The design and analysis of on farm agronomic experiments
What this workshop won’t be

• A treatise on statistical theory

• Full of equations (unless you really want them)

• A discussion on p values and the least significant difference (unless you want that later)
Trialling

• Why Do It?

Audience discussion
Why run a trial?

• Trialling can help you decide whether to adopt a new technology

• You can take a risk with a trial.

• A properly run and executed trial can be informative

• A poorly run trial can give misleading results that if implemented could be costly

• So how do you get the most out of the trials you do run?

• How do you get the most out of your grower group?
Workshop Goals

• Help understand what a trial is

• Why do you run a trial?

• How do you run a trial?

• What do you run a trial on?

• How do you interpret the findings from a trial?
The trialling process

What you ask

How you ask

Where you look

What you find
Develop Your Research Question – What you ask

• Make sure the topic is interesting!

• Too Broad
  • “Does nitrogen influence wheat crop yield?”
Focus the Topic

• Break down your statement into specific questions.

• What constitutes “a yield improvement” e.g. More grain yield, more biomass, better plant establishment, greener leaves, more tillers, fewer head deaths?

• What aspects of the environment are we talking about? e.g. Season type? Soil Type? Crop Type? Time of Sowing? Stubble treatment?

• What time period are we talking about? Only wet years, only dry years, every year?

• Focus on a SPECIFIC attribute of nitrogen management.
Key message

• Focus and tighten the research question

• 1. What am I interested in? Nitrogen management

• 2. When am I interested in it? In an average season on a wheat crop on a sand plain soil with an unconstrained root system.

• 3. Why am I interested in it? I feel I can put less nitrogen on my crop and still produce the same yield

• 4. How am I going to measure a yield effect? I will measure soil nitrogen at sowing and harvest, grain protein and stalk nitrogen. I will also monitor plant establishment, tillering, biomass at anthesis, greenness, grain yield, grain size, grain number and HI
Why go to the extra trouble to tighten the question?

• We applied nitrogen to the wheat crop and yields increased by 100 kg/ha. This difference was small.

• Conclusion – not really worth putting on the extra N. OR!

• We applied 50 kg/ha of nitrogen at sowing to the soil that had 20 kg/ha of soil mineral N at the time of sowing. By Z30 the high nitrogen treatment had increased greenness by 10% and these plants had 1 more tiller than the treatment with low nitrogen. The season had a tight finish. Only 32 mm of rainfall fell in September and October. The superior plant establishment generated by an increased nitrogen supply did not lead to increase yield primarily because of the tight finish. However grain proteins were 0.5% higher in the high nitrogen treatment, and had higher grain numbers indicating that the yield potential of the high N treatment was greater, even in a dry season, the crop did suffer nitrogen stress. Overall, it would be prudent, given long term seasonal average rainfall, to consider the higher rate of nitrogen.
A worked example

- Problem – long term continuous wheat resulted in possible lack of N, brome grass build up and possible disease increase, leading to low wheat yields.


- Conduct a crop sequence experiment to see.

- CAN YOU GUESS THE RESEARCH QUESTION?
Mildura results

• Research question (i) – can you restore a paddock economically, so wheat yields exceed that of a continuous wheat rotation?

• Research question (ii) - can you achieve this with with one year of break crops or two?
Wheat yields required 2 year breaks!

Yield t/ha

Treat_NM

CSIRO. Insert presentation title, do not remove CSIRO from start of footer
Your Turn

• Formulate a research question you want to run with a grower group

• What is the question

• How will you determine what to measure

• When or where will information from the trial be applicable?

• At this stage DO NOT FOCUS on the treatments or design, just the question.
What next?

You have your question, now select your treatments.

Your treatments need to make a difference to the amount or the timing of crop growth to influence yield in some way.

Why – 50 – 100 kg/ha differences in crop yield are notoriously difficult to detect.

If you can visually see a difference in the crop, the yield difference is about 15 – 20% (ie ~ 0.5 t/ha at least)
Choosing a treatment

• Large treatment differences

• 50 kg/N 10 kg/Ha P,

• 2.5 t/ha Lime, 2.5 t/ha Gypsum (or more!)

Time of sowing varies by at least 3-4 weeks,

Break crops are different species (oilseed and legume crop, volunteer pasture and cereal)

• Stubble management ~ 10 t/ha (or more!)

• Sowing rate (@ least 30 kg/ha in cereals, ie ~ 30% difference)
How many treatments?

• Every treatment should be discussed and argued.

• When we plan a trial, I expect to debate the treatments for at least half a day!

• Every treatment creates work, there must be a very good reason to include it in the trial.

• Avoid “It’d be interesting to have a look at ....” and
• “But what about ........”

• Ask yourself how the treatment helps address the question!
Your turn

• Define the treatments for your research question

• Measuring more things about fewer treatments is better than measuring yield on lots of treatments.

• If you have asked the right question, you should not need more than 4 treatments

• Make sure you have a valid control.
Trial Design

• What is confounding?

Confounding occurs where you cannot identify the basis behind a particular response.

• It is why we replicate; the confounding that occurs in a trial without replication could be because the soil type, weed burden or disease levels in one plot are greater than they are in a neighbouring plot.
Inference and analysis

• We applied nitrogen to the wheat crop and yields increased by 100 kg/ha. This difference was small.

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Inference

• Think about the inference, or what am I going to learn from conducting the trial.

• How might I change a management decision given the information generated by the trial.

• How can extrapolate the information from the trial to another farm, location, soil type, or season.

• Silver bullets do not exist, don’t look for them.
Principles of design

• Avoid confounding

• Replicate

• Randomise

• Avoid splitting plots, embed this into the treatment structure

• Large plots are not a surrogate for replication!
An example of how confounding can occur

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What is the problem with this?
How could we modify the design to overcome it?
Some jargon

• One way experiment
  • Just one set of treatments, eg 3 varieties, all managed the same.

• Split plot (don’t). Where Nitrogen is applied to the top half of the experiment, in an unrandomised fashion to “have a look”

• This destroys the replication within the experiment.

• Two way experiment, two way factorial
  • Two sets of treatments, varieties and nitrogen.

  DO NOT ATTEMPT more than a two way factorial unless you are working with a statistician.
5 traps regarding trial setup and design

• 1. No obvious research question

• 2. Too many treatments

• 3. Splitting plots

• 4. Changing treatments after year 1 or 2

• 5 Confounded design and lack of replication
5 traps regarding the analysis of farm trials

• 1. Ignoring inherent variation in the trial

• 2. Simple analysis for a very complex trial design

• 3. What was the reason for the observed response

• 4. Making inference from one year of data, without considering the season from an historical perspective

• 5. Please conduct a nutrient and/or water balance if the outcome of the trial is on either of these topics.
How to make better inferences from the data

• Measure more than yield, remember fewer treatments more measurements.

• The absolute minimum
  • - Plant density
  • - Tiller number
  • - Grain Protein

• Diagnose problems
  • Weed density, frost, rust, sowing problems,

• Ideally
  • - Either measure or model the soil water balance
  • - Greenness (eg green seeker)
Let's design a rotation experiment together

• 1. Research Question

• 2. Treatments

• 3. Design and Layout

• 4. Duration of trial (how many years will it run for)

• 5. Analysis.

• THE END
Final TAKE HOME MESSAGE

• Good trial design, analysis, implementation is time consuming and expensive.

• Quick “look see” trials are a waste of time, resources and money.

• Reduce the number of quick look trials and do fewer, better trials.
Principles of an on farm trial – Precision Ag supplement

1. Few rather than more treatments

- One treatment may suffice

- Ask an appropriate question and test it
  - What effect does increased nitrogen have on grain yield?
  - How will the crop respond to increased nitrogen?
  - When will the crop yield more if nitrogen is increased (season)?
  - Where will the crop yield more if nitrogen is increased (region)?
Principles of an on farm trial

2. Go for large treatment differences

- The objective of a trial is to learn something about how the crop responds to inputs

- The treatments must be large enough to bring about a change in crop yield
  - Increase N by at least 20 kg/N/ha (ie ~ 50kg/ha of urea)
  - Increase P by at least 4 kg/P/ha
  - Apply gypsum at a rate of at least 2 t/ha
  - Apply lime at a rate of at least 2 t/ha
3. Orientate the trial up and back

• At least two seeder bar widths for each treatment

• Record treatment with a GPS

• Treatment should be located next to the control in a strip

• Standard paddock management can be the control

• At harvest keep the comb within the confines of the treatment
3. Orientate the trial and treatments ‘up and back’

- The Control should be adjacent to the treatment.
- Treatment orientated across the different zones.
- High yielding zone
4. Analyse the trial data with a paired t-test or by eye.

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370 kg/ha difference in zone 1, 0 kg difference in zone 2
A worked example – Vlaming Barley trial - WA

- 4.5 t/ha barley crop @ ~ 2.0 t/ha – 6.5 t/ha
- 2 zones based on em38 and gamma radiometrics survey
- Sown 12\textsuperscript{th} May @ 70 kg/ha
- 60L of Flexi N (29 kg/N/ha) was applied at sowing.
- Additional Flexi N @ GS 22 (50 L, 25 kg/ha)
  
  GS 30 (30 L, 14.7 kg/ha)
- CSBP Agstar fertiliser (N 15.5%, P 12.8 % and S 11%) @ sowing

- Treatment 1, 60 kg/ha, (11.1 kg/N/ha, 9.2 kg/P/ha, 9 kg/S/ha)
  Treatment 2, 120 kg/ha (18.6 kg/N/ ha, 15.4 kg/P/ha and 13.2 kg S/ha)
Zones and kriged yield map

30 m block kriging in vesper (3 header widths)
100 points / variogram cloud (exponential)
5 m grid
Trial orientated across zones
Select rows from each strip
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Trial protocols continued

• Export file to csv, read in with excel

• Conduct moving average difference calculation (5 cells)

• Conduct moving average t–test (5 cells)

• Plot with respect to Easting or Northing
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Yield and Significance in excel
Combined yield difference and significance plot
Key conclusions

• Zone 1, treatment 1 yielded 4.55 ± 0.05 t/ha
• Zone 1, treatment 2 yielded 4.85 t/ha

• Zone 2 treatment 1 yielded 3.9 ± 0.07 t/ha (p < 0.001).
• Zone 2 treatment 2 yielded 3.6 t/ha

• But conventional anova hides within zone differences

• Moving average approach allows you to question your zones.
Yield and Responsive Index from N rich strip
Key messages

• Carefully select location
• Choose treatments that are likely to shift yield
• Make treatments at least 2, preferably 3 header widths
• Krig data onto 5m grid, 30m block kriging
• Select a middle row from each treatment and export to excel
• Analyse using a moving average t-test

• If time – look at some of my trial stuff ups
Data from yield strips along the paddock

![Graph showing yield data from different strips along the paddock.]
Yield (t/ha)

Canola

- < 0.75
- 0.75 - 1
- 1.0 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2.0 - 2.25
- > 2.5

CSIRO. Insert presentation title, do not remove CSIRO from start of footer
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Yield (t/ha)
Canola yield across the strips

CSIRO.

Easting

Yield t/ha

t1_90_kg/ha Nutrigras
t2_50_kg/ha
t3_90_kg/ha
t4_110 kg/ha
t5_90_kg/ha

Easting

411800 411900 412000 412100 412200 412300
Carter response to fertiliser
Carter response to fertiliser

- Low: 10kg/ha MAP, 20L/ha Flexi-N
- Medium: 30kg/ha MAP, 40L Flexi-N
- High: 50kg/ha MAP, 60L Flexi-N

Units: Yield (t/ha) vs. Easting (m)
Summary

• Ask a question
• Apply treatments that are likely to make a difference
• Orientate the trial across the change in soil type
• Sow and harvest the trial in the same direction
• Take care at harvest
• Analyse the data from a kriged yield map, select a strip from the middle of the treatment
• Avoid combining data and simply comparing the means or averages of the two strips