Trial design and analysis using precision agriculture and farmer's equipment

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Background
Farmers are often interested in trialling a new technology before adopting it across the farm. If farmers have precision agriculture technology including yield monitors and variable rate controllers they can use it to conduct an on farm trial. They can use one new technology to test another.

To date, quite complex designs have been developed to provide farmers with the information necessary to run on farm trials (Bramley et al. 1999). Some of these approaches evolved from techniques developed to analyse large agronomic or variety trials and unfortunately they can be complex to implement, and analyse and interpret. In 2008 CSIRO and the Liebe Group attempted to run some trials using these complex techniques with farmer's machinery. Every trial failed; they are simply not farmer friendly. Replicated and randomised block designs were not designed to be planted with a 15 m seeder bar, managed with a 30 m spray boom and harvested with a 10 m front.

Paddock level experimentation differs from plot level experimentation in so far as the experiment is conducted in a commercial field that must return a profit with commercial equipment. The farmer is unlikely to allocate large areas to a treatment 'control' as this will generate sub optimal and uneconomic yields. The entire cropping operations must take place in a continuous manner (i.e. split plots are not allowed!) and be conducted in a manner that does not hinder conventional paddock operations, such as seeding, spraying and post emergent applications of fertiliser. Trial management should be integrated into normal paddock operations as farmers are too busy to deal with a complex trial that requires their attention at critical periods during the crops life.

To overcome some of these practical problems faced by farmers we outline a methodology that was successfully implemented by 4 farmers in the 2009 growing season using commercial seeding and harvesting equipment.

Principles of on farm trials

1. Few rather than more treatments

The most important process in experimentation is to ask an appropriate question and test it. Conventional experiments can be complex, where scientists may evaluate multiple rates of fertiliser on multiple crop species. In on farm experiments, where treatments must fit in with a commercial operation we recommend restricting the number of treatments to just one or two at most. The remainder of the paddock should be thought of as a control. A simple trial that generates a definitive outcome is better than a very complex and time consuming trial that confounds the issue.

When deciding on a treatment it is important to decide on a question that you want to ask and these are usually prefaced with words such as 'what, how, when or where'. For example:

- 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)?

2. Go for large treatment differences

Once the question has been asked, it is important to make sure the treatment counts and is likely to change the yield of the crop. It is important to remember that the objective of a trial is to learn something about how the crop responds to inputs. To ensure this happens, the treatments must be large enough to bring about a change in crop yield. Even though the treatment might be uneconomic, it will provide insights into how the crop grows or how management should be changed in different regions in the paddock. Examples of treatments that will have an impact on crop yield if there is a deficiency or constraint might include:

- Increasing N by at least 20 kg/N/ha (ie ~ 50kg/ha of urea)
- Increasing P by at least 4 kg/P/ha
- Applying Gypsum at a rate of at least 2 t/ha
- Applying Lime at a rate of at least 2 t/ha.

3. Orientate the trial and treatments 'up and back'

If farmers have a yield monitor they will be able to identify zones in the paddock that are high yielding and zones that are low yielding. These areas may require different management strategies and may respond differently to the same treatment.

To explore this, the trial should be orientated to traverse the high zone and the lower or average yielding zone in the paddock, as indicated in Figure 1. It is also essential the sowing harvesting and treatments are all orientated in the same up and back manner. This is vital, as it facilitates an analysis known as a 'pair wise comparison or t-test' on the different zones within the paddock. This challenges the conventional wisdom of trial design, where researchers' would normally set the trial up in blocks on the good zone and the poor zone. However this approach keeps the trial design simple and ensures famers will be able to implement it with ordinary farm machinery.

The treatment should occupy at least two seeder bar widths (Figure 1). The location of the treatment must be recorded using a GPS so it can be overlayed on a yield map. The treatment should be located next to the control, which would often be the standard paddock management. This minimises the amount of the paddock that is 'experimental' and ensures the costs associated with running a trial are kept to a minimum. When the trial is harvested, it is important to keep the comb within the confines of the treatment and keep the comb full through the centre of the treatment, otherwise the yield information generated will be incorrect.

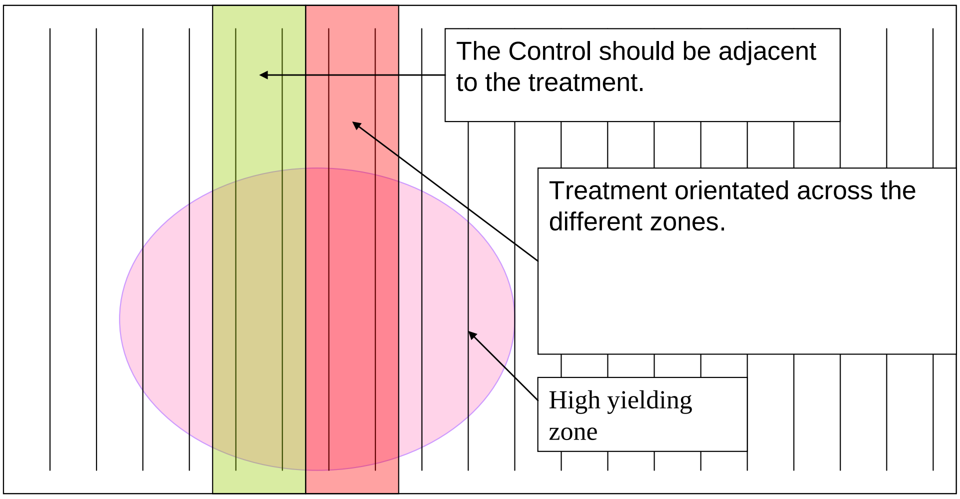

Figure 1. Orientation of strip trials across a paddock with high yielding and averaging yielding zones.

4. Analyse the trial data with a paired t-test or by eye.

It is important that data from each strip (control and treatment) are not averaged and simply compared. From the farmers perspective trial data can be analysed in formally or by eye. A paired t-test should be employed to formally analyse the trial. There is a lot of spatial information collected by the harvester and by pairing pixels adjacent to each other, it is possible to conduct a paired t-test across the whole strip, and separately on the low performing zone and the high performing zone. This is a powerful form of an analysis and is as statistically as robust as an analysis of variance.

The approach is demonstrated in figure 2 where each pair of pixels from the yield maps is treated as an experimental unit. One of the pixels is a control, the other is the treatment. Each pair of pixel provides a form of replication. Assuming a paddock is 500 m wide, and a yield is recorded every 10 m, there will be 50 pixels with control and treatment information. If this is split across high and low performing zones there should still be approximately 20 pixels for each zone with trial data.

From figure 2, the average difference between the treatment and the control is just 0.18 t/ha and using a paired t-test comparison, the difference is not significant ($p = 0.09$). When the low and zone is analysed separately, the difference between the treatment and the control was just 0.06 t/ha and not significant ($p = 0.06$). In contrast in the high zone the difference between the treatment and the control was 0.375 t/ha and highly significant ($p = 0.004$). In this instance, it is worth applying the treatment on the high zone.

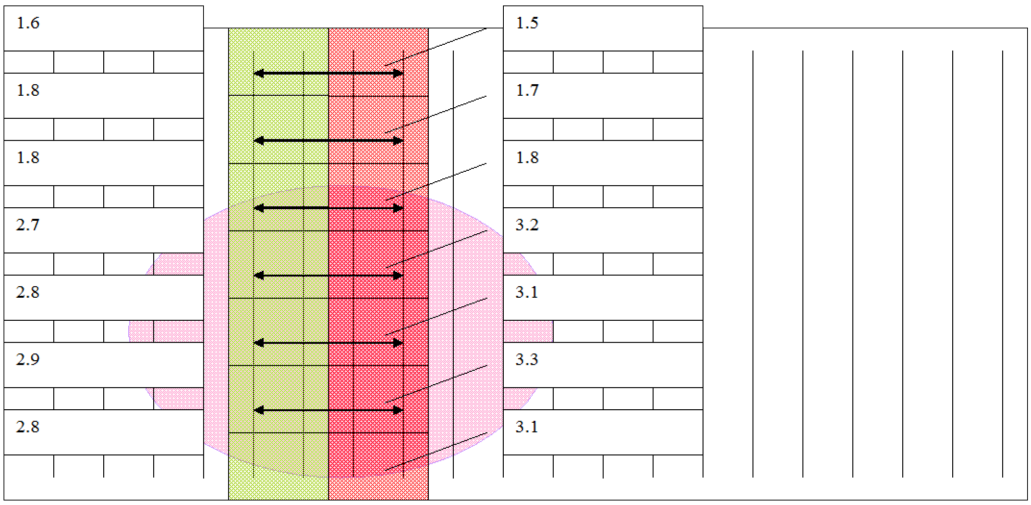

Figure 2. An example of a paired t-test comparison of treatment means with the yields derived from multiple pixels in each zone.

Providing the trial has been conducted in an up and back manner and the treatments were chosen to generate a yield response, it may be sufficient to analyse the trial by eye and avoid formal statistical testing. To do this, simply zoom into the trial and carefully examine the yield in the treatment and the control. If the treatment is significant, a yield difference should be observed. It will be easier to identify treatment differences if the treatment is two seeder bar widths wide.

Summary

The approach presented here has been trialled with data farmers in the Eastern Wheatbelt, in the Northern Agricultural Region and in the South Coast. In one instance the trial was frosted and the trial was not harvested, but in other cases the trial was successfully completed. In 2009, we successfully implemented and obtained results from 4 farm trials. This compares favourable with the 4 trial failures in 2008.

In conclusion, when running a trial it is important to

1) Ask a question
2) Apply treatments that are likely to make a difference
3) Make sure the trial covers the range of soil types or zones of interest.
4) Sow and harvest the trial in the same direction
5) Ensure the trial is harvested where the comb does not enter the neighbouring treatment. This prevents the data becoming confounded by the experimental approach.
6) Analyse the data as individual pixels using a paired t-test or by eye. Strong treatment effects may even stand out by eye on some parts of the paddock.
7) Avoid combining data and simply comparing the means or averages of the two strips.

References

Bramley R, Cook S, Adams M and Corner R (1998) Designing your own on-farm experiments. How precision agriculture can help. GRDC, Kingston.