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WEEDETECT®

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Contents

Bilberry System Overview

Bilberry is a market leading weed detection and spraying system utilises cutting edge artificial intelligence and camera technology to isolate weeds within crop situations, as well as fallow situations to vastly reduce the input costs of herbicide application within a farming system.

The cameras, coupled with proprietary artificial intelligence algorithms (which are protected by over 40 patents worldwide), drastically reduces the cost of herbicide applications within crop use or fallow situations, whilst still ensuring that weed control is the number one objective. With the use of the Bilberry system, a grower can reduce their herbicide input costs by up to 90%, without sacrificing weed control, all within a system that is embedded onto the boomspray for ease, accuracy and convenience.

Bilberry has been developing these proprietary algorithms in Australia since 2017, and officially opened the Australian office in Perth in 2019, with 4 full time staff in Australia (plus 20 in France).

During the development of these algorithms, we have collected hundreds of thousands of images in conjunction with our service partners and also with our users. In fact, one grower has individually collected over 600 thousand images of various crop types and weeds in the Western Australian growing region for further algorithm development, it is not an unfounded statement to say that Bilberry is developed with growers, for growers.

Why spot spraying?

Traditionally, herbicides are applied to a paddock in a blanket spray in an effort to reduce weed numbers, and ensure that there are minimal survivors which decreases the chance of seed set. In fallow or summer spraying situations, this has historically been achieved through blanket spraying broad spectrum or non-selective herbicides to eliminate all plants present.

This can be done for many reasons, including:

- Conservation of moisture for the following crop
- Reduce the green bridge for potential disease carryover
- Machinery trafficability and less blockages at seeding time

Spot spraying is the alternate way in which weeds in fallow and crop situations can be managed. This reduces the cost of herbicides, saves water, aids in the reduction of herbicide resistance by being able to deploy stronger chemicals on a smaller scale and saves time due to less filling up of boomsprays.

Historically, with the WEED-it and WeedSeeker, fallow spot spraying has been achieved through the use of chlorophyll sensors to identify weeds on bare paddocks, or green plant matter on soil (Green on Brown). This technology has been available for many years with good results, and has reduced the herbicide use of non-crop situations up to 90%.

How do they work?

Both the WEED-it and WeedSeeker work in a similar way:

- Measure the reflectance of green plants (using near infrared wavelengths) which triggers the weed to be sprayed
- Have high numbers of sensors – Weedseeker™ has one per nozzle while WEED-it™ has one per metre
- Ideal working speed around 15km/hr
- Can be used day and night as they have their own light source
- Can reduce herbicide application by 80 to 90% (depending on density of weeds)
- By reducing area sprayed it also reduces number of tank fills required (fewer litres of spray mix per ha)
- Boom height control is critical to ensure adequate coverage of weeds
- Coverage is affected by strong winds which moves the spray pattern away from the targeted weed

Can we improve this technology?

Yes! With the advancement in artificial intelligence technology, we are no longer limited to using chlorophyll sensors to identify green from brown, but we now can use cameras to distinguish weeds from the crops, both with drones, or 'on the go' with embedded cameras and computing modules on sprayers. This is known as 'Green on Green'.

Many companies, including start-ups, large corporations and universities are now developing systems with green on green capability. The technology used is similar: artificial intelligence with cameras (sometimes RGB/colour cameras, sometimes hyperspectral cameras).

How does AI work?

Artificial intelligence and especially deep learning is another way of working on images to recognise different objects. It is now the most widely used technology for computer vision when it comes to complex images (recognising weeds within crops, or on bare soil, is definitely a complex image).

Complex images could be defined as images that show high variability between the same category of object (an object being a cat, a dog, a human, or a weed).

Three technological changes enabled the rapid advancement of artificial intelligence and deep learning:

- Improved computing power through the use of graphics processing units (GPUs)
- Huge sets of data, or what is now being termed 'big data'
- Powerful and complex algorithms through the stacking of neural networks

Deep learning is part of the family of machine learning and is inspired by the way the human brain works (deep learning often uses deep neural networks architecture). The learning part can be either supervised or unsupervised.

How does this apply to weed?

The use of supervised deep learning is being applied to picking wild radish out of a wheat crop by the following steps:

- Define algorithm objectives – Recognise flowering radish in wheat with > 90% accuracy
- Gather data – Take pictures in the paddocks of flowering wild radish in wheat under many different conditions (light, crop stage, direction of travel etc.)
- Sort and label data – On each picture, indicate what is wheat, what is wild radish, other weeds, stubble etc. This is a manual process which is very labour intensive

Also separate all images into 2 sets, training set and testing set. Training set is only used for training, and testing set is only used for testing (images cannot be on both sets)

- Train the algorithm – Show the training set thousands of times to the algorithm so that it learns the patterns
- Test the algorithm – Show the test set (once) to the algorithm to compare the results of the algorithm with the reality
- Once happy with the results of the algorithms, go into the paddock to test (paddock testing is the most crucial part of the process)
- Repeat until you reach your objectives

What is the Bilberry system?

So now we have an idea how AI is being used to detect weeds, but how does this actually work in a paddock?

With the use of the Bilberry system, which is protected by over 40 patents worldwide, growers have the ability to pick out weeds on the go in green on green situations, as well as the older technology of isolating the green plant material in fallow situations, or green on brown.

How exactly does this happen though?

In simplistic terms, there are three components to the Bilberry system:

- Hardware
- Embedded software
- Artificial Intelligence

We have already covered how the AI algorithms are developed through deep learning with thousands of images. The next step is the cameras having the capability to detect in real time.

Cameras & computers on the sprayer boom

+

Proprietary embedded software to communicate with the sprayer

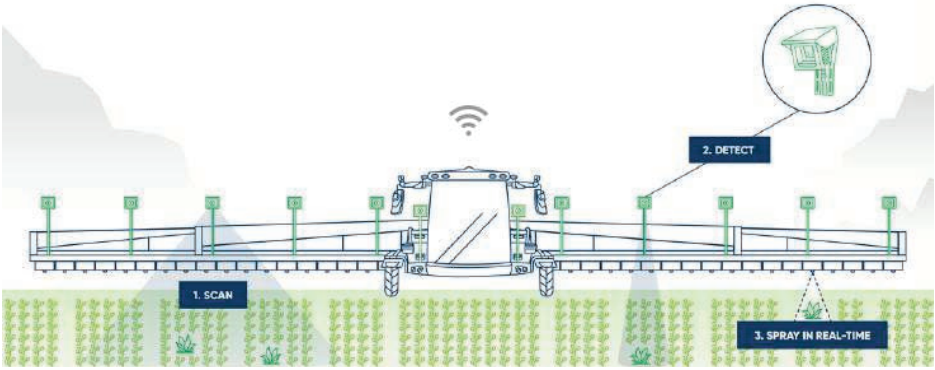
+

In house artificial intelligence algorithms to detect weeds

Elements of the Bilberry system

The artificial intelligence that we have previously mentioned needs to be able to see and compute images to identify the weeds in real time. To do this, the system requires eyes, a brain, and a voice.

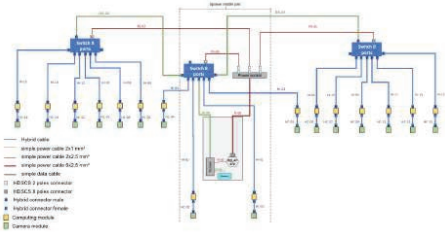
- **Eyes** - Cameras to see the crop. The RGB cameras take 16 images per second to identify the crop and the weeds in real time. These cameras are similar to the style that is found in a smartphone.
- **Brain** - An artificial intelligence computer module that is capable of computing large amounts of data, in real time, detecting the weeds through patented algorithms and determining the correct location, time, and duration for a nozzle to trigger to spray the individual weed.
- **Voice** - A screen is mounted in the cab of the machine to interpret the signals from the AI computing module, interact with the GPS and nozzle controller, allow user input to change algorithms, sensitivities to weeds etc.



Hardware specifications

System architecture

The architecture shown below is for a 48 meter boom. A 36 meter boom would just have less cameras and computing modules (but same number of switches).



Camera

Role: Capture the images in real time for the weed detection process.

Specifications:

- 6MP RGB (red green blue) camera
- Input voltage DC : 12-24V
- Power consumption: 2.6-3.1W
- Weight: 0.7 kg
- IP67 rating case
- External connector: 1x Hybrid cable

Calculation module

Role: Process weed detection based on images coming from an associated camera.

Specifications:

- Input voltage DC: 24V
- Power consumption max: ~25W
- Weight: 1.5 kg
- IP67 rating case
- Connectors: 2x Hybrid

Screen

Role: Collect detection messages from calculation modules, deliver nozzle opening orders over CAN communication, enable user to interact with the system

Specifications:

- Input voltage DC: 12-36V
- Power consumption: 14 W
- Weight: 2.8 kg
- 1 camera and calculation module every 3 metres

Modem

Connectivity with Bilberry for software updates, mapping features, remote maintenance and troubleshooting. Not needed for operational use of the system, as the Bilberry system is designed to work independently offline at all times. The Bilberry system is also designed to connect seamlessly with any pre-existing modem.

Switch

Role: Connect the calculation modules to the console (over ethernet links), provide power to the calculation modules and cameras

Specifications:

- Passive element: Gather & Dispatch (power / data)
- Input voltage DC: 24V
- Power consumption max: ~10W
- Weight: 2.3 kg
- IP67 rating case
- Connectors:
  - 8x Hybrid cable
  - 1x automotive Power Connector

Cabling

Custom made hybrid cables have been designed and manufactured specifically for the Bilberry system, keeping in mind the harsh Australian conditions that sprayers endure such as dust, sun, uneven terrain etc. These cables allow the cameras and the modules to relay information with both the screen and each other, while also providing power for the cameras and computing modules. This integrated power reduces the need for separate cables to be run and streamlines the weight distribution and cable management for the install and correct ongoing operation.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How does the system work?

Using the Bilberry system is extremely simple, all the hard work has been taken care of.

With a clean and user-friendly user interface (UI), the grower selects the appropriate algorithm for the intended crop use, primes up the boom as per usual and drives at a max speed of 20km/hr.

The camera captures images (16 per second) and directly feeds these to the computing module. The module will then detect the weeds in real time, and pass this detection on to the screen in the cab.

The module runs a specific algorithm for each application with the use of artificial intelligence; these algorithms have been developed with the use of tens of thousands of images per application.

The screen in the cab will interact with the nozzle controllers, based on information that it is constantly receiving from other systems on the machine (GPS etc). With this added information, it will calculate the correct timing of nozzle opening and duration to ensure the targeted weed receives a lethal dose of herbicide, on time, every time.

Images are computed in real time. Note the highlighted weed in this image, an additional data layer computed in real time by the AI in the computing module. The white rectangle is the 'Region of Interest' for the cameras and the computing module.

Above: 2 videos of what the cameras see in real time (the cameras are active only in the region delimited by the white rectangle, and the detections are shown in red)

System limitations

Cameras can also be affected by high stubble loads, crop shading, and canopy closure. This is a limitation of all optical sprayers (GoB or GoG as well), if they cannot see the weeds in question, they cannot spray them. **A camera system will never have a 100% hit rate, and for this reason a two spray strategy is highly recommended.** More on how to combat this is in the best use section below.

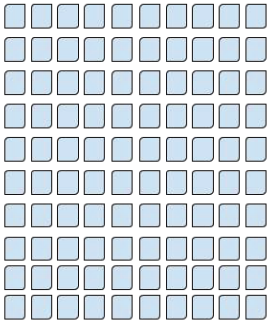
For night spraying the system must be fitted with specific custom-made lights with cross beams under each camera. Being realistic with the expectations of the camera system is paramount when discussing the system with potential new users. We believe the best way to sell systems is through having happy users, having happy users is about expectations being met, **let's underpromise and overdeliver.**

Why we believe in a 2 spray strategy

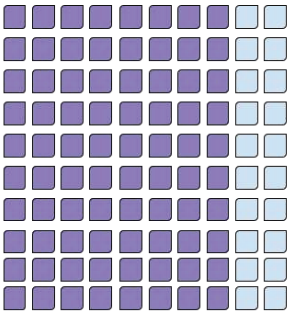
Through our experience with developing and using the cameras, we believe that employing a two spray strategy is necessary to ensure there are minimal weed survivors. The two spray timings will usually ensure there is a higher kill rate than one blanket spray, as any later germinating weeds are targeted with the later spray timing, reducing the number of escapees.

It is an interesting exercise to calculate the numbers of hit rate percentage when employing a two spray strategy. We are confident that the system will have a hit rate of 80% and above. When combining two sprays that achieve an 80% hit rate, the end result will actually be 96%.

For this example, we will show the percentage kill rate below, and how using the cameras with a two spray strategy can vastly increase the overall hit rate and weed control in a paddock



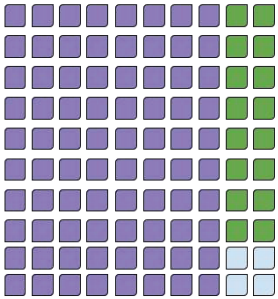
100 weeds in a paddock unsprayed.



100 weeds in a paddock after initial spray, 80% hit rate, 80 weeds hit total (purple).

With the same reasoning but 90% hit ratio for each individual spray, the total hit rate for the two passes would be 99%. On this line of thinking, a 60% hit rate over two passes equates to an overall 84% hit rate as well.

We firmly believe that the Bilberry camera system is another tool in the toolbox for integrated weed management, and should be included with double knocks, any harvest weed seed management and other components of the Weedsmart 'Big 6'.



100 weeds in a paddock after second spray, 80% of remaining weeds hit (green), 96 weeds hit in total (purple + green).

System benefits

With the Bilberry system, a grower can be sure that they have the right dose, in the right place, at the right time.

Benefits include:

- **Up to 98% chemical savings**
  Cut your chemical expenses by spraying only where weeds are
- **Increase knowledge of your paddock**
  Generate and store weed maps of each spray to understand your paddock better
- **Resistance management**
  Use more effective chemicals at a higher dose to get better weed control
- **Sustainable farming**
  Prolong herbicide life on your farm while helping the environment
- **Reduce crop damage**
  Increase yield by minimising unnecessary crop injury
- **Spray fast**
  20 km/h average speed and up to 48 meter boom
- **Reduce filling time**
  By spraying 10 times less, you will also fill up 10 times less
- **Reduce chemical exposure**
  By filling less, you will be less exposed to chemicals

Spot spraying benefits example

Here is an example of how a grower changed his spraying program in 2021 to control wild radish (and other broadleaf weeds) in Three Springs, WA.

Previous Program

1 blanket spray with expensive herbicide

- Sprayer / Labour / Fuel = 5 AUD / ha
- Velocity = 30 AUD
- Total = 35 AUD

Camera Program

2 camera sprays with expensive herbicides

- Sprayer / Labour / Fuel x 2 = 10 AUD /ha
- Velocity = 4 AUD (15 % of blanket)
- Precept = 6 AUD (10 % of blanket)
- Total = 20 AUD

The main benefits of switching to that program are the following*:

- Cost savings = 15 AUD / ha (or 75 000 AUD over 5000 ha)
- Better weed control (use of more efficient chemicals at higher rates)
- Increased productivity (fewer refills needed)
- No crop damage

* Each situation is different (different hit ratio, different savings …)

While this suggested use of the cameras does include an additional operation, and depending on the weed density of the paddock, the grower is still saving considerable herbicide costs, and has a higher hit rate when compared to blanket spraying as well.

Getting the best out of the Bilberry system

A shift in thinking

Using the Bilberry system entails a shift in thinking, as it is a farming system change using the cameras. This means that if growers are investigating the deployment of cameras in their farming operation, we suggest an operational system shift to get the best results when using the system to its full potential. As the cameras can only spray what they can see, it is logical to use this to our agronomic advantage. The overall outcome is firmly in the integrated weed management line of thinking, to reduce weed seed set and reduce the weed numbers for the following crops as well as the current season's crop.

As an example, we can look at the broadleaf in cereals algorithm as a case study.

Using the cameras to their full benefit would logically mean a two spray strategy in wheat. One spray could be early, i.e. 3-5 leaf crop stage, when the broadleaves are present and highly visible, but the crop has not produced a canopy to shade the weeds yet. The second timing would most likely be once any remaining weeds have appeared above the canopy of the weeds late in the season (sometimes identified as salvage spray on labels). At a later stage of the crop, the cameras will help kill the weeds but more importantly they will prevent the weeds from setting seeds, and thus help in the overall integrated weed management process.

Algorithm development and roadmap

Due to the evolving nature of the Bilberry system & software, we are constantly updating the commercial algorithms to improve performance, as well as development of new in crop Green on Green algorithms to increase the value of a Bilberry system on farm. We believe that a Bilberry system can become a vital component in a farming system & deliver value to our users all year round.

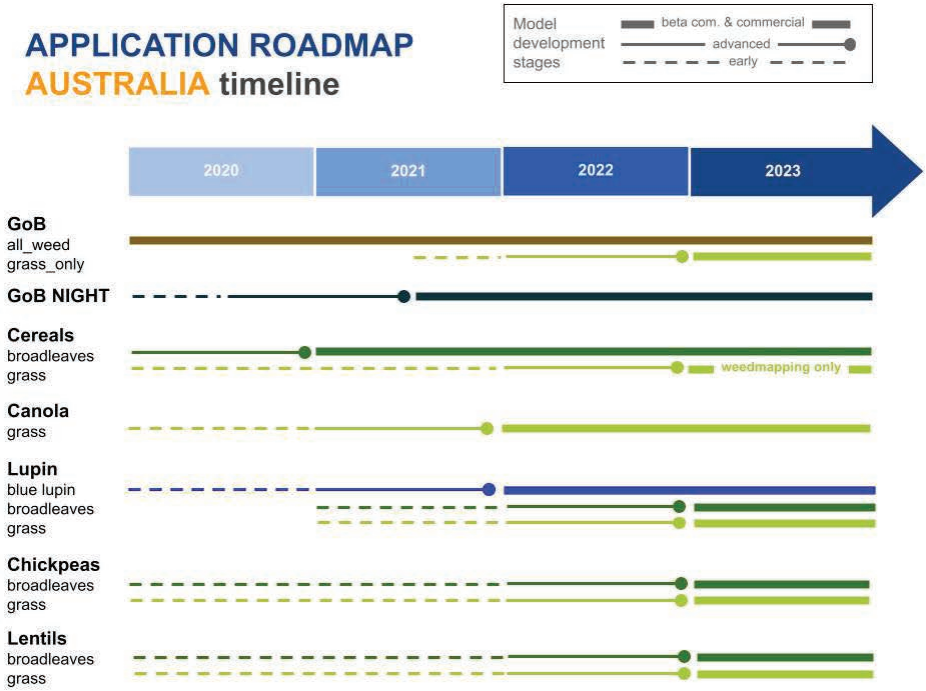
Through working closely with our numerous commercial users, we have shown that the Bilberry system offers significant ongoing value to Australian growers, and in an effort to continue these benefits, we are improving our offer constantly for the Australian market.

Our first commercial algorithm was broadleaves in cereals, as this is the major crop segment and use case in Australian farming. Our aim is to develop algorithms for most, if not all, of the major crop rotations associated with broadacre farming to increase the return on investment for integrating a Bilberry system into a farming enterprise. The most logical way in which we can create value is to identify the algorithms which we need to develop next, starting with cereals, followed by canola & then various break crops, and so on.

With our local Australian team and partnerships with spray manufacturers, we are working closely with growers in all major growing regions. This allows us to understand the growing conditions and challenges faced in crop, and design the Bilberry system to react accordingly. Having our Australian staff in constant communication with our network of users and manufacturers, we have been able to identify local issues, gather data and train an algorithm in a timely manner. The blue lupins in lupins algorithm being one recent example of this local knowledge, flexible nature and ability to react quickly.

Below is an indicative roadmap for algorithm research and development, highlighting proposed crop types and crop uses, as well as development and deployment timelines.

We endeavour to reach these milestones, and we always aim to have industry partners and growers involved in the development process.



Indicative application roadmap for current and future algorithm research and development.

System Weed mapping as a key tool to improve even more weed control benefits

An anticipated development for the 'Green on Brown' and 'Green on Green' uses of the system is weed mapping. This will allow the system to record GPS data from the sprayer and map where weeds have been identified and targeted. The anticipated use for this mapping feature is to create a prescription map for any weeds previously detected, and be used in conjunction with the cameras on the go to increase the hit rate year on year.

With the ongoing development of algorithms for green on green in crop spraying, the weed mapping and any further use cases that come online in the future for Bilberry, it is clear to see how the Bilberry camera system can save growers large amounts of money in their cropping program. This, coupled with the crop having the ability to optimise yield by achieving it's yield potential unhindered by unnecessary herbicide use, can ensure that a grower gets the most out of their cropping program with the aid of using a Bilberry camera system.

Spot spraying in cereals

Detecting broadleaf weeds in cereals

Crop types: Wheat, barley and oats
Weeds detected: All broadleaf weeds (including radish, volunteer canola, capeweed, doublegee …)
Average hit rate per spray: 80 to 95% (in the right conditions, ie when the weeds are visible)
Availability: Now

Potential use of the technology

- Spot spray radish and other broadleaf weeds on the go
- Reduce costs of expensive products such as Velocity and Precept by up to 90% without inhibiting the herbicide efficacy
- Map radish while spraying
- Produce weed map from multiple years of data, increase the accuracy of the system and minimising the chance of any survivors

Spot spraying in lupins

Detecting blue lupins in lupins

Crop types: Narrow-leaf lupins (white lupins)
Weeds detected: Blue lupins
Average hit rate per spray: 80 to 95% (in the right conditions, ie when the weeds are visible)
Availability: Beta release anticipated for the 2022 cropping season

Potential use of the technology

- Isolate and target blue lupins in narrow-leaf lupins
- No solution previously existed, cutting edge technology
- Can be used for mapping, or for further herbicide options talk with your agronomist

Weed mapping in canola

Detecting grasses in canola

Crop types: Canola (all herbicide technologies)
Weeds detected: Blue lupins
Average hit rate per spray: 80 to 95% (in the right conditions, ie when the weeds are visible)
Availability: Beta release anticipated for the 2022 cropping season

Potential use of the technology

- All grass species, including ryegrass, volunteer cereals, wild oats, brome grass and barley grass.
- Develop prescription maps with grasses for following cropping phase, usually cereal
- Use as a prescription map for robust pre-emergent chemistry for grasses in cereals, reduce cost and crop damage of the pre-emergent chemistry
- Use grass selective in cereal (if still effective)