



Fluid Fertilisers Farm Evaluation Trials

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Testing fluid fertilisers with strip trials on the farm

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Research over the past 10 years has shown that fluid fertilisers are able to increase the efficiency and relative effectiveness of phosphorus (P) applied to highly calcareous soils compared with standard granular fertilisers. The results of field research indicate that fluid P with nitrogen (N) and micronutrients can be up to 15 times more effective in promoting grain yield when applied at the same rate of nutrients. These results have been verified by laboratory research and with studies using advanced spectroscopic methods to examine the soil reactions down to the molecular level

Besides highly calcareous soils, it is also possible that fluids may be effective relative to granular on other alkaline soils or acid soils which rapidly fix phosphorus. However, while glasshouse pot trials have indicated that some non-calcareous soils can be very responsive to fluid fertilisers, there is no conclusive evidence from field trials at this stage.

In Western Australia, fluids are becoming popular because of the logistical benefits they offer in terms of flexibility of use, ease of storage, convenience of transport, accuracy of placement and application. Because it is unlikely that all soils will be tested in the field for their response to fluid fertilisers, the best thing farmers can do is to run strip trials on their own farms to assess for themselves how fluid and granular fertilisers compare.

The aim of any farm strip trial should be to eliminate as much as possible those factors which may affect the comparative performance of treatments, except the factor that is being compared, in this case, the type of fertiliser. The other external factors which will influence the result in addition to the fertilisers being compared are collectively called *random variation*. Some random variation (e.g. due to soil variation) is inevitable in the way treatments respond besides the effect of the fertilisers. It is the size of this variation which determines whether the result of a comparison between two treatments can be accepted as reliable or not. Farm strip trials can be designed to indicate whether or not the results of the strip trial are valid.

Most agricultural research is done with small plots because of the need to transfer equipment to a range of sites and because variation is easier to control with small plots than large ones. However, even with farm-scale strip trials, reliable comparisons are possible if certain basic rules are followed.

Choosing a site

The site chosen for a strip trial should be as level as possible with the same soil type across the whole area. Soils of different colour and texture and areas with differences in slope or height should be avoided.

It is also extremely important not to have strips in areas with different histories. The whole area should have a uniform crop/pasture, weed, fertiliser, herbicide and tillage history. For this reason it is best to avoid headlands - they have a different fertiliser and sowing rate history to the rest of the paddock. Obviously an area used for test trips in the recent past would not be a good selection site for another trial. If you can not avoid these areas, then try sowing across the areas with different histories so that they occur in every treatment strip. Differences in history can have as much or even a greater effect on the results than the treatments being applied. This is why it is almost impossible to rely on comparisons between two treatments applied in two neighbouring paddocks with different cropping histories.

The basic reason for comparing fluid and granular fertilisers is really to compare the effectiveness of the two different forms of phosphorus applied (accompanied by nitrogen and zinc or other micronutrients). The site therefore must be responsive to P fertilisers. This can be difficult to determine but soil testing is a reasonable guide. Soils with Colwell

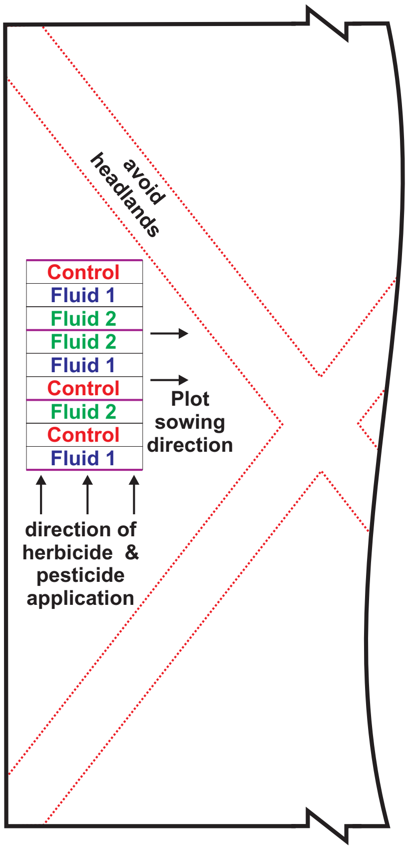

Figure 1. Paddock layout showing Randomised Block Design (Figure 2) and sowing direction of plots at 90^0 to normal farm working direction

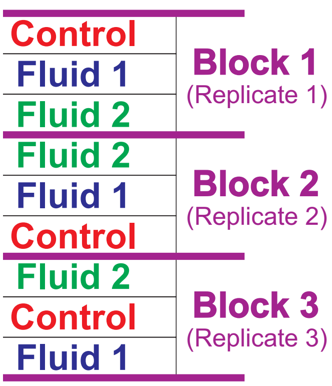

Figure 2. Trial plans for a Randomised Block Design where the treatments are replicated randomly within each block for statistical analysis

P values as low as possible are likely to provide the best comparison. Obviously critical soil test P values vary from site to site – it is best to choose the paddock with the lowest soil P test value for any comparison. On many of the highly calcareous soils of Upper Eyre Peninsula, adding normal rates of granular fertiliser containing P does not produce a yield response because the P in the fertiliser is so rapidly fixed that very large amounts of P (e.g. 100 kg/ha) may be needed to allow the plant to respond. On the other hand, plants may respond to as little as 4 kg P/ha applied as fluid.

Laying out the site - direction of strips is important

Treatment strips should be placed at right angles to the normal working and spraying directions of the paddock, if possible. This means that overlaps, gaps and header rows and the variation caused by them runs across all of the treatment strips, instead of through just one of them (see Figure 1).

After the strips are sown, they can be sprayed in the normal direction for the whole paddock so that gaps, blocked nozzles, overlaps or other sources of variation apply to all of the strips instead of along just one (see Figure 1).

Weeds and invasive pests are often worse near the edge of the paddock so it is usually a good idea to begin one or two seeder widths from the edge.

Important: Keep good records and mark all plots clearly as correct identification of plots is critical to interpretation of data.

Treatments

When comparing fluid with granular fertilisers, ensure that the rates of application of all nutrients are the same in both cases and that both fertilisers contain the same nutrients. Further to this it would be useful to evaluate how the relative rates for the same cost of fertiliser per hectare compare. In this situation you would have three treatments: the **Control**, normal granular practice; **Treatment 1**, fluid with the same rate of nutrient application; and **Treatment 2**, fluid with the same cost as the granular application.

Usually it is easiest to begin with the standard granular fertiliser and rate used on the farm. For example, if the farm application rate is 52.6 kg of 17:19 Zn 2.5%/ha this will provide 10 kg P/ha 8.9 kg N/ha and 1.3 kg Zn/ha.

To provide the same rate of nutrients in fluid fertiliser, N, P and Zn must be provided at the same ratio as in the granular fertiliser. If there are no commercial fertilisers available providing the same ratio of nutrients, it is often easier to modify the fluid fertiliser to bring it to the same proportion of nutrients.

For instance, if a fluid fertiliser was available as 9:14 Zn 1%, w/v%, an application rate of 71.4 L/ha of the solution would provide 10 kg P/ha, 6.4 kg N/ha and 0.7 kg Zn/ha (see appendix 1 for w/v% and w/w% calculations). This matches the rate of P in the granular fertiliser but the shortfall of 2.5 kg N/ha and 0.6 kg Zn/ha will have to be made up by adding N and Zn to the fluid. Before doing this it is necessary to make sure that the N and Zn are compatible with the commercial fertiliser **and that no safety issues are being breached by mixing incompatible fluids (e.g. phosphoric acid and UAN should never be mixed).** If not, it may be possible to use a separate application system (twin pumps and distribution systems) to supply the two products separately but to the same general area of soil slightly below the seed

Selecting treatments

The number of treatments should be kept low; ideally, limit the comparisons with the control (current farm fertiliser treatment) to two fluid treatments. Increasing the number of treatments requires more land, more time, increases the variation and also the difficulty of interpreting the results. Comparison between the farm's current granular fertiliser treatment and two formulations of fluid fertilisers would be well suited to a farm strip trial without the need to use complicated designs and statistical procedures (Figure 2).

Figure 3. Distribution manifold showing non-drip nozzle fittings housing orifice plates to control pressure and flow.

Orifice plate: is a device which controls the rate of flow of liquids in the delivery line. For different rates of flow different orifice plates are required with different apertures (holes) so they maintain the desired constant flow for the application rate and ground speed.

Figure 4. A continuous stream of fluid emitted under pressure

Possible fluid rates could include same the P application rate as the current granular practice and a P application that is the equivalent cost per hectare as the current granular practice.

Setting up machinery to apply treatments

It is important at this point to consider how trials are going to be sown and harvested. Consider the width of your machinery, which is a critical factor in trial design. Ideally, one header width should run up each treatment strip, with the outside rows remaining (i.e. so that a full comb width can be reaped).

Before setting up a fluid application machine for test strips, it pays to talk to the experts who are continually designing and improving delivery systems. The Fluid Fertiliser Website (www.fluidfertilisers.com.au) is a good source of information for farmers wanting to set up fluid delivery systems. An important feature of fluid fertiliser application systems is that they are constructed of suitable material that will not corrode in the presence of trace elements or strong acids. Nylon for example is highly sensitive to corrosion by phosphoric acid.

Perhaps the easiest way of applying fluid fertiliser using test equipment is to mount a tank and 12V electric pump with a boom spray type distribution outlets with orifice plates or restrictors, (Figure 3) and flexible tubes (e.g. 4-6 mm id tubing) onto the seeding bar, set up so that the fluid is applied below the seed in a continuous stream to a section of the seeder (Figure 4). Another option is anhydrous ammonia distributors which can be purchased and installed as shown in Figure 5.

If using an air seeder the tynes to be used for fluid fertiliser, wider than a header width, are blocked off from the granular delivery system. The remaining tynes of the seeder can be used to apply granular fertiliser. It is a critical point to remember that if the flow of granular fertiliser is blocked off to the part of the air seeder receiving fluids, the fertiliser rate may need to be adjusted so that the remaining tubes do not receive the excess and increase the granular application rate. The fluid tubing should be terminated by nozzles or on line meters of some kind designed to give a solid stream (Figure 4) rather than a cone of liquid. Normally an application pressure of 35 kPa or more is required to ensure that the output from each tube is identical, a critically important feature of fertiliser application.

Otherwise, a trailer (Figure 6) can be set up with the fluid output system with hoses leading to the number of tynes required. The advantage of a trailer is that it can be towed behind the seeder at sowing and used on several machines in the area.

If you opt to use a separate sowing machine already set up for fluid fertiliser, belonging to a neighbour or an old combine, the opportunities to introduce more variables are increased - care needs to be taken that the variety sown, the depth of sowing, the row spacing and so on are as close as possible between the two machines.

Figure 5. Anhydrous ammonia distributor used on an experimental seeder for fluid fertiliser distribution.

Figure 6. Fluid fertiliser trials trailer donated to the Minnipa Agriculture Centre by Liquid Systems, for on farm strip trials

Dilution rates of fluids

To ensure a continuous stream of fluid rather than droplets, and to allow the addition of other nutrients, it is usually necessary to dilute the fertiliser with water.

Normally, an output rate of 120 L/ha is considered appropriate for most application conditions. Research has shown that application rates less than 120 L/ha can reduce yield responses to fluids. As the dilution rate increases, larger orifices can be used in the output system with a reduced blockage problems.

Sowing

For a strip trial to be valid there needs to be some replication (repeat) of the treatments and of the control (farm fertiliser rate) so that the random variation in the trial (the variation not caused by the fertilisers) can be estimated. Most research trials aim to have four replicates but three, or even two, may be enough for a simple strip trial (Figure 2)

Important considerations to reduce variation at sowing

Maintain a consistent sowing depth throughout the trial	Variation in sowing depth can have a large impact on time to emergence, plant density, early vigour, and grain yield.
Seed selection – use the same seed throughout	Different seed sources are likely to have different nutrient contents and this can affect early vigour and grain yield
Machinery selection	Use the same machinery throughout the trial if possible. If different machines have to be used, be sure that they are set up the same. Make sure that harvesting equipment is properly adjusted before reaping the trial and avoid further adjustments unless absolutely necessary.
Check output of equipment	Measure the output of your equipment so you know that your comparisons are accurate. Make sure that fertiliser and seed outputs are uniform across the machine. A simple dipstick can be used to measure actual output from a fluid tank.
Speed of sowing	With most seeding equipment, sowing and fertiliser rates are controlled by ground drives so that the output remains constant regardless of speed. With a simple fluid system using a small electric pump, fluid output rate depends on speed of travel so it is important that once the speed is selected for a fixed fluid output, it should remain constant. If the tractor does not have radar ground speed output, it may be necessary to use a stopwatch over a measured distance with the machine in the ground and in gear to determine the ground speed and allow for wheel-slip.
Timing of sowing	Trial plots should be sown in the best possible conditions on the same day to minimise variation due to different sowing times.
Weed control	When selecting a site, be sure that you can manage the weeds, particularly those that are herbicide resistant . Uncontrolled weeds in a trial can make the results invalid.
Sowing width vs harvesting width	The major concern is that the harvester can fit within the sowing width so that the outside rows are left unreaped . Outside rows may have access to extra soil water and not reaping them removes another source of variation.

Measuring and sampling

Mostly, farmers will want to know the grain yield differences between the treatments but it may also be important to consider treatment differences during the season, determined usually by differences in the dry weight of shoots sampled at mid tillering (Zadok 21) and/or nutrient concentrations determined by leaf tissue analysis.

Shoot production

The sowing rates of tynes can vary across a machine so when taking shoot samples, select cutting sites in a random pattern across the plot. Take care not to cut the outside row because of possible variation caused by the fallow effect in the gap between the plots. To sample, cut the shoots at ground level from say the left hand corner of the strip and move diagonally up to the right hand, selecting four sites at random on the way. Place a 0.5 m rod between two rows and cut plants on both sides of the rod to give 1 m of row. Combine the four sub-samples into one sample representing each plot.

The sample should be dried as quickly as possible after cutting in an oven for 24 hours at 70°C. To test when drying is complete, weigh the sample every 2 hours and when there is no further weight loss then the sample is adequately dry.

Yield Response

Yield measurements can be done by reaping into a weighing trailer or a truck or mobile bin if there is a convenient weighbridge nearby.

It is important to have sampling or yield measurements well organized beforehand with details of who will be involved and who will be responsible for various parts of the operation. Any sampling or yield tests need to be done on the same day if at all possible, and the same sampling methods should be used throughout. The entire sampling operation needs to run as efficiently as possible without long delays. The areas of sampling need to be measured accurately and record keeping for the trial (e.g. rainfall, herbicides, tillage, other weather factors), needs to be conscientiously done while the trial is under way. A layout plan is an essential part of running the trial.

Results from one year will be due to a combination of many circumstances which will not be repeated again, so results from more than one year will be required to properly evaluate treatment differences.

Interpreting Results

Interpretation of results is an important part of agricultural trials. It is important to understand and be able to report on the differences in the production means (averages) produced between treatments in replicated trial data.

In evaluating the effectiveness of fluid versus granular fertilisers, sampling can be performed through the growing season and of key importance, final yield at harvest. As discussed earlier, dry weight cuts and leaf nutrient analysis will provide valuable information about early growth (vigour) and fertiliser use efficiency. Final yield will be valuable in the determination of yield and cost benefit analysis of the different treatments.

As growers are well aware, and as discussed earlier, there is a lot of variation in production across the farm, between paddocks and even within paddocks. This variation needs to be factored into the analysis of any trial data so it can be determined whether the differences in treatment means are really significant or a result of variations in production systems.

This interpretation of the trial data requires complex statistical software to sort out what is variation due to the production system and what is an actual difference between the treatments. There are many software packages capable of doing this analysis; some are very expensive and complex to use. The data for simple trials can be analysed using the data analysis package contained in Excel, part of the Microsoft Office Suite.

3 x 3 Trial Analysis

If the design of your trial is of the form of 3 treatments (including the control) with 3 replications, randomised in blocks (figure 2), a calculator can be used from the Fluid Fertilisers web site, www.fluidfertilisers.com.au. It is important that this calculator can only be used for 3 x 3 Randomised Block Designed Trial as shown in Figure 2 and must have complete data sets. If your data set does not match this requirement, or is missing a value due to some unforeseen problem, don't despair as the data can be analysed with more complicated software. You will need to contact research officers in your region.

When you have your trial data; yield, leaf analysis or dry weight cuts, you can go on the web and enter your data for analysis, then "Submit data" (Figure 7).

Note: in this case the yield data is entered for each treatment and block (replication). Enter the data as numeric data only (without units) for analysis. This can be done before or after the data has been converted into yield per hectare.

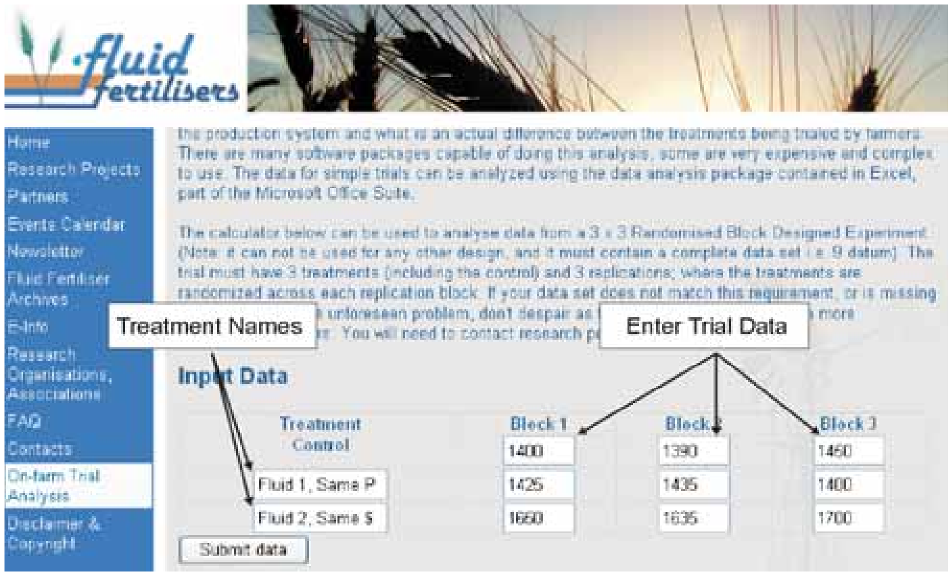

Figure 7. Shows input data screen on the Fluid Fertiliser Website screen. Enter data including names of treatments and then enter the trial data. Then click on the submit data button.

Significant Difference: a sufficiently large difference in two or more groups of data that it can not be explained by random variation within the data. i.e. there is statistical evidence to support the conclusion that the difference in the averages of two or more treatments are in-fact "different" and not just due to sampling errors or chance

In the result window it can seen that the differences in means (averages) of each pair of treatments is calculated and also the statistical significance for the different treatments (Figure 8). In this case it can be seen that there is no statistical difference between the means of the Control and Fluid 1 (i.e. they are identical in terms of their respective yield responses). Comparing the means alone shows there is potentially a difference in the yield. However, when the variation in the trial is accounted for it is not large enough to be significantly different.

The differences between the control & Fluid 2 and Fluid 1 & Fluid 2 are significantly different at the $p < 0.05$, $p < 0.01$ and $p < 0.001$ levels. That is, treatment Fluid 2 is significantly different to the Control and Fluid 1 treatments, with a confidence level of 95%, 99% and 99.9% respectively

Once it has been established that the differences in the means are not due to chance, yield differences can be calculated simply by subtracting the respective means. For example the yield response between treatment Fluid 2 and the control is 1661.67 - 1413.33 = 248.34 kg/ha. From these results, cost benefit analyses can be calculated by comparing relative costs of the treatments and with net returns.

Note: If using the analysis package on the Fluid Fertiliser Website you can have your results E-mailed to you by simply entering your E-mail address and click on the E-mail results button (Figure 8).

Treatment Interactions	Difference of Means	Statistical Significance p < 0.05	p < 0.01	p < 0.001
Control x Fluid 1, Same P	6.67	No	No	No
Fluid 1, Same P x Fluid 2, Same $	241.67	Yes	Yes	Yes
Control x Fluid 2, Same $	248.33	Yes	Yes	Yes

Treatment Means	
Control	1413.33
Fluid 1, Same P	1420
Fluid 2, Same $	1661.67

Figure 8. Results of the statistical analysis showing the average of each treatment, treatment interactions and their statistical significance