

VARIABLE-RATE APPLICATION FACT SHEET

NORTHERN, SOUTHERN AND WESTERN REGIONS

MAKE VARIABLE-RATE APPLICATION PAY

Variable-rate application (VRA) of some inputs delivers cost benefits and improved yields. Before adopting VRA, growers can optimise their chances of better returns by running simple on-farm trials.

KEY POINTS

- ▶ When considering variable-rate application, question whether variation exists. The level and area of variability needs to be large enough to justify adoption.
- ▶ Varying application rates can be done manually or by using precision agriculture equipment.
- ▶ Obtain data to build a picture of the different management zones. Crop biomass, yield and soils information, plus a grower's knowledge can be used to create zones.
- ▶ When managing different zones within a paddock, diagnose the constraint or factor that limits crop yield. On-farm trials can help.
- ▶ Prioritise lifting the yield potential of constrained soils with ameliorants before adjusting nutrient inputs.
- ▶ The return from varying rates can change from season to season.
- ▶ Keep on-farm trials simple: stick to one or two treatment differences and make the size difference between treatment rates large. Consider your equipment capability in the trial design.



PHOTO: EMMA LEONARD

When considering using variable-rate application, establishing the size of the yield variation and what is driving it are the first steps required. Technologies including guidance systems and yield mapping are assisting growers to vary application rates across a range of inputs.

Observation and experience are only part of the equation. For variable rate (VR) to be effective, good data are needed to quantify and map the zones of variability and to determine why it exists.

On-farm trials are an important step in this process. Well-designed and implemented trials can generate data that builds confidence in variable-rate technology and improve the potential for positive economic returns.

Individual results are site-specific and can vary between seasons. How well variable rate delivers on any property can depend on past practices, such as how well nutrient levels have been maintained.

What is variable-rate application?

In most areas, changes in soil and topography across a paddock result in yield differences. Historically, inputs have

Many growers observe consistent patterns of yield variation in their paddocks over a period of years. This experience provides a good starting point for the adoption of variable-rate application (VRA) of some inputs to lift yield potential and/or improve returns.

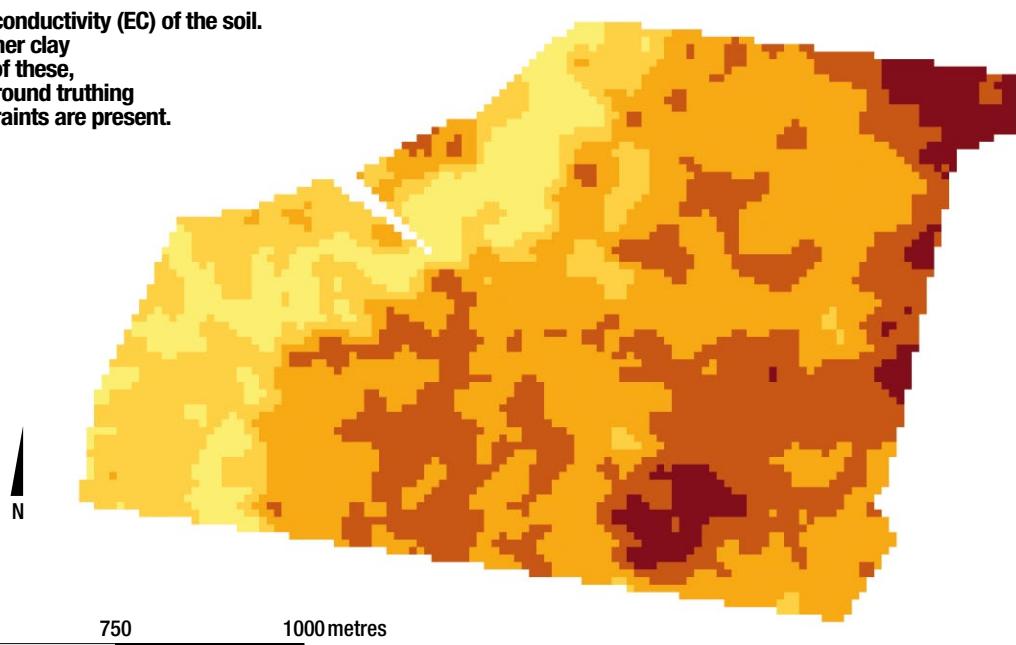
Figure 1 EM38 mapping measures electrical conductivity (EC) of the soil.

A high EC value reflects a high measure of either clay content or water or salts or any combination of these, and the spatial distribution of any variation. Ground truthing is necessary to determine exactly what constraints are present.

LOWER LIMIT

EC_a (mS/m) dry profile — lower limit (LL)

- <50
- 50-75
- 75-100
- 100-125
- >125



been applied evenly across a paddock, irrespective of variation. Differing crop performance results in uneven removal of nutrients or competition to weeds. Over time, this process can lead to greater variability of soil constraints such as pH, a reduction in soil fertility on the better-performing regions of the paddock or high weed seed banks.

Variable-rate application matches inputs

to optimise the economic return from a paddock. It works on the principle that instead of applying a blanket rate of an input across an entire paddock, the rate is adjusted to match changing local requirements.

When well executed in many situations, VRA can substantially reduce input costs and waste, lift yields and increase financial returns and optimise the environmental health of the paddock (see case studies).

VRA could be used for any rate-based operation that influences crop yield and profit. The application of cropping inputs such as seed, fertiliser, soil ameliorants (lime, gypsum), irrigation, pesticides (herbicide, insecticide, fungicide), desiccants and growth regulators can all be varied successfully. Not all of these inputs have been tested widely with grain crops.

Cost savings through headland management

Western Australian grower Phil Longmire knows first-hand the challenges and benefits of defining different management classes on his 5735ha property east of Esperance, WA.

Phil's paddocks range in size between 31 and 400ha, and many are not square or contain internal headlands due to dams and trees. Phil calculated that due to overlap, he was sowing 11 per cent more land and in doing so, adding more inputs.

Some parts of the property have been mapped using EM38 and this data was used for VRA of gypsum on the grey sodic clay loam soils. He has also been varying fertiliser rates at sowing based on soil type for the past few years.

However, his yield maps still indicated areas of poor productivity on headlands. He suspected that this related to a mismatch between crop density and available water.

Phil implemented a system of headland management that modified the fertiliser and seed rate applied on the headlands (Figure 4, right). This involved mapping the paddock boundaries and internal headlands, and then creating variable-rate maps for the headlands, based on level of overlap, the location of trees or other yield-limiting factors.

In one year this approach saved him nearly 24 tonnes of

fertiliser, valued at \$16,700, as well as savings in seed, which have not yet been calculated.

For Phil, variable rate is about reducing waste and making his business more profitable. Apart from varying nutrients and soil ameliorants, Phil uses VRA on problem weeds such as wild radish and couch grass. CropCircle™ biomass sensors mounted on the front of the tractor detect subtle differences in the crop colour that have been revealed through soil testing to be a manganese (Mn) deficiency. When the sensors pass over these areas, a full rate of liquid nutrients is delivered through the front spray.

Figure 4 Varying rates of fertiliser 14.5N : 14.5P : 0K : 9S plus trace and seed barley

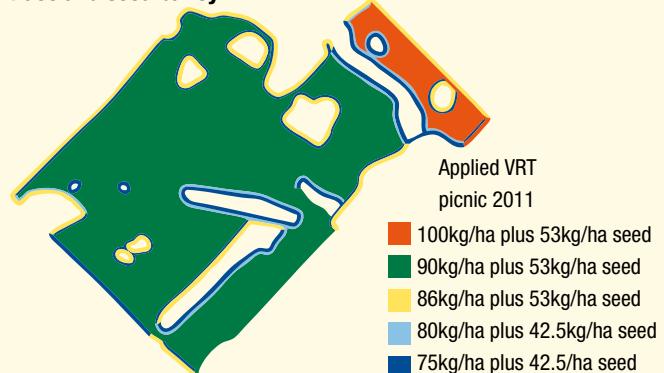


Figure 2 Potential management classes based on grain yield and electrical conductivity (EC).

The arrow represents the direction of paddock operations, while the white dots and numbers denote the location of soil samples taken in each paddock. The black lines represent the location of strip plots for an on-farm trial.

- Low
- Medium
- High

VRA is still a relatively new technology for some inputs in broadacre cropping, such as pesticides, seed and tillage. However, it is becoming increasingly common for the application of soil ameliorants and nutrients.

Variable-rate technology (VRT) allows for more sophisticated positioning (using a GPS signal) and rate adjustments. However, VRA is also possible by using manual switching or multiple passes.

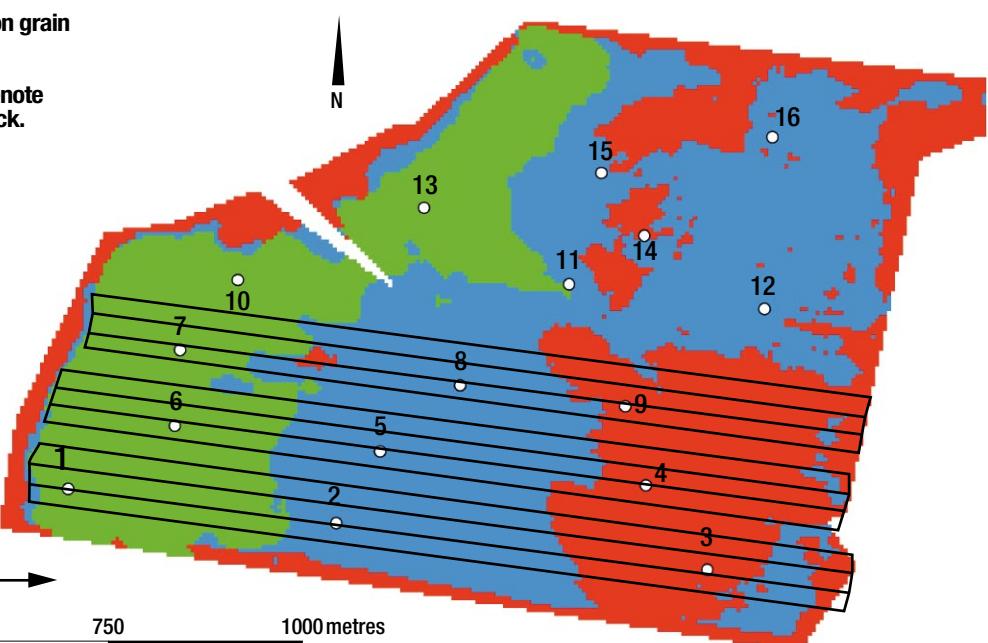
Soil remediation trial adds \$232/ha over three years

A variable rate gypsum trial on Nev Boland's southern Queensland property delivered positive results and confirmed the value of soil remediation for long-term economic gain. Queensland Department of Environment and Resource Management (DERM) soil scientist, Yash Dang, commenced a trial in 2004. It was designed to evaluate wheat yield response to gypsum in the lowest yielding management class.

The experiment involved 2.5t/ha of gypsum spread on the soil surface of the poor-yielding side of the paddock and incorporated to a depth of zero to 0.5m. Yield monitor data for the experiment were then obtained for a wheat crop the following year (2005), a chickpea crop in 2007, and a second wheat crop in 2008.

The gypsum application had no effect on wheat yield in 2005 but in year 2 chickpea yields increased by 0.46t/ha in 2007 and again significantly increased wheat yield by 0.56t/ha in 2008 (Figure 5, page 3). This two-year delay in yield gain was not surprising, as the movement of gypsum through the soil is dependent on rainfall.

The trial concluded that the cumulative economic benefit of a single gypsum application to the lowest yielding management class for two wheat crops and one chickpea crop would translate to an accumulated profit of \$232/ha over the three-year period.



While growers may already have equipment able to vary inputs, selecting the most appropriate input rates requires careful consideration. Simple on-farm trials can help establish the best rates for different areas in a paddock.

First identify variability

The first and most important issue to address is whether yield varies in the

paddock. If so, by how much, and what is the economic value of that crop yield variation? Every paddock should be examined and only those paddocks with substantial variation, for example, more than 1t/ha for cereals, should be targeted for variable rate.

While growers generally have knowledge of variation, yield maps can help to accurately quantify and locate variation.

This figure was obtained using a value of \$100/tonne for gypsum, a wheat grain price of \$210/tonne and a chickpea grain price of \$410/tonne.

Figure 5 Yield response to applied gypsum on a constrained soil in southern Queensland. The gypsum application had no effect on wheat yield in 2005 but significantly increased chickpea yield in 2007 and wheat yield in 2008. This two-year delay in yield gain is due to the slow movement of gypsum through the soil profile.

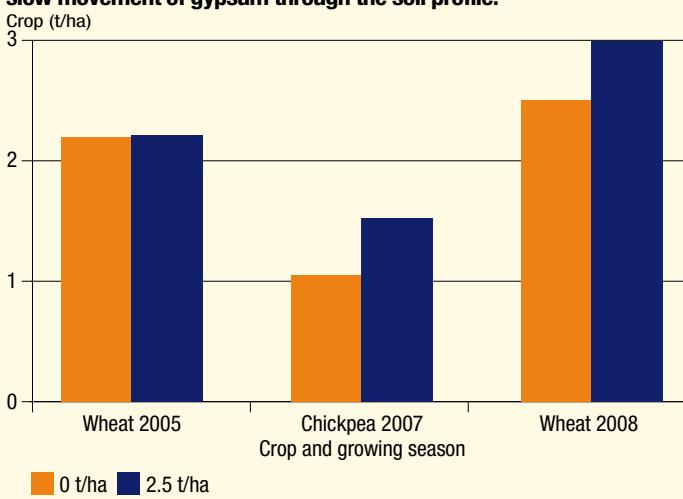
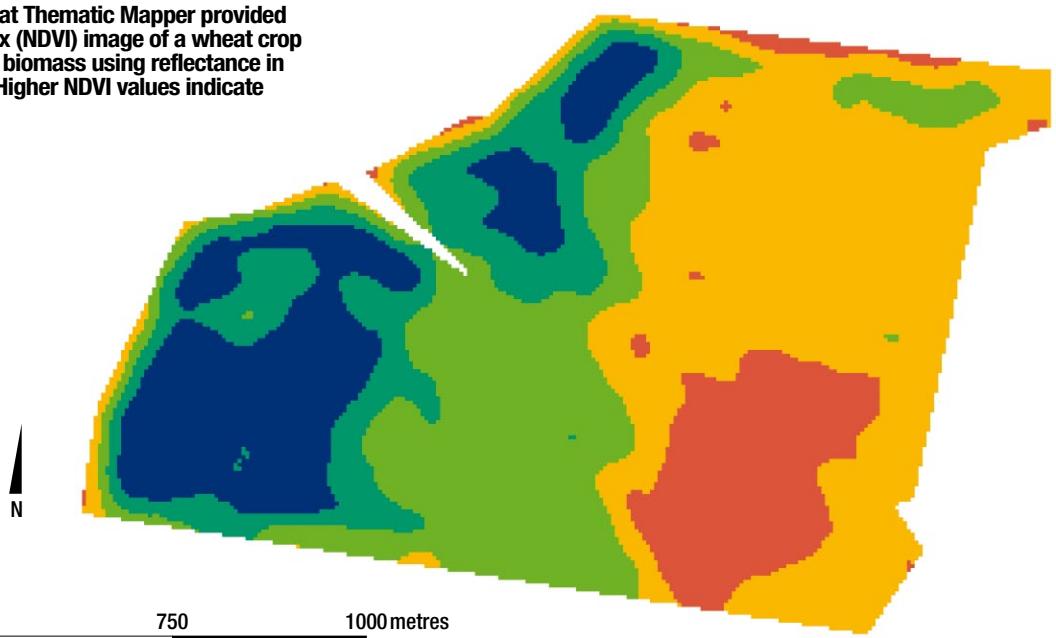


Figure 3 A cloud-free image from a Landsat Thematic Mapper provided this normalised difference vegetation index (NDVI) image of a wheat crop close to anthesis. NDVI estimates the crop biomass using reflectance in the near-infrared and red spectral bands. Higher NDVI values indicate more biomass.

NDVI 2007
 ■ 0.15-0.25
 ■ 0.26-0.35
 ■ 0.36-0.44
 ■ 0.45-0.54
 ■ 0.55-0.64



The degree of yield variation required to make VRA pay depends on input and grain prices as well as the farming system and available equipment. Growers need to crunch their own numbers and on-farm trials can help. The bigger the production differences, the greater the potential cost benefit from adopting VRA.

Diagnose the cause of variability

To ensure VRA is most effective, it is important to have a clear understanding of what is causing variability in any given paddock. For this, good data is needed. Causes can be divided into two broad categories: temporal and seasonal.

Temporal data are relatively stable over

a period of years and include measures of soil characteristics such as salinity, sodicity or electrical conductivity (EC). EC can be determined using EM38 mapping. It is a useful measure because it correlates with a number of soil properties, including texture, water-holding capacity, pH and salinity (Figure 1, page 2). Different colours in aerial images can be used to identify soil types in the paddock.

VR seed and fertiliser improves gross margin in a good season

A four-year trial conducted by SARDI at Minnipa, a low rainfall region of South Australia, commenced in 2008. This found varying inputs to soil type can pay but the degree of variation links to the season.

Low, medium and high seed and fertiliser rates were sown in alternating nine-metre strips across the paddock. The low rate consisted of 55kg/ha of seed and nil DAP and foliar N. The standard rate consisted of 65kg/ha of seed, 40kg/ha of DAP and nil foliar N, while the high rate was 65kg/ha of seed, 60kg/ha of DAP and 10kg/ha of foliar N. The paddock was then segregated into three production classes, good, medium and poor, using a combination of yield, EM38 and elevation maps.

The poor class produced lower grain yields than the good and medium classes, irrespective of treatment.

In 2010, grain protein levels were higher for the medium class than for the good or poor class but there has been no difference in grain quality in the three years.

To assess if varying rates in each of the production classes listed above were more lucrative than applying one of the three blanket rates of inputs, gross margin analysis was applied. Two VR approaches ('Go for Gold' and 'Hold the Gold') were compared to each of the gross margins for the blanket input treatments (high, standard, low).

The 'Go for Gold' treatment aimed to increase overall profitability by reducing inputs on areas with poorer yield potential and increasing inputs on areas of higher yield potential. The 'Hold the Gold' low-risk approach kept inputs at standard in the good class and low in poor and medium classes.

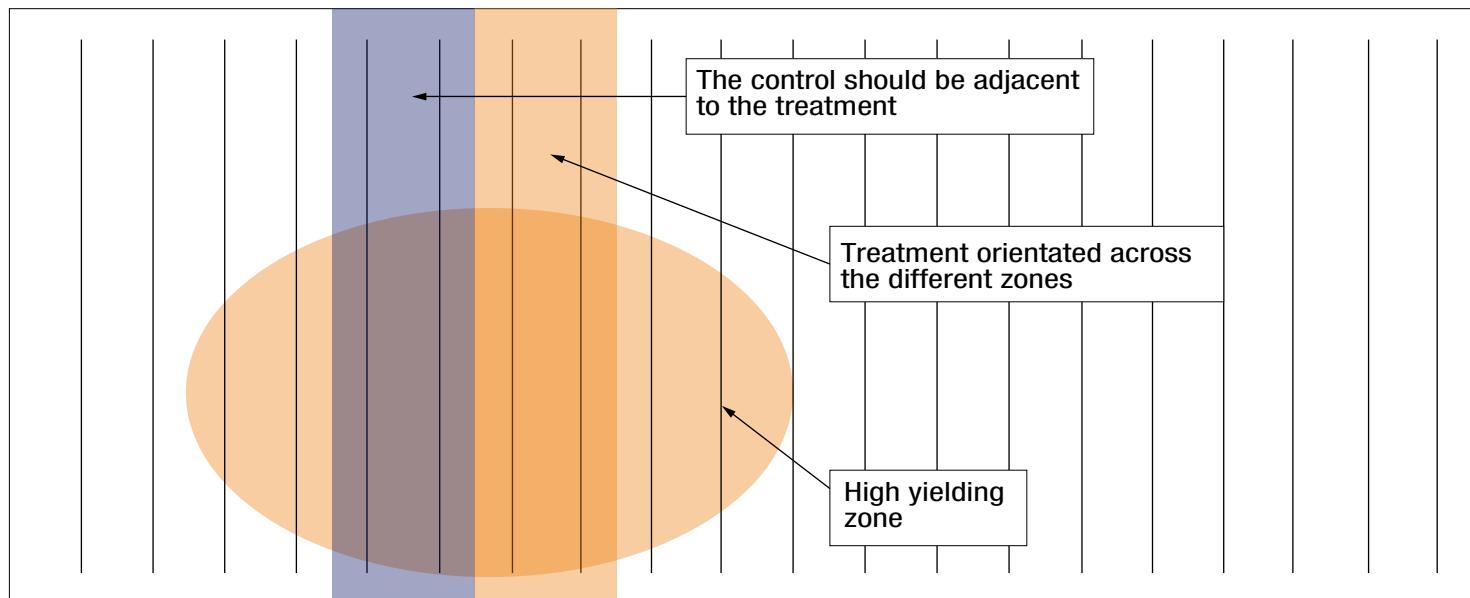
In 2010, 'Hold the Gold' produced a higher gross margin than any of the three blanket treatments (high, standard, low). The low-input blanket approach was the most profitable of the blanket treatments at \$631/ha, slightly more than the standard-input blanket approach at \$630/ha and the high-input blanket approach at \$613/ha (Table 1).

The trial showed that in low-rainfall areas, variable rate can help growers minimise risk and cash in on nutrient reserves in poorer areas, while looking after the more consistent areas of the paddock.

Table 1 2010 Gross margin analysis results across paddock classes

Paddock class/zone	'Go for Gold'	'Hold the Gold'	High-input blanket approach	Standard-input blanket approach	Low-input blanket approach
Good	High	Standard	High	Standard	Low
Medium	Standard	Low	High	Standard	Low
Poor	Low	Low	High	Standard	Low
Gross Margin	\$620/ha	\$656/ha	\$613/ha	\$630/ha	\$631/ha

Figure 6 Orientation of strip trials across a paddock with high yielding and average yielding zones.



Ground truthing is required for all data that is gathered remotely. Soil samples should be collected from the areas of difference identified by the images, and tested.

Temporal data combined with yield data has been successfully used to create management classes/zones showing different production potential. When establishing management zones, machinery widths and responsiveness of rate controllers also need to be considered (Figure 2, page 3).

Management zones have been used for variable application rates of gypsum, lime and inputs at seeding including seed and phosphorus.

A comprehensive picture of a paddock's variability and therefore yield potential can be built with 'layers' of historical data. 'Mud maps' of yield developed by the grower (based on experience) can be a starting point and then quantified with a combination of soil sampling and testing, on-board yield monitoring and/or EM38 mapping and surveying.

Once temporal limitations are quantified, in-season crop performance based on a measure of biomass builds on the picture and provides a guide on how in-crop inputs can be varied.

Seasonal data captures factors affecting crop performance including rainfall, frost or hot dry finishes, pests and disease, weeds and nutrient availability.

Biomass sensors – handheld, or retrofitted to tractors and boomsprays – can measure

differences in growing crops, as can remote sensing using a satellite image to measure biomass (Figure 3, page 4). This information is presented as a vegetation index – Normalised Difference Vegetation Index (NDVI). Personal observation and experience should also always play a role in determining in-season crop performance as should ground truthing.

Biomass sensors are being successfully used to vary rates of in-crop nitrogen, fungicides and growth regulators. They are also being used for weed management in-crop and during the fallow period.

Make long-term yield potential the priority

The greatest cumulative gains from VRA come from improving the longer-term yield potential of the soil, so the first priority should be to deal with subsoil constraints. Gypsum is often used to address structural problems and similarly, lime is applied to raise the pH of acid soils.

While amelioration can provide benefits for a range of soil problems, there are some soils that cannot be fixed. For these soils, the management option may be to accept that they are low-yielding and modify inputs to these zones on an ongoing basis.

When varying the input rate of nutrients, three factors should be considered:

1. replacing the nutrients removed by the crop;
2. the different crop requirements between management classes/zones; and

3. avoiding waste and environmental issues through run-off, leaching and denitrification.

Once yield variation has been established and quantified, it is advisable to run a paddock-scale trial to test variable rate before rolling out the strategy across the entire operation.

It is essential to be clear on the question being tested before designing and setting up a trial. For example, will varying the rate of nitrogen provide a significant yield benefit on low-yielding areas of the paddock? The trial is more likely to generate useful information if the design and implementation are done correctly.

Keep the trial design simple

A simple trial with a defined outcome is preferable to a complex trial that confuses the issue. Test the differences in yield response to different rates of a single input or practice. Do not include additional variables. Keep the following guidelines in mind when designing an on-farm trial.

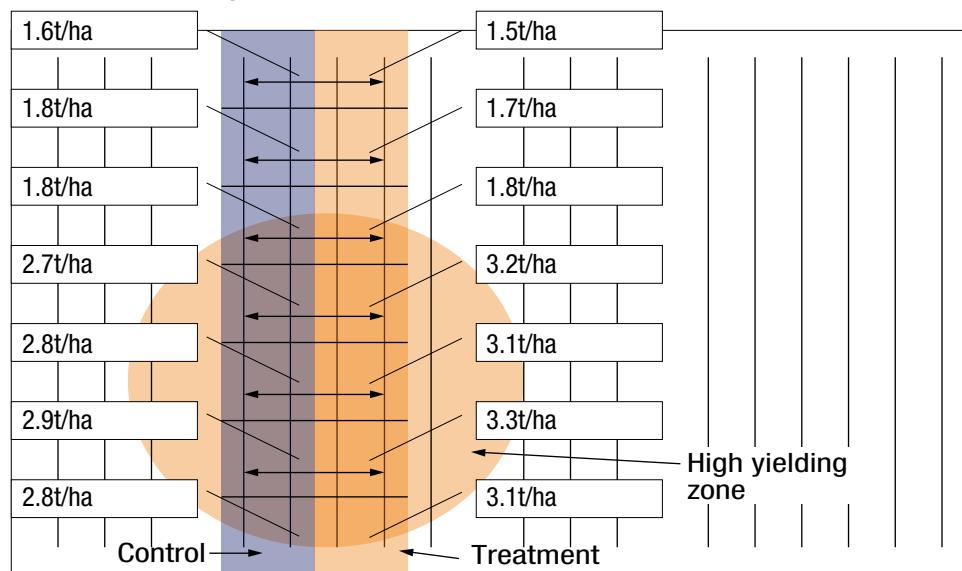
1. Few rather than more treatments

The treatments being tested need to fit with existing sowing operations. For that reason, take a pragmatic approach and keep the trial design simple: one or two treatments at most.

2. Aim for large treatment differences

The purpose of the trial is to identify system constraints, so take a radical approach.

Figure 7 An example of a paired t-test comparison of treatment for yield (t/ha) based on a 50m grid laid over the control and trial strips. The yield data recorded is an average for the grain harvested within each pixel.



For example, one treatment of nil nitrogen, or at least 20kg difference in nitrogen applications. It is not necessary at this stage to consider the economics of a certain treatment; it is more important to gain an insight into how the crop responds to particular inputs and therefore how management might be changed in different zones of the paddock.

3. Choose the correct orientation

As the variation in yield within a paddock may require different management strategies in different zones, the trial should be oriented so it traverses the high zone and the low zone in the paddock (Figure 6, page 5). It is also essential that the sowing, harvesting and treatments are oriented in the same up-and-back manner, as this facilitates an analysis known as a ‘pair wise comparison’ or ‘t-test’ on the different zones within the paddock (Figure 7, above). This approach keeps the trial design simple and ensures farmers can implement it with existing farm machinery.

The treatment should occupy at least two seeder bar widths, and the location of

the treatment recorded using a GPS, so they can be overlaid on a yield map. The treatment should be located next to the control which is the standard agronomic practice for that paddock.

When harvesting, keep the comb centred within the confines of the treatment, otherwise the yield data may not be accurate.

4. Do not simply average and compare the data from each strip (control and treatments). A paired t-test should be employed to formally analyse the trial.

A lot of spatial information is collected by the harvester and by pairing pixels adjacent to each other and it is possible to conduct a paired t-test across the whole strip and separately on the low and the high performing zone. This is a powerful form of an analysis and is statistically robust. The paired pixels should cover a block about 50m long, as this should contain enough data from the harvester to even out any one-off problems.

USEFUL RESOURCES

PA Links

www.grdc.com.au/palinks

GRDC Precision Agriculture Manual

www.grdc.com.au/pamanual

PA in Practice – Grain growers' experience of using variable rate and other PA technologies

www.grdc.com.au/PA-in-practice

The Australian Centre for Precision Agriculture (ACPA)

www.usyd.edu.au/su/agric/acpa

Fertiliser optimiser, online calculator

www.environmentagriculture.curtin.edu.au/people/rmandel.cfm

MORE INFORMATION

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