Sensors offer potential for in-crop decisions

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PA in-crop is about collecting additional information to refine existing paddock zones, testing the results of on-farm trials and ground-truthing VRA implemented before or during sowing.

PA in-crop technology, such as canopy sensors, helps determine whether decisions made at sowing have met their aims and allows growers to measure what’s happening during the growing season. It is not just about focusing on this year, but building layers to develop more comprehensive decision support tools. A grower may produce biomass maps using sensing technology to assess crop performance, or start identifying weed-density maps and weed hot spots that could influence next year’s weed management.

Often termed ‘crop sensors’ or ‘weed detectors’, optical sensing devices that use light reflectance to detect actively-growing plant tissue are growing in popularity among grain growers throughout Australia who want to fine tune their cropping operations, managing inputs cost-effectively while maximising crop yields.

Technically speaking the optical sensor technology referred to in PA in Practice II does not discriminate between crops and weeds, but simply measure the amount of light reflected from an actively-growing plant. But in a practical sense, the information provided by the different units can be used to ‘spot spray’ weeds during summer (when there is no crop), or determine the amount of crop growth during the season, allowing growers to adjust top-dressing inputs accordingly. It needs to be noted that growers cannot use one sensor to spot spray and measure crop growth — dedicated sensing technology is required for each type of sensing application.

key messages

- Sensing technology allows growers to collect additional information that can be used to measure the success of early-season decisions and support future management activities.
- Weedseeking technology allows growers to selectively target weeds, saving on herbicide costs while maintaining weed control efficacy.
- In-crop sensing technology highlights crop requirements as the season progresses, allowing targeted top-dressing without wasting inputs.

Summer control: plant sensing technology such as the WEEDit™ system can reduce input costs by only targeting weeds, as opposed to a blanket herbicide application across the whole paddock. PHOTO: ED CAY
There are five main commercially-available sensors on the market in Australia that growers are using — WeedSeeker™, WEEDit™, GreenSeeker™, OptRx™ (formerly Crop Circle™) and CropSpec™ (see Table 1, page 91 for more information).

**Sensors for weed control**

The WeedSeeker and WEEDit products use sensing technology to detect and spray weeds, mainly during the summer-autumn period (see Figure 1). Growers can gain substantial cost savings targeting herbicide application at weeds only, as opposed to blanket applications across a paddock.

Although a less common practice, these tools can also be used for in-crop weed control either very early or very late in the season or used under shrouds between crop rows during the season.

**In-crop sensing**

The GreenSeeker, OptRx and CropSpec sensors are responsive to both crop biomass (amount of vegetation) and crop colour (which relates to chlorophyll concentration and/or nutrient concentration).

A darker green crop gives higher values than a paler green crop for the same given biomass. While the use of this technology is slowly evolving, growers are starting to apply this information to vary inputs during the growing season, for example nitrogen, trace elements and herbicides.

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**Figure 1. How weed seeking sensor technology works**

1. Light emitting diodes (LEDs) produce a combination of invisible infrared and visible red light, which is projected onto the target about 600mm below the sensor.

2. The light reflected from the target is captured by a detector at the front of the sensor.

3. Sophisticated electronic circuits inside the sensor analyse the reflected light and determine when it matches the light reflected by green plants.

4. When green a plant’s reflectance is identified, the sensor waits until the plant is under the spray nozzle and then triggers a fast-fire solenoid valve, which sprays the plant.

After the information from the sensor is processed, growers can interpret the results into a VRA paddock map, which they can then load into a controller with VRA capacity.

Alternatively, where growers are confident the information supplied by the sensors reflects exactly what is happening in the paddock, inputs can be varied on-the-go as data is collected from sensors mounted on a tractor, sprayer or similar machinery.
In-crop adjustments: Growers are increasingly using plant sensing technology such as CropSpec (left) to fine tune top-dressing decisions during the growing season. PHOTO: MATT MCCALLUM

On-the-go: Growers can use information supplied by the plant sensors, represented as a realtime NDVI map (pictured) to apply VRA inputs as information is collected or after further analysis and ground-truthing. PHOTO: MATT MCCALLUM

Interpretation is the key
Correct interpretation of the data is the key to successful in-crop VRA, otherwise crop management decisions based on sensors can be misguided costing time and money.

Ground-truthing is a term used by PA consultants and growers, which refers to going back out into the paddock to verify that the information collected by the technology relates to what is actually happening on the ground.

Targeted plant or soil testing may be required to increase the confidence of any in-crop decision making around plant sensing technology.

On-farm experience
PA is a moving target — it’s about evolution of agronomy and using information to fast track and make decisions around that. It allows growers to identify and address key limiting factors, ticking them off one at a time. With careful data collection and analysis PA allows growers to constantly refine their systems.

In this section readers will read about SPAA trials and grower experiences with sensors for weed control and VRA programs. Compared with yield mapping, paddock zoning and VRA at sowing, the uptake of this technology is only in its infancy, but on-going research and grower experiences will drive adoption into the future.

about the author
Together, PA consultants Sam Trengove, Andrew Whitlock and Matt McCallum have more than 10 years combined experience in assessing the performance of plant sensing technology for weed control and crop nutrient management.

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PHOTO: BRENDAN WILLIAMS

PHOTO: BRENDAN WILLIAMS
### Table 1. Details of OptRx™, GreenSeeker™ and CropSpec™ sensors currently commercially available in Australia and New Zealand

<table>
<thead>
<tr>
<th>Model:</th>
<th>OptRx (Crop Circle)</th>
<th>GreenSeeker</th>
<th>CropSpec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer:</td>
<td>ACS470 HollandScientific</td>
<td>RT200 NTechIndus.Inc.</td>
<td>IP67 Topcon</td>
</tr>
<tr>
<td>Data logger</td>
<td>GeoSCOUTGLS400</td>
<td>RTCommander</td>
<td>X20</td>
</tr>
<tr>
<td>Light source</td>
<td>Modulated polychromatic LED array</td>
<td>LED</td>
<td>Lasers</td>
</tr>
<tr>
<td>Power</td>
<td>10 to 17 VDC</td>
<td>12VDC</td>
<td>10–32VDC</td>
</tr>
<tr>
<td>Operational wavebands</td>
<td>670/20 (Red) and 760/LWP (NIR)</td>
<td>660/15 (Red) and 770/15 (NIR)</td>
<td>735/10nm (Red) and 808/10nm (NIR)</td>
</tr>
<tr>
<td>Footprint/field of view</td>
<td>15 × 5cm (changes with height)</td>
<td>5 × 60cm</td>
<td>2–3m</td>
</tr>
<tr>
<td>Viewing angle</td>
<td>32/6°</td>
<td>32°</td>
<td>45–55°</td>
</tr>
<tr>
<td>Operating height</td>
<td>0.6–1.2m</td>
<td>0.8–1.2m</td>
<td>2–4m</td>
</tr>
<tr>
<td>Number of sensors</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Mount</td>
<td>Hand-held or sprayer boom</td>
<td>Hand-held or sprayer boom</td>
<td>Tractor cab</td>
</tr>
</tbody>
</table>

Canopy sensors keep ryegrass at bay

Mark Branson, Stockport, SA has had ryegrass resistance for more than 10 years and although he thinks it will be impossible to eradicate, PA is helping to keep it under control.

From the two-leaf stage, Mark uses the Topcon CropSpec™ canopy sensors on his sprayer to identify areas of ryegrass infestation as the sensors will detect the patches of increased green biomass in comparison to a young crop.

From this information, Mark can then map where the ryegrass is dominant and direct specific herbicide mixes in these areas.

Currently, Mark is trialling a range of different herbicide mixes at high rates at the limit the crop can handle to try and reduce the ryegrass.

In conjunction with herbicide, Mark has also increased sowing rates in the ryegrass dominant patches.

Through experience he has found that the crop is competitive against ryegrass, so in paddocks sown to wheat the sowing rate is increased in the ryegrass areas to ensure a plant establishment of 200-300 plants/m² while in the more competitive barley crops, Mark aims for a plant establishment of 150-200 plants/m².

Mark uses the crop sensors to assess the success of the herbicide applications and has been happy with the results so far, as it is possible to visibly see reductions in the ryegrass populations on his paddock maps. He believes if the ryegrass infestations can be treated in specific zones and prevented from expanding, this will be the main method of control.

In the future Mark plans to refine the herbicide mixes and also look at double spraying bad ryegrass patches.

contact

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Precision spraying options reduce chemical costs

The Postlethwaite family use a combination of band and shielded spraying to reduce chemical use and costs by up to $27 per hectare on their 2400ha mixed farming enterprise near St Arnaud, Victoria.

A 2cm autosteer and tailor made spraying equipment, fitted to their sowing and spraying tractors have enabled the Postlethwaite’s to adopt precision spraying techniques to wide-row crops such as faba beans and chickpeas.

All pulse crops (lentils, beans, chickpeas and vetch) are sown 1m apart in paired rows (225mm apart) and Neale uses a combination of shielded and band-spraying techniques to strategically apply chemicals to these crops.

Wheat, barley and canola are all sown on straight 225mm spacings.

During the past, all wide-row pulse crops were sprayed on the inter-row, using a shielded sprayer with cheaper knockdown herbicides (glyphosate, paraquat, diquat).

The more expensive selective herbicides and fungicides were sprayed just on the row itself (band spraying) saving Neale $27/ha on chemical in total.

During recent years the cost of in-crop grass control herbicides has dramatically reduced, so Neale now blanket sprays products such as clethodim on pulse crops, although he still band sprays fungicides, which are more expensive.

In addition to clethodim, shielded spraying with knockdown products is still used to strategically control ryegrass on a few paddocks each year.

Tailor made

The Postlethwaites manufactured their own shielded spraying unit due to a lack of commercially-available equipment suitable for their operation. They now produce them commercially, along with other controlled traffic farming equipment (for more information go to tpos.com.au).

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Cutting costs: Inter-row spraying using 2cm autosteer accuracy and wide rows provides opportunities to significantly reduce chemical costs. PHOTO: NEALE POSTLETHWAITE
PA in Practice II

Using precision agriculture technologies:

Spot spraying weeds can pay dividends

PAA trials have revealed that the use of WeedSeeker™ technology to spot spray low-to-moderate-density weed burdens can reduce water use (and hence chemical use) by up to 78% when compared with blanket application.

But where weed densities exceed about 60–80% across a paddock, a blanket application can actually be more cost-effective.

During the summer of 2010, a SPAA trial investigated the viability of WeedSeeker technology in a paddock near Rupanyup in the Wimmera region of Victoria.

The paddock was infested with a range of weeds including milk thistle, dead nettle and stemless thistle. The density of weeds across the paddock varied from low (5–10% ground cover), to moderate (10–20%) and high (60–80%) (see Figures 1a and 1b).

To investigate the potential savings in chemical use, water rates and total water usage were compared between a WeedSeeker spray unit and a conventional boomspray.

**Trial results**

The amount of water applied varied greatly between the different weed-density zones — low, moderate and high (see Table 1).

Under the high weed density, the WeedSeeker technology actually used more water, and hence more herbicide, than the blanket approach. This was probably due to the way the technology is designed. Often in relatively high weed densities, two sensors would come on to spray one weed, hence twice the amount of water.

However, at both the low and moderate densities, by using the WeedSeeker, water use was reduced significantly.

When comparing the overall paddock gains from using WeedSeeker technology, there were substantial water savings made (see Table 2).

Using the WeedSeeker, the average water rate was 19L/ha (incorporating each different zone) compared with 88L/ha for the blanket application. This equated to a 78% saving in water (with an equivalent saving in herbicide).

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**Table 1. Water usage comparisons**

<table>
<thead>
<tr>
<th>Weed Density</th>
<th>WeedSeeker</th>
<th>Blanket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>19L/ha</td>
<td>88L/ha</td>
</tr>
<tr>
<td>Moderate</td>
<td>19L/ha</td>
<td>88L/ha</td>
</tr>
<tr>
<td>High</td>
<td>38L/ha</td>
<td>88L/ha</td>
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</table>

**Table 2. Water savings**

<table>
<thead>
<tr>
<th>Weed Density</th>
<th>Water Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>69%</td>
</tr>
<tr>
<td>Moderate</td>
<td>78%</td>
</tr>
<tr>
<td>High</td>
<td>78%</td>
</tr>
</tbody>
</table>

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Figure 1a. Varying weed densities across the trial paddock

Low density: 1–5% ground cover, small to medium size thistles, no emerging dead nettles.

Moderate density: 5–10% ground cover, medium to large size thistles, patches of dead nettles.

High density: 60–80% ground cover, large size thistles with a consistent understory of dead nettles.
Figure 1b. An illustration of the variability across the paddock. The high-density areas are where water laid for one month after the January floods.

Table 1. Water rates found at each plant density

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Low density</th>
<th>Moderate density</th>
<th>High density</th>
</tr>
</thead>
<tbody>
<tr>
<td>WeedSeeker</td>
<td>36</td>
<td>52</td>
<td>120</td>
</tr>
</tbody>
</table>

Table 2. Water rates used when the entire paddock was sprayed

<table>
<thead>
<tr>
<th>Application</th>
<th>Area sprayed (ha)</th>
<th>Total water used (L)</th>
<th>Water rate (L/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blanket spray</td>
<td>37.5</td>
<td>3300</td>
<td>88</td>
</tr>
<tr>
<td>WeedSeeker</td>
<td>37.5</td>
<td>700</td>
<td>19</td>
</tr>
</tbody>
</table>

Note: WeedSeeker technology has been approved from 2 June 2011 for use with a number of herbicides under an Australian Pesticides and Veterinary Medicines Authority (APVMA) permit (FER11163). Permit herbicide rates depend on percentage weed cover. If percentage weed cover exceeds 30% approved use, normal boom spray rate (blanket) only.
Sensors aid in-crop nitrogen decisions

A successful variable rate in-crop nitrogen program is often described by growers as the ‘holy grail’ in PA, and crop sensing technology may prove to be a valuable tool in achieving this goal.

A series of SPAA trials carried out during 2010 has helped growers evaluate a range of crop sensors, and their role in nitrogen decision making.

**GreenSeeker™ vs EM38**

On Bruce and Robert Pococks’ farm in the South Australian Mallee, the GreenSeeker NDVI map, showing variation in crop biomass and greenness, was compared against the paddock’s EM map.

The NDVI map produced by the GreenSeeker correlated well with the EM38 map, and proved that paddock zones in the Mallee could be mapped according to NVDI (see Figures 1a, 1b and 1c).

**Figure 1c.** Correlation curves for NDVI and EM38 readings, Mallee, SA, 2010
CropSpec™ vs Landsat™

Another SPAA trial on the Yorke Peninsula of SA compared a tractor-mounted CropSpec with satellite imagery from Landsat. These two sources of NDVI maps also correlated well (see Figures 2a, 2b and 2c).
Ground-truthing important

These two trials demonstrate there are several sources of crop imagery available for potential use for in-crop variable rate applications (for example, nitrogen fertiliser). However, the images will always need some ground-truthing to verify what you think you are seeing in the office is what is actually happening in the paddock.

With funding from SPAA, the Riverine Plains Inc group has been working to ground-truth crop sensing technology and assess its suitability for in-crop nitrogen decisions in wheat crops.

Measurements of tiller number, dry matter (DM), and plant nitrogen uptake were compared with NDVI data taken by a Crop Circle™ and yield at the end of the year (see Figure 3).

Tiller number (r^2 0.74), DM (r^2 0.91) and plant nitrogen uptake (r^2 0.85) all correlated well with NDVI.

NDVI also correlated well with yield (r^2 0.82), which gives growers in the region confidence that NDVI can be used as a tool on which to base an in-crop variable rate nitrogen program when combined with predicted yield potential for each paddock zone (see Figure 4).

Note: R^2 is a statistical measure of how well two data sets correlate, with an R^2 of 1.0 being a perfect fit. In agriculture, an R^2 of >0.7 is considered a valid correlation.

What gave growers in the region further confidence was when they combined the same data from 2009 (a lower production year) with the 2010 results (see Figure 5).

Figure 5 shows that the data corresponds well and provides a useful guide to the production and efficiency limits that can be expected with regard to nitrogen and wheat yields across a reasonably broad nitrogen and yield range.

Telling the truth: While crop sensors provide valuable feedback, any data needs to be ground-truthed to verify that what you see in the office matches what is happening in the paddock. PHOTO: BEN WHITE
Figure 3. Crop reflectance data (NDVI) and sampling sites for wheat crop 2010

Figure 4. Wheat yield for 2010

Figure 5. Combination of 2009 and 2010 data for efficiency with which crops nitrogen is converted to grain (a) and absolute yield relative to crop nitrogen (b)

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