With the assistance of a GRDC travel grant, SARDI researcher John Heap travelled to Europe in October 2007 to investigate SSWM research and its potential application to Australian broadacre grain production. Germany and Denmark are two countries where research into this promising precision agriculture technique is particularly advanced.

SITE SPECIFIC WEED MANAGEMENT

By John Heap[1] and Sam Trengove[2]

Site Specific Weed Management involving variable herbicide application has potential economic and environmental benefits and overseas research has made good progress. SSWM in Australia will probably be initially applied to herbicide resistant weeds such as annual ryegrass and wild oats. The most promising SSWM system for Australia may involve a cheap basal herbicide application, with variable application of a more effective and expensive herbicide to patches.

Trials assessing ryegrass control with pre-emergent herbicides highlight the benefit of using a more expensive herbicide mix with greater efficacy in high density populations for improved control, while achieving adequate control in low density populations with a lower cost application of trifluralin.

WHY SSWM?

Weeds often grow in patches within a paddock. Spraying the whole paddock is the current norm, but there are potential economic and environmental benefits to spraying only where there are weeds. Precision agriculture techniques – particularly GPS and Variable Rate Technology – have opened the way for Site Specific Weed Management – targeting control measures only to where they are needed.

Potential benefits

German agricultural researcher, Dr Roland Gerhards very simply gets to the common sense behind SSWM by pointing out that broadacre blanket spraying invariably results in the wrong application decision at almost every point in the paddock.

Herbicide under-dosing and over-dosing are inevitable when weed distribution and density varies across a paddock. SSWM has the potential to reduce herbicide applications by 10 to 80 per cent. The herbicide cost savings are obvious, but weed-free crop areas not sprayed may also yield five to 10 per cent more when phyto-toxic effects of the herbicide are removed. In Europe there is also a strong interest in SSWM for environmental reasons.

The aim of SSWM spraying systems is to get the right dose of the right herbicide in the right place. Sounds simple enough but there are a number of technical hurdles to be overcome, and this has resulted in an array of research approaches with different levels of complexity.

The system components chosen will be influenced by the individual weed control situation.

Four main components of SSWM

- **Weed mapping/sensing**

Mapping prior to spraying is easier, but may involve an extra pass. Real-time detection requires sensors and on-board computers to process imagery and control nozzles.

Simple reflectance systems can measure total plant biomass – but this measures both crop and weeds together and can be misleading. Scanning only in the inter-rows is more challenging, but more accurate. More complex systems use both reflectance and image shapes to identify plant type. The more advanced research systems can identify up to 25 weed species.

- **Treatment decision**

The simplest to implement is On/Off but missed plants outside of patches may cause problems. Another approach is to apply a uniform basal treatment and use an On/Off system to apply another treatment only to patches. More complex systems identify spatial variation in weed species and density, and may apply up to three herbicides at varying rates.

Most SSWM research has concentrated on treating patches (metres across) using boom section control. But more recent research in Denmark is working on very small cells of 11x3 cm or even single plant targets.

- **Treatment application/sensor type**

The most readily available and sophisticated sensor is the human eye. But manual mapping prior to spraying is time consuming and real-time manual control may not be reliable due to operator distraction. Digital imagery can be captured from the ground or remotely (satellite or aircraft), but for systems aiming to treat patches smaller than several metres, remote imagery has insufficient spatial resolution.

WeedSeeker is currently the only commercialised system with sensors linked to spray control. This system senses green plant biomass using a ratio of red and near infra-red (NIR) reflectance and is mainly used for non-selective weed control in non-crop areas.

There are other commercially available sensors (CropCircle, GreenSeeker and Yara N-Sensor) that can map biomass using red/NIR. More sophisticated systems under development in Denmark and Germany use a combination of red/NIR imagery with image shape analysis to identify weed species.

- **Documentation**

Most systems under development log the 'as applied' herbicide application map as a useful record of application.

R&D CHALLENGES

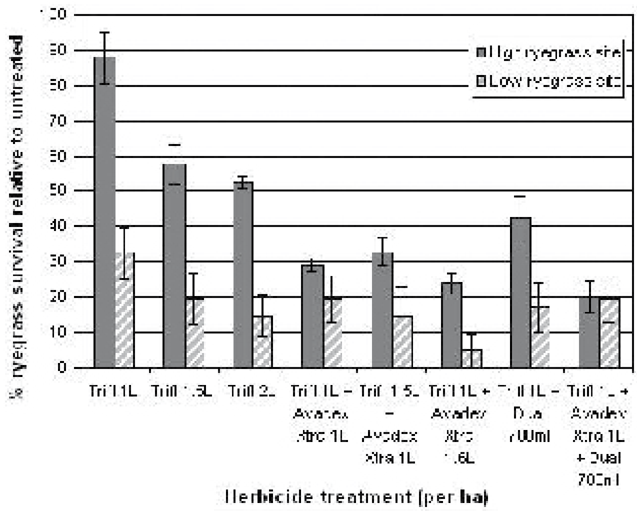
The main bottlenecks for SSWM are efficient and accurate mapping/scanning systems and suitable direct injection systems for herbicides. Direct injection systems currently suffer from long lag-times – it can take from four to 30 seconds for the herbicide to travel from the injection point to the nozzle.

But recent advances in field trials and research labs in Europe suggest that these problems may be overcome.

arch Review: SSWM

assistance of the GRDC, investigates a significant international development in weed control.

FIGURE 1: Pre-emergent herbicide effects on ryegrass survival relative to nil control at two sites in one paddock with differing ryegrass populations



High ryegrass site: Nil = 574 plants/m2 LSD (5%) = 13.2;
Low ryegrass site: Nil = 11 plants/m2 (differences not significant)

Research in Europe

Germany and Denmark have strong SSWM research efforts, driven by government funding aimed at meeting environmental pesticide reduction targets. There has been excellent technological progress made, but commercialisation of SSWM has been slow because European growers generally consider herbicides to be fairly cheap and have little incentive to adopt more complex systems.

The closest system to commercial release appears to be a 21 metre three-tank sprayer developed by Dr Roland Gerhards and his team at the University of Hohenheim, near Stuttgart, Germany (see panel story). The Cerberus sprayer has three parallel independent spray lines supplied by three separate tanks filled with different herbicides. Weed maps are used to switch 7x3 metre boom sections on and off simultaneously in each of the three spray lines. The control lag time is around 0.5 seconds, and they are currently working on real-time weed identification (of up to 25 species) and treatment mixture determination.

Studies in 13 paddocks over three years have given 10 to 80 per cent herbicide reductions while maintaining good weed control. Efficacy has been tracked in 38 paddocks with around 95 per cent control, with no apparent weed seed-bank build-up.

Laser-induced leaf fluorescence (Germany) and polarised light reflectance (France) are also being explored for weed identification.

Autonomous spray delivery

In Denmark Dr Svend Christensen and his team are developing extremely accurate autonomous spray delivery systems. The systems are modelled on ink-jet printers and will initially be used in horticultural crops. One system treats small areas (cells) of 11x3 cm by switching nozzles on and off, while a second system identifies individual weed seedlings and fires either a laser beam or herbicide micro-droplets (0.2 micro-litres) at the growing point.

Prototypes treating 100 broadleaved seedlings per m^2 have achieved water volumes as low as 0.2 litres per hectare.

AUSTRALIAN POTENTIAL

Overseas experiences suggest that SSWM may have a place in Australia. Initial development appears to be most suited to treatment of herbicide resistant weeds (such as annual ryegrass and wild oats) where patches might be treated with more expensive herbicides.

As an example, annual ryegrass might be treated with a uniform basal application of trifluralin, with triallate injected into the spray line in patch areas.

The cost of herbicides as a proportion of returns is higher in Australia than in Europe, providing additional incentive. Retention of stubble is not common in Europe and may present us with some mapping/scanning challenges, but our wider row spacings may be an advantage.

Table 1 outlines some potential windows of opportunity for SSWM.

Some local research

To date, research locally has focused on the detection and mapping of ryegrass patches using commercially available crop sensors (CropCircle, GreenSeeker and Yara N-Sensor), and the herbicide treatment decisions for high and low-density ryegrass populations.

In cropping situations, variation in plant biomass is a result of two variables – the crop and weeds. At early crop growth stages crop biomass tends to be relatively uniform (with uniform crop densities) with little expression of any underlying soil or landscape variability.

Weed biomass at early growth stages varies according to variations in weed plant populations. Therefore, variability in plant biomass mapped with these sensors at early crop growth stages can usually be associated with variable weed densities.

Ryegrass patches have been successfully mapped in lentil and canola crops at early growth stages in South Australia before crop

...28 ▷

TABLE 1: Windows of sensing/mapping opportunity for SSWM in Australia

Stage	Timing	Field situation	Opportunity
Summer fallow	Dec–Mar	Dry stubble. Green summer weeds.	Summer weed mapping. Ground or remote. SSWM non-selective herbicide application possible.
Pre-sowing	Apr–Jun	Emerged winter seedlings. Probably standing stubble.	Emerged weeds – no crop rows. Ground or remote. SSWM non-selective herbicide application possible.
Early post-em	Jul–Aug	Early post-em crop and weeds. Distinct crop rows.	Inter-row sensing (ground only);Crop+weed sensing (ground or remote).
Late crop	Sep–Nov	Closed crop inter-rows. Weed heads visible.	Wild oat, brome, annual ryegrass head mapping (probably remote only); SSWM 'crop-topping' possible.

variability becomes large. As crop growth progresses through the season, variability in crop biomass increases, complicating the detection of weed patches by biomass variation.

It is also important to ascertain by ground truthing, which weed species vary across the paddock, as all weeds can contribute to plant biomass variability.

The plan for future research is to determine the threshold density of ryegrass that can be detected in different crops at different growth stages. From work done so far these sensors can readily detect dense patches of ryegrass at early growth stages of lentils and canola.

Herbicides and ryegrass patches

Herbicide treatment decisions for high and low density ryegrass patches have focussed on two treatment opportunities – pre-emergent herbicide application in cereals and post-emergent grass selective herbicide application in legumes and canola.

Pre-emergent herbicide treatments are higher and lower doses of trifluralin (480 g/L ai) and the on/off decision for the addition of Avadex Xtra (triallate 500 g/L ai) or Dual (metolachlor 720 g/L ai) to trifluralin.

Ryegrass patches have been mapped in lentils in one paddock in 2006 and this map was used to locate pre-emergent herbicide trial sites in high and low-density populations in 2007. Results showed that the addition of Avadex Xtra or Dual to a base rate of trifluralin led to a significant improvement in control at the high ryegrass site (Figure 1).

But at the low ryegrass site in the same paddock a base rate of trifluralin provided adequate control. There was no additional benefit for increasing trifluralin rate or the addition of another herbicide at this low ryegrass site.

So the area treated with the higher cost herbicide mix could confidently be restricted to the areas where the ryegrass density was highest. The results also indicate that there may be a higher level of trifluralin resistance at the high ryegrass site compared with the low ryegrass site.

If herbicide resistance in ryegrass is found to have a greater prevalence in higher density patches, then this will provide added impetus for using more aggressive herbicide mixes in those areas.

The usefulness of maps in subsequent years will be dependent on patch stability, where patch stability will be influenced by natural dispersal, movement of seed by machinery and the seasonal conditions affecting ryegrass recruitment. Adding a bigger area around the patches should account for these factors in most cases.

Grass selective dose rates

Ryegrass patches were also mapped in a lentils paddock in 2007 and this map was used to position Select herbicide (clethodim 250g/L ai) trials in high and low-density populations.

The reasons for using higher rates of grass selective herbicides in thicker weed patches include:

- Dense ryegrass patches where plants overlap and shade each other, the risk that an individual plant will not receive a lethal dose;
- Ryegrass resistance to Select may vary spatially across a paddock in patches; and,
- Achieving an acceptable level of control. In a low density population 95 per cent control may be acceptable, but this will leave an unacceptably high level of survivors in a high-density population.

More information:
John Heap Ph: 08 8303 9444, E: heap.john@saugov.sa.gov.au
Sam Trengove Ph: 08 8842 3230, E: samtrenny34@hotmail.com
1. John Heap is with the South Australian Research and Development Institute (SARDI), Adelaide, SA.
2. Sam Trengove is with Allan Mayfield Consulting, Clare, SA. ■

HI-TECH HERBICIDE HOUND

At the heart of a German designed hi-tech SSWM prototype sprayer dubbed 'Cerberus' – appropriately named after the mythical three-headed hound – are three digital cameras. These cameras photograph the field on-the-go and send the images to a computer. The computer extracts the contours of the photographed plants and removes flaws. A second computer then compares the pictures with sample plants in a data bank. So Cerberus recognises not only whether the plant is a weed or not, but also what sort of weed it is.

The machine selects the correct herbicide from a choice of three tanks and also selects the correct dosage.

University of Bonn' engineer, Dr Rolf-Dieter Therburg, developed the camera technology. The automatic image recognition – difficult enough even under laboratory conditions with optimum light – works in the field in all kinds of weather. And it works pretty fast – the sprayer trundles across the field at a speed of up to 10 km per hour, with each of the three cameras taking two photos per second.

In current field trials the computer program identifies the weeds – and on the basis of this – produces a GPS-supported 'spray map' where the amounts of herbicide required are identified. Then, in a second stage, the 21 metre wide sprayer uses this map to spray the herbicides. Theoretically, all this is possible in a single operation.

The Norwegian company Kverneland – one of the world's leading manufacturers of herbicide spraying equipment – has recognised the potential of the new technology and is planning to mass-produce the spraying machine. The marketing prospects are not bad either in view of the increasingly stringent regulations on the use of herbicides, especially since there are not likely to be any quantum leaps any time soon in making herbicides more environment-friendly and effective.

As Dr Gerhards puts it: "The next revolution will be technological, not chemical."

More information: Dr. Roland Gerhards E: r.gerhards@uni-bonn.de

The Cerberus prototype in action. (PHOTOS: Frank Luerweg, Uni Bon)