Site Specific Weed Management (SSWM) - weed mapping and patch spraying

John Heap[1] and Sam Trengove[2]
[1]South Australian Research and Development Institute (SARDI), Adelaide, SA.
Phone 08 8303 9444 Email heap.john@saugov.sa.gov.au
[2]Allan Mayfield Consulting, Clare, SA
Phone 08 8842 3230 Email samtrenny34@hotmail.com

Summary
SSWM 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, e.g. 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.

Background
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. GPS has opened the way for Site Specific Weed Management (SSWM) – targeting control measures only to where they are needed.

Potential Benefits
Dr Roland Gerhards summarised SSWM in a conference in Germany last year, and observed that: "Using broad-acre blanket spraying 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%. The cost savings are obvious, but additionally weed-free crop areas not sprayed may yield 5 to 10% more, when phyto-toxic effects of the herbicide are removed. In Europe there is also a strong interest in SSWM for environmental reasons.

SSWM Systems
The aim of SSWM spraying systems is to get the right dose of the right herbicide in the right place. 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. SSWM has four main components: 1) weed mapping/sensing; 2) treatment decision 3) treatment application; and 4) documentation. The system components chosen will be influenced by each individual weed control situation.

Prior mapping vs real-time detection. 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.

Weed/crop biomass vs weed species ID. Simple reflectance systems can measure total plant biomass – 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 decisions. The simplest is ON/OFF – this is most easily implemented, 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. These systems use sophisticated computerised weed control expert systems (eg Plant Protection On-Line).

Treatment scale. Most SSWM research has concentrated on treating patches (metres across) using boom section control, but more recent research in Denmark is working on "cells" (c. 11x3 cm) or even single plant targets.

Sensor types. 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 periodic distraction of the operator. 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 linking 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 bottle-necks for SSWM are efficient and accurate mapping/scanning systems and suitable direct injection systems for herbicides. Recent advances in research labs in Europe suggest that these problems may be overcome. Advanced imaging prototypes can identify 25 weed species real-time. Direct injection systems currently suffer from long lag-times because of the time taken for the herbicide to travel from the injection point to the nozzle (4 to 30 seconds). Late last year a German research team described an effective direct injection nozzle that would allow concentrated herbicide to be injected directly into nozzles with a lag time of less than a second.

Overseas developments

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 growers generally consider herbicides to be cheap and have little incentive to adopt more complex systems. The closest system to commercial release appears to be a 21m three-tank sprayer ("CERBERUS") developed by Dr Roland Gerhards and his team at the University of Hohenheim, near Stuttgart, Germany. The sprayer has three parallel independent spray lines supplied by three separate tanks filled with different herbicides. Weed maps are used to switch 7 x 3m 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 (c. 25 species) and treatment mixture determination. Studies in 13 paddocks over 3 years have given 10 to 80% herbicide reductions while maintaining good weed control. Efficacy has been tracked in 38 paddocks with c. 95% 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. 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 c. 11 x 3cm 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 L ha^{-1}.

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 (eg 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 (Avadex Xtra) 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 suggests some potential windows of opportunity for SSWM.

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 (eg Skeleton weed, SLN)	Summer weed mapping. Ground or remote. SSWM non-selective herbicide application possible.
Pre-sowing	April-June	Emerged winter seedlings. Probably standing stubble.	Emerged weeds – no crop rows. Ground or remote. SSWM non-selective herbicide application possible.
Early post-em.	July-Aug	Early post-em crop and weeds. Distinct crop rows.	Inter-row sensing (ground only);Crop+weed sensing (ground or remote);
Late crop	Sept-Nov	Closed crop inter-rows. Weed heads visible.	Wild oat, brome, ARG head mapping. (probably remote only); SSWM "crop-topping" possible.

Some local research experience

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.

Ryegrass mapping

The commercially available crop sensors (CropCircle, GreenSeeker and Yara N-Sensor) measure light reflectance in the red and NIR wavebands. Red light reflectance is sensitive to changes in plant chlorophyll content and NIR light reflectance is sensitive to changes in plant biomass. 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 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.

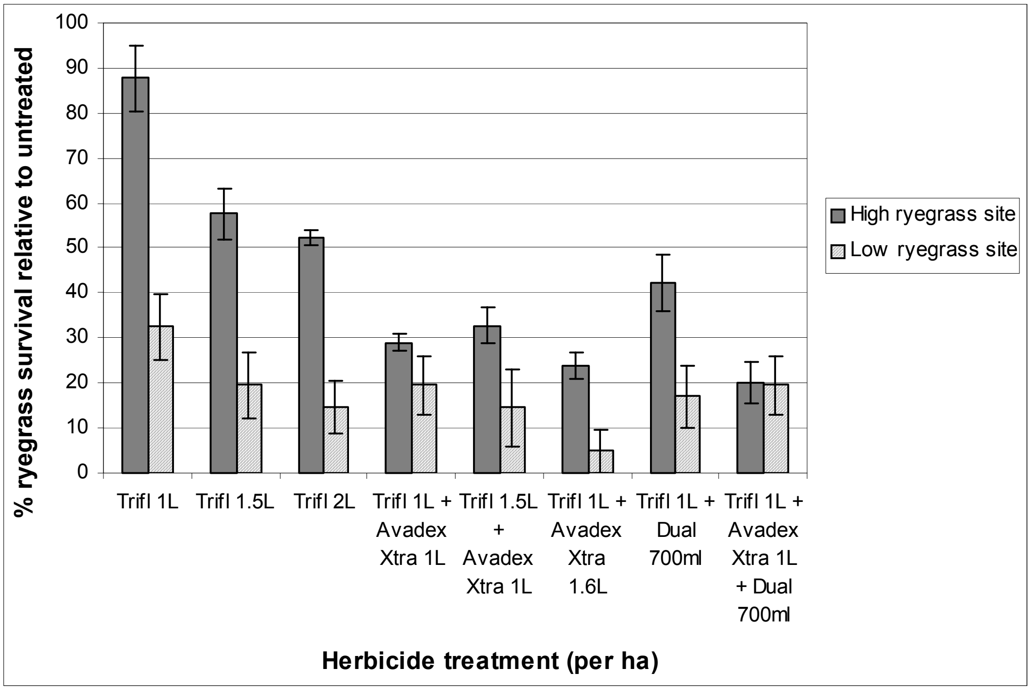
Herbicide treatment decisions in ryegrass patches

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 show that the addition of Avadex Xtra or Dual to a base rate of trifluralin has led to a significant improvement in control at the high ryegrass site (Figure 1). However, 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. Therefore, 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 (this is being assessed). If herbicide resistance in ryegrass is found to have a greater prevalence in higher density patches, then this will provide added incentive 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, in particular harvesters and the seasonal conditions affecting ryegrass recruitment. Adding a bigger area around the patches should account for these factors in most cases.

Figure 1: Pre-emergent herbicide effects on ryegrass survival relative to nil at two sites in one paddock with differing ryegrass populations (High ryegrass site: nil = 574 plants/m^2, LSD (5%) = 13.2; Low ryegrass site: nil = 11 plants/m^2, differences not significant).



Ryegrass patches were mapped in lentils in one paddock in 2007 and this map was used to locate Select herbicide trials in high and low-density populations. Reasons for using higher rates of grass selective herbicides in thicker patches are:

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

Ryegrass counts (Table 2) show that at the high ryegrass site 350 and 500 ml/ha of Select provided significantly greater control than 250 ml/ha. At the low ryegrass site there was no significant difference between these three rates, and these rates provided significantly greater control than 150 ml/ha. Thus, higher rates provided greater control at the high ryegrass site indicating that plants may have been overlapping, thereby limiting herbicide contact to all plants or may indicate an increased level of Select resistance in the high ryegrass patch. This trend is not evident at the time of ryegrass head counts though, with the highest Select rate providing the best control at both sites. The decision to vary rates based on the ryegrass head count results would therefore be related to what is an acceptable level of control.

Table 2: Effect of Select (clethodim 250g/L ai) rate on ryegrass (RG) numbers and ryegrass head production at two sites in one paddock with differing ryegrass populations (different letters denote treatments that are significantly different at 5% level).

	RG plant counts (plants/m^2)		RG head counts (heads/m^2)	
	High RG site	Low RG site	High RG site	Low RG site
Nil	935.5 a	70.7 a	1558.0 a	557.0 a
Select 150 ml/ha	49.7 b	6.8 b	249.3 b	59.1 b
Select 250 ml/ha	11.5 c	2.3 c	83.3 c	32.9 b
Select 350 ml/ha	5.5 d	0.4 c	42.6 c	17.4 c
Select 500 ml/ha	3.3 d	0.6 c	15.0 d	3.3 d