PWM) nozzles that can activate in 50cm sections. Looking ahead, a dual spray line could allow a lower rate of broadacre spraying while also applying a targeted spot spray to give larger problem weeds a heavier dose in a single pass.

**Economic implications**

With the drone technology priced at \$120,000, Jordan needs to cover 10,690ha over five years at a discount rate of 7 per cent to break even on his investment. This calculation underscores the scale of operation required to justify the cost of such technology.

Overall, the Single Shot technology offers significant improvements in speed, efficiency and chemical use, leading to considerable time savings and a deeper understanding of weed management on a per-paddock basis. This advanced approach enables Jordan and his team at MCA to provide highly efficient, precise and economically viable weed management services to their clients.

**Table 17: Economic analysis, MCA, Goondiwindi.**

Economic parameter	Value
Initial investment in technology (\$)	120,000
Discount rate (%)	7
Time period (years)	5
Cost charged per hectare (\$/ha)	8
Break even hectares required (ha)	10,690



Photo: GRDC

# 06. KEY CASE STUDY FINDINGS

The study of emerging weed management technologies through specific case studies has revealed key insights about economic viability, rapid technology evolution and the influence of individual business goals on technology adoption. Here are three primary findings.

## A. Different technologies suit differing regional farming systems

The adoption of precision weed management technologies varies significantly across different geographic regions. Adoption is often driven by the economic benefits tailored to each setting and the scale of farms.

Wade Bidstrup's transition from OSST to drone mapping technology highlights the adaptability and economic advantage even when initial technologies do not meet expectations. For Wade, the switch resulted in significant operational efficiencies due to the lower capital costs, amplified by his farm's scale, and summer and winter cropping usage. Wade also used the technology for other purposes, such as assessing plant populations within crops, highlighting extra uses of technologies.

In contrast, Warakirri's operations in Merredin, WA, covering 24,000ha, make it feasible to quickly recoup substantial capital investments through savings. Conversely, Tim Rethus operates on a much smaller scale (4000ha) but still chose to invest in high-cost technology. Despite its high upfront cost, the new technology brought savings on chemicals. It also enabled lentils to enter the crop rotation mix due to the capabilities of GoG technology, and gave him the ability to spray fungicide using GoB.

Operational and business structures also dictate technology needs. Warakirri's diverse operational staff necessitated robust and simple-to-operate technologies. MCA leveraged contracting to spread the capital costs of Single Shot technology across multiple clients, enhancing investment viability.

## B. Technology advances require adaptability on-farm and in governance structures

The case studies demonstrate that ongoing adaptations to existing technology platforms and changes in chemical usage are pivotal in reducing costs and increasing operational efficiency.

This adaptability enables more strategic chemical use, potentially employing more expensive but effective options to mitigate weed resistance. The Single family's use of the Single Shot technology with a split tank exemplifies how precise mapping and targeted application can sustain long-term efficiency and prevent herbicide resistance.

Rapid evolution of these technologies poses challenges for governance bodies such as APVMA, which must ensure that regulatory frameworks for chemical use and technology application keep pace with technological advancements. The impending expiration of the current OSST use permit highlights the need for timely updates to regulations to capture the full benefits of these innovations.

## C. OSST helps achieve broader business goals

Many growers were initially attracted to precision weed management technologies for their direct benefits in reducing herbicide use and increasing application accuracy. However, they soon realised that the technology also provided a wealth of data that could be used for broader farm management decisions.

This data has provided a valuable evidence base for more informed strategic decision-making. As an example, Wade Bidstrup was able to use the technology to assess plant populations within crops and provide evidence to farm consultants on the success of different seeds used.

The adoption of precision weed management technologies also aligns closely with broader business objectives, including meeting sustainability targets. For example, Warakirri's implementation of such technologies across its holdings supports its broader sustainability goals, with the data collected providing a dataset of evidence to demonstrate improvements.

# 07. CONCLUSION

The integration of advanced weed management technologies offers substantial economic benefits and aligns with strategic business goals, enhancing sustainability and operational efficiency. However, the dynamic nature of these technologies requires continuous evaluation of their economic impact, technological suitability and regulatory compliance. Growers considering such investments should seek tailored economic advice to ensure compatibility with their specific operational needs and long-term business objectives.



# GLOSSARY

Photo: Evan Collis/GRDC

# GLOSSARY

### **Annual annuity**

An economic indicator used to assess the annual impact by smoothing out all cashflows over five years and generating an average cashflow for each year.

### **Artificial intelligence (AI)**

Technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy.

### **Blanket spray**

Uniform spray rate across the paddock.

### **Camera-based technologies**

Technologies employing RGB (red, green, blue), distance or multispectral cameras to capture images of weeds. These images are processed in real-time using AI algorithms for precise spraying.

### **Drone weed mapping technologies**

Technologies using drones to map paddocks, identifying weed locations and enabling precision in weed management decisions.

### **Efficiency**

Using fewer resources to maintain yields, focusing on the reduction of inputs while maintaining or enhancing outcomes.

### **FORM**

Fuel, oil, repairs and maintenance costs associated with machinery. FORM costs consider machinery – horsepower, maximum fuel use, percentage of full load used when used – and the number of years of life expected for a tractor and implement. This is then used to calculate the requirements for oil and air filter changes, seal replacements, tyres and nozzle changes over its life.

### **Green-on-brown (GoB) technologies**

Optical spot spray technology that uses RGB or near infrared (NIR) camera sensors to detect and spray weeds during the fallow period, improving stored plant-available water and nutrient availability at planting.

### **Green-on-green (GoG) technologies**

Optical spot spray technology using AI to differentiate weeds from crops during the growing season and fallow period. Algorithms are continually developed for broader implementation.

### **Integrated weed management (IWM)**

A comprehensive approach to long-term weed management that uses a variety of control methods to avoid chemical resistance and increase the likelihood of successful control.

### **Investment analysis**

An investment analysis evaluates whether the initial capital investment yields a positive return over a five-year period when calculated in today's dollar terms. The metric for this is the net present value (NPV) calculation.

### **Precision mechanical weed control technologies**

Technologies in development that include methods such as lasers and weed chipping, requiring further testing for Australian conditions.

### **Optical spot spray technology (OSST)**

Technologies used to enhance weed management by detecting weeds using optical means and spraying precisely.

### **Partial budget analysis**

Estimates the marginal effects of implementing a weed management technology, focusing on savings and overall efficiency gains but excluding fixed and overhead costs.

### **Precision weed management technology**

Spray technology that targets specific weeds within a paddock. Technologies include optical spot spray technology, green-on-brown technologies, sensor-based technologies, camera-based technologies, drone weed mapping and targeted mechanical weed management.

### **Productivity**

Increasing output or yield using existing inputs more effectively, generating more with the same resources.

### **Sensor-based technologies**

Technologies that detect green weeds using near infrared (NIR) technology and emit light to distinguish living plants from other substances.

### **Targeted spray**

Use of precision weed management technology to focus on specific weeds and spray only the specified weed.



# APPENDICES

Photo: Paul Mathews/GRDC

# APPENDICES

## Appendix A: Input costs

Table 18: Chemical input costs.

PRODUCT	\$/L/kg
Ammonium sulfate 980g/kg	0.57
Basta® (200g/L glufosinate-ammonium)	18.00
Garlon® 600 (600g/L triclopyr)	21.25
Glyphosate (600g/L)	15.00
Glyphosate Green (360g/L)	11.25
Glyphosate (450g/L)	6.88
Gramoxone® 360 (360g/L paraquat)	9.75
Paraffinic oil	7.70
Spray.Seed® (135g ai/L paraquat + 115g ai/L diquat)	11.48
Terrad'or® (700g/kg tiafenacil)	326.70
Verdict® 520 (520g/L haloxyfop)	51.09
2,4-D Ester 680 (680g/L 2,4-d present as the 2-ethylhexyl ester)	11.25

Table 19: Labour and diesel input costs.

	<p>A labour cost of \$40 per hour was used. The basis for calculating this rate was the MA000035 Pastoral Award 2020. Here is a detailed breakdown of the calculation.</p> <ol style="list-style-type: none"> <li><b>1. Base wage.</b> The gross pay rate for the award wage ranges from \$26.95 to \$32.47 an hour.</li> <li><b>2. Superannuation.</b> Superannuation at 12 per cent is calculated on the base wage: superannuation per hour = <math>0.12 \times 32.47 = \\$3.90</math> per hour.</li> <li><b>3. Leave loading.</b> Leave loading is 17.5 per cent for four weeks of leave a year. To find the additional cost per hour: leave loading per hour = <math>0.175 \times 32.47</math> divided by 38 = \$0.15 per hour.</li> <li><b>4. Total cost per hour.</b> Adding the base wage, superannuation and leave loading gives: total cost per hour = <math>32.47 + 3.90 + 0.15 = \\$36.52</math> rounded to \$40.</li> </ol> <p>The rounding up to \$40 per hour allows for possible additional costs and contingencies. When growers pay themselves they might set a higher wage, but often they work more than the standard 38 hours a week. This can complicate wage calculations as it may not directly align with the standard wage calculations provided in the award.</p>
<b>\$40 per hour labour cost</b>	
<b>Diesel cost \$1.58 per litre</b>	Based on a cost of \$2.06 a litre and a rebate of 47.7 cents a litre.

# APPENDICES

## Appendix B: Case study 1, spray operations and details

Table 20: Previous boom system.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha based on % of paddock sprayed and FORM cost	Total cost (\$) 4000ha
<b>Summer fallow</b>							
Glyphosate (600g/L)	1.6	24.00	1	100	1.83	25.83	103,320
Glyphosate (600g/L)	0.6	9.00	1	100	1.83	76.17	304,680
Terrad'or® (tiafenacil)	0.2	65.34					
Basta® (glufosinate-ammonium)	3.75	67.50	1	100	1.83	69.33	277,320

Table 21: Current Bilberry system.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha based on % of paddock sprayed and FORM cost	Total cost (\$) 4000ha
<b>Summer fallow</b>							
Glyphosate (600g/L)	1.6	24.00	1	25	1.15	7.15	28,600
Glyphosate (600g/L)	0.6	9.00	1	25	1.15	19.74	78,960
Terrad'or® (tiafenacil)	0.2	65.34					
Basta® (glufosinate-ammonium)	3.75	67.50	1	25	1.15	18.03	72,120

# APPENDICES

## Appendix C: Case study 2, spray operations and details

Table 22: Previous boom blanket spray system implemented.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha based on % of paddock sprayed and FORM cost	Total cost (\$) 14,000ha
<b>Summer fallow</b>							
Glyphosate (600g/L)	1.6	24	1	100	1.72	25.72	360,080
Gramoxone® 360 (paraquat)	2	19.5	1	100	1.72	21.22	297,080
Glyphosate (600g/L)	1.6	24	1	100	1.72	25.72	360,080

Table 23: OSST Weed-IT sprayers.

Current OSST system	Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha based on % of paddock sprayed and FORM cost	Total cost (\$)
<b>Weed-IT 7000ha</b>								
Knockdown	Glyphosate (600g/L)	1.6	24.0	1	100	2.29	26.29	184,030
Knockdown	Gramoxone® 360 (paraquat)	2	19.5	1	30	2.29	8.14	56,980
Knockdown	Glyphosate (600g/L)	1.6	24.0	1	30	2.29	9.49	66,430
<b>Ground Glider 7000ha</b>								
Knockdown	Glyphosate (600g/L)	1.6	24.0	1	100	2.72	26.72	187,040
Knockdown	Gramoxone® 360 (paraquat)	2	19.5	1	30	2.72	8.57	59,990
Knockdown	Glyphosate (600g/L)	1.6	24.0	1	30	2.72	9.92	69,440

# APPENDICES

## Appendix D: Case study 3, spray operations and details

Table 24: Previous boom blanket spray system implemented.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha	Total cost (\$) 24,000ha
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.50	18.93	1	100	1.64	20.57	493,680
Garlon® 600 (triclopyr)	0.10						
Glyphosate 450 (450g/L)	1.50						
Paraffinic oil	0.05						
Ammonium sulfate	0.80						
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.50	18.93	1	100	1.64	20.57	493,680
Garlon® 600 (triclopyr)	0.10						
Glyphosate 450 (450g/L)	1.50						
Paraffinic oil	0.05						
Ammonium sulfate	0.80						
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.50	18.93	1	100	1.64	20.57	493,680
Garlon® 600 (triclopyr)	0.10						
Glyphosate 450 (450g/L)	1.50						
Paraffinic oil	0.05						
Ammonium sulfate	0.80						

## THE ECONOMICS OF PRECISION WEED MANAGEMENT

Table 25: Current Weed-It OSST system implemented.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost Ground Glider \$/ha	Total \$/ha	Total cost (\$) Ground Glider 8000ha
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.5	18.93	1	100	3.55	22.48	179,840
Garlon® 600 (triclopyr)	0.1						
Glyphosate 450 (450g/L)	1.5						
Paraffinic oil	0.05						
Ammonium sulfate	0.8						
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.8	33.04	1	22	3.55	10.82	86,560
Garlon® 600 (triclopyr)	0.12						
Glyphosate 450 (450g/L)	3						
Paraffinic oil	0.05						
Ammonium sulfate	0.8						
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.8	33.04	1	22	3.55	10.82	86,560
Garlon® 600 (triclopyr)	0.12						
Glyphosate 450 (450g/L)	3						
Paraffinic oil	0.05						
Ammonium sulfate	0.8						
Chemical	Rate L/ha	Total \$ exc. GST	Passes	% of paddock	FORM cost WEED-IT Sonic \$/ha	Total \$/ha	Total cost (\$) 2x Sonic WEED-IT 16,000ha
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.5	18.93	1	100	2.14	21.07	337,120
Garlon® 600 (triclopyr)	0.1						
Glyphosate 450 (450g/L)	1.5						
Paraffinic oil	0.05						
Ammonium sulfate	0.8						
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.8	33.04	1	22	2.14	9.41	150,560
Garlon® 600 (triclopyr)	0.12						
Glyphosate 450 (450g/L)	3						
Paraffinic oil	0.05						
Ammonium sulfate	0.8						
2, 4-D Ester 680 (680g/L 2,4-D present as the ethylhexyl ester)	0.8	33.04	1	22	2.14	9.41	150,560
Garlon® 600 (triclopyr)	0.12						
Glyphosate 450 (450g/L)	3						
Paraffinic oil	0.05						
Ammonium sulfate	0.8						

# APPENDICES

## Appendix E: Case study 4, spray operations and details

Table 26: Previous OSST system implemented.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha	Total cost (\$) 4500ha
Years 1, 3 and 5							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	23.76	106,920
Basta® (glufosinate-ammonium)	3.75	67.50	1	35	2.88	26.51	119,295
Years 2 and 4							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	23.76	106,920
Gramoxone® 360 (paraquat)	1.67	16.28	1	35	2.88	8.58	38,610

Table 27: Current Single Shot system with a split dual line.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha	Total cost (\$) 4500ha
Years 1, 3 and 5							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	31.19	140,355
Basta® (glufosinate-ammonium)	3.75	67.50	1	11	1.26	31.19	140,355
Years 2 and 4							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	25.55	114,978
Gramoxone® 360 (paraquat)	1.67	16.28		11	1.26	25.55	114,978

Table 28: Blanket spray example scenario.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha	Total cost (\$) 4500ha
Years 1, 3 and 5							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	23.76	416,340
Basta® (glufosinate-ammonium)	3.75	67.50	1	100	1.26	68.76	416,340
Years 2 and 4							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	23.76	185,850
Gramoxone® 360 (paraquat)	1.67	16.28	1	100	1.26	17.54	185,850

## THE ECONOMICS OF PRECISION WEED MANAGEMENT

Table 29: Single Shot example scenario.

Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha	Total cost (\$) 4500ha
Years 1, 3 and 5							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	47.39	213,255
Basta® (glufosinate-ammonium)	3.75	67.50	1	35	1.26	47.39	213,255
Years 2 and 4							
Glyphosate Green (360g/L)	2	22.50	1	100	1.26	29.46	132,525
Gramoxone® 360 (paraquat)	1.67	16.28	1	35	1.26	29.46	132,525

# APPENDICES

## Appendix F: Case study 5, spray operations and details

Table 30: Previous OSST system implemented.

Previous OSST system	Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha based on % of paddock sprayed and FORM cost	Total cost (\$) 4000ha summer and winter fallow
Year 1								
Winter fallow	Glyphosate (600g/L)	2	30.00	1	100	1.18	31.18	124,720
	Spray.Seed® 250 (paraquat and diquat)	1.6	18.37	1	50	4.14	13.33	53,320
Summer fallow	Verdict® 520 (haloxyfop)	0.15	7.66	1	100	1.18	8.84	35,360
	Gramoxone 360 (paraquat)	2.4	23.40	1	50	4.14	15.84	63,360
Year 2								
Winter fallow	Glyphosate® (600g/L)	1.6	24.00	1	100	1.18	25.18	100,720
	Basta® (glufosinate-ammonium)	3.75	67.50	1	50	4.14	37.89	151,560
Summer fallow	Verdict® 520 (haloxyfop )	0.15	7.66	1	100	1.18	8.84	35,360
	Gramoxone® 360 (paraquat)	2.4	23.40	1	50	4.14	15.84	63,360

Table 31: Current Single Shot technology implemented.

Current Single Shot OSST system	Chemical	Rate L/ha	Total \$ exc. GST	Passes	Average % of paddock	FORM cost \$/ha	Total \$/ha based on % of paddock sprayed and FORM cost	Total cost (\$) 4000ha summer and winter fallow
Year 1								
Winter fallow	Glyphosate (600g/L)	2	30.00	1	100	1.18	31.18	124,720
	Spray.Seed® 250 (paraquat)	1.6	18.37	1	30	1.18	6.69	26,760
Summer fallow	Verdict® 520 (haloxyfop)	0.15	7.66	1	100	1.18	8.84	35,360
	Gramoxone® 360 (paraquat)	2.4	23.40	1	30	1.18	8.20	32,800
Year 2								
Winter fallow	Glyphosate (600g/L)	1.6	24.00	1	100	1.18	25.18	100,720
	Basta® (glufosinate-ammonium)	3.75	67.50	1	30	1.18	21.43	85,720
Summer fallow	Verdict® 520 (haloxyfop)	0.15	7.66	1	100	1.18	8.84	35,360
	Gramoxone® 360 (paraquat)	2.4	23.40	1	30	1.18	8.20	32,800

