Crop updates 2006 - Farming Systems

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2006

FARMING SYSTEMS UPDATES

WESTERN AUSTRALIA

PRESENTED AT THE BURSWOOD CONVENTION CENTRE, PERTH

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Compiled and edited by Bill Porter

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Investigating fertiliser investment

Wayne Pluske, Nutrient Management Systems

With disparity between growth of nutrient costs (fertilisers) and grain values, the once tight relationship between fertilising for production and fertilising for profit is widening. As a consequence, the focus of fertiliser advice is shifting from its historical base of technical information to increase production, towards greater focus on maximising profit and minimizing financial exposure from the fertiliser investment. This means there is increasing scrutiny on the financial aspects and consequences of fertiliser advice.

Financial focus in the short term is on operating surplus and cash flow. Given that impacts of fertiliser use on these are rarely considered in advice for the next crop, it is hardly surprising there is even less financial scrutiny of advice on a plethora of supposedly longer-term strategies and products for nutrient management and soil health. It is likely that more financial scrutiny of short-term fertiliser advice may impose similar criteria on longer-term advice. Providing more financial information with fertiliser recommendations, combined with standards to assess advice, will improve fertiliser use efficiency and alleviate some current concerns about fertiliser advice.

THE IMPORTANCE OF ADVICE

As startling as it may be, many growers are starting to treat fertilisers like other on-farm and off-farm investments. Better returns at lower risk from substantial investments in fertiliser would overcome a major constraint of many growers (Table 1). As for any investment, growers want to know that the people who are providing them with fertiliser investment advice are capable and credible.

Table 1. Major constraints to the way fertilisers are used (percent of 1214 respondents who rated the issue as a constraint)

<table>
<thead>
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<th>Issue</th>
<th>Percent</th>
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<td>Risk of low grain price</td>
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<tr>
<td>Risk of low crop yield</td>
<td>43</td>
</tr>
<tr>
<td>Lack of relevant trial results</td>
<td>26</td>
</tr>
<tr>
<td>Lack of soil knowledge</td>
<td>23</td>
</tr>
<tr>
<td>Lack of suitable soil and/or tissue</td>
<td>22</td>
</tr>
<tr>
<td>Equipment constraints</td>
<td>22</td>
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<tr>
<td>Lack of suitable advice</td>
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Quality advice is crucial because fertiliser investments are substantial and misuse of fertilisers can be financially and environmentally costly. Advice on how fertilisers are used (e.g. nutrient/product selection, rate, timing, placement) is especially important because how fertiliser is used has a huge impact on returns. Given advisers have a significant role in the fertiliser decisions of most growers, it is important they provide suitable advice. It is disconcerting then that many growers value information from their advisers less than that from other sources (Table 2). But given a large and established network of advisers, there is a huge opportunity to improve fertiliser efficiency and returns with even slight improvements in the advice provided through the adviser conduit.

Table 2. Importance of some sources of information for improving fertiliser decisions (per cent of 1214 respondents who rated the source as important)

<table>
<thead>
<tr>
<th>Source</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal experiences</td>
<td>91</td>
</tr>
<tr>
<td>Local trial results</td>
<td>82</td>
</tr>
<tr>
<td>Soil and/or plant tissue tests</td>
<td>79</td>
</tr>
<tr>
<td>Farm consultants</td>
<td>74</td>
</tr>
<tr>
<td>Fertiliser company advisers</td>
<td>38</td>
</tr>
<tr>
<td>Merchandise company advisers</td>
<td>29</td>
</tr>
<tr>
<td>Computer programs</td>
<td>18</td>
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<td>Internet</td>
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SOURCES OF ADVICE

Australian growers are fortunate to have a large number and wide variety of fertiliser advisers. Individuals and advisory teams have expertise in an array of areas, from specific technical aspects of fertilisers to complete financial analyses. Importantly most advisers are regionally based and have good knowledge of their local area and its conditions. The amalgamation and meshing of advisers with varied education, backgrounds and experience ensures growers have access to a massive amount and diversity of information, views and recommendations in regards to fertilisers. However this diversity can be confusing and lead to concerns for growers, the environment and communities when there are extremely divergent recommendations, when there is little evidence of how advice has been generated or when large sums of money are involved.

EVALUATING FERTILISER ADVICE

Like anyone, growers will be their own judges of all types of advice. To be very generalised about fertiliser advice, judgement is currently based on personal relationships, the adviser's rapport and trust. Of these three, technical advice has most influence on establishing and then maintaining trust. It is important that advisers are locally based, not only to make them more accessible and accountable, but so they have local knowledge and experience to deliver specific, rather than generic, advice.

Growers’ own criteria are currently the only ‘standards’ they have to assess fertiliser advice. The lack of established standards is most apparent when a new adviser enters a region because it takes time for growers to 'weigh up' the new adviser, establish a relationship, accept their advice and trust their advice. Comparisons are inevitably made to other and previous advisers, but rarely is advice compared to established standards. This is also a major concern to others in the industry and the wider community, especially given the potential for negative environmental impacts from poor fertiliser advice.

It is ridiculous to suggest eliminating variation between advisers, but there is a need for some standard by which advice can be assessed. If nothing else, such a standard will ensure there is a sound basis for fertiliser advice and smooth out some of the discrepancies that currently exist. Just as expertise varies between advisers, so do limitations in providing fertiliser advice so a standard will help develop a base level of knowledge from which all fertiliser recommendations are derived.

THE FERTCARE STANDARD

The Australian government and the Australian fertiliser industry, as part of an eco-efficiency agreement, have started addressing the issue of fertiliser advice by establishing the Fertcare program. Fertcare training aims to enhance and standardise the skills and knowledge that advisers need to provide advice to a grower that maximises farm productivity, environmental care and food safety.

In developing Fertcare’s training, quality assurance and certification programs a strong emphasis has been placed on the quality, independence and rigour of the material and processes. A technical committee, including leading public sector scientists, oversees the quality of the technical material and the program is delivered by registered training organizations under the Australian Qualifications Framework. Additional input has been sought from recognised experts in particular fields, for example the material on heavy metals was reviewed by members of the National Cadmium Management Committee and sections on greenhouse gasses was reviewed by a member of the CRC for Greenhouse accounting.

The eco-efficiency agreement is partly funded by the National Landcare Program, so a major focus of Fertcare is on minimizing environmental risks from fertiliser advice. Given that many growers rarely think of the environmental consequences of their fertiliser decisions (Table 3), Fertcare accredited advisers will have a major role in improving environmental aspects of fertiliser use. Advice on how to use fertilisers more profitably can achieve the same objective, even if the impetus for change is slightly different. Given that achieving the highest economic returns from the fertiliser investment at lowest risk is the major aim of many growers, better advice to achieve this is required. When this is achieved,
there are likely to be other benefits like reduced environmental risk through higher nutrient uptake efficiency, growers being provided with the information they most want and improved credibility of those providing the advice.

Table 3. How often growers think of environmental implications of nutrient management decisions (per cent of 1214 respondents)

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<tbody>
<tr>
<td>Always</td>
<td>11</td>
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<tr>
<td>Often</td>
<td>34</td>
</tr>
<tr>
<td>Sometimes</td>
<td>39</td>
</tr>
<tr>
<td>Rarely</td>
<td>14</td>
</tr>
<tr>
<td>Never</td>
<td>3</td>
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The Fertcare program is applicable and available to all advisers (e.g. sales advisers, public sector advisers, independent advisers) and therefore provides growers with some assurances about the technical competence of their adviser. Providers of good fertiliser advice welcome such a standard as an endorsement of the quality of their advice and as a means of continuing to improve their advice. Growers can influence the quality of advice they receive by using Fertcare accredited advisers and by encouraging other advisers to complete Fertcare training.

FERTILISER ADVISERS

Providers of fertiliser advice could be grouped into two broad groups:

- Sales advisers who are employed by product manufacturers or sellers; and
- Those who are independent, presumably from product sales and other biases, either real or perceived.

Independent advisers are increasingly private consultants rather than government advisers. Many independent advisers have grounding in sales advice and their shift from sales to independent advisers is a contributor to the inexperience of many sales advisory teams.

Given such huge variation between individuals within both groups, it is dangerous to generalise about both groups. However in the broadest of terms, sales advisers (sometimes called agronomists) tend to have a technical and input focus and deal with ‘in-paddock, here and now’ issues like deciding whether additional nitrogen is required for a crop. In these circumstances there is usually some consideration, but rarely any documentation, of the costs relative to likely return and risk. Undoubtedly advice is treated with a degree of scepticism because of the link to sales. Although a few individuals add weight to such cynicism, most sales advisers are more concerned about their own integrity and credibility and about forming long term and profitable relationships with growers. Advice is often criticised for promoting productivity to the detriment of profitability; although if there is to be any criticism, it’s probably truer that higher productivity is sometimes promoted where it’s not possible. This not only reinforces the need to better combine technical and economic information, but also highlights opportunities for more and better use of spatial information and variable rates of inputs.

Some independent advisers or agronomists perform similar roles to sales advisers. Just like their sales counterparts, advice on higher productivity from higher inputs can be questioned by independent advisers who focus more on the financial aspects of technical decisions. This latter group of independent advisers tend to have a sound grasp of figures for likely return and risk for broad situations (e.g. nitrogen across the whole farm) but don’t necessarily have the time and/or technical knowledge to assess each individual situation, many preferring to leave this in part or totally to more technically focused advisers. Management of the farm business is their main aim and they apply the same principles to fertiliser investments as they do to the farm business investing in the likes of the share market, more farm capital or residential property. Many service providers are now combining technical and financial skills to provide better, more rounded advice.
The issue here is not to judge groups of advisers or individual advisers, but to acknowledge that different types of advisers currently exist and have roles in providing fertiliser advice. With adviser diversity comes diversity in opinions and fertiliser recommendations. When economic transparency is provided with advice to growers it is likely to reduce scepticism, be a better means to assess fertiliser advice, strategies and products, and most importantly, better deliver the information that grain growers most want.

FERTILISERS AND DOLLARS

As profit maximisers, growers are interested in the economics of their fertiliser decisions, yet many fertiliser decisions are currently devoid of economics. Many growers believe their advisers consider economics before arriving at their recommendations. Even where this is the case, it is rarely detailed just what this information is or how it has been used. With few tools and limited advice for growers and others to assess the fertiliser investment, it is not surprising that technical and least cost issues dominate decision-making. Likewise it is hardly surprising that into such a lax and potentially lucrative market there is a constant flow of new fertiliser strategies, advice and products, many with claims and suggestions of productivity and/or soil health improvements that aren’t substantiated technically, let alone financially. The leniency on investment aspects of fertiliser and other soil amendments has left the door ajar for ‘shampoo’ (it won’t happen overnight, but it will happen) advice and products that appeal to growers’ sense of sustainability.

There is an abundance, perhaps an overabundance, of technical information on fertiliser use that is specific to WA. Most information is consistent with and forms part of universal soil science and plant nutrition principles. Yet this information is rarely used to predict or quantify the financial consequences of fertiliser decisions. If fertiliser efficiency is to improve to combat declining terms of trade, there is a strong argument for putting effort into making better use of validated information and advice, rather than into ‘silver bullets’ that would have to defy validated principles of soil chemistry, soil science and plant nutrition if they’re to be successful.

Growers will always want technical information, even though they may not always understand it. They also want information on the economic consequences of using inputs, whether they understand the technical aspects of the inputs or not. There is an opportunity for the adviser conduit to combine and simplify complex technical information, using it to predict the consequences of different fertiliser decisions. While transfer of technical information to growers will always be important, it is becoming secondary in the current climate to financial information that has immediate relevance for fertiliser decisions.

GRDC NMI INITIATIVE NMS 00002

This paper includes information from the report:

‘Adoption of Better Nutrient Management Practices – written and on-line survey, phone survey and focus group workshops report’

GRDC Project: GRDC NMI Initiative NMS00002 June 2005


Paper reviewed by: Bevan Addison and Bill Porter
KASM, the potassium in Agricultural Systems Model

Bill Bowden and Craig Scanlan, DAWA Northam and UWA, School of Earth and Geographical Sciences

KEY MESSAGES

A potassium decision support tool (KASM) is available for use by advisers consultants and agronomists. Using the power of comparison of situations, the spreadsheet model can address most of the potassium related questions now being asked by growers in WA. Factors such as time of application, level of application, soil profile distributions, constraints to rooting depth and season can be assessed in terms of short and long term crop responses. KASM is more an educational tool than a recipe method of delivering management recommendations.

Organise a workshop and learn how to use this valuable tool.

BACKGROUND

The area of agricultural land in Western Australia (WA) where potassium (K) deficiency occurs is steadily increasing (Brennan, Bolland et al. 2004; Wong, Edwards et al. 2000). Along with this, there has also been an increase in diversity of farming systems, soil types and yield potential in the K deficient area. The current industry standard for K fertiliser recommendations is not proving reliable across this spectrum of situations.

We have developed a DSS for K that not only answers the fundamental questions of how much to apply and how often, but is able to demonstrate the yield and therefore economic consequences of comparative strategies. KASM can also be used to demonstrate the dynamic processes behind model outputs and field observations.

The approach taken in developing this model is driven by the philosophy that we are supporting decisions being made by individuals, who have their own unique situations at the paddock and whole farm level. We believe that a 'feel' for the sensitivity of the economic effects of inputs is as important as an estimate of a most profitable rate or time of application.

Our challenge was to develop a decision support system (DSS) that is able to address the fundamental questions of ‘do I need to apply K?’, if so ‘how much?’, and ‘how often?’ In addition to this, we needed a tool that can address other questions such as ‘what happens to applied K?’, ‘why hasn’t the surface soil test K changed as much as expected?’, and ‘why and when is timing of application important?’.

MODEL DESCRIPTION

KASM is a weekly time-step, one-dimensional soil-plant model developed in Microsoft® Excel. KASM simulates soil water and chemistry and plant growth using relatively simple routines in comparison to daily time-step models such as APSIM. Soil water is modelled using the capacity method and soil chemical equilibrium is modelled as a multi-cation exchange system involving Ca$^{2+}$, Mg$^{2+}$, K$^{+}$ and Na$^{+}$. In order to maintain a reasonable running time soil water flux and cation equilibrium and transport are modelled using approximate explicit methods. The soil profile is represented as nine layers to a depth of one metre, each of which has individually defined soil water and chemistry characteristics.

The growth of tops is modelled as function of potential biomass growth for a given week, which is derived from a logistic growth curve, and a K scalar. The asymptote for the logistic growth curve is calculated from the user defined potential grain yield and a default harvest index. The use of the logistic growth curve to determine potential weekly growth allows the user to input a potential grain yield that is reasonable for their circumstance.

The K demand and supply constraints determine K uptake for each time-step. The K demand scalar is determined for each time step based upon current whole tops K per cent in relation to the critical level for the current above-ground biomass (Greenwood and Karpinets 1997). The critical levels are from
an exponential function fitted to local data. The amount of K that can be supplied is the diffusible K in the cylinder of soil surrounding new roots. The radius of this cylinder is governed by the buffering capacity (cation exchange capacity) and water content of the soil in any given layer.

KASM has a central 'engine' somewhat similar in principle to APSIM (McCown, Hammer et al. 1996). The engine is called by the short-term analysis, long term analysis and animation features. The short term and long term analyses are essentially the output from a series of simulations where one variable is being changed.

MODEL INPUT

Inputs are entered mainly from drop-down menus. The main user inputs and their effects in the model are:

- **Crop type**: Parameters for biomass logistic growth function, critical and maximum K in whole tops, root length density distribution, root diameter and harvest index.
- **Potential yield**: Provides an asymptote for the biomass logistic growth function.
- **Location/year**: Rainfall input file.
- **Soil type**: An initial soil profile with nine layers to a depth of one metre. Each layer has defined soil water characteristics and cation composition.
- **Product**: All the commercial products in WA that contain K. Cation composition of each product and price.

MODEL OUTPUT

KASM can generate three types of output which are all displayed graphically. These are Short-Term Analysis, Animation and Long-Term Analysis.

A novel feature of KASM is its use of comparative strategies. In both the short-term and long-term analysis the user is able to compare two situations with defined initial conditions. Output from the short-term analysis is shown in Figure 1. Comparing two situations allows the user to assess how sensitive K response is in their circumstance to a change in initial conditions. The example below shows the effect of the initial K profile on grain response to applied K.

**Figure 1.** Output from the short-term analysis in KASM.
This display clearly shows the absolute grain yield response for the two soils as well as the rate of response in terms of yield and gross margin. In this case, the different soil profiles have a significant effect. The user is then able to change the K concentration in any layer, and get an immediate quantitative assessment for this particular scenario.

THE ROLE OF KASM

The realistic role of KASM in the agribusiness sector is as a problem solving and educational tool. It is likely that the model will have its greatest impact in a commercial sense when advisors use KASM to develop recommendations for K in situations where existing models are failing.

The Department of Agriculture will continue to use the model as an extension and educational tool.

CONCLUSION

We have developed a DSS for K nutrition of field crops in WA that is focused on delivering support for individuals addressing unique situations. Blanket simplistic recommendations are not appropriate in WA as the variability of situations where K deficiency is occurring is ever increasing. KASM allows users to assess the yield and economic response and sensitivities of their unique situations

KEY WORDS

potassium, decision support, soils, crops, nutrition

ACKNOWLEDGMENTS

GRDC project DAW00010 and a cast of thousands.

REFERENCES


Paper reviewed by: Dr James Fisher
Long-term productivity and economic benefits of subsurface acidity management from surface and subsurface liming

Stephen Davies, Chris Gazey and Peter Tozer, Department of Agriculture, Western Australia

KEY MESSAGES

- Surface lime applications can maintain or increase the subsoil pH after 4 or more years.
- Grain yield responses to surface liming are often in the order of 10-15 per cent and may increase with time.
- Surface lime application rates of 2 t/ha may be required to ameliorate and prevent subsurface acidification and increase productivity over the long term.
- Not liming can result in a continued decline in pH, low productivity and can make correcting soil pH much more difficult and expensive in the future.
- Subsurface lime injection can more rapidly increase the pH of a column or seam of soil to greater depth and where successful increase profit with yield increases of up to 30-40 per cent.

AIMS

Acidification of agricultural soils in southwest Western Australia is an ongoing problem. Farm survey data and industry estimates indicate that the amount of lime applied to agricultural soils in WA has increased substantially particularly from the mid 1990s onwards and approximately 650,000 ha of agricultural land was treated with lime in 2002-03 (ABS 2003). However, estimates from the WA Department of Agriculture (DAWA) map unit database indicate that nearly one-third, approximately 5 million ha, of dryland agricultural soils in WA are either highly susceptible to, or presently have, subsurface acidity (Van Gool personal communication). Subsurface acidity can be difficult to manage due to the long time it takes surface applied lime to neutralise acidity in the subsoil. Subsurface injection of lime could be a potential solution to increase the speed with which subsurface acidity can be ameliorated. In this paper we present data and economic analyses of surface and subsurface lime trials including long-term trials to assess the benefits associated with the amelioration of subsurface acidity and prevention of ongoing acidification.

METHOD

Short-term impact of surface liming on crop productivity and soil pH

Over the past 25 years the DAWA has conducted numerous surface liming trials and experiments throughout the WA wheatbelt mostly on sandy and sandy loam textured soils. We collated this data and determined the average impact of surface liming on crop yield (Table 1) and soil pH (Figure 1) across numerous locations and seasons.

Long-term impact of surface liming on crop and pasture productivity and soil pH

In 1996 an on-farm surface liming trial was established at Bindi Bindi on a sandy gravel. In addition to the unlimed control limesand was spread at rates of 1 and 2 t/ha onto large plots 50 m by 200 m. Pasture and crop yield responses have been periodically measured over the past 8 years. Spring wheat, *Triticum aestivum* (cv. Dagger) was grown and productivity measured in 1996, 1998 and 2004. Volunteer pasture was grown in 1997 and 2005. Pasture shoot biomass was measured on 9 September 2005 but was not measured in 1997.

Impact of subsurface lime injection on grain yield

In 2001 a subsurface lime application and on-farm experiment was commenced near Bodallin on a yellow sandy earth. Limesand was fed from a belt type spreader and distributed through a venturi to tubes with Morris Gumbo boots and 3 outlets. These were placed behind the shanks and lines of a deep ripping machine with 16 tines about 18 cm apart. Plots were 12 m wide and 100 m long.
different ripping treatments were applied each with or without lime: 1) Soil ripped in a single pass 13 cm deep with no lime or with 1 t/ha limesand applied during ripping; 2) Soil ripped in one pass to a depth of 13 cm then ripped 18 cm deep in a second pass in or as close as possible to the rip lines of the first pass with 1 t/ha limesand applied during each pass for the limed treatment. Wheat (cv. Calingiri) was sown in 2001 and 2003, and barley (*Hordeum vulgare* cv. Stirling) in 2004. French serradella (*Ornithopus sativus* Brot. cv. Cadiz) was grown in 2002 but failed because of drought and was allowed to regenerate in 2005 but no pasture growth measurements were made.

**Economic analysis**

Current grain and input prices were used in the analysis. These prices were used as it was not possible to gather input prices for the periods of the trials. Because of this it was decided to use current prices to maintain consistency of comparisons. The costs for lime and lime applications were amortised over 10 years at an annual interest rate of 8 per cent to account for the opportunity costs of capital.

**RESULTS**

*Short-term impact of surface liming on crop productivity and soil pH*

On average soil pH in the top 10 cm was increased by more than 1 unit where 2 t/ha lime was applied and by 0.6 or more where 1 t lime was applied (Figure 1). The maximum impact of the lime on pH in the top 10 cm occurred after 3 years. In the 10-20 cm layer soil pH increased gradually over time reaching a maximum after 5 years of half a pH unit for 2 t/ha lime and 0.3 of a pH unit for 1 t/ha lime (Figure 1).

![Graph showing increase in pH after liming](image)

*Figure 1.* Average increase in soil pH at two soil depths over time in response to lime applied at 1 or 2 t/ha. Data are based on the average pH response for 88 Department of Agriculture, Western Australia field trials conducted in the WA wheatbelt.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Lime rate (t/ha)</th>
<th>Years after lime application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Wheat</td>
<td>1.0-1.5</td>
<td>1 (16)</td>
</tr>
<tr>
<td>Wheat</td>
<td>2.0-2.5</td>
<td>2 (19)</td>
</tr>
<tr>
<td>Canola</td>
<td>1.0-3.0</td>
<td>21 (3)</td>
</tr>
<tr>
<td>Barley</td>
<td>1.0-3.2</td>
<td>-4 (1)</td>
</tr>
</tbody>
</table>

**Table 1.** Average crop grain yield responses shown as the per cent yield change compared to unlimed plots to surface lime applications with time. The number of trials included in each average is shown in parentheses.
There is consistently little or no yield response for wheat and barley to liming in the year of application but on average there is a yield increase in the following years (Table 1). Negative responses may occasionally occur due to induced deficiency of some nutrients, particularly manganese and zinc. Canola has a large initial response to lime application, although this has only been looked at in a limited number of field trials (Table 1).

**Long-term impact of surface liming on soil pH and crop and pasture productivity**

In 1997 at the Bindi Bindi site the soil pH where no lime was applied was 4.9 at 5 cm and declined to a minimum of 4.4 at 15 cm. The pH continued to decline where no lime had been applied over the next 8 years to 4.4 at 5 cm to minimum of 3.9 at 15 cm a decline of half a pH unit down the profile to 25 cm. Where 1 t/ha lime was applied the pH in 2004 was maintained slightly above the pH measured in 1997 for the top 15 cm but the soil had acidified at 25 cm. At the higher lime application rate of 2 t/ha the pH of the topsoil at 5 cm was 5.6, substantially higher than the other treatments in 2004. At 15 cm the soil pH was maintained at 1997 levels but the pH had still declined below 1997 levels at 25 cm.

![Figure 2. Soil pH with depths over time in response to lime applied at 0, 1 or 2 t/ha in 1996 at an on-farm site near Bindi Bindi, Western Australia.](image)

Surface liming had no significant impact on crop yield in the year of application (Table 2). There was a trend towards higher yields in the limed plots in the third year following lime application but this was not statistically significant. However, when the trial was revisited 8 years after it commenced the wheat yield was 28 per cent greater where 2 t of lime had been applied (Table 2). In 2005 pasture biomass measured on 9 September was 70 per cent higher (2.9 t/ha) where 2 t/ha of lime had been applied compared with the unlimed control (1.7 t pasture biomass/ha; data not shown).

**Table 2. Grain yield responses to surface incorporated lime sand applied in 1996. For each column, yields followed by the same letter are not significantly different at P = 0.05**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Wheat yield (t/ha)</th>
<th>Grain income less annual lime cost ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 t lime/ha</td>
<td>2.2a</td>
<td>1.61a</td>
</tr>
<tr>
<td>1 t lime/ha</td>
<td>2.3a</td>
<td>1.74a</td>
</tr>
<tr>
<td>2 t lime/ha</td>
<td>2.2a</td>
<td>1.82a</td>
</tr>
</tbody>
</table>

The productivity benefits of the lime applications in 1996 have lasted 9 years resulting in increased grain income (Table 2). In 1998 the increase in income where 2 t lime/ha had been spread was $19/ha with greater impact in 2004 with grain income being $87/ha more than the unlimed plots (Table 2).
Impact of subsurface lime injection on grain yield and soil pH

At the Bodallin site subsurface injection of limesand at a rate of 2 t/ha at depths of 13 and 18 cm with two passes of a deep ripping machine achieved the goal of obtaining a continuous seam of pH ameliorated soil from the surface to a depth of about 25 cm. In unlimed soil the average pH ranged from 4.5 for the surface 5 cm to 4.2 at 20-25 cm. In the limed seam the average pH was 5.9 for the surface 5 cm and 6.4 at 20-25 cm (Table 3). Soil extractable aluminium decreased with liming from levels as high as 15 ppm in unlimed subsoil to 0.5 ppm in the limed seam (Table 3).

Table 3. Soil pH and exchangeable aluminium (ppm) measured in 2004 for unlimed soil and a limed seam of soil in which 2 t lime/ha had been applied in two passes to a depth of 18 cm in 2001

<table>
<thead>
<tr>
<th>Soil depth (cm)</th>
<th>Unlimed soil</th>
<th>Soil seam limed to 18 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH</td>
<td>Exch. Al (ppm)</td>
</tr>
<tr>
<td>0- 5</td>
<td>4.5</td>
<td>1.3</td>
</tr>
<tr>
<td>5-10</td>
<td>4.4</td>
<td>1.6</td>
</tr>
<tr>
<td>10-15</td>
<td>4.2</td>
<td>8.9</td>
</tr>
<tr>
<td>15-20</td>
<td>4.2</td>
<td>13.8</td>
</tr>
<tr>
<td>20-25</td>
<td>4.2</td>
<td>13.8</td>
</tr>
<tr>
<td>25-30</td>
<td>4.1</td>
<td>12.9</td>
</tr>
<tr>
<td>30-35</td>
<td>4.2</td>
<td>10.5</td>
</tr>
<tr>
<td>35-40</td>
<td>4.2</td>
<td>8.5</td>
</tr>
</tbody>
</table>

When 2 t lime/ha was applied in two passes significant wheat yield responses of 6 per cent in 2001 and 31 per cent in 2003 and a 40 per cent barley grain yield response in 2004 were obtained when compared with the yields on deep ripped soil that wasn’t limed (Table 4). Deep injection of 1 t lime/ha in a single pass to a depth of 13 cm did not improve grain yield (Table 4).

Table 4. Grain yields of wheat and barley following deep ripping and lime treatments implemented in February 2001. Data mean of 4 replications. For each column, yields followed by the same letter are not significantly different at \( P = 0.05 \)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (t/ha)</th>
<th>Grain income less annual lime costs ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control: Not ripped, no lime</td>
<td>2.63a</td>
<td>1.74a</td>
</tr>
<tr>
<td>Rip 13 cm, no lime</td>
<td>2.75a</td>
<td>1.70a</td>
</tr>
<tr>
<td>Rip 13 cm then 18 cm, no lime</td>
<td>2.86a</td>
<td>1.69a</td>
</tr>
<tr>
<td>Rip 13 cm while applying 1 t/ha lime</td>
<td>2.56a</td>
<td>1.81a</td>
</tr>
<tr>
<td>Rip 13 cm while applying 1 t/ha lime, + rip 18 cm while applying 1 t/ha lime</td>
<td>3.04b</td>
<td>2.22b</td>
</tr>
</tbody>
</table>

Applying 2 t lime/ha in two passes to a depth of 18 cm was the only treatment that consistently proved to be more profitable than the unlimed control despite the additional costs associated with two ripping passes (Table 3). The additional value for this treatment over the unlimed control was $21, $31 and $11/ha for 2001, 2003 and 2004, respectively.

CONCLUSION

Surface liming

Despite substantial increases in lime use in WA over the past decade the average application rate over this time has remained constant at 1.1 t lime/ha (ABS 2004). Summarised trial data shows that while lime application rates of 1 t/ha may still increase yields, the yield responses at higher lime rates of 2 t/ha are greater, and the increase in subsurface pH at these higher rates are larger and more rapid. Previous research has shown that surface applied lime at rates of 2.5-5 t/ha can significantly increase subsurface pH after 4-7 years by about 0.2 pH units for numerous sandy textured soils in WA.
(Whitten et al. 2000). In the long term trial at Bindi Bindi crop and pasture yield were higher with lime applied at 2 t/ha. Surface liming prevented surface and subsurface acidification getting worse to a depth of 15 cm with a decline in pH of half a unit throughout the profile where no lime was applied in the 8 years from 1997 to 2004. Soil pH continued to decline at 25 cm below that measured in 1997 irrespective of the surface lime applications. This suggests additional lime applications and more time is required to increase subsurface pH at a greater depth. Not liming resulted in worsening acidification throughout the soil profile which would be more costly and difficult to ameliorate than where lime had been used which prevented further soil degradation. It is estimated that in the unlimed treatment at least 4 t lime/ha (possibly split over several applications) would be required to begin correcting the topsoil and subsoil pH. This may take as long as 8-10 years whereas the 2 t lime/ha treatment would only require maintenance lime applications (approximately 1 t lime/ha) to further improve subsoil pH within 2 to 3 years of lime being applied. The value of surface lime in preventing or slowing soil degradation needs to be considered in addition to yield and productivity benefits.

**Subsurface liming**

Subsurface liming can more rapidly increase soil pH in the subsoil but is only successful when a continuous column or seam of limed soil is generated into the soil profile. In the Bodallin experiment liming to a depth of 13 cm was insufficient to overcome the impact of subsurface acidity on crop performance. Substantial and profitable increases of up to 30-40 per cent in yield were achieved when lime was injected in two passes to a depth of 18 cm. Modelling and field studies indicate subsurface acidity can reduce cereal yields in WA by 20-60 per cent (Tang et al. 2003a,b). Success with deep application of lime is technically difficult and failures are usually due to inadequate mixing of the lime, an inability to create a continuous seam of limed soil, or seams of limed soil being spaced too far apart. Thus, while subsurface lime application has advantages, it is unlikely that modifying existing farm machinery to apply lime to depth will be the solution. In the absence of purpose built machinery and equipment capable of successfully and consistently injecting lime farmers should monitor the soil pH profile and apply sufficient lime to the surface to maintain a pH above 5.5.

**KEY WORDS**

subsurface acidity, lime, soil, pH

**ACKNOWLEDGMENTS**

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**REFERENCES**


Project No.: DAW0014 and UWA00081

Paper reviewed by: Dr Bill Porter
Furrows and ridges to prevent waterlogging

Dr Derk Bakker, Research Officer, Department of Agriculture, Albany, WA

KEY MESSAGES

Wide-spaced furrows can be very effective in providing surface drainage to reduce the impact of waterlogging and improve productivity.

Ridge seeding provides a viable option to improve crop productivity in waterlogged conditions.

PART I. FURROWS

AIM

Several aspects of raised beds have surfaced that, in my mind, seem to be hampering the adoption of raised beds as a farming system. These are: i) the need to match the wheel spacing to the furrow spacing on all vehicles working raised bed paddocks; ii) stock being trapped in the furrows; iii) difficult access to raised bed paddocks; iv) requirement of special bed forming equipment; and v) awkward to implement in paddocks with many physical obstacles such as trees and rocks. In addressing some of these issues the question should be asked, ‘How critical is the furrow spacing for raised beds?’ This paper will address this issue.

Background

Many areas in WA experienced some very wet conditions in 2005, which led to widespread waterlogging and affected the yield. To combat waterlogging, raised beds have been researched during the last 8 years by the Department of Agriculture, Western Australia (DAWA) and funded in part by the GRDC and at a later stage the CRC of Plant-based Management of Dryland Salinity. That work indicated that raised beds could increase the productivity by 10-15 per cent in many years.

In the DAWA approach a furrow spacing of 1.83 m has been based on the wheel spacing of the tractor making the beds and seeding them rather than on drainage considerations. For beds to work properly they need to drain water quickly (i.e. 24 hrs) which depend on the hydraulic conductivity (ease of water flow) of the soil and the hydraulic gradient (driving force of the water flow) in the soil. The first depends on the soil type and structure while the latter depends on the depth of the furrow and the distance between the furrows.

In WA the poor hydraulic conductivity of the subsoil rather than the topsoil is the main contributing factor to waterlogging on duplex soils. The conductivity of the topsoil is usually good, provided the soil structure has not deteriorated too much. Therefore the furrows, which are located in the topsoil can be spaced more than 1.83 m apart and still provide enough internal drainage. This is illustrated in Figure 1 for two soil types with two different hydraulic conductivities (Ks) and a furrow depth of 25 cm.

Figure 1. Drop in the perched water table over time in the middle between two furrows (depth = 25 cm) for two bed widths (2 m and 6 m) and two hydraulic conductivities (Ks) of the topsoil: 5 and 50 mm/hr.
Field measurements of the topsoil at different locations indicated a $K_s$ ranging from 50–100 mm/hr which would suggest that a furrow spacing of 6m would still provide sufficient internal drainage such that within 1 day the water table in the middle between the furrows drops to 12 cm below the soil surface.

**Wide-spaced furrows**

A furrow spacing of, for example, 6 m would allow vehicles and equipment to utilise the beds without making any modifications. In fact the furrow spacing can be such that it matches half the width of the seeder bar, the furrow in the middle is then used for tracking with two furrows on the extremities of the seeder bar. The wheel tracks are cropped as normal. When the traffic, which does not occur in the furrows is restricted to traffic zones, a tramline system with intensive surface drainage is established.

**METHOD**

At three sites: North Stirling, Woodanilling and Mt Barker Research Station wide-spaced furrows (WSF) were implemented in 2005 and compared to renovated raised beds (RB), non-renovated raised beds (NTB) and a normal seed bed (Control). The furrows were made using an old AgroPlough frame carrying one Gessner furrower and a set of back-raking levelling blades (see Figure 2). The raised beds were formed with a Gessner bedformer. Seeding of the WSF and normal seed bed was done with seeders used by the farmer while the raised beds were sown with the custom-made raised bed seeder from DAWA.

![Figure 2. Rear view of the furrower (left) and a side view of the furrower (right).](image)

The crop biomass was estimated from a digital multi-spectral image (DMSI) taken before flowering and the yield was obtained from plot weights combined with yield mapping information.

**RESULTS**

At the time of writing this paper only the results from North Stirling were available and will be presented. The area was sown to canola in early May. After 230 mm of rain in April, May and June extensive damage from waterlogging occurred in the Control. Areas dissected by WSF or RB were 'puddle-free' with a good crop establishment between the furrows. The DMSI in the beginning of August, prior to flowering is presented in Figure 3.
Figure 3 illustrates the effect of the WSF and the RB. The WSF were installed in sections of the Control plots (1) and a clear distinction between the areas can be made where the WSF (4) were implemented. The biomass was comparable to the NTB (2) while the RB (3) had the highest biomass due to the deeper furrows and a loosened top soil.

The final yield at North Stirling is presented in the following table.

Table 1. Canola grain yield (T/ha) from the North Stirling site in 2005

<table>
<thead>
<tr>
<th>Plot</th>
<th>NT</th>
<th>RB</th>
<th>WSF</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.09</td>
<td>1.56</td>
<td>1.00</td>
<td>0.62</td>
</tr>
<tr>
<td>2</td>
<td>0.95</td>
<td>1.16</td>
<td>1.31</td>
<td>1.12</td>
</tr>
<tr>
<td>3</td>
<td>1.14</td>
<td>1.35</td>
<td>0.72</td>
<td>0.59</td>
</tr>
<tr>
<td>4</td>
<td>1.62</td>
<td>1.17</td>
<td>1.28</td>
<td>0.95</td>
</tr>
<tr>
<td>Mean</td>
<td>1.20</td>
<td>1.31</td>
<td>1.08</td>
<td>0.82</td>
</tr>
</tbody>
</table>

The renovation of the RB which included loosening of the soil as well as cleaning out and deepening the furrows was beneficial compared to the NT treatment. However implementing WSF in the Control areas significantly improved the yield from those areas to a level comparable to the NT beds.

CONCLUSION

A system like the WSF is very effective in removing waterlogging, cheap to implement, no need to alter machinery, very limited obstructions to traffic, a substantially reduced chance for livestock to get trapped in the furrows and is ideally suited to be included in a tramlining farming system. The effect of the system in dry years is mainly expressed through a reduction in area seeded, but even in dry years chances are that occasional waterlogging events occur.

Future direction

Without the need to match wheel to furrow spacing surface water management using furrows has become more flexible. The development and implementation of WSF in the high rainfall areas and other areas prone to waterlogging will be done through the formation of a furrow spacing framework based on soil type, landscape, and equipment requirements as a decision making tool for farmers.
PART II. RIDGE SEEDING

AIM
To assess the impact of ridge seeding on drainage, crop growth and yield in a high rainfall zone.

BACKGROUND
An alternative method of seeding to combat the effects of waterlogging has been tested in 2005 at the Mt Barker Research Station and is called ‘ridge-seeding’. Normally the seed is placed in the seed furrow, created with a tyne and then usually pressed with a press wheel. The seed is thus placed in the wettest part of the topsoil resulting in poor germination and stunted plant growth.

Seeding in the furrows is very beneficial when moisture needs to be captured to get the crop started. However the plant is most susceptible to waterlogging at seed germination and the seedling stage up to tillering (for cereals). In areas prone to waterlogging it might therefore be more beneficial to place the seed on a ridge adjacent to the furrow rather than in the furrow. The seedling can then develop in a well-drained ridge hence reducing the impact of waterlogging. Waterlogging later in the season is less of an issue. Also no area is ‘lost’ to furrows such as in raised beds or WSF.

METHOD
The trial consisted of three treatments, ridge seeding, raised beds and normal seedbed, using two types of wheat, Camm and Wyalkatchem, which were sown on the 17 June, just before the onset of a drier period. The ridges were made using a specially modified tyne, that looked like a wedge with two wings that passed through the topsoil, making a narrow furrow and a ridge on both sides of the furrow. The seed was placed in the loose soil on the side of the ridge with disc seeder units suspended from the frame with a wire so as not to squash the ridge. One tyne made two ridges about 30 cm (12 inches) apart and were running down hill. Each plot was 1.8 m wide and 30 m long. Soil temperature and soil moisture suction in the top soil were monitored for one month after seeding. Fertilisers, MAP and Urea (50%) were applied at seeding time while the rest of the Urea was applied in late July.

RESULTS
Some crop productivity results and soil properties are presented in Table 2.

Table 2. Soil bulk density, dry matter production and yield at the MBRS ridge seeding trial sampled on 2 different days

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bulk density in seed row (g/cm³)</th>
<th>Dry matter (5 Aug) (t/ha)</th>
<th>Dry matter (30 Sept) (t/ha)</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge</td>
<td>1.00</td>
<td>0.35</td>
<td>7.57</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.99</td>
</tr>
<tr>
<td>Normal</td>
<td>1.19</td>
<td>0.20</td>
<td>6.25</td>
<td>3.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.27</td>
</tr>
<tr>
<td>Raised beds</td>
<td>1.22</td>
<td>0.23</td>
<td>5.93</td>
<td>2.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.67</td>
</tr>
</tbody>
</table>

The dry matter production of the crop of the ridges was higher than of the normal and the raised beds while the bulk density was lower. The variety Camm yielded the same on the ridges and normal seed bed with the raised beds yield the lowest because the productive area of the beds was adjusted for the presence of the furrows (20%). This was not done for the normal treatment even though those plots, which were really designated buffer plots for the raised beds, did receive a drainage benefit from the furrows. This happened because the ‘official’ Normal treatment plots were too boggy to seed at the time the trial was sown and could not be used. Wyalkatchem wheat yielded less in all the treatments for an unknown reason even though variety trials for the Mt Barker region have found that variety to yield more than Camm.

There was no obvious difference in the soil temperature between the treatments but the soil moisture suction in the top 5 cm of the ridges increased more rapidly after rainfall (i.e. drained faster) than the other treatments. This supports the assumption that ridges would provide a well-drained zone.
Beside the topographic effect of the ridge a cultivation effect would have been beneficial for early
growth vigour of the plants particularly during prolonged moist conditions. The conditions were too wet
to utilise the areas with a loose seed bed.

CONCLUSION AND FUTURE DIRECTION
Whilst the preliminary results are interesting more work needs to be done to establish the robustness
of this system and several issues would need to be looked at.

- Tyne design is important. A new tyne is being developed that makes the furrow and sows seed
in one pass and should bolt on to standard seeder units. Note, only one tyne is required per two
seed rows.
- The incorporation of herbicides needs to be addressed.
- The orientation relative to the slope needs investigation.
- How is stubble being handled? The engagement of soil with stubble could be an advantage?
- How would the yield in dry seasons be affected? Proper seed placement is important, even
more so in dry years. Just dropping the seed on the ridge is not recommended.
- How sensitive is the system to wind erosion?

It is very possible that the WSF as a system is more appropriate for the sandy/gravely duplex soils
while ridge seeding might be more appropriate for the heavier soil types such as the grey clays.
Future research should identify these areas and applications.

ACKNOWLEDGEMENT
The assistance of Rob Hetherington in the implementation of the trials and the manufacturing of the
various tynes is greatly acknowledged. The collaboration of Russel and Margaret Thomson
(Woodanilling), Michael and Marie White (North Stirling) is acknowledged as well as the financial
contribution of the Sustainable Grazing of Saline Land (SGSL) project to the manufacturing of the
furrower bar. The financial contribution of the GRDC and the CRC of Plant-based Management of
Dryland Salinity to parts of this work has been much appreciated.

Paper reviewed by: Dr Wal Anderson
Nitrous oxide emissions from a cropped soil in Western Australia

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²Department of Agriculture, Western Australia, South Perth

KEY MESSAGES

Nitrous oxide (N₂O) emissions from soils are a concern as they contribute to global warming and the destruction of the ozone layer. The Australian Grains Industry is seeking to maintain a clean, green industry to guarantee its long-term productivity and to ensure access to premium markets. Currently there are no reliable data on the contribution of the Western Australian grain production to N₂O emissions.

The Department of Agriculture, in collaboration with The University of Western Australia, commenced measuring N₂O emissions from a Western Australian cropping soil in May 2005. The project utilises soil chambers in combination with an automated gas sampling unit to ensure emissions are measured year round.

Preliminary results show fluxes vary with time and range from < 0–120 µg N₂O-N m⁻² h⁻¹ (< 0–29 g N₂O-N ha⁻¹ d⁻¹). Fluxes increased immediately following seeding in June, and then again intermittently from late July onwards. Further emissions were measured following summer rainfall.

The variability of N₂O emissions with time demonstrate that continuous measurements are required to fully characterise of N₂O emissions.

INTRODUCTION

Nitrous oxide emissions from the earth’s surface to the surrounding atmosphere are increasing (Bouwman, 1990). Although N₂O is only present as a ‘trace gas’ in the earth’s atmosphere, its presence contributes to reactions that influence atmospheric chemistry and radiative properties. In the troposphere, N₂O is stable for about 120 years and contributes to the greenhouse effect; while in the stratosphere, N₂O is reactive and participates in the destruction of the ozone (Crutzen, 1981). Nitrous oxide emissions from agricultural soils are considered to account for 70–81 per cent of the increase in N₂O emissions to the atmosphere, with the increase linked to a global increase in N fertiliser use (Bouwman, 1990).

In Australia, agriculture is estimated to contribute approximately 30 per cent of Australia’s greenhouse gas emissions. Nitrous oxide is estimated to contribute about a third of these emissions, and is derived mainly from the application of fertilisers, soil disturbance and animal waste (Dalal et al. 2003). Grain producers are seeking to maintain a clean, green industry to guarantee their long-term productivity and to ensure access to premium markets. High N₂O emissions from the WA grains industry could threaten this position.

Much of our understanding of agricultural N₂O emissions comes from temperate climates of the Northern Hemisphere and currently there are no reliable data detailing the contribution of Western Australian grain production to greenhouse gas emissions. The overall aim of this project is to estimate greenhouse gas emissions from the Western Australian grain belt using a combined approach of in situ measurements, simulation modelling and ‘life cycle assessment’. In the following paper we report N₂O emissions measured from May 2005 to January 2006 at the Cunderdin Agricultural College.
METHOD

Soil and study site

Nitrous oxide emission were measured at a cropped site at Cunderdin (31° 36' S, 117° 13' E), Western Australia. The site includes a yellow/brown sandy duplex soil (Table 1) and forms part of a cereal-lupin rotation. The area experiences a Mediterranean-type climate, with an annual rainfall of 368 mm, and mean daily max air temperature of 34.1°C (January), and mean daily minimum air temperature of 6.0°C (August).

Table 1. Selected soil characteristics of Cunderdin site

<table>
<thead>
<tr>
<th>Soil depth (mm)</th>
<th>pH (0.01M CaCl₂)</th>
<th>EC (µS cm⁻¹)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>Sand (%)</th>
<th>Bulk density (g cm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 100</td>
<td>5.9</td>
<td>139</td>
<td>4</td>
<td>5</td>
<td>92</td>
<td>1.42</td>
</tr>
<tr>
<td>&gt; 100- 200</td>
<td>4.4</td>
<td>94</td>
<td>5</td>
<td>5</td>
<td>89</td>
<td>1.61</td>
</tr>
<tr>
<td>&gt; 200- 500</td>
<td>5.1</td>
<td>318</td>
<td>6</td>
<td>34</td>
<td>60</td>
<td>1.83</td>
</tr>
<tr>
<td>&gt; 500- 700</td>
<td>7.1</td>
<td>642</td>
<td>10</td>
<td>22</td>
<td>68</td>
<td>1.92</td>
</tr>
<tr>
<td>&gt; 700-1700</td>
<td>7.7</td>
<td>616</td>
<td>5</td>
<td>36</td>
<td>58</td>
<td>2.02</td>
</tr>
</tbody>
</table>

Experimental design and approach

A randomised plot design with three replicates was employed at the site, with plots measuring 141 m². The treatments consisted of either plus N fertiliser or no N fertiliser (i.e. control). In the plus N treatment 100 kg N ha⁻¹ yr⁻¹ was applied as urea (25 kg N ha⁻¹ drilled at seeding, 75 kg N ha⁻¹ topdressed 6 weeks after seeding). The N application rate was based on site history (rotation and yield) and soil chemical composition. In addition, all treatments plots received 15 kg P ha⁻¹ at seeding as ‘Superphosphate CuZnMo®’.

Measurement of N₂O fluxes

Nitrous oxide emissions measurements commenced on the 5 May 2005, with wheat (cv. Carnamah) sown on the 1 June 2005. Emissions were measured in each treatment plot using chambers (500 mm x 500 mm, varying height depending on crop height). The chambers were placed on metal bases inserted into the ground (100 mm), and fitted with a top that could open and close. The chambers were connected to an automated gas sampler that was programmed to open and close the chambers, and to collect gas samples at regular intervals while the chambers were closed. Gas samples were then automatically analysed for N₂O using a gas chromatograph fitted with an electron capture detector. The automated gas sampling unit enabled N₂O emissions to be monitored continuously, providing up to 6 emission rates per day. To avoid the chambers altering soil properties and plant growth within the chambers, four bases were located in each treatment plot to enable the chambers to be moved to a new position each week. Furthermore, the chambers were programmed to open if the air temperatures exceed a specific air temperature (43°C during the growing season, 60°C at other times) or if rain fell while the chambers were closed. The height of the chambers was progressively increased to accommodate crop growth, with a maximum height of 950 mm. For further details of the design and operation of the chambers the reader is referred to Breuer et al. (2000) and Kiese et al. (2003).

In addition to N₂O emissions, a number of soil, plant and climatic and variables were be measured to assist in the explanation of N₂O emissions. These included soil mineral N, soil water contents, rainfall and plant growth parameters. Carbon dioxide and methane concentrations in the chambers were also measured but are not reported here.

RESULTS

Nitrous oxide emissions from a cropped soil in the Western Australian grain belt varied greatly within the first 10 months of a three year study. Losses ranged from < 0–120 µg N₂O-N m⁻² h⁻¹ (< 0–29 g N₂O-N ha⁻¹ d⁻¹), and did not appear to vary between N treatments (Figure 1). Increased losses coincided with elevated soil water contents (following rainfall events), and increased soil mineral N contents (data not shown). Consequently emissions increased following seeding, following rain during the growing season, and following summer rain (Figure 1).
Elevated N$_2$O emissions were short-lived (i.e. < day) and unpredictable. The automated gas sampling equipment captured changes in N$_2$O emissions that would have been missed using conventional methods (e.g. static, manual chambers).

Figure 1. (A) N$_2$O fluxes (µg N$_2$O-N m$^{-2}$ h$^{-1}$) and (B) daily rainfall (mm) to 9 a.m. measured at the Cunderdin Agricultural College from 1 May 2005 to 15 January 2006. Prior to seeding, flux values are arithmetic means of six values (± SE), while after seeding values are arithmetic means of three values (± SE).

**FUTURE WORK**

Quantifying annual N$_2$O emissions accurately requires intensive and continuous measurements over an extended period of time (e.g. > 2 years), therefore we will continue to measure associated soil, climatic and plant parameters. Developing models that predict N$_2$O emissions from agricultural soils from easily measurable soil, climatic and crop parameters may provide an alternative to measuring emissions, plus enable the effects of different farm management practices on greenhouse emissions to be investigated. Consequently, data collected from the first year of the study will be used to test the suitability of a N$_2$O simulation model (Water and Nitrogen Management Model, WNMM) (Li, 2002) for predicting N$_2$O emissions from Western Australian grain belt soils.
CONCLUSION
Nitrous oxide emissions from a cropped soil in Western Australia vary temporally, ranging from $< 0-120 \mu g N_2O-N m^{-2} h^{-1} (< 0–29 g N_2O-N ha^{-1} d^{-1})$ during the first 10 months of a two year field study. Greatest losses occurred when the soil was moist and mineral soil N is present. Using chambers connected to an automated chamber system enabled emissions to be fully characterised throughout the year.

KEY WORDS
greenhouse gas, global warming, nitrous oxide, grain production, environment

REFERENCES


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Paper reviewed by: Dr Tina Acuna, The University of Western Australia
Managing the unmanageable

Bill Bowden, DAWA, CCS, Northam

KEY MESSAGES

- Estimates of yield potential should be the major determinant of input related management decisions for crop production.
- Playing the season rather than trying to predict the season, is the best strategy.
- Plan different cropping strategies for early mid and late break seasons.
- Farming by soil type (yield potential) is a must for improving the efficiency of input management.
- Low early vigour strategies can be appropriate on shallower soils and in low rainfall regions.
- Advisers should offer clients options and sensitivity analyses rather than management recipes or packages.

BACKGROUND

What is the value to farmers of better knowledge of uncontrollable and usually unpredictable, factors like soil, price and season?

Yield potential (defined here as the yield, limited only by water) is the major determinant of many management decisions (e.g. nutrition, herbicide use, cultivar choice?) for crop production. Other management decisions (e.g. ripping, row spacing, sowing date, seeding rate) can change yield potential at a given site in a given year. The estimation or prediction of yield potential and its variability in space and time has received a lot of effort in WA in the last few decades (Halse 1977 et seq.).

Have our predictive skills improved enough so that estimates of yield potential can be useful in decision making for more than a handful of growers?

Unfortunately, because they are God given, season and soil type, are both largely unmanageable without major resource inputs such as the use of irrigation or the amelioration of poor soils. So predictions of yield potential are always subject to the serendipity of the season and how it interacts with spatially variable soil types.

This paper looks at some of the different levels of yield prediction available to growers. It also suggests ways they could adjust their management given the probabilistic nature of the predictions. In the light of the avalanche of information now overwhelming them in the areas of climate prediction and yield mapping, what are the reasons growers why may or may not largely ignore it for management?

How good are our predictions when they are based on variables like season and soil type?

SEASON

Despite the endeavours of our best meteorological minds, the prediction of the season to come is still hopeless from a decision maker’s point of view. Certainly outcomes can be hedged in betting or probabilistic terms (percentiles, decile ratings, boxes and whiskers, ‘you have a 30% chance of this and a 70% chance of that’), but once you choose the strategy which suits your risk preferences, you are not playing 100 seasons to get the predicted outcome, you are playing only one. And as such you are playing a chocolate wheel – with chances (albeit slim?) that your chosen strategy will lead to a wipe out. Maybe there are other ways of playing the same information such as ‘spreading your risks’ and/or being more flexible and/or ‘playing the season’ as it comes? For some people, having a failsafe option is better than playing the probabilities.

Time of break and plans A, B and C

The timing of the break is one of the major seasonal variables impacting on crop yield potential and management. Although the time of the break is unpredictable, most of the important crop management decisions are made at or before sowing and so the grower has full information for those decisions at that time. I was educated by a group of farmers at Varley in 1982, to the importance of
adjusting their cropping plans for the timing of the break. Those farmers had in place, whole farm cropping plans for A, an early break, B an average break, and C a late break. These plans involved having fertiliser, herbicides and seed for different cultivars and species on hand. Different paddocks and crops would be used in the program according to plans A, B and C. I assume that most farmers now have this sort of flexibility built into their cropping programs simply because you can not predict when the season will break? If they do not then it should be the first step they take in managing seasonal variability.

**Time of break and spreading the risks**

Choice of cultivar depends markedly on sowing date which in turn is dictated to some extent by the time of the break. For any time of sowing, the ‘flowering window’ concept tries to find a cultivar which finds the compromise between flowering late enough to markedly reduce the risk of frost damage, but early enough to minimise the impact of post anthesis water stress on grain fill. My worry about current seeding ‘packages’ is that, in concentrating on a ‘flowering window’, they have led to more synchronous flowering of crops and thus increased the likelihood of total escapes or wipe outs from frost and/or pest invasions.

The concept of ‘first opportunity sowing’ has been in place since our great grandfathers kept the horses in trim to start preparing the seed beds on the first rains. It came to the fore again in the early ‘80s with the increased push on herbicides and one pass seeding. Farmers bought large machinery so that they could seed crops in a minimum of time because of the ‘myth’ (see the Fisher and Abrecht paper in these proceedings) that you would lose 30 to 60 kg/ha grain per day delay in seeding. These losses are true for late break seasons but are questionable for average or early break seasons. More synchronous seeding time has also lead to more synchronous crop development.

Staggered seeding with standard cultivars also spreads the risk to grain yield of completely unpredictable seasonal finishes. Yes, part of the crop may be wiped out but other parts could perform well. I have seen enough time of sowing trial results to see late sown treatments out perform early sown treatments. The results are completely explicable in hindsight but not in looking forward from the break, simply because we do not yet (and probably never will) have the ability to predict the season to come with any certainty. We can generate probabilities and a grower can choose his gamble, but I suggest that he may be better off by hedging bets and spreading risks.

**Time of break and season to come**

An early break gets farmers excited because there is a chance of a good season to come (late breaks can only deliver poor to average seasons). An early break does not guarantee a good season to follow and as such, growers should hedge their bets in management terms unless they have soil types containing stored water from either fallows or significant summer rains.

In 2003, much of the NE wheatbelt had an early break. Some growers read the break as the green light for a good season and sowed early with maximum inputs as suggested by high yield potential packages. Other growers were more cautious. The former group had the best looking crops all season but they harvested low yields and very high screenings. The WADA climate group’s soil moisture maps for April and May 2003 showed the NE wheatbelt as having very low (< 10 percentile of years) stored moisture (as indeed, farmers would know from their local rainfall records or could try to determine from a probe for moisture). It is a real gamble to pull out all the stops without some guarantee of moisture to finish the crop. The cyclone Clare summer rains this year would imply that farmers could pull out all stops if they get an early break – except of course if they are farming shallow soils where there would never be enough stored moisture to finish a big crop.

**Predicting yield potential using growing season rainfall**

There are several levels of entry in this game. They all depend on some projection of the season to come from the good old ‘average’ through to probabilities of certain season types based on historical records or simulated results. And of course there is the ‘analogue year’ approach where the analogue years are derived from various more global indicators (e.g. ENSO or GESS – see David Stephens’s talks). Having come up with a prediction of rainfall (on whatever time step), yield potential is predicted according to different models with different time steps. The problem for the adviser/grower here, is one of what level of approximation is useful for the task in hand? I would suggest that, given the vagaries of the system, for most of them, the models and outputs do not have to be very sophisticated.
Some levels of entry are:

1. For wheat grain, I always used 10 kg/mm of growing season rain. To my mind, if you just want an estimate of what a region could grow, that would be good enough. Have your 3 tonne clubs at Kellerberrin and your 5 tonne clubs at Kojonup.

2. The French Schultz (F/S) equation is commonly used. It adds a bit of sophistication (and credibility?) to 1. above because it allows for a water loss component in the yield/rainfall relationship. Its introduction was instrumental in getting people to think a bit quantitatively about the truism that yields increase with rainfall. But do we only gain value by adding sophistication to our models? In this case, I suggest not because, through its widespread adoption in agronomic circles, the F/S model has been misused and abused by some naive agronomists and advisers.

The F/S equation originally related grain yield to measured water use, but for wider use, it was simplified to take an input of April to October rainfall as a surrogate for water use. The equation takes April to October rainfall, subtracts an intercept (110 mm) and multiplies the result by a water use efficiency (WUE = 20 kg/mm for wheat) to give an estimate of yield.

To better match data, various users then adjust this model. This may be by adding in fractions of pre-April rain or by changing the intercept and slope (WUE), particularly for different soil types, species and regions. All of this is legitimate for some purposes but can get quite out of hand.

A major problem with the use of F/S is that it is sometimes assumed that any observed yields that are less than the F/S prediction, are low because of agronomic constraints. This is often far from the truth. Because there is only one number to summarise a whole season’s rainfall, the F/S yield prediction does not take account of differences in the distribution of any rainfall input. If simulation models (or Wal Anderson 1992) are to be believed, then it predicts yields in the top 95-98 percentile range. And so most yields less than the F/S prediction can occur simply because of the shape of the season rather than any agronomic constraints. So, unless you have some other evidence of agronomic mismanagement, do not blame the grower when his yields do not come up to an F/S prediction!

The F/S model does not take account of excess rainfall which gives either runoff or drainage losses. As a result, actual yields in high rainfall situations fall markedly below the F/S predictions.

The F/S model is too simple to handle soil type, sowing date, temperature and vapour pressure deficit (Perry 1987) effects on yield potential. All of these factors can be used to falsify the F/S approach and so another level of sophistication is needed for more specific yield predictions.

3. Intermediate models such as Geoff Baldock’s Mallee Calculator add in simple soil type adjustments (he moves the intercept according to soil texture groupings). I have a simple water balance/availability model (WAVAIL) which breaks the seasonal rainfall into monthly time-steps to account for the distribution effects. WAVAIL also puts a soil type effect in by limiting the effective monthly rain to the moisture storage capacity (PAWC – bucket size – see later) of the given soil. Other models such as PYCAL and STIN and one from FAO, all adjust water availability using more time-steps (monthly, 10 daily, weekly, daily) and some use soil type adjustments. They convert these water budgets to yield in simplistic ways. All have a role to play for some particular problems. Your problem is whether any of them can help you with your decision making

4. The final class of yield prediction models that I must mention are the daily time-step simulation models (e.g. APSIM and its commercial version, Yield Prophet – see the Harm van Rees talk in these proceedings) which go well beyond just transforming rainfall data and attempt to simulate how the various crops grow in response to soil type, season and management. Such models can run off yield potentials (and also N constrained yields) for most soil, season and management situations.

All of these levels of approach only produce probability distributions (box and whiskers, decile ratings) of potential yields. The problem again in getting useful information out of them, is how to interpret and then use the probabilistic output. If you can not do this then you are better playing the season as it comes and hedging bets!
SOIL TYPE

Soil type is obviously an important factor in determining yield and yield potential. You need only look at one yield map to see that yields vary markedly for exactly the same rainfall and management conditions. True, part of this variation may well be due to management factors and run-on/run-off situations, but many studies (using soil pit observations, correlations through time and space, pre-clearing photos, etc.), have shown that it is due largely to soil type variation. Part of the joy of the PA diagnostician, is to work out if the variation is due to soil type or management because in the case of fertiliser usage, opposite recommendations may depend on the outcome.

In the past year, I have jumped in and out of holes in the ground with a range of farmers and scientific worthies including Bob Gilkes and Tania Liaghati (UWA), Neil Dalgliesh, Yvette Oliver and Mike Robertson (CSIRO), Ian Maling (Silverfox), Nick Middleton, Paul Blackwell, Henry Smolinski, Dave Gartner, Bindi Isbister and Alison Slade (DAWA). We have been looking for reasons why crops perform differently in different parts of the paddock in question. Yield mapping and zoning work which is now in vogue in the cropping areas of WA supports the contention that soil type is the major cause of spatial yield variation. Consistently poor versus consistently high, performing areas on farms are often seen to continue across paddock boundaries and into the adjacent virgin bush. The original land class mapping in WA was based on the height of the vegetation and this seems to be reflected in the size of crops being measured by modern day yield monitors. Although management differences (e.g. rotation and fertiliser history) between paddocks can be large, the zones seem to transcend them.

Studies are in place around the nation to better characterise soil water relations. The GRDC funds a precision agriculture initiative (SIP09) and a subsoils constraints project (SIP08) as well as low rainfall cropping projects (co-ordinated by Geoff Thomas in SA) and a project to undertake soil water training with farmer groups in Australia’s southern and western grain production regions (Dalgliesh, CSIRO). Central to these projects is getting real numbers on the PAWC of soils.

Soil water storage measures

Soil type effects yield in several ways, but the main unmanageable contributor to yield variation is ‘soil moisture relations’. Soil texture and bulk density determine soil water holding capacity which together with crop rooting depth gives the plant available water holding capacity (PAWC or bucket size). Bucket size dictates the potential moisture storage of a soil and interacts with rainfall and water use (evapotranspiration) patterns to give the plant available water (PAW) in a soil at any time. If we are able to characterise these, then we will have gone a long way towards understanding the spatial variation in water limited yield potential.

For example, by using simple calculations, you can explain the different degrees of haying off or maturity in a crop in spring as you move around a paddock. The time between rainfall events before a crop will start to wilt and eventually to die can be approximated for different soil types by knowing simple soil water storage characteristics (Anne Hamblin 1982). Having a rough idea of a crop’s water use per day at different times of the growing season and knowing the amount of PAW for the rooting depth gives the following table.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Water use PAWC mm/M</th>
<th>July 1.0 mm/day</th>
<th>August 1.8 mm/day</th>
<th>September 2.4 mm/day</th>
<th>October 1.5 mm/day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>G</td>
<td>S</td>
<td>G</td>
<td>S</td>
</tr>
<tr>
<td>Medium sand</td>
<td>33</td>
<td>12</td>
<td>33</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>Fine sand</td>
<td>60</td>
<td>20</td>
<td>60</td>
<td>11</td>
<td>33</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>90</td>
<td>30</td>
<td>90</td>
<td>17</td>
<td>30</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>120</td>
<td>40</td>
<td>120</td>
<td>22</td>
<td>66</td>
</tr>
<tr>
<td>Loam</td>
<td>170</td>
<td>57</td>
<td>170</td>
<td>31</td>
<td>94</td>
</tr>
</tbody>
</table>

Table 1. Number of days for growth (G) and survival (S) per metre of rooting depth of a fully wet profile (after Hamblin 1982)
You would halve these numbers for sub-clover because it does not root much below 50 cm and you would double them for species like lupins, serradella and sometimes wheat, on deep sand plain soils because those species can root to beyond 2 metres in the absence of subsoil constraints.

**Can we improve soil water storage?**

Not much can be done to change soil moisture storage properties apart from adding high moisture holding ameliorants such as clay, peat or ash, and/or by building up soil organic matter.

Many agronomists and growers see the retention of organic residues and the build up of soil organic matter as a means of turning poor sands into fertile soils. Though the idea is sound, the process will be very long term because you have to grow organic matter to build up organic matter and you have to retain it rather than respire it away. Sandy soils with low clay content do not protect organic matter from break down very well.

To lift soil organic carbon by 0.1 per cent you have to retain of the order of 1.5 t/ha carbon per 10 cm of soil. This equates to about 3 t/ha of organic matter and because one half to two thirds of organic inputs are lost to respiration during the break down of residues and root material, you need to retain 6-9 t/ha EXTRA organic materials to build on your existing soil OC per cent (which is being maintained by your current cropping practices). If soil organic carbon holds 10 times its weight as water (unlikely though some commercial products may), then an extra 1.5 t/ha organic carbon would hold an extra 15 t/ha of water which equates to an increase in water holding capacity (though not necessarily PAWC) of 1.5 mm. Do your own sums on how long it would take to significantly improve the soil water holding characteristics of your poor sands simply by growing crops and pastures and retaining residues.

Adding 100 t/ha of clay which may hold 30 per cent by weight of water to the soil, will only increase the soil water storage by 30 t/ha or 3 mm. However it may well improve wettability and infiltration and it could well pin a water column to the surface and so reduce leaching through drainage. Deep ploughing to mix subsoil clay with surface sand can change the water distribution in the profile but does little for total store moisture unless soil porosity and/or bulk density is changed significantly.

**Infiltration, drainage and runoff**

Whether rainfall events add significantly to soil moisture storage depends on a lot of factors such as rainfall intensity and slope (unmanageable, though contouring is possible) and manageable factors such as infiltration which may be constrained by surface sealing and wettability. Obviously if rainfall does not infiltrate, it either ponds or, more often, runs off to another part of the landscape. Good soil infiltration rates are of the order of 20-30 mm/hour so intense rainfall events of any duration can result in run-off. An event of 50 mm in an hour will result in half the rainfall adding nothing to stored soil moisture. Some storms have delivered 100-150 mm in a couple of hours resulting in flooding of low lying parts of paddocks or waterways because 50-100 mm has run off.

Better infiltration can be achieved by reducing surface sealing with appropriate amendments (Hamza, etc.), by reducing non-wettability (claying, rotations, wetting agents) and even by the use of furrows and contour farming. Not much can be done about rainfall intensity patterns – except to use failsafe contour banks to prevent erosion problems from extreme events.

On some soils, better infiltration has a downside in the form of higher leaching of nutrients, drainage beyond the root zone and recharge of the water table.

**SO WHAT IS THE USE OF BETTER RAINFALL AND SOIL TYPE INFORMATION?**

‘So what?’ you may well ask

Can knowledge about soil water holding capacity help us in our management? It obviously can because yield potential determines how we manage crops and particularly, how large the inputs should be. Low yield potential zones and soils will be dropped out of cropping first if not due to the cost/price squeeze, then certainly due to the encroaching effects of drier seasons associated with climate change (if you believe that!).
If it rains all the time, bucket size does not matter (except for the leaching of mobile nutrients) – you can produce good crops on shallow soils. However, if you have droughts as we most assuredly do at the end of each season in WA, then soil moisture storage is crucial. A simple model of grain fill in wheat requires 40 days of stress free growth between anthesis and maturity to reach yield potential. In the last 25 days of that period, grain size increases at about 2 mg/day so that, for each day of stress, yield is reduced by 4 per cent. Crops using 2 mm/day (probably more?) in that post anthesis period, need at least 80 mm of PAW to attain yield potential in the absence of rain.

Although WA has soils of notoriously low PAWC, our reliable (vis-a-vis other parts of Australia) winter rains mean that early season growth of crops is rarely impeded by post seeding and mid-season droughts though they do seem to be more frequent in recent years. Take our soils to the eastern states and you find that they are not farmed with annuals as we do here, simply because the rainfall is irregular and unpredictable such that crops would often fail on them while crops on higher PAWC soils flourish.

In some regions (e.g. northern and eastern fringes of the WA agricultural areas, Eyre peninsular in SA), and on some shallower or heavier soil types, excessive early moisture use by a crop may leave very little moisture for grain fill. An analysis of rainfall may show that this happens consistently enough for some growers that they should have a management strategy aimed at producing poor early vigour of the crop. Such strategies include lower seeding rates, wider row spacing, lower and later nutrient inputs as well as more frequent cropping to reduce soil nitrogen levels. The problem with such strategies is that in good years and on deeper soils, lower early vigour will lead to lower yields than if a big crop had been set up early. Responses to deep ripping in WA illustrate this point. Large, positive, vegetative and grain yield response to deep ripping on soils with traffic pans, are regularly seen in the greater wheatbelt of WA. On the eastern and northern fringes, positive vegetative responses are equally as common, but these often do not translate into positive grain yield responses and can even give negative responses.

Where rainfall is low but PAWC is high, perhaps fallowing becomes an option such that crops use two years rainfall input rather than one. Fallow effects can be positive in a wide range of situations – not just from fallowing heavy soils in wet years. We got a half tonne response to brown manuring a lupin crop in 2002 (drought year) in the following (wet) wheat year at the CCS in Northam. It was not an N response (it only responded at the end of 2003) and it was not a cleaning crop effect because all 2002 plots were lupins – the non brown manure crop was taken through to harvest.

In the absence of useful predictions of season, but knowing they are variable, a strategy for using fertiliser nitrogen is to fertilise for a decile 3 year yield potential at seeding and then, if the crop or season looks like it will be significantly better, apply more nitrogen as the season progresses. The strategy is to be flexible and play the season if possible. For post tiller N applications, you would give priority to high yielding areas in the crop paddocks and only in seasons and soils where PAW is high or promises to be high.

If you understand PAWC and PAW for your soils you can make better decisions about opportunistic summer cropping options. Using soil moisture in the summer can have positive (de-waters water logging situations) and negative (reduces PAW) effects on the following winter crop. This is independent of the dollar and environmental considerations.

**PRICE VARIATION**

It is real, it is largely unpredictable and it is large. About 15 years ago, we ran a series of 15 trials looking at different tactics/strategies for giving fertiliser advice. Our rational economic approach determined an optimum rate based on costs of fertiliser and prices for the crop at the beginning of the year and we determined the most profitable rates after harvest. In the 3 years of the trials, the price of wheat plummeted, stayed the same and rose spectacularly between sowing and harvest with up to $150 differences in returns to fertiliser depending on which price was used!

I will leave it to the experts and/or economists to tell you how best to manage that uncertainty, but I still can not get one to tell me I was rational in investing in my children’s education.
PERSON TO PERSON VARIATION

The biggest variable affecting management in our agricultural systems, is farmer to farmer differences in their approach to farming. They too are quite unmanageable but, in recognising the variation exists, we should approach management decision support in a different way.

While economists like to believe that farmers are economically rational businessmen, farmers differ markedly in their skills, risk aversion preferences, economic situations, spending preferences and on farm resource mixes. Face several growers with the one problem and they will find a range of solutions according to their individual perceptions of their overall situation.

In 1978 I would have given two farmers the same fertiliser advice because they were in the same biological response situation. When faced with my best bet of yield and dollar responses to fertiliser for good, average or bad seasons, one grower chose to put on high inputs every year, because ‘the returns in the good years well and truly pay for the break even and losses from over-fertilising for the average and poor seasons’. The other grower chose to fertilise every year at a level which made most dollars in the crook years, because this was when he most needed a positive cash flow. He was not worried about the fact that his crops were under-fertilised and did not give maximum returns in the good years because he still made a profit then. If these growers make their choices given the best information available, then both strategies are correct, despite the fact that we might independently determine a different, dollar maximising, strategy for the long run or the whole industry, which takes account of the frequency of good bad and indifferent seasons (e.g. Chris Carter – this CU). Individual growers have different priorities for how they want to spend their dollars at any time and these priorities can change through time for one individual depending on things like age and stage of life, runs of seasons and liquidity.

Advisers should not use ‘one size fits all’ packages or approaches. Rather they should educate their clients to the full range of management options available on a given issue. They should also provide ‘sensitivity analyses’ by discussing the consequences in production and dollar terms of any management strategy their client chooses to follow, in the context of ‘what happens if’ the season is different (e.g. Harm van Rees and Yield Prophet, this CU) or prices change markedly.

In short, advisers and consultants should highlight the management options available to their clients, do sensitivity analyses which in effect, tell the client ‘what happens to production, quality and profitability, if he chooses a certain management option…’ and show how that changes with input levels, season, soil type, prices going up/down, etc.

Do not impose ‘optimum’ management strategies because there is no single optimum anything – except in hind-sight.

CONCLUSION

Season, soil type, prices and people (your clients), all vary considerably and contribute markedly to crop productivity and profitability. We can rarely interfere to change that variability but there are some limited management actions which can be taken in response to a better understanding of how the factors work and interact with each other.

KEY WORDS
season, soil type, people, variability, precision agriculture, subsoil constraints, risk management

ACKNOWLEDGMENTS
Thanks to my many colleagues, GRDC for project funding over the years and DAWA for my salary.

Paper reviewed by: Dr Michael Robertson
Review of climate model summaries reported in Department of Agriculture’s Season Outlooks

Meredith Fairbanks, Department of Agriculture, Western Australia, South Perth

KEY MESSAGES
At Crop Updates since 2001, ENSO (El Niño Southern Oscillation) predictions and rainfall outlook produced from DAWA experimental ENSO Sequence System (ESS) for the coming growing season (May to October) are presented. This paper reports that ESS successfully selected two of the five ENSO states and seasonal rainfall of 2001 to 2005.

The Department of Agriculture’s Climate Risk and Opportunities Project produces a series of Growing Season Outlooks (GSO) available on DAWAs website (www.agric.wa.gov.au/climate). Presented here are three month rainfall outlooks sourced from six climate models. By looking for consensus (agreement) in the outlooks, the reader can feel more confident of the outlook. The three month outlooks were reviewed over 2003 to 2005, and it was found that there was little consensus amongst models, with only six out of 34 outlooks successfully indicating rainfall.

AIM
The aim of this paper is to review the seasonal outlooks given at Crop Updates, and the three month rainfall outlooks which are provided throughout the year in the GSO.

METHODS
Seasonal outlooks
The experimental ESS predicts ENSO state, and gives a rainfall outlook for the growing season (May to October). The value of these outlooks can be ‘tested’ by comparing the predicted ENSO state (El Niño, neutral or La Niña or a combination) and rainfall outlook (below average, average or above average or a combination) to the actual ENSO state and rainfall for May to October 2001 to 2005. This can give us an idea of how well ESS predicts ENSO state and rainfall in February.

Three month rainfall outlooks
The GSO lists outlooks from six climate models. The original probability outputs from the models are classified by DAWA researches into above/below median or no preference (even odds). The term even odds, does not signify median rainfall is forecast, but that there is no strong signal indicating either a dry or wet period. To obtain the most benefit from these models, we look for outlook consensus, where half or more of the outlooks are the same (either below or above median rainfall). So how many times was there outlook consensus (January to December 2003 and 2004, and January to October 2005), and did the outlook match the actual rainfall?

The six climate models listed in the GSO are; the operational models from Bureau of Meteorology (BoM) and Queensland Department of Natural Resources and Mines (QDNR), and the experimental models from International Research Institute (IRI), European Centre for Medium Range Weather Forecasts (ECMRWF), Experimental Centre for Climate Prediction (ECPC), and DAWA (ESS). ESS outlooks are either for below average, average or above average rainfall, while all other models give either a below or above median outlook (or even odds).

RESULTS AND DISCUSSION
Seasonal outlooks
Over 2001 to 2005, ESS successfully picked the ENSO state and rainfall twice (Table 1). ESS also partially picked ENSO state a further two times and rainfall a further three times. A partial pick either means that ESS gave a combined outlook (e.g. La Niña –neutral, average to below) and the actual climate fell into one category (e.g. neutral, below), or the rainfall outlook is one category (e.g. average) and the actual rainfall was a combination (e.g. average to above). ESS successfully picked the El Niño of 2002 and partially picked the corresponding below average rainfall.
Three month rainfall outlooks

Many outlooks offered little practical guidance, as the outlook seldom varied from even odds. When either a below or above median outlook was given, only 14 of the 34 seasons reported here had outlook consensus. Of these, only six outlooks matched the actual rainfall, with five of the rainfall events being below average. Models contributing to the correct outlook consensus were the ECMRF, ECMPC (all six times), ESS (four times), IRI (three times) and QDNR (once) (Table 2).

Individual outlooks had more success in indicating rainfall than the outlook consensus. Of note ESS indicated 15 of the 34 rainfall events (11 average, 4 below average). ECMRF indicated 8 rainfall events (7 below average, 1 above average) and ECMPC indicated 7 events (5 below average and 2 above average).

Table 2. Three month rainfall outlooks compared to actual rainfall for 2003, 2004 and 2005. Rainfall outlooks for the first 5 models are either below median, above median or even odds. Shading of outlook consensus indicates outlook consensus matched actual rainfall. Where underlined, individual outlooks matched actual rainfall. Indications where model has skill, based on model's own validation. Note limited data for ECMC for 2003
CONCLUSIONS

Seasonal outlooks
This review found that the Seasonal Outlooks presented at Crop Updates in February give a good indication of the following growing season. This is supported by a previous review by Tennant and Fairbanks (2004), who found that ESS successfully picked 13 of 16 ENSO states for the period 1988 to 2003. ESS has significant skill levels at predicting rainfall for the WA wheatbelt (although no skill for the Esperance region). The main advantage of ESS is the lead time of 3 months (February to May). Longer lead times are available, with seasonal outlooks accessible from the previous November.

Three month rainfall outlooks
Outlook consensus occurred so rarely that they are of little use to readers, and therefore three month rainfall summaries will not be continued in any future GSO. Outlook consensus, however, did pick five of the eight below average rainfall events. The outlook consensus was wrong eight times, and in July 2004 indicated an above average event when below average rainfall occurred. If farmers have acted on this outlook by increasing inputs, they would have lost a considerable amount of money. The outlook consensus in March 2005 was below average, and farmers thinking it would be a dry three months, may not have been ready for the wet start and early break which occurred.

As outlook consensus failed to indicate three month rainfall events, individual model outlooks may be reported in the GSO. Experimental models such as ESS and ECMRWF are under constant review and development which should further improve the skill and therefore confidence in outlooks.

REFERENCES

ACKNOWLEDGEMENTS
Thanks to Dr David Bowran for editing an earlier review of the models. Funding for this research was from Ministerial funding ‘investment in short term climate forecasting’.

Paper Reviewed by: Ian Foster and David Stephens
Mapping the frost risk in Western Australia
Nicolyn Short and Ian Foster, Department of Agriculture, WA

KEY MESSAGES
An improved network of temperature observations over the past 15 years has been used to develop maps of frost risk. These can be used to indicate the spatial variability of frost occurrence in southern Western Australia.

Preliminary studies of time series data has shown some increase in the number of frost occurrences over the past 15 years for some locations, while the main trend is for a decrease in the number of frost events.

AIMS
- To present updated information on the spatial occurrence of frost in the grainbelt of WA.
- To investigate any trends in the number of frost events over recent years (this is work in progress).

METHOD
Frost mapping
Daily minimum temperatures from 73 frost prone locations in agricultural areas and the South West were obtained from the Patched Point Database (Queensland Department of Natural Resources and Mines) and Department of Agriculture weather stations for the years 1990 to 2004. The Department of Agriculture software package Climate Calculator was used to derive the number of days that the minimum temperature was 2°C or less. Monthly average occurrence was calculated for July to October. The Client and Resource Information Service produced mapped this data for each month.

Frost occurrence for specific locations
A selected sub-set of the 73 locations from around the grain belt of Western Australia were analysed for trends and differences between last 15 years compared with 1976-1991, as a preliminary study. Locations studied were Bencubbin, Beverley, Corrigin, Dalwallinu, Katanning, Lake Grace, Merredin, Morawa, Mullewa, Narrogin, Ongerup, Ravensthorpe and Wongan Hills. Trend fitting and statistical significance testing was performed using generalised regression analysis with a Poisson distribution in Genstat. This is work in progress and other frost prone locations will be analysed in the future.

RESULTS
Frost mapping
The frost risk maps do not show the actual observation of frost, but use the occurrence of a minimum temperature 2°C or less as an indicator of the likelihood of frost. Air temperature is recorded at a height of 1.25 metres, so temperatures of around 2°C generally equate to 0°C or less at ground level, if there is minimal air movement. An example of the September frost risk map is shown here. This indicates that the greatest
risk from frost occurs in the central and eastern agricultural regions, with a progressive decrease in risk northwards and near the coast. Note that the regions coloured white can still experience frost in September; but the risk in any year is lower than other regions. Care needs to be taken in interpreting the map, as small-scale variations are not shown, such as those on a farm scale. Average frost risk maps for July, August, September and October can be found at http://www.agric.wa.gov.au/climate.

**Frost occurrence for specific locations**

Over the past 50 years the general trend is for a decrease in the number of frost events. An example time series is shown for Bencubbin in Figure 2. Although this is consistent with the influence of global warming, recent decades show an increase in the number of frost events.

![Figure 2. The number of frost days (minimum temperature 2°C or less) at Bencubbin during July to October, for all years of record, with a very weak correlation of 0.0385.](image)

In this preliminary study, the number of potential frost events over the past 15 years (1991-2005) had been compared with those over 1976 to 1990. An increase in the number of frost events during July, August, September and/or October was apparent at Morawa, Wongan Hills, Dalwallinu, Bencubbin, Mullewa, Narrogin, Lake Grace, Katanning, Ongerup and Ravensthorpe. Figures 3 and 4 show examples for Bencubbin and Lake Grace. There was little or no change in the average number of frost events at Merredin, Beverley and Corrigin.

Bencubbin shows some increase in the number of possible frost days during August and September and little change during October (Figure 3). Statistically there is a weak significant (p = 0.039) difference between 1991-2005 and 1976-1990 data for the four months.

Lake Grace shows some increase in the number of possible frost days during July and August and little or no change during September and October (Figure 4). The difference between 1991-2005 and 1976-1990 data periods for the four months is significantly different (p < 0.01).

Care needs to be taken in interpreting these preliminary results as only a few locations have been studied and as such other locations may show different trends.

![Figure 3. Bencubbin weekly average number of days minimum temperature was 2°C or less during July, August, September and October during the past 15 years (1991-2005) and 1976-1990.](image)
CONCLUSION

Frost mapping

The updated maps of frost occurrence show central and southern agricultural regions to have the highest occurrence of frosts, with coastal and northern agricultural areas receiving fewer frosts. The maps for July, August, September and October are available at www.agric.wa.gov.au/climate.

Frost occurrence for specific locations

The preliminary study of trends of frost events has shown a number of locations where there has been some increase in the number of frost events in recent years. The mean occurrence of frost events over the most recent 15 years is significantly greater than the previous 15 years at some locations. These recent increases have occurred paradoxically in a general background of decreasing frost risk over the past 50 years. It is intended to extend the study to other locations in southern Western Australia.

KEY WORDS

frost, maps, frost risk, minimum temperatures

ACKNOWLEDGMENTS

We would like to thank Tony Leeming in the CRIS group for compiling the frost risk maps.

Project No.: Climate Risks and Opportunities Project (CROP)
Paper reviewed by: David Beard
35 kg/ha.day and other myths
James Fisher, Doug Abrecht and Mario D’Antuono, Department of Agriculture

KEY MESSAGES
We all know the rule of thumb; the yield declines by about 17 to 35 kg/ha for each day that sowing is delayed after the optimum time. Do such rules of thumb help with managing crops in variable seasons, or should we be smarter about the advice that is given? To date the ability to be more precise has been limited by the relative paucity of factorial data across sowing times and management. This is no longer the case as we have validated crop models and powerful computers. Analysis of 105 years of simulated data for wheat production at Merredin reinforces some of our preconceptions, but challenges the value of simple rules of thumb.

In this paper we will outline the analysis that we have conducted and demonstrate how rules of thumb based on the average response miss the important detail about types of responses, managing for different seasons and deciding what matters.

BACKGROUND
Time of sowing is one of the key factors determining the yield potential of wheat in the dry-land agriculture of Western Australia (Anderson et al. 2000). This is highlighted by rules of thumb such as the average yield decline after the optimal sowing time, which is 35 kg/ha.day for the north-east and eastern wheatbelt. Variability in the timing and distribution of rainfall is the key determinant of variable productivity of crops in the WA wheatbelt and brings into question the usefulness of recommendations based on average responses. The availability of crop simulation models and powerful computers should provide us with tools to undertake a more comprehensive analysis than is possible using field data alone. Can we use these tools to do better than on average?

METHOD

Data
Wheat yield was simulated using the Agricultural Production Systems Simulator, (APSIM). The APSIM model has been validated against a range of data sets from the WA wheatbelt (Asseng et al. 1998a; Asseng et al. 1998b; Fisher et al. 2001; Asseng et al. 2002).

Scanlan et al. (2003) used APSIM v1.55s to produce a database, WA Wheat, of wheat production in response to a factorial arrangement of agronomic options for 102 years (1900-2001) and 20 locations in WA. We used a subset of data from the WA Wheat database, updated to include recent years, to examine the agronomic factors that impact on yield and how they vary with season. These data were for wheat grown at Merredin on a yellow deep sand and a shallow loamy duplex (‘light’ and ‘heavy’ soil) based on a factorial construction of 2 rotations (continuous wheat and pasture-wheat), 2 levels of stored soil moisture at the beginning of April (lower limit and half-full profile), 2 ‘varieties’ (long and short season), 6 times of sowing (25 April, 10 May, 30 May, 5 June, 15 June, 5 July), 4 rates of nitrogen at sowing (0, 30, 50, 100 kg N/ha), 3 rates of nitrogen at four weeks after sowing (0, 30, 50 kg N/ha) and 3 rates of nitrogen at ten weeks after sowing (0, 30, 50 kg N/ha). This gave 1,728 records for each year and a total of 181,440 records.

The yield decline with time of sowing for individual years was examined using a further subset of these data for 1960-2004. This subset was for a single ‘treatment’ (continuous wheat rotation, lower limit at the beginning of April, 50 kg/ha nitrogen at sowing, 30 kg N/ha four weeks after sowing and 0 kg/ha nitrogen at ten weeks after sowing) and was factorised only by variety and time of sowing.

Analyses
An analysis of variance (ANOVA) was carried out on the entire dataset to identify which factors or factorial combinations were the dominant sources of variation in the data. For each year, ANOVA of the yields was used to fit main effects and first-order interactions for the 7 factors. The variation in
yield for a sample year from each of the groups was visualised using trellis plots. These analyses and summaries were performed with the R Statistical System (2004).

RESULTS

Yield variability

Variance components accounting for more than 2 per cent of variance for simulated wheat yield on yellow sand at Merredin for 1900-2004 were: year (29%), year*time of sowing (20%), time of sowing (29%), time of sowing*variety (4%), year*variety (3%), year*stored soil water (2%). Of the total variance in wheat yield, variance due to year or interactions between year and agronomic factors accounted for 55 per cent, variance due to factors determined by sowing (rotation, stored soil moisture, time of sowing) and their interactions accounted for 24 per cent and variance due to factors determined from sowing (variety, nitrogen fertiliser) and their interactions 5 per cent of the total variation. The residual variance (second order and higher interactions) was 9 per cent of the total variance.

The same analysis for simulated wheat yield on shallow loamy duplex at Merredin for 1900-2004 found that the variance components accounting for more than 2 per cent of variance were: year (26%), year*time of sowing (16%), variety (8%), stored soil water (11%), time of sowing (20%), time of sowing*stored soil water (4%), year*variety (3%), year*stored soil water (3%). Of the total variance in wheat yield, variance due to year or interactions between year and agronomic factors accounted for 48 per cent, variance due to factors determined by sowing (rotation, stored soil moisture, time of sowing) and their interactions accounted for 30 per cent and variance due to factors determined from sowing (variety, nitrogen fertiliser) and their interactions 8 per cent of the total variation. The residual variance (second order and higher interactions) was 6 per cent of the total variance.

Figure 1. The change in yield of wheat with time of sowing for long (l) and short (s) season varieties on a yellow deep sand at Merredin (1960-2004). Data are simulated yields from the WA Wheat database which were generated using the APSIM model 1.55s.
Figure 2. The change in yield of wheat with time of sowing for long (-o-) and short (-△-) season varieties on a yellow deep sand at Merredin (1960-2004). The calculated break of the season for each year is indicated by the vertical lines. Data are simulated yields from the WA Wheat database, which were generated using the APSIM model 1.55s.
Yield decline

Over the 45 years examined, the average yield penalty was 16 kg/ha/day for the long season variety and 18 kg/ha.day for the short variety on the yellow deep sand (Figure 1). The corresponding values for the shallow loamy duplex were 20 kg/ha.day and 28 kg/ha.day for the long and short varieties respectively. There was considerable variability around these mean values. The yield decline after the optimal sowing date for the individual years varied from 0 to 50 kg/ha.day (Figure 2).

DISCUSSION AND CONCLUSION

Analysis of this large set of simulated data highlights well-known points about crop production in WA. These include the large impact of season and its interactions on the range of possible yields at a location; average yield decline after an optimal sowing date and greater variability in yield on ‘heavy’ compared to ‘light’ soil (it is import to note that the soils were examined independently in this analysis).

The most important factors impacting on the range of possible yields in this environment are those that are determined at or around sowing, with time of sowing being particularly significant. That said there is large variability between years in the response of yield to time of sowing. While there is a tendency to a decline in yield after the break, the magnitude of this decline varies greatly and there were years in the subset examined in which the change in yield with time of sowing was flat, variable or increased (such as 1963, 1965, 1971, 1976, 1977, 1983, 1985, 1987, 1991, 2000 and 2002).

These results illustrate the folly of focussing on an average rate of yield decline. While there is undoubtedly a strong tendency to a yield decline with later times of sowing in a dry-land environment with strongly seasonal rainfall, growers that take the first opportunity sowing will not always see a yield benefit. Other factors, such as frost risk, disease risk, weed control or input costs, should be bigger considerations in years when the response to time of sowing is flat, variable or gradual. The challenge is to identify in advance the years in which time of sowing is all important and when it is less so. This is the focus of our on-going analysis.

Conclusion

The rule of thumb that yield declines by 35 kg/ha.day for wheat crops in the north-east and eastern wheatbelt sown after the optimum time bears up well to general scrutiny. However, like all such rules that capture the average response from a distribution, it misses out on the important variability that is the reality of farming at a location in a specific season. A more complete picture is obtained from an analysis using a balanced dataset, which is possible due to the power of a large factorial of computer-generated data. This highlights the important, complimentary relationship between information from models and principles and specific cases that are determined by laboratory and field research.

KEY WORDS

wheat, optimal sowing time, yield, simulation model, APSIM, seasonal variability, crop management

REFERENCES


**ACKNOWLEDGMENTS**

WA Wheat was developed in GRDC project DAW 632. Continued development has occurred with assistance from the Value Added Wheat CRC and National Whopper Cropper project in the MCVP.

**Project No.:** GAS (Quantifying and Predicting Agricultural Systems)

**Paper reviewed by:** Bill Bowden
Gaining with growers – Lessons from a successful alliance of WA Grower Groups

Tracey M. Gianatti, Grower Group Alliance

KEY MESSAGES

- After three years of operation, the single most important success factor of the project is that it began, and has remained, a grower group driven initiative.
- A clear purpose is paramount for the successful development of partnerships between grower groups and industry.
- The creation of space for two-way interaction allows personal networks to expand and sustainable partnerships to develop.
- Starting small and tangible gave the project quick runs on the board. It connected the grand vision to the local level of the member grower groups and made it inclusive.

INTRODUCTION

Over the last ten years, there has been a rapid increase in the number of grower-led groups across Australia engaging in research and extension. The most successful groups were those that took responsibility for planning, implementing and monitoring their own activities. Growers wanted to have more control over the information they needed and the way it was delivered. There was a move away from linear 'top-down' approaches from scientists to farmers, towards extension methodologies that emphasised information flows, adult learning principles and participation by stakeholders (Marsh and Pannell, 2000).

In 2002, a number of locally focused groups received funding from the Grains Research and Development Corporation (GRDC) to form the Grower Group Alliance (GGA). The aim of the Alliance is to enable growers to access the latest information and research which will allow them to make the best possible decisions for their farming businesses. It provides the opportunity for collaborative projects between grower groups across the State. By working together, it allows the groups to maintain their local focus, yet also operate with a ‘critical mass’ to take action on a range of issues which they would not have been able to do individually.

The GGA project has always placed a high priority on maintaining independence. The funding is administered by a grower group, and growers have the majority vote in setting the strategy of the project. In its three years of operation, the project has developed a strong profile within Western Australia and will consider involvement in any opportunity that adds value to its grower member activities.

RESULTS

In this section, lessons learnt from the past three years of operation of the Grower Group Alliance project are outlined.

A GROWER GROUP DRIVEN PROJECT

The successful initiation of the GGA project in 2002 is one of the few examples in WA where funding from the GRDC was awarded directly to a grower group. Prior to this, funds were generally awarded to State agencies who then worked with grower group collaborators to complete project milestones. By receiving their own budget, the groups became responsible for addressing their own issues. Together, they use a participative and inclusive delivery mechanism that allows each grower group to have input into the project aims and activities, and then deliver the outcomes to group members.

To manage the GGA project, a Reference Group has been established, consisting of representatives from all the project stakeholders. This group meets twice a year and the grower group majority is able to recommend and direct the project activities to ensure the project remains relevant to its grower.
Outside of meeting times, the GGA project coordinator is able to receive feedback from growers through the executive officers of the core grower groups.

The grower group executive officers are a vital link in the operation of the project. They provide the GGA coordinator with updates of grower group activities occurring in their region, communicate the results of their group’s trial and demonstration programs and pass on requests from grower members for new information or opportunities. The GGA coordinator is then able to share this information with other members of the network. Researchers and agribusiness use the GGA coordinator as a ‘portal’ to access the grower group members for feedback on a variety of issues.

As the profile of the GGA project increases, the number of requests for grower feedback has increased exponentially. The executive officers can not keep up with the demand and the growers do not have time to respond, especially during peak labour periods through the year. As a result, the GGA has streamlined this process by introducing an ‘Expression of Interest’ (EOI) form. Potential collaborators who have new products to trial or can offer project opportunities for grower groups are encouraged to complete an EOI.

GROWER GROUPS DESIGNED PURPOSE

At the beginning of the GGA project, a clear and agreed purpose was created through consultation with representatives from all grower group stakeholders. Like many grower groups, GGA members had an active input into the strategic and operational direction of the project. Having clearly defined problems that are understood by the membership contributes to the success of farmer-driven groups (Campbell, 1992).

Once the purpose was established, two outcomes for the project were identified. The project then developed tightly focussed objectives suited to the available time frame. The purpose and outcomes of the project are reviewed each year and if necessary, renegotiated with grower group representatives at the annual GGA Forum. This is an inclusive process that ensures individual groups know and understand the benefits of participating in the GGA project.

THE POWER OF NETWORKING

The GGA consciously creates space for two-way interaction rather than just ‘pumping more down the pipes’. It does this in a variety of ways, but principally by encouraging networking to occur between GGA members. Networks are strengthened through visits by the project officer to all fifteen GGA member grower groups at least twice each year. Staff and grower representatives from the groups meet once a year in person at the GGA Forum. In addition, grower groups visit each other on bus tours during Spring. Ideas and experiences are passed on from one group to another. A tangible result from GGA groups working together are two successful study tours to Interstate and overseas destinations with participants drawn from several different grower groups.

The Grower Group Alliance project was created to improve the communication between farmers, researchers and industry. According to Colliver (2000), one thing that will produce faster evolution of sustainable farming systems is a better flow of ideas and information. Responsiveness to this communication is determined by being able to ‘match’ the available information with what members of the network want. This requires ‘an understanding of how different communities interact and communicate’ (Andrew et al. 2005). The GGA coordinator works to gather information on the needs and interests of the different groups to improve the process of understanding. In doing so, the coordinator could be described as a ‘knowledge broker’. The coordinator acts to ensure that a network is created that maintains itself without the coordinator being its hub.

To develop a culture of information sharing, the project coordinator works with the grower group executive officers to increase understanding in the research community of how grower groups operate and how to engage them in research projects. For example, a key message from the GGA has been that researchers who wish to include a grower group as a partner in a research project should involve the group at the project design stage, not contact them the day before a proposal is completed and the funding application is due.
START SMALL AND TANGIBLE

In the beginning, the project concentrated on providing benefits at the local level with production of small and tangible outputs (Table 2).

Table 2. Examples of tangible benefits produced in the initial stages of the project

<table>
<thead>
<tr>
<th>Exchange of grower group contact details</th>
<th>Coordination of a calendar of events</th>
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<tr>
<td>Annual grower forum</td>
<td>Exchange of trial result books between groups</td>
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<tr>
<td>Exchange of grower group newsletters</td>
<td>Travelling grower workshops</td>
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<tr>
<td>Production of field day booklet covers</td>
<td>Training for executive officers</td>
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These were small things which made a big difference. Once groups began receiving information about each other, they realised that they were not in competition, and by working together, they could achieve a lot more. Small benefits increased group confidence to share ideas with other groups. For the project officer, gaining some early ‘runs on the board’ was important to reassure project partners that the Alliance was a feasible prospect.

The two most successful activities are the calendar of events and the travelling workshops. The GGA calendar of events is designed to reduce the clashes between grower group and researcher events. The travelling workshops are initiated and organised by grower group members and travel to five or six locations around the State. It is a very useful way to address key issues of the season faced by all growers.

The overarching structure of the GGA allows it to provide economies of scale for its grower group members in three main ways:

1. Source and deliver training for grower committee members and staff – Previous topics include corporate governance and evaluation of projects.

2. Leverage of funding dollars – A project with several grower group collaborators working together has a greater chance of receiving funding than a number of individual projects submitted by different groups.

3. Organisation of study tours – The GGA project has organised two study tours assisted by its ability to involve growers from a range of groups across the wheatbelt.

PARTNERSHIPS FOR RESEARCH AND EXTENSION

A key characteristic of successful grower-driven groups is their ability to build constructive partnerships (Campbell, 1992). Core grower group members of the GGA are extremely successful in attracting public and private-sector researchers, economists and extension agents to help address their local issues. The role of the GGA is to actively add value to these partnerships by linking groups to people with the required expertise. The partnerships formed allow groups to progress their locally driven research and development programs and are essential for growers to deal with the increasing complexity of farming systems in WA. They allow growers become ‘active generators of new knowledge applicable to their local context’ Andrew et al. (2005).

Improved networking and partnerships has led to benefits such as members of grower groups being consulted about their ideas for the future directions of research, and more specifically, what research and extension activities they would like to see conducted in their region. A change found over the three years of the project was that as the groups’ knowledge of research activities increased, they were able to make more informed decisions about which specific researchers they could approach to conduct work in their region or invite to present findings at grower events.

The GGA project has enabled many new partnerships to form between grower groups across the State. These may be informal and brief, such as the joint hosting of a workshop or field day, or more formal and long term. Marsh and Pannell (2000) state that ‘structures and processes that encourage cooperation and coordination in a commercialised environment are needed’. Over the past three years, the GGA project has developed a framework that allows growers, researchers and agribusiness
to formally interact and network with each other on many different levels. Local partnerships allow each group to conduct their own program of trials and demonstrations. Regional partnerships between grower groups increase information sharing directly between growers. Results from Statewide partnerships are distributed throughout the GGA network allowing all members to benefit from work conducted at geographically distant locations. The transparent operation of the network means groups are able to form partnerships and extract benefits from the network only when they choose to be involved.

CONCLUSION
After three years of operation, the single most important success factor of the Grower Group Alliance project is that it began and has remained a grower group driven initiative. Contributing to the project’s success is a clear purpose. In addition, the GGA consciously creates space for two-way interaction rather then just pumping more down the pipes. It does this in a variety of ways, but principally by encouraging networking to occur between GGA members.

Finally, the GGA project has developed a framework that allows growers, researchers and agribusiness to formally interact and network with each other on many different levels. The transparent operation of the network means groups are able to form partnerships and extract benefits from the network only when they choose to be involved.

KEY WORDS
grower group, interaction, communication, participation

ACKNOWLEDGEMENTS
The Grower Group Alliance project is funded by the Grains Research and Development Corporation.

Project No.: MIG00008
Paper reviewed by: Paul Carmody

REFERENCES


WA Agribusiness Trial Network Roundup – 2005

Paul Carmody, Local Farmer Group Network, UWA

KEY MESSAGES

A pilot project was introduced by GRDC in 2005 to help enhance the communication and dissemination of research to smaller more isolated local farmer groups. The Local Farmer Group Network and the Grower Group Alliance provide a valuable support to local groups in obtaining and communicating their trial work, however there is still much room for improvement in the concept.

AIMS

To provide an overview of the 2005 WA Agribusiness Trial Network, promote discussion on it as a means of conducting participatory research and extension with local grower groups.

METHOD

GRDC called for tenders to the Agribusiness Trial Network in December 2004 to address what was seen as a gap in the servicing of grower groups, who are often isolated and limited in accessing resources to conduct their own trials locally. Projects submitted had to address local cropping issues and involve a professional collaborator for planning, analysis and dissemination of the results.

Local Farmer Group Network and Grower Group Alliances members were encouraged to submit their projects to GRDC with a value of up to $25,000 in partnership with a local agribusiness or farm consultants. Over 23 proposals were received by GRDC of which six were accepted but one group withdrew later due to over-commitment. Of the five remaining successful projects, four groups were members of the Local Farmer Group Network (LFGN) and the Grower Group Alliance. The successful groups and their collaborators were:

1. Ninghan Farm Focus Group and Agritech Research.
2. Jerdacuttup Top Crop and Pasture Group and David Eksteen, Four Farmers.
4. Kellerberrin Demonstration Group and Farm Focus Consultants.

Trials had to be of an agronomic nature within local grain farming systems and address the concerns of the group rather than the researcher or others’ ideas. Groups were also required to provide evidence of how they were going to communicate their work with other growers and grower groups. The Local Farmer Group Network (24 groups) and the Grower Group Alliance (15 groups) provide a excellent opportunity for successful groups to extend their work with linkages to over 36 grower groups with more than 1500 members across the wheatbelt. The Local Farmer Group Network project is closely aligned with the Grower Group Alliance and both are based at the Faculty of Natural and Agricultural Sciences at The University of Western Australia.

Trials of the Agribusiness Trial Network by Grower Group Network, 2005

- Disease management in wheat with effective use of fungicides (Moora Miling, Kellerberrin).
- Seeding systems for low rainfall environments (Ninghan).
- Sources, placement and responses to potash (Moora Miling, Kellerberrin).
- Lime and gypsum to reduce subsoil acidity and improve rooting depths (Jerdacuttup).
- Optimise rates of nitrogen by phosphorus on wheat (Moora Miling).
- Timing, rate and placement of nitrogen on canola (Jerdacuttup).
- Optimising nitrogen fixation in pasture for improved wheat production (Moora Miling).
- National Variety Testing of wheat varieties (Ninghan).
This is not a complete list of all the trials the groups here were involved in, but only trials which the groups were able to implement using GRDC funding towards the Agribusiness Trial Network.

LFGN assisted three groups with their submissions to GRDC and were able to relay what each of the groups were doing once plans of their trials were available. LFGN assisted the successful groups and their agribusiness partners to promote group field days and set up visits by neighbouring groups and will soon present findings in local and Statewide press. LFGN will assist groups to distribute trial results efficiently to other groups via e-mail and the website.

Examples of where LFGN was successful in inviting some of the neighbouring groups to visit other agribusiness trials were members of the Oldfield Group visiting Jerdacuttup Top Crop and Pasture Group spring field walk and a bus load of members of the Kellerberrin Demonstration Group visiting the Ninghan Farm Focus Group main Spring Field Day.

**DISCUSSION**

As a pilot program, the Agribusiness Trial Network encourages more coordinated communication of activities between private agronomists, agribusiness and local farmer groups and is a welcome strategy from GRDC. One of the important features is that it allows for more involvement at the grassroots level of agronomists and local farmer groups. Therefore it helps empower the existing local grower groups to continue to develop and seek further partnerships for research in their own district. The Local Farmer Group Network has been able to provide a link between the different groups and create opportunities to share in the information generated from the agribusiness trials. By working closely with the successful consultants and agribusiness, it is able to circulate trial information across the network via the website or directly through its Newswire service (e-mail Newsletter, visit lfgn.com.au/newswire).

Group partners or consultants at times may see the network projects competing with their services and this may explain some of the difficulties in obtaining the results from some in the pilot stages of this program. Networking or extension project like LFGN should not been seen as completing for the release of group or trial result but rather as adding value to their hard work by getting it published widely in local and Statewide media.

Competition between the groups is healthy, but once the successful projects have been accepted, neighbouring groups should be offered the opportunity to participate in the fine tuning of the project. Artificial barriers from the past may prevent some groups contacting each other to share in their trial or demonstration concepts. It is very difficult to arrange for members of one group to visit a neighbouring group because either they do not see their neighbours as having anything really different to offer to what they already know or simply time constraints.

**Recommendations**

Clearly the long term success of the Agribusiness Trial Network will depend on the ease with which participating groups share in their proposals and results. One of the future challenges for the GRDC will be to establish a central register of all the agribusiness trial networks or demonstrations. The GRIST (National Farmer Group Manual) could provide the ideal template for this to occur. The production of an easily accessible publication like the GRIST manual in either an electronic or booklet form could be widely distributed with priority access for participating grower group members in the Agribusiness Trial Network. The grower group network coordinators should be in the best position to assist groups and their project partner to do this.

To overcome some of the difficulties (local politics and time constraints) of groups visiting neighbouring group trials, the Network needs to work out ways to over come some of these barriers with the groups themselves. Grower tours to other parts of the State also need to pick up where possible a visit to an Agribusiness Trial Network.

The current number of agribusiness trial network projects, each valued at $25,000, should be increased because there are over 24 local grower groups and they are only just touching the potential of this program. By engaging more local groups formally with agribusiness and possibly on a rotational basis, this could help sustain these local groups independence for longer and broaden the
adoption of new and existing technology by local groups. Initial feedback from participating groups has been very positive and more groups would welcome the opportunity for exposure to this professional help and sharing of knowledge with other groups.

Some consideration needs to be give to how to improve the dissemination of trial planning and results by participating groups. Some extra incentive for groups and their collaborators to extend their results beyond the groups could be one way of address this issue. The consultant are still focused on their own ‘patch’ and don’t have a strong incentive to extend beyond it. Some better strategies are needed in this regard so that the wider community of grain growers benefits more from the Agribusiness Trial Network.

One obvious strategy to encourage delivery across the network is to allow formal poster sessions at the Agribusiness Crop Update and time slot at the regional Updates for the presentation by groups and their collaborators of the results. A criteria of awarding funding for trials should be that results are to be published in the Crop Updates publications would provide extra incentive for groups and partners to disseminated the results.

From our observations last year of the pilot Agribusiness Trial Network in WA, we recommend that all participating groups share their trial proposals with one another and with groups in their region before seeding. Groups should invite network and group coordinators, where possible, to planning meetings. This would help in the exchange of information across district, regions and nationally before seeding. One of the challenges is getting plans and results from the groups and their collaborators in soon as they become available – it is very important that this information is shared early, especially the planning stages of the trials.

CONCLUSION

There is much room for improvement for groups participating in the Agribusiness Trial Network. One of the biggest challenges is informing neighbouring groups about what trials are planned and when are field walks being held throughout the season. Grower group coordinators and group networks are essential to the speedy communication of trials between the various groups.

It is also essential that future collaborators within the Agribusiness Trial Network submit result summaries to either their groups or the network coordinators as soon as they are available. The only incentive that the Network can offer the collaborators is that it can assist in getting their results published. There should also be a stipulation for the successful group collaborators that they are to invite neighbouring groups to share in some of the project activities. Not only would this expand the impact of the Agribusiness Trial Network, but it would potentially expand the collaborators’ client base.

Ultimately, with some improvements, the Agribusiness Trial Network has dramatic potential to increase the adoption of new technology by a broader base of growers throughout the industry. It encourages independence and self reliance by local groups. It increases the need for communication between grower groups and reduces unnecessary duplication of trial work by them. It even has the potential to increase the professionalism of services delivered by agribusiness to groups and groups to become more professional themselves. The Agribusiness Trial Network is a welcome strategy by GRDC to increase the rate of adoption of new and existing technologies by grower group throughout Australia.

KEY WORDS

local farmer group network, local groups, agribusiness trial network, farmer based trials, grower groups

ACKNOWLEDGMENTS

David Eksteen, Four Farmers Agronomist, Esperance; David William, Bedbrook, Johnsonm and Williams, Perth; Peter Burgess, Agritech Research, Mundaring; Angie Rowe, Farm Focus Consulting, Northam.

Project No.: UWA00082
Paper reviewed by: Tracey Gianatti
Drivers of no-till adoption

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KEY MESSAGE
Several R, D and E opportunities exist to increase uptake of no-till in southern Australia, however, weed management is a dominant factor affecting the sustainability of extensive no-till use.

AIMS
By identifying key factors that influence the rate of no-till adoption across southern Australian cropping regions this study aimed to inform the many research, extension and grower organisations that have the objective of increasing the sustainable use of no-till cropping systems.

METHODS
Growers from selected wheatbelt regions in Western Australia (northern and central-eastern), Victoria (southern Wimmera), New South Wales (Upper Murrumbidgee) and most South Australian cropping regions took part in the study, with 384 phone interviews being conducted in 2003. The research made use of a statistical method called duration analysis that allows variables which change over time, such as prices, weather and farm size to be accounted for. The influence of these and other factors on the time it took for growers to first use no-till on their farm during the period 1983 to 2003 was determined.

RESULTS
The proportion of growers using some no-till till ranged from 88 per cent in the northern wheatbelt region of WA to 20 per cent in the north-eastern mallee of SA. A rapid increase in no-till adoption is being observed now in many SA regions and was observed several years earlier in WA (see Figure 1). The proportion of SA growers using some no-till is expected to increase from 42 per cent in 2003 to 70 per cent by 2007. When the other environment, farmer and information variables included in the study were taken into account, growers from WA were still found to be more likely to be early-adopters. This shows that additional factors are needed to fully explain the relatively rapid adoption in WA, e.g. summer rainfall patterns and no-till farmer association activity are two factors that were not included in this study.

The probability of no-till adoption was strongly influenced by the length of time in which growers first became aware of no-till being used in their district (Table 1). The opportunity to learn from nearby growers is likely to explain the surge in no-till adoption once a ‘critical mass’ of early adopters is reached. The importance of other local information sources also demonstrates the information-intensive nature of no-till adoption (Table 1).

Figure 1. Cumulative time of first no-till adoption as stated by respondents in SA and WA.
The study found that the likelihood of growers trying no-till for the first time rose after drier than average years. Anecdotal evidence following droughts and dry early-season conditions suggests that this can be a prompt for adoption as some of the relative advantages of no-till such as moisture conservation and the ability to seed on less rain become more apparent. Seeding timeliness was shown to be an important factor in the decision to adopt no-till. Overall, however, regions with low average rainfall have been slower to adopt. Perceived soil erodibility and time of Landcare membership were not found to be significant factors.

Table 1. Factors associated with earlier no-till adoption in southern Australian cropping regions

- Awareness of nearby adopters.
- Greater use of extension events and consultants.
- Perceived soil moisture conserving benefits and improved seeding timeliness of no-till relative to conventional (i.e. full-cut) tillage system.
- Expected high effectiveness of pre-emergent herbicide (trifluralin) in no-till systems.
- The fall in price of glyphosate relative to diesel.
- Higher average annual rainfall (adoption slower in very low rainfall areas).
- Occurrence of a year much drier than average.
- State.

Weed management factors

The availability of cost-effective herbicide options was shown to be very important in the decision to adopt no-till. The fall in the price of glyphosate since the early 1990s (Figure 2) has played a significant role. The results suggest that the current low glyphosate prices (approx. $4.50/L) make no-till adoption twice as likely than if prices were still at 1983 prices ($18.30/L). Changes in the prices of other key herbicides (trifluralin and diclofop) relative to diesel price were not shown to be influential. Growers who expect pre-emergent herbicides such as trifluralin to be less effective under a no-till system were shown to be less likely to adopt. Perceived herbicide resistance risks under no-till were not found to be significant in the initial decision to adopt no-till.

Figure 2. Three-year moving average prices of glyphosate (GLY_DIES), trifluralin (TRF_DIES) and diclofop (FOP_DIES) relative to the price of diesel.

Further work looking at no-till use among adopters showed that herbicide resistance and/or weed control issues are the main reasons given by growers who have, or plan to, reduce their use of no-till. As many as 39 per cent of adopters in this study had reduced or were planning to reduce their use of no-till, with up to 64 per cent of these growers attributing this to weed management problems.

CONCLUSIONS

This study confirms that the availability of quality localised information and cost-effective weed management options are particularly important in the initial decision to adopt no-till and to sustaining high use of no-till over the longer term. WA growers were more likely to adopt early. Across all
regions, research and extension that results in increased awareness of: no-till use by local growers; more cost-effective early-season herbicide options, and; can demonstrate relative soil moisture/seeding timeliness benefits of no-till, is most likely to lead to more rapid adoption.

KEY WORDS
no-till; adoption; glyphosate; weed; information; conservation, economics

ACKNOWLEDGEMENTS
Funded by the CRC Weeds with additional support from SANTFA. Thanks to the growers and interview team.

Paper reviewed by: David Roget
Maintaining wheat and lupin yields using phase pastures and shielded sprayers to manage increasing herbicide resistance

Caroline Peek, Nadine Eva, Chris Carter and Megan Abrahams, Department of Agriculture, Geraldton and Three Springs

KEY MESSAGES

- Introducing phase pastures and sheep into the rotation as an option to manage herbicide resistance has the potential to maintain the profitability of the sandplain farming system.
- Growers who do not graze their phase pastures will need to focus on growing high yielding crops with excellent input management to maintain profitability.
- The use of shielded sprayer technology to maintain the wheat lupin rotation is profitable if it results in effective resistance management. A reduction in lupin herbicide costs will help to pay the costs of purchasing this technology.

AIMS

The lupin wheat rotation has been a very profitable rotation on the sandplain soils of the Northern Agricultural Region. Annual ryegrass and wild radish are rapidly developing a resistance to the major herbicide groups. Management options will need to be implemented to maintain the profitability of this system. The release and introduction of several new pasture species, together with higher livestock prices, may encourage growers to re-examine the place of pasture in the wheat lupin rotation. The use of shield sprayer technology is a potential option for growers who are keen to maintain the wheat lupin rotation without the need to shift to a livestock production system. The aim of this study was to evaluate the impact on the farm business of several rotations that include pastures to find a profitable alternative in the face of resistance. It also examined the economics of introducing shielded sprayer technology into the current cropping system.

METHOD

The analyses were carried out over a 10 year period using the STEP (Simulated Transitional Economic Planning) model. STEP is a computerised series of whole farm annual financial budgets. The main output is an annual surplus/deficit and the cumulative addition of the surplus/deficit which results in the cumulative financial position of the different options. The farm used in the model is representative of a 3500 ha northern wheatbelt sandplain farm. Model runs were used to:

- compare several phase pasture systems with the current wheat lupin rotation. Sensitivity to changing lamb price, stocking rate, grain price and grain yield were included;
- determine the effect of transition costs of increasing the area of pasture and sheep;
- determine the financial implications for the farm business of purchasing and using shielded sprayer technology to manage herbicide resistance.

A reduction in lupin yield to 80 per cent and 60 per cent of the full yield was used to simulate a herbicide resistance problem in the current system. A key assumption made in the analysis was that introducing a pasture phase into the rotation maintained lupin yields at 100 per cent due to the reduced impact of herbicide resistance on crop yield.

To simulate the cost price squeeze, costs increased at 3 per cent per annum and returns increased at 2 per cent per annum. A discount rate of 7 per cent was applied to the 10 year cumulative financial position to give the Net Present Value. Crop yields were increased by 2 per cent per year due to technological advances in management and breeding. Variable, fixed and capital costs were sourced from BankWest benchmarks, Planfarm surveys and Department of Agriculture calculations. The analyses assume average seasons over the 10 year period.
Table 1. Grain prices and crop yields used in the analyses

<table>
<thead>
<tr>
<th></th>
<th>Wheat (W)</th>
<th>Canola (C)</th>
<th>Lupins (L)</th>
<th>Lupins 80%</th>
<th>Lupins 60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average yield t/ha</td>
<td>2.5</td>
<td>1.2</td>
<td>1.7</td>
<td>1.36</td>
<td>1.02</td>
</tr>
<tr>
<td>High yield t/ha</td>
<td>3.0</td>
<td>1.5</td>
<td>2.0</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Farm gate price $/t</td>
<td>155 and 140</td>
<td>362 and 322</td>
<td>155 and 140</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pasture phases
A two and three year phase pasture was used to help control resistant weeds in the presence and absence of livestock. Pod of the hard seeded French serradella Erica or Margurita is grown on farm and sown at 50-80 kg/ha either with the preceding wheat crop or top dressed after harvest to allow time for the hard seed to break down over summer. It is hypothesised that sowing such high rates of seed will negate the need for further sowing during the period of the pasture phase. Weed control strategies are therefore not influenced by the need for legume seed set. This hypothesis is currently under investigation. A three year phase may need additional serradella seed.

The rotations analysed were WL (current rotation), a 2 year pasture phase followed by WLW or WLWW and a 3 year pasture phase followed by WCWLW (Table 2). Where sheep were not included in the analysis the pasture costs were reduced and wheat yield following pasture slightly increased. These phase systems were run as fully established systems. Annual supplementary feeding ranged from none for the WL system to $13,660-$34,000 for the phase systems depending on ewe numbers. A transition analysis was run on the pppWCWLW where $240,000 of extra costs was applied over the ten year period to facilitate the change.

Table 2. Area of crops and pasture, selected winter stocking rate and ewe numbers for each rotation on the 3,500 ha sandplain farm

<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th>Lupin</th>
<th>Canola</th>
<th>Pasture</th>
<th>Stocking rate (DSE/WG ha)</th>
<th>Ewe numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>43%</td>
<td>43%</td>
<td></td>
<td>14%</td>
<td>3</td>
<td>1,050</td>
</tr>
<tr>
<td>ppWLW</td>
<td>39%</td>
<td>17%</td>
<td></td>
<td>44%</td>
<td>4 or 6</td>
<td>3,586 or 6,000</td>
</tr>
<tr>
<td>ppWLWW</td>
<td>48%</td>
<td>14%</td>
<td></td>
<td>38%</td>
<td>4</td>
<td>3,000</td>
</tr>
<tr>
<td>pppWCWLW</td>
<td>38%</td>
<td>11%</td>
<td>11%</td>
<td>42%</td>
<td>0, 4 or 6</td>
<td>0, 3,374 or 5,850</td>
</tr>
</tbody>
</table>

Shielded sprayer technology
A shielded sprayer and auto steer unit were purchased at a cost of $100,000 with average annual principle and interest repayments of $25,000 and $6,250 (10% interest rate) over a 4 year period. This resulted in an extra $125,000 of payments over the 4 year period. Annual depreciation and replacement costs were also increased over the ten year period. The cost of lupin sprays was reduced from $60/ha to $35/ha where the shielded sprayer was used. The shield sprayer was used on 50 per cent of the 1,500 ha lupin program per year. The extra cost of labour was $3,000 per annum. The runs were analysed for the farm at both average and high yields. It was assumed that the use of the shielded sprayer on 50 per cent of the lupin program combined with normal herbicide use on the remainder of the program was enough to manage herbicide resistance.

RESULTS
The results of the analyses should be used only as a comparative guide to the relative differences between the systems.

Table 3 highlights the comparative differences in cumulative financial position between the systems. The WL rotation where crop yields are maintained is the most profitable system. The reduction of lupin yield impacts heavily on the financial position of the farm, particularly where lupin yields are average to begin with. Low grain prices compound this effect. The lower the lupin yields fall, the more attractive the phase pasture and livestock options become, particularly if they can be used to maintain the lupin yields at 100 per cent. This would also apply if wheat yields were reduced by weed competition. The pasture phase systems also look more attractive when grain prices fall. All the phase pasture systems with sheep are reasonably comparable. The price and yield of canola in one of the systems looks to be influencing the comparative results with the other phase rotations. Initial
profitability of these systems will be heavily influenced by the livestock infrastructure currently on the farm. A transition analysis where some infrastructure has to be built or improved, shows that profitability is reduced during the 10 year period and is similar to where lupin yields are reduced by 20 per cent (Table 3). This could be much worse if no current infrastructure exists. Where growers prefer not to run livestock they will need to concentrate on growing high yielding crops to compensate for the loss of income from paddocks that are dropped out for weed control and are not used to generate income in that year. This system still has the potential to be reasonably profitable. The shielded sprayer option looks promising. The reduction in herbicide costs with the shielded sprayer technology resulted in the 10 year cumulative position being comparable with the current wheat lupin system despite the purchase of the shielded sprayer and auto steer units. The higher the crop yields the better the relative returns will be. If this system can be used to successfully help manage herbicide resistance within the wheat lupin rotation it could suit growers who would prefer to keep continuous cropping. This could potentially be combined with the inclusion of an occasional pasture phase.

Tables 4 and 5 indicate that stocking rate and lamb price have a significant impact on cumulative financial position. We believe that a winter stocking rate of 6 DSE/ha is achievable. In reality 4 DSE/ha is more likely, particularly where growers are concentrating their efforts on growing high yielding crops and management of large numbers of sheep could conflict with the cropping program. There is also the question of sheep management over the summer period on sandplain soils which may increase the risk of wind erosion and soil degradation. Table 3 shows that at low grain price and average yield and average lamb price of $45/head and stocking rate of 4 DSE/ha that none of the systems analysed are profitable. Where an average lamb price of $65/head is used (Tables 4 and 5), the phase pasture systems have the potential to be more profitable than the traditional wheat lupin rotation for a range of grain yields and prices, for example where grain prices remain low for ten years. This also applies to a lamb price of $45/head and a stocking rate of 6 DSE/ha. Table 6 also reveals that the transition into sheep is made less painful where lamb prices are high.

CONCLUSION

Introducing pasture into the rotation to help manage herbicide resistance and maintain crop yields has the potential to maintain the profitability of the sandplain farming system. How well each system will perform will depend primarily on the productivity of each of the components of the system. Commodity price will also play a role. For growers who have not had experience with livestock and do not want to manage large numbers of sheep, the key will be in the continuous improvement of crop yields. High stocking rates will require good sheep and pasture management and the ability of the sandplain to carry large numbers of sheep without causing environmental problems such as soil erosion. The analyses are based on set systems and growers are likely to mix and match depending on soil type, yield potential, herbicide resistance status, commodity prices and personal preferences and skills. The level of current livestock infrastructure will also impact on the ability and speed of the farm business to make change. The results however provide some interesting insights into the factors influencing the profitability of systems for the medium rainfall sandplain soils.

Shielded sprayer technology has the potential to maintain the wheat lupin rotation where growers are keen to maintain high levels of cropping. This system will still be reliant on herbicides. It is possible that a combination of the occasional pasture phase with or without sheep and shielded sprayer technology would be a better option and still allow for high levels of cropping. Shielded sprayer technology is of most assistance where crop yields are high.

KEY WORDS

phase pastures, shielded sprayer, stocking rate, herbicide resistance, lupin yields, profitability

ACKNOWLEDGMENTS

Alan Herbert, Department of Agriculture, South Perth; Marty Harries, Department of Agriculture, Geraldton and Andrew Sandison, Planfarm, Geraldton for helpful comments and advice.

Project No.: Northern Region Farming Systems project 69F
Paper reviewed by: Dr Clinton Revell
### Table 3. The impact of grain price, grain yield and rotation on the discounted 10 year cumulative financial position. Lamb price is $45/head gross

<table>
<thead>
<tr>
<th>Grain price $/t</th>
<th>W $155 L $155 C $362</th>
<th>W $140 L $140 C $322</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rotation</strong></td>
<td><strong>High yield</strong></td>
<td><strong>Average yield</strong></td>
</tr>
<tr>
<td>WL 100% L yield</td>
<td>$2,000,000</td>
<td>$500,000</td>
</tr>
<tr>
<td>WL 80% L yield</td>
<td>$1,250,000</td>
<td>-$100,000</td>
</tr>
<tr>
<td>WL 60% L yield</td>
<td>$500,000</td>
<td>-$600,000</td>
</tr>
<tr>
<td>ppwlw 4 DSE/ha</td>
<td>$1,278,000</td>
<td>$210,000</td>
</tr>
<tr>
<td>ppwclw 4 DSE/ha</td>
<td>$1,450,000</td>
<td>$288,000</td>
</tr>
<tr>
<td>ppwclw 6 DSE/ha</td>
<td>$1,500,000</td>
<td>$220,000</td>
</tr>
<tr>
<td>ppwclw 6 DSE/ha</td>
<td>$1,024,000</td>
<td>-$201,000</td>
</tr>
<tr>
<td>Transition costs pppwclw 4 DSE/ha</td>
<td>$1,096,000</td>
<td>-$90,000</td>
</tr>
<tr>
<td>Shielded sprayer</td>
<td>$2,052,000</td>
<td>$473,000</td>
</tr>
</tbody>
</table>

### Table 4. The effect that lamb price has on the discounted cumulative position where the average stocking rate is 4 DSE/ha in the pppwclw rotation

<table>
<thead>
<tr>
<th>Grain price</th>
<th>W $155 L $155 C $362</th>
<th>W $140 L $140 C $322</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lamb price $/head</strong></td>
<td><strong>High yield</strong></td>
<td><strong>Average yield</strong></td>
</tr>
<tr>
<td>25</td>
<td>$1,125,000</td>
<td>-$115,000</td>
</tr>
<tr>
<td>45</td>
<td>$1,500,000</td>
<td>$220,000</td>
</tr>
<tr>
<td>65</td>
<td>$1,900,000</td>
<td>$600,000</td>
</tr>
</tbody>
</table>

### Table 5. The effect that lamb price has on the discounted cumulative position where the average stocking rate is 6 DSE/ha in the pppwclw rotation

<table>
<thead>
<tr>
<th>Grain price</th>
<th>W $155 L $155 C $362</th>
<th>W $140 L $140 C $322</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lamb price $/head</strong></td>
<td><strong>High yield</strong></td>
<td><strong>Average yield</strong></td>
</tr>
<tr>
<td>25</td>
<td>$1,290,000</td>
<td>$33,914</td>
</tr>
<tr>
<td>45</td>
<td>$1,850,000</td>
<td>$585,000</td>
</tr>
<tr>
<td>65</td>
<td>$2,500,000</td>
<td>$1,190,000</td>
</tr>
</tbody>
</table>

### Table 6. The impact of the inclusion of livestock transition costs on cumulative financial position where average stocking rate is 4DSE/ha in the pppwclw rotation

<table>
<thead>
<tr>
<th>Grain price</th>
<th>W $155 L $155 C $362</th>
<th>W $140 L $140 C $322</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lamb price $/head</strong></td>
<td><strong>High yield</strong></td>
<td><strong>Average yield</strong></td>
</tr>
<tr>
<td>45</td>
<td>$1,096,000</td>
<td>-$90,000</td>
</tr>
<tr>
<td>65</td>
<td>$1,409,000</td>
<td>$202,600</td>
</tr>
</tbody>
</table>
Analysis of a wheat-pasture rotation in the 330 mm annual rainfall zone using the STEP model

Andrew Blake and Caroline Peek, Department of Agriculture, Geraldton

KEY MESSAGES

- Self regenerating biserrula pastures grown in rotation with wheat were more profitable than volunteer pastures based on the assumption that the legume phase can lift wheat yields and improve grain quality.
- In the event of the pasture legume failing to persist, reseeding the biserrula every pasture phase was affordable if wheat yields were increased by 10 per cent (to 2 t/ha).

AIMS

Primary producers across the wheatbelt face many challenges including a severe cost price squeeze on top of biological problems such as increasing levels of herbicide resistance in weeds. For those in lower rainfall areas, the challenge is even greater as their yield potentials are lower making them less able to absorb increased input costs. Their rotational options are also more restricted due to unreliable yields of non-cereal crops and the risk of investing in improved annual pastures that may fail to persist.

A grower from the 330 mm rainfall zone of the northern wheatbelt has recently been prompted to look for alternative rotations for his 7,450 ha farm of predominately medium to heavy red soils. His traditional system involves 70 per cent wheat, 30 per cent volunteer pasture with a self replacing merino flock producing cross bred lambs. He has about 2,100 ewes and also grows a small area of lupins. While returns from this system was meeting all fixed and variable costs and paying for the farmers labour, he was interested in improving his pastures, lifting his stocking rates and improving his wheat yields. He wants to move toward a ley pasture system that involves 2-3 wheat crops followed by a biserrula pasture phase. With this system he hopes to maintain the wheat area of 70 per cent and increase his stock numbers to 4,000-5,000 head. He also believes he will lift his average wheat yields from 1.8 to 2 t/ha by including a legume phase. This paper describes an economic analysis of these two systems.

METHOD

The analyses were conducted using the STEP (Simulated Transitional Economic Planning) model over a 15 year planning horizon. STEP is a computerised series of whole farm annual financial budgets. It is designed to investigate the progressive annual cash flow consequences of changing the enterprise mix. The main output is an annual surplus/deficit and the cumulative addition of the surplus/deficit which results in the cumulative financial position (CFP). To simulate the cost price squeeze, costs increased at 3 per cent per annum and returns increased at 2 per cent per annum. A discount rate of 7 per cent was applied to the 15 year cumulative financial position. The results of the analyses should only be used as a comparative guide to the relative differences between the systems.

Financial and production details were obtained for a case study farm business located in the northern agricultural region with average annual rainfall of 330 mm. These details provided by the farmer were used as the basis for the analyses. Other assumptions included in the main analysis included a farm gate grain price of $162/tonne for hard wheat and a price of $65/head for fat lamb. In the traditional system $15,000 pa was budgeted for supplementary feeding. This was increased to $30,000 pa when dse was 3.3 and to $36,500 pa at 4 dse.

The analyses included:

- Comparing the case study farm’s traditional rotation that included mainly wheat, unimproved pasture and small areas of lupins with a ley pasture system (2-3 wheat crops followed by one year of biserrula pasture).
- Examining the financial implications of having to reseed the legume pasture in the event of the pasture legume failing to persist.
- Examining the sensitivity of the system to wheat yield and price, stocking rate and input costs.
RESULTS

Table 1 summarises the relative areas of different crops and pasture as well as livestock numbers and stocking rate. Although the systems are similar in wheat area, the ley system has no lupins and has higher stocking rates and ewe numbers.

Table 1. Relative area of crops, pasture, ewe numbers and approximate winter stocking rate on the 7,450 ha case study farm under their traditional rotation and the ley pasture system they are moving towards

<table>
<thead>
<tr>
<th>System</th>
<th>Wheat</th>
<th>Lupins</th>
<th>Pasture</th>
<th>Ewe no.</th>
<th>Stock rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>68%</td>
<td>3.5%</td>
<td>28.5%</td>
<td>2,096 head</td>
<td>1.5 dse</td>
</tr>
<tr>
<td>Ley pasture</td>
<td>68.5%</td>
<td>0%</td>
<td>31.5%</td>
<td>4,280-5,340</td>
<td>3.3-4 dse</td>
</tr>
</tbody>
</table>

Analysis of the traditional system shows the cumulative financial position increased by over $12,000 after fifteen years (farm gate wheat price $162/t). In this system CFP did not increase much because the lupin phase is unprofitable and the low stocking rates means income from livestock fails to cover costs. Income from wheat covers all variable and fixed costs but this only just overcomes the losses made from livestock and lupins. The grower was aware that this system was not making much money which prompted him to seek help regarding more profitable systems.

Table 2 shows the discounted cumulative financial position after 15 years of both the traditional and proposed systems, at two wheat yields, two wheat prices and two stocking rates. The farmer is moving towards a ley pasture system where the volunteer pasture is replaced by a self regenerating annual legume pasture and wheat is the only crop grown. This system was also analysed to compare the financial consequences of reseeding the pasture. Analyses of this ley pasture system show the farm business is in a better financial position after 15 years than under his traditional system as long as wheat yields are lifted by the inclusion of the legume.

Table 2. The impact of wheat yield and stocking rate on the discounted 15 year cumulative financial position of the case study farm. Assumed lamb price is $65/head

<table>
<thead>
<tr>
<th>System</th>
<th>Wheat yield</th>
<th>Stocking rate (DSE winter grazed)</th>
<th>CFP after 15 years (farm gate hard wheat @ $162/t)</th>
<th>CFP after 15 years (farm gate hard wheat @ $147/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>1.8 t/ha</td>
<td>Low (1.5)</td>
<td>$12,000</td>
<td>$-1,561,000</td>
</tr>
<tr>
<td>Ley pasture</td>
<td>High (2 t/ha)</td>
<td>4</td>
<td>$1,394,000</td>
<td>$-81,000</td>
</tr>
<tr>
<td>Ley pasture</td>
<td>High (2 t/ha)</td>
<td>3.3</td>
<td>$1,140,000</td>
<td></td>
</tr>
<tr>
<td>Ley pasture</td>
<td>Low (1.8 t/ha)</td>
<td>4</td>
<td>$-162,000</td>
<td>$-1,582,000</td>
</tr>
<tr>
<td>Ley pasture</td>
<td>Low (1.8 t/ha)</td>
<td>3.3</td>
<td>$-419,000</td>
<td></td>
</tr>
<tr>
<td>Ley pasture</td>
<td>Low (1.8 t/ha), $10/ha less inputs</td>
<td>3.3</td>
<td>$130,000</td>
<td></td>
</tr>
<tr>
<td>Reseed all pastures</td>
<td>High (2 t/ha), reseed pastures</td>
<td>3.3</td>
<td>$654,000</td>
<td></td>
</tr>
</tbody>
</table>

If yields are not lifted then the CFP is negative at both stocking rates. This is because the increased stocking rate does not cover all the costs of establishing the annual pasture so without a yield benefit in the cereal phase, inclusion of the biserrula has a negative effect on CFP. Obviously this was even more negative at the lower stocking rate as the income from livestock covered even less of the cost of pasture establishment than at the higher stocking rate.

If the ley system lifts wheat yields to 2 t/ha the system is better financially for several reasons. Firstly, higher wheat yields generated higher returns. Secondly there is no lupin phase which was costing the grower money as his lupin yields did not generate enough returns to cover his fixed and variable costs. Finally, it was assumed that wheat grown in the first or second year after legume pasture would be higher in protein and therefore attract the $10/tonne premium paid in the AH segregation. In the traditional system with mainly wheat on wheat or wheat on volunteer pasture the grower felt only some
of his wheat would be classified hard. We therefore assumed only half of his wheat produced in the
traditional system would attract the premium. Therefore, even at the same yields, greater returns are
generated from his cereal phase in the ley system through an improvement in grain quality.

One potential threat to the success of the ley pasture system is the failure of the pasture legume to
persist through multiple crops. This was addressed in the analyses by assuming all biserrula pasture
following three wheat crops would need reseeding, whilst that following two wheat crops would
self-regenerate. A separate analysis was done with the assumption that the pasture legume never
self-regenerated and needed to be reseeded at the start of each pasture phase. This analysis showed
that despite the cost of reseeding all biserrula every pasture year, the system was still profitable if
wheat yields of 2 t/ha were achieved (see Table 1).

Another threat to this system is that the legume pasture may fail to carry the higher stocking rates.
Analysis suggests that as long as the legume pasture results in improved wheat yields (at least 10%)
and improved quality, the grower is better off including the legume phase even with no stock than
persisting with his traditional system.

If the ley pasture system fails to increase wheat yields the model predicts a negative discounted
cumulative financial position after 15 years at both stocking rates. However, this is very sensitive to
input costs. If inputs costs are reduced by $10/ha in the wheat crop, the cumulative position is
increased by $549,000 after 15 years (see Table 1).

The case study farmer grew Casbah biserrula for the first time in 2005. He was extremely impressed
by its production and believes it grew better than any other legume he has tried. Unfortunately it failed
to set seed because a severe aphid infestation decimated the pasture whilst he was on holidays.
Based on its performance last year he intends to progressively establish the majority of his farm to
biserrula and implement the ley pasture system. One final risk worth mentioning is the threat of
photosensitivity in livestock grazing exclusively on biserrula pasture. He saw no sign of the condition
in his sheep last year but until we learn how to eliminate the risk of photosensitivity this remains a
threat to his system.

Most of the analyses were done assuming a 15 year average farm gate wheat price of $162/t for hard
wheat. As a worst case scenario some runs were also done assuming a wheat price $15/t lower and
all these runs resulted in a negative CFP after 15 years. It is clear that to remain viable at lower wheat
prices, either additional income must be generated from crop and pasture phases (higher yields) or
input costs must be reduced.

CONCLUSION
If the biserrula pasture system delivers the grower higher wheat yields (to 2 t/ha) and better grain
quality this system is far more profitable than his traditional system. If wheat yields remain at 1.8 t/ha,
but quality is improved and livestock numbers are lifted the system is less profitable than his traditional
system and the overall discounted cumulative financial position is negative after 15 years. At lower
yields, input costs must be reduced to remain profitable. The impacts of incorporating biserrula
pasture into the cropping rotation need to be assessed on a paddock scale over several years.

KEY WORDS
biserrula, pasture legume, wheat, rotation, economic analysis, STEP

ACKNOWLEDGMENTS
Thanks to the case study grower for making these analyses possible by sharing the financial and
production details of his farm business. Thanks also to Peter Tozer from the Geraldton Department of
Agriculture for his comments and suggestions.

Project No.: Northern Region Farming System Project 69F
Paper reviewed by: Clinton Revell
Response to winter drought by wheat on shallow soil with low seeding rate and wide row spacing

Paul Blackwell¹, Sylvain Pottier² and Bill Bowden¹
¹DAWA; ²Esitpa (France)

KEY MESSAGES

• Very wide rows (600 mm) and low seeding rates (30 kg/ha) can reduce stress from a July/August drought in the NAR on sandy clay loam about 500 mm deep.

• Reduced early biomass and inter-row water use from wide rows and low seeding rates helped tiller survival, reduced head damage and allowed heavier grain; this resulted in 180-380 kg/ha (14 to 30%) better yield with wide rows and low seeding rates; grain quality also benefited. Winter irrigation of Arrino corrected the drought and almost doubled yield to 4 t/ha.

• Canopy temperature depression (CTD) from a hand held infra red thermometer correlated well with grain yield and quality responses of many cultivars to the mid-season drought stress.

AIM

Understanding how very wide rows and low seeding rates help reduce crop drought stress.

METHODS

The experiment was at Pindar, 35 km east of Mullewa; agronomic details are in Blackwell et al. 2006. The soil is sandy clay loam over granite with pH of 4.2 available P of 50 ppm and organic matter of 1.4 per cent. Ten wheat varieties were sown on 7 May. Crop establishment, biomass, yield components, grain yield and quality were measured. Soil water content was measured with TDR, and crop drought stress by canopy temperature depression (CTD) using an infra red thermometer (Fischer et al. 1998).

RESULTS

Poor rainfall induced drought in July and early August (Dry and warm period in Figure 1; also identified by rapidly declining soil moisture). 53 mm fell after 13 August and 23 mm in September.

Figure 1. Weather at Pindar 2005 from sowing to anthesis showing growth stages of Arrino in the trial and a classification of the different periods of temperature and soil moisture.
Soil and crop responses

Wide rows (WR) and low seed rate (LS) gave 380 kg/ha more yield (30%) compared to narrow rows (NR) and high seeding rates (HS). The crop canopy in WR and LS was 2.4°C cooler in the drought period compared with NR and HS which had greater early biomass and more water use. Wide interrows conserved moisture, as did fewer plants at LS. Stress caused 125/m² more tiller loss in the NR and HS crop than the WR and LS crop, which had 90 per cent less head damage, 80 per cent more grains/head and 13 per cent heavier grain. Later flowering varieties, such as Janz, had more head damage (i.e. heads ‘caught in the boot’), compared to earlier flowering varieties; Kalannie and Westonia.

Wide rows alone gave an average yield benefit of 182 kg/ha (13%). The crop canopy was 1.6°C cooler in the drought period. Stress caused 90/m² more tiller loss, which had 80 per cent less head damage, 40 per cent more grains/head and 7 per cent heavier grain.

Lower seeding rate alone gave an average yield benefit of 198 kg/ha (14%). The crop canopy was 0.7°C cooler in the drought period. Stress caused 30/m² more tiller loss, which had 40 per cent less head damage, 30 per cent more grains/head, 6 per cent heavier grain and 9 per cent more head wt at anthesis.

Table 1. Mean variety effects and changes by row spacing and seeding rate. Bold figures within rows indicate significant difference at P < 0.05

<table>
<thead>
<tr>
<th>Spacing, mm</th>
<th>300</th>
<th>300</th>
<th>600</th>
<th>600</th>
<th>lsd0.05</th>
<th>Difference 300/60 to 600/30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing rate, kg/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>30</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial conditions before drought stress</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plants/m²</td>
<td>77.0</td>
<td>124.0</td>
<td>69.0</td>
<td>106.0</td>
<td>8.29</td>
<td>-55</td>
</tr>
<tr>
<td>Biomass (15 June), g/m²</td>
<td>89.0</td>
<td>109.0</td>
<td>60.0</td>
<td>69.0</td>
<td>10.0</td>
<td>-49</td>
</tr>
<tr>
<td>Expression of drought stress</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf temperature 25 July hotter than air cooler than air</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTD, °C (air-canopy temp)</td>
<td>-0.85</td>
<td>-1.52</td>
<td>0.87</td>
<td>0.06</td>
<td>0.693</td>
<td>2.4</td>
</tr>
<tr>
<td>Effects on growth to anthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tillers/m² (June)</td>
<td>332.0</td>
<td>408.0</td>
<td>207.0</td>
<td>251.0</td>
<td>26.5</td>
<td>-201</td>
</tr>
<tr>
<td>Shoots at anthesis/m²</td>
<td>268.0</td>
<td>296.0</td>
<td>220.0</td>
<td>247.0</td>
<td>18.8</td>
<td>-76</td>
</tr>
<tr>
<td>Tiller change/m²</td>
<td>-65.0</td>
<td>-112.0</td>
<td>13.0</td>
<td>-5.0</td>
<td>31.5</td>
<td>125</td>
</tr>
<tr>
<td>Anthesis green leaves/head</td>
<td>1.38</td>
<td>1.40</td>
<td>1.16</td>
<td>1.10</td>
<td>0.139</td>
<td>-0.25</td>
</tr>
<tr>
<td>Anthesis heads/m²</td>
<td>174.0</td>
<td>183.0</td>
<td>155.0</td>
<td>174.0</td>
<td>10.3</td>
<td>-27</td>
</tr>
<tr>
<td>Head wt, g anthesis</td>
<td>0.58</td>
<td>0.55</td>
<td>0.62</td>
<td>0.55</td>
<td>0.030</td>
<td>0.07</td>
</tr>
<tr>
<td>Head dry wt, g/m² anthesis</td>
<td>101.1</td>
<td>100.3</td>
<td>95.6</td>
<td>94.7</td>
<td>6.48</td>
<td>-4.70</td>
</tr>
<tr>
<td>Head damage, hds/m² (anth)*</td>
<td>4.4</td>
<td>7.2</td>
<td>0.9</td>
<td>1.7</td>
<td>2.15</td>
<td>-6</td>
</tr>
<tr>
<td>Effects at harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damaged spktls/hd, % (hvst)#</td>
<td>14</td>
<td>15</td>
<td>7</td>
<td>8</td>
<td>2.71</td>
<td>-6</td>
</tr>
<tr>
<td>Harvest heads/m²</td>
<td>201.0</td>
<td>214.0</td>
<td>170.0</td>
<td>186.0</td>
<td>9.81</td>
<td>-44</td>
</tr>
<tr>
<td>Grains/head</td>
<td>20.7</td>
<td>15.6</td>
<td>27.8</td>
<td>21.7</td>
<td>1.63</td>
<td>12.22</td>
</tr>
<tr>
<td>Grains/spikelet</td>
<td>1.91</td>
<td>1.59</td>
<td>2.30</td>
<td>2.03</td>
<td>0.14</td>
<td>0.71</td>
</tr>
<tr>
<td>Hectolitre wt, g</td>
<td>83.0</td>
<td>82.0</td>
<td>83.6</td>
<td>83.6</td>
<td>0.62</td>
<td>1.60</td>
</tr>
<tr>
<td>Screenings, %</td>
<td>1.07</td>
<td>2.81</td>
<td>1.00</td>
<td>1.19</td>
<td>0.93</td>
<td>-1.81</td>
</tr>
<tr>
<td>1000 grain wt, g</td>
<td>36.49</td>
<td>34.28</td>
<td>38.6</td>
<td>36.82</td>
<td>1.15</td>
<td>4.32</td>
</tr>
<tr>
<td>Small grain (2.2-2.5 mm), %</td>
<td>10.2</td>
<td>12.8</td>
<td>7.9</td>
<td>9.0</td>
<td>2.19</td>
<td>-4.91</td>
</tr>
<tr>
<td>Large grain (&gt; 2.5 mm), %</td>
<td>88.6</td>
<td>85.4</td>
<td>91.0</td>
<td>89.7</td>
<td>2.39</td>
<td>5.63</td>
</tr>
<tr>
<td>Yield, kg/ha</td>
<td>1510</td>
<td>1262</td>
<td>1642</td>
<td>1494</td>
<td>103</td>
<td>380</td>
</tr>
<tr>
<td>Grain protein, %</td>
<td>13.27</td>
<td>13.58</td>
<td>13.07</td>
<td>13.35</td>
<td>0.37</td>
<td>-0.51</td>
</tr>
</tbody>
</table>

* Observed necrosis; equivalent whole heads.
# Observed spikelet damage; mostly fungal infected.
Irrigation was used on the Arrino crop during the drought; about 80 mm total was added by weekly applications. This added to the 190 mm of growing season rainfall. Table 2 shows that the yield could have been about doubled if the transient winter drought had not occurred to damage tillers and heads!

Table 2. Yield and yield components of Arrino with or without irrigation during the drought. Same letters within ‘Rainfed’ rows indicate no significant difference at P < 0.05. (Irrigated plots were treated with 250 mL/ha of ‘Tilt’ fungicide on 15 September)

<table>
<thead>
<tr>
<th>Spacing, mm</th>
<th>300</th>
<th>300</th>
<th>600</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing rate, kg/ha</td>
<td>30</td>
<td>60</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Tiller loss/m²</td>
<td>Rainfed</td>
<td>99 b</td>
<td>131 b</td>
<td>55 a</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>55</td>
<td>39</td>
<td>34</td>
</tr>
<tr>
<td>Heads/m²</td>
<td>Rainfed</td>
<td>186 b</td>
<td>201 b</td>
<td>165 a</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>269</td>
<td>275</td>
<td>214</td>
</tr>
<tr>
<td>Head wt, g/m²</td>
<td>Rainfed</td>
<td>97</td>
<td>96</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>123</td>
<td>111</td>
<td>98</td>
</tr>
<tr>
<td>Damaged spikelets, % per head</td>
<td>Rainfed</td>
<td>21a</td>
<td>18a</td>
<td>6b</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yield, kg/ha</td>
<td>Rainfed</td>
<td>1494a</td>
<td>1496a</td>
<td>1937b</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>3987</td>
<td>3580</td>
<td>3849</td>
</tr>
</tbody>
</table>

More detailed measurements in the Arrino crop showed the drought retarded growth in the narrow row spacing treatments, but at wider row spacing crop biomass accumulation was more constant during the drought period (Figure 2). Wider row spacings also conserved more soil moisture during the period of drought (Figure 3). The wide row spacing and low seeding rate retained relatively high soil moisture during the early growth period, before the mid season drought (Figure 3). All treatments were close to ‘wilting point’ before the relieving rain in August. 53 mm fell in the rest of August and 23 mm fell in September.

Figure 2. Biomass accumulation of Arrino in the four treatments. Standard deviation bars are attached to each mean, growth stages and weather periods are shown.
Canopy temperature depression (CTD) during the drought period was closely related to grain yield of individual cultivars (Figure 4). Calingiri (dashed line) appears more sensitive to drought stress than the other varieties used. Strong correlation was also found between CTD and hectolitre wt of the grain (Table 3). Calingiri, Cunderdin and Janz yield was more sensitive to drought stress, Wyalkatchem, Westonia and Bonnie rock least sensitive. Calingiri grain size was most sensitive to drought stress, Drysdale least sensitive.

Table 3. Slope, intercept and degree of fit of regression between grain yield or quality and Canopy Temperature Depression during the mid-season drought. The r² values > 0.6 are made bold. The varieties are listed in order of slope value

<table>
<thead>
<tr>
<th>Variety</th>
<th>Slope</th>
<th>Intercept</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrino</td>
<td>115x</td>
<td>1752</td>
<td>0.5273</td>
</tr>
<tr>
<td>CALINGIRI</td>
<td>199x</td>
<td>1531</td>
<td>0.8878</td>
</tr>
<tr>
<td>Janz</td>
<td>130x</td>
<td>909</td>
<td>0.8075</td>
</tr>
<tr>
<td>CUNDERDIN</td>
<td>141x</td>
<td>1359</td>
<td>0.7624</td>
</tr>
</tbody>
</table>

Crop Updates is a partnership between the Department of Agriculture, Western Australia and the Grains Research & Development Corporation
CONCLUSIONS

In situations of reasonable rainfall and/or deep soils which can store a lot of water, promoting early growth and vigour in crops, promotes bigger yields. However, in lower rainfall regions and on shallower and relatively fertile soils, promoting early vigour causes the limited water supplies to be used early to the detriment of later crop growth and grain fill. In such circumstances it may be better to adopt practices which reduce early vigour (e.g. reduce seeding rates, use less fertiliser – particularly nitrogen, and sow at wider row spacings) and so allow the crop to survive mid season and end of season droughts. In some, wet seasons, low early vigour practices will give lower yields, but in drier years, the low vigour practices will help drought-proof the crop and guarantee a return in all but the worst situations. Canopy Temperature Depression during the drought was a good indicator of drought stress and subsequent effects on yield and grain size for many wheat cultivar used here. Caution is advised for application of these results; adjacent less fertile sites sown at the same time showed less early growth, less drought stress and more benefit of lower seeding rate. Later sown sites showed penalties to very wide rows because of less water stress due to frequent September rain. Observations at other locations and seasons in the same area have shown that wide rows can have less yield than narrower rows where the rooting depth is very shallow (~300 mm) because evaporation easily dries the inter row.

KEY WORDS

drought, shallow soil, very wide rows, wheat, low sowing rate, canopy temperature

ACKNOWLEDGMENTS

Marlingu farms (Mike Kerkmans) for hosting the research, Stewart Edgecombe, GRSU, Reg Lunt, Stephen Davies, Tony Vyn (Purdue) and Lyle Mildenhall for technical assistance and advice. National Landcare Program and GRDC Subsoil Constraints for funds; United Farmers Cooperative.
REFERENCES


Project No.: NLP 043053

Paper reviewed by: Stephen Davies
How much yield variation do you need to justify zoning inputs?

Michael Robertson and Greg Lyle, CSIRO Floreat
Bill Bowden, DAWA Northam; Lisa Brennan, CSIRO Brisbane

KEY MESSAGES

Significant variation in yield potential, enough to potentially justify zoning fertiliser inputs on economic grounds, can occur in both small and large paddocks and low and high yielding situations.

The economic benefits from targeting nutrients to yield potential in each zone, rather than fertilising the paddock to an average yield potential, can be estimated and is influenced by the range of factors. The wider the variation in potential yield, the greater the benefit. Benefits will be further enhanced if there are differences between zones in soil fertility status, a decrease in wheat price, an increase in fertiliser cost, or if the low yielding zone dominates the area of the paddock.

Accounting for seasonal influences on yield potential will be crucial in maximising the benefits for variable rate application of nutrients.

BACKGROUND

Most emphasis on precision agriculture (PA) to date has been on variable rate application of nutrients to different areas or zones in paddocks (hereafter called zone management). Use of this approach to crop management requires investment in equipment and managerial effort. Despite awareness of the benefits of PA by some leading grain growers there has been little uptake of zone management in the Australian grains industry. Some of the uncertainty surrounding its adoption is whether enough within-paddock variation in yield exists to justify the investment. Intuitively, one would expect that the economic and environmental benefits of zone management will be proportional to the extent of sub-paddock yield variation, where the biggest gains to be made will be in paddocks with the widest differences in yield potential. This is because yield potential (defined here as the yield, limited only by water) is the major determinant of crop nutritional requirements (see Bowden paper these updates).

With the widespread availability of yield monitors on harvesters many farmers are in the position to collect yield maps over much of their properties each season and ascertain the range of variation in yield within paddocks. However, a common cry heard is that it is difficult to know how to interpret yield maps and use the information to make a management decision. This paper makes an attempt to develop some rules of thumb for within-paddock yield variation that would translate into economic advantages for zone management. We also report on the results of a survey of yield maps collected on the northern sandplain in order to document the extent of sub-paddock yield variation and to debunk some myths associated with sub-paddock yield variation, e.g. larger paddocks have more yield range than small paddocks.

The aims of this paper are to:

- document sub-paddock variability in grain yield from yield maps of wheat in the northern sandplain region of WA;
- test if variation is related to variables like paddock average yield and paddock area;
- show how differences in yield potential, size of management zones, costs and prices, soil fertility status will influence the economic gains achievable from zone management.

HOW MUCH VARIATION IS OUT THERE?

To answer this question we conducted a survey of 200 yield maps of wheat obtained from the northern sandplain region. Yield maps were accessed from farmers who have collaborated with CSIRO in PA research over the recent years (1997-2002) in Buntine, Three Springs, Wongan Hills and Yuna. As such the survey was not random, however the assumption was that by analysing yield maps from a wide range of locations and seasons we could gain an overall picture of the extent of yield variation that exists. Paddock average yield varied from due to paddock-to-paddock and seasonal variation
from 0.5 to 4.9 t/ha, and paddock size ranged from 7 to 172 ha. A number of yield maps came from the same paddock over a few seasons.

Management zones can be defined on the basis of patterns in yield variation, using statistical techniques called clustering, which groups similar yielding areas into the same cluster or zone. Management zones would not usually be defined on the basis of yield variation alone and would normally involve additional information on factors responsible for yield variation such as soil type or topography. For the purposes of this paper we clustered each of the 200 maps into three zones. The breakdown of the zones did not neatly fit into three zones consisting of one-third of the paddock area each, however more than 90 per cent of the paddocks had zones that varied between 25 and 40 per cent of the paddock area. We then calculated the average yield in each zone. Our measure of within-paddock yield variation was the difference in average yield between the highest yielding and the lowest yielding of the three zones (the middle one was close to the paddock average usually). An example of a clustered yield map is shown below (Figure 1).

![Figure 1. Example of a yield map clustered into three zones.](image)

What did we find? An interesting finding is that large paddocks were no more variable than small paddocks (Figure 2a).

![Figure 2. Relationship between yield difference between high and low yielding zones and (a) paddock area and (b) paddock average yield.](image)

High yielding paddocks were no more variable than low yielding paddocks (Figure 2b). Even when maps from individual seasons were examined the lack of relationship held for paddock yield and area. Across all 200 yield maps the difference between the average yield of the high and low yielding zones ranged from 0.5 to 3.3 t/ha, with the median around 1.7 t/ha. This gives us an idea of the upper and lower bounds of within-paddock yield variation.

If we zone the 200 yield maps into 5 clusters rather than 3 then the difference between the lowest and highest yielding zones (which equates to about 20% of the paddock each) increase from a median of 1.7 t/ha to 2.4 t/ha. Going the other way, from 3 to 2 zones the median difference went from 1.7 t/ha to 1.1 t/ha. This shows that with more zones in a paddock we can separate higher and lower yielding
areas more distinctly. But is it worth the bother? That’s both an economic question and a logistical/personal preference question, which is beyond the scope of this paper.

**ECONOMIC SIGNIFICANCE OF VARIATION IN POTENTIAL YIELD**

We have a well developed ability to estimate crop nutrient requirements for wheat if we know yield potential and soil fertility status. Moreover, with some information on the price of grain and the costs of fertiliser we can estimate the economically-optimum rate of say N and P. This information lies behind the current key fertiliser decision support systems available to the industry in WA.

Take the simple case of a paddock with low soil N status, broken up into three equal-sized zones with the low-yielding zone having an average yield of 0.5 t/ha. If we take some standard prices and costs for wheat ($150/t) and fertiliser N ($1.2/kg), we can calculate what advantage there is to applying N at the economically-optimum rate to each zone based on its yield potential versus just applying the economically-optimum rate to the whole paddock, and therefore under-fertilising the high yielding zone, over-fertilising the low yield zone and matching fertiliser requirements to the middle zone. Figure 3 shows that the yield benefit varies from no advantage where the yield difference between the low and high zones is only 1 t/ha or less, to $15/ha where the yield difference between high and low zones is the maximum found in our survey of 3.5 t/ha. These results show that differences in yield potential have a huge influence on expected benefits from zone management.

![Figure 3](image.png)

**Figure 3. Economic advantage over uniform application of fertiliser N over zone management, as a function of the difference in yield potential between high and low-yielding zones.**

If we take one point on the curve in Figure 3 where there is an average of 0.5, 2.0 and 3.5 t/ha in the low, middle and high zones. The economically-optimum N rate for the three zones was 20, 60 and 80 kg N/ha (and the paddock average was 60 kg N/ha), so the $12/ha advantage for zone management came from avoiding the over-fertilising on the low zone and under-fertilising on the high zone. Let’s now consider some additional variables that may influence the economic advantages of zone management.

If the low zone dominates the paddock at 50 per cent of the area rather than 33 per cent then the paddock optimum N rate when applied to the high zone falls short of its requirements and penalises yield, so the advantage to zone management increases to $14/ha. A similar increase occurs under the situation of a higher grain price ($250/t) or higher N cost ($1.6/kg).

Let’s now consider differences in soil fertility status as well as yield potential. This might arise where previous non-legumes may have left behind less available soil N on high yield zones and left more behind in low yielding zones. If we assume in our example that the high zone has 10 kg N/ha available and the low zone has 60 kg N/ha available, then the range in economically-optimum N rates in the three zones gets larger (0, 60 and 80 kg N/ha versus 20, 60 and 80 kg N/ha). By accounting for the zone differences in soil N status, as well as yield potential, moves the economic advantage to zone management from $12/ha to $27/ha. If we consider the opposite case where less available soil N occurs in the low zone and more in the high zone, which might occur following a legume pasture or a pulse crop, then the economic advantage drops back to $13/ha. This is because the extra soil N in the high zone insures that there is less shortfall in its N requirement when applying one N rate throughout the paddock.
What about other nutrients? If we assume that in addition to N we also variable rate P to each zone (and it’s a P responsive paddock) then the economically-optimum rates of P for this paddock are 10, 20 and 25 kg P/ha. The advantage of applying the economically-optimum N and P rate to each zone over applying the paddock optimum increases from $12/ha to $17/ha. If soil P status levels are lower on the high zone and higher on the low zone (as described above for N) then the advantage increases to $24/ha.

If we start stacking the various effects described above then it starts to give us an upper limit to the economic advantages than can be expected from zone management. For example, take the case of N and P, where soil fertility status for both nutrients is lower on the high zone and higher on the low zone, and where the low zone comprises 50 per cent of the paddock. In this case the paddock optima are 40 kg N/ha and 5 kg P/ha, compared to the low zone of 0 kg N/ha and 0 kg P/ha, middle zone of 40 kg N/ha and 5 kg P/ha and high zone of 80 kg N/ha and 25 kg P/ha. In this case the advantage for zone management over uniform paddock management is $57/ha. Instead of assuming a paddock with a wide range of yield potentials (0.5, 2.0 and 3.5 t/ha) and taking something more representative of the survey results (1.0, 1.75, 2.5 t/ha) then the advantage to zone management drops to $44/ha. This highlights the overall importance of differences in yield potential and soil fertility status within a paddock driving the potential economic benefits that can be gained from zone management.

**IMPORTANCE OF SEASON**

The economic benefits described above to zone management all depend on fertiliser being able to be matched to yield potential, which is difficult if yield potential is unknown at the time of the fertiliser decision being made! The issues involved in estimating or predicting the seasonal influence on yield potential have been described well by Bill Bowden in these proceedings. The table below shows the likely variation in yield potential we estimate for Buntine climate and a range of soils we are aware of occur on the northern sandplain varying in plant available water capacity (PAWC). It highlights that while in an ‘average’ season, potential yield might vary by 3 t/ha (from 0.9 to 3.8 t/ha) across the range of soil types, in a below-average season the variation might only be 1.3 t/ha, thus diluting the potential benefits for zone management, while in above-average seasons the range might increase to 3.6 t/ha.

**Table 1. APSIM simulated estimates of potential yield for wheat on three soils contrasting in plant available water capacity (PAWC), for Buntine climate data**

<table>
<thead>
<tr>
<th>Season</th>
<th>Soil PAWC (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 mm</td>
</tr>
<tr>
<td>Above average</td>
<td>1.4</td>
</tr>
<tr>
<td>Average</td>
<td>0.9</td>
</tr>
<tr>
<td>Below average</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Considerable variation occurs in potential yield within paddocks in WA, small and large, and low and high yielding. The larger the difference in yield between zones the more economic benefit from zone management. The economic benefits also increase with higher grain and fertiliser prices and depend on levels of soil nutrients in the different zones. However, use of this approach requires a good indication of yield potential. Yield maps can be put to good use by giving estimates of within-paddock variation in yield potential.

**KEY WORDS**

precision agriculture, zone management, yield potential, economics, nutrient requirement

**ACKNOWLEDGMENTS**

Ian Maling, Matt Adams, Mike Wong, Yvette Oliver, Bob Belford and Phil Price have provided stimulating discussions that have influenced the ideas in this paper. The work has been funded through the GRDC SIP09 program on precision agriculture.
Automatic guidance and wheat row position: On-row versus between-row seeding at various rates of banded P fertilisers

Tony J. Vyn¹, Simon Teakle², Peter Norris³ and Paul Blackwell⁴
¹Purdue University, USA; ²Landmark; ³Agronomy for Profit; ⁴DAWA, Geraldton

KEY MESSAGES

- On-row seeding enhanced P and K concentrations of wheat plants at early growth stages up to flowering, relative to between-row seeding, when the respective soil-test P and K concentrations were low and/or when MAP fertiliser was not banded at seeding.

- Mean wheat yields (i.e. average of 2 or 3 MAP fertiliser rates ranging from 0 to 50 or 80 kg ha⁻¹) were: (a) 11-14 per cent lower with on-row seeding at Binnu (where wheat followed wheat in 25 cm rows); (b) 7 per cent higher with on-row seeding at Mullewa (where wheat followed barley in 30 cm rows); and (c) not different at Pindar (where wheat followed wheat in 30 cm rows).

- Positive wheat yield response to increasing MAP application rate was observed only at Binnu (soil P = 40 ppm), but not at Mullewa (soil P = 20 ppm, and the only location with no control rate treatment), or at Pindar (soil P > 40 ppm). However, maximum yields at Pindar were achieved after on-row seeding with no MAP fertiliser applied.

- On-row seeding never improved the concentrations of macronutrients (N, P, K) or micronutrients (Cu, Zn and Mn) in the grain or straw at harvest.

- There was no conclusive wheat yield or grain nutrient composition evidence that MAP fertiliser rates could be lowered further with on-row versus between-row seeding.

- The combination of RTK-guided, on-row wheat seeding with lower rates of banded P fertilisers may perform best in one or more of the following scenarios:
  - In low-rainfall zones with low soil-test concentrations of K or P and certain micronutrients present in the banded fertiliser materials.
  - When prior crop stubble doesn’t interfere with seed placement or plant growth,
  - When wheat follows crops other than wheat.
  - Where wheat is grown in row widths of 30 cm or more.

AIM

To evaluate whether precision no-till seeding of wheat rows directly on former crop rows, versus between crop rows, in low rainfall zones would improve plant nutrient efficiency, yield and grain quality.

METHODS

Field trials involving 3 replications of on-row or between-row seeding of no-till wheat with 2 or 3 rates (i.e. between 0 and 80 kg/ha) of banded MAP-based fertilisers were established in 2005 near Binnu (deep yellow sand in 350 mm annual precipitation zone, and soil-test P of 40 ppm), Mullewa (yellow sand in 350 mm annual precipitation zone, and soil-test P of 20 ppm), and Pindar (red loam in 250 mm annual precipitation zone, and soil-test P of > 40 ppm). Because of cooler temperatures close to the coast, Binnu typically has less moisture deficit stress than Mullewa. Soil fertility samples were taken from in-row and between-row areas prior to seeding. Plant density, tiller/head density, biomass, leaf nutrient concentrations, grain yield, and both grain and straw nutrient concentrations were measured. Nutrient concentrations were determined by the CSBP Laboratory in Kwinana, WA. More details of the rationale for the experiment, the methodology, and the nutrient concentration results are available in Vyn et al. (2006).
RESULTS

Binnum location
Wheat plots (Calingiri at a seeding rate of 80 kg/ha) were planted on 11 May 2005 with a DGPS (Farm Scan) guided DBS tyne seeder in 25-cm row widths. Wheat crop yield in 2004 was approximately 2.5 t/ha, and the wheat stubble occasionally ‘bunched up’ and interfered at times with proper seed placement. Individual plots were the width of the air seeder (40’) as well as the harvest header (40 feet), and were from 300 to 400 m in length. The custom MAP-based blend had a fertiliser element composition (on a percentage basis) of N = 8.8, P = 19.2, S = 2.1, Cu = 0.3, Zn = 0.4, and Mn = 2.8. This MAP fertiliser was applied at rates of 0, 40 and 80 kg/ha in the seed furrow at a depth of 2-5 cm. Nitrogen and potash fertilisers were broadcast-applied after seeding. Total N rate was approximately 67 kg N/ha from 2 applications, and total K rate was 25 kg/ha. Total precipitation in 2005 was 325 mm.

Whole-plant sampling conducted on 11 July 2005 (results reported in Vyn et al. 2006). Whole-plant sampling at flowering occurred on 29 August 2005 (based on 4 sub-samples of 1.0 m row length per plot). Plants were lifted by shovel, and soil removed from the roots and crowns. Plant number, tiller number, head number, and dry weight were determined for each sub-sample; about 10 plants per sub-sample (minus the roots) were combined to form a plot sample of approximately 40 whole plants to submit to CSBP for nutrient analyses. Whole-plant sampling at maturity occurred on 1 November 2005 (based on 3 sub-samples of 1.5 m² each per plot). Whole plots were machine harvested with a Case AFX 8010 with DGPS guidance (Auto-Track) to correspond with the seeding unit width.

The soil sample results in Table 1 suggest residual effects of previous row position on concentrations of certain nutrients. Exchangeable K concentrations were higher for the in-row sample as expected because of the accumulation of K in the stubble in the previous year’s wheat, and the subsequent leaching and decomposition from the higher stubble levels in-row versus between-row. Available P levels were similar for in- and between-row sampling positions. Certain micronutrients (particularly Mn) were also higher for the in-row samples, and this may simply be a response to the previous year’s banded micro-nutrient application. Higher concentrations of soil P and K in former wheat crop rows were also observed by Grant Thompson in a Crop Update report in 2003.

Table 1. Soil fertility concentrations for in-row versus between-row sampling (Binnum, 2005)

<table>
<thead>
<tr>
<th>Row position</th>
<th>O.M. (%)</th>
<th>pH H₂O</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Cu (ppm)</th>
<th>Zn (ppm)</th>
<th>Mn (ppm)</th>
<th>CEC</th>
<th>Ex. Al (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-row</td>
<td>1.3</td>
<td>6.7</td>
<td>40</td>
<td>105</td>
<td>0.9</td>
<td>1.1</td>
<td>15.8</td>
<td>2.8</td>
<td>0</td>
</tr>
<tr>
<td>Between</td>
<td>1.2</td>
<td>6.6</td>
<td>40</td>
<td>75</td>
<td>0.7</td>
<td>0.9</td>
<td>10.9</td>
<td>2.6</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2. Effects of row position and banded fertiliser rates at seeding on wheat plant response at the flowering stage (Binnum, 2005)

<table>
<thead>
<tr>
<th>Fertility treatment</th>
<th>Row position</th>
<th>Biomass (kg/ha)</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>Cu ppm</th>
<th>Zn ppm</th>
<th>Mn ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>On-row</td>
<td>4516</td>
<td>1.30</td>
<td>0.142</td>
<td>1.49</td>
<td>2.46</td>
<td>10.2</td>
<td>98.1</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>4424</td>
<td>1.36</td>
<td>0.124</td>
<td>1.44</td>
<td>2.62</td>
<td>12.1</td>
<td>84.2</td>
</tr>
<tr>
<td>Half-rate</td>
<td>On-row</td>
<td>4308</td>
<td>1.24</td>
<td>0.134</td>
<td>1.40</td>
<td>2.16</td>
<td>10.3</td>
<td>96.7</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>4372</td>
<td>1.46</td>
<td>0.130</td>
<td>1.36</td>
<td>2.36</td>
<td>12.3</td>
<td>89.7</td>
</tr>
<tr>
<td>Full-rate</td>
<td>On-row</td>
<td>4436</td>
<td>1.24</td>
<td>0.134</td>
<td>1.37</td>
<td>2.00</td>
<td>9.6</td>
<td>99.7</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>4316</td>
<td>1.45</td>
<td>0.153</td>
<td>1.54</td>
<td>2.54</td>
<td>12.7</td>
<td>93.1</td>
</tr>
<tr>
<td>Mean of 3</td>
<td>On-row</td>
<td>4420</td>
<td>1.26</td>
<td>0.137</td>
<td>1.42</td>
<td>2.21</td>
<td>10.0</td>
<td>98.2</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>4371</td>
<td>1.42</td>
<td>0.136</td>
<td>1.45</td>
<td>2.51</td>
<td>12.4</td>
<td>89.0</td>
</tr>
</tbody>
</table>

Whole-plant dry weights were not affected by either wheat row position or by the MAP fertility rate treatments (Table 2). Whole plant biomass at this stage is perhaps more a function of the broadcast N application (made more than 2 months before this sampling) and to growing-season rainfall or to possible variability in soil moisture in the experimental area than to treatments themselves. A large
response to the P banding treatments was not expected because mean soil-test P was already 40 ppm (Table 1). The lack of row position effects on biomass weights is also not surprising if wheat tiller and head development were not detrimentally affected by on-row seeding (Vyn et al. 2006).

Although there was a benefit in both P concentrations and total P uptake (data not shown) associated with on-row seeding in the control fertility treatment, there was generally a disadvantage in N concentrations and total N uptake with on-row seeding for all banded fertility rates. The N and P responses to treatments at the flowering stage were similar in pattern to that observed at the first-node stage (Vyn et al. 2006). On-row seeding provided no benefit to wheat plants in terms of K concentrations or total K uptake. However, the farmer broadcast-applied K fertiliser in June. Manganese concentrations and uptake were higher for on-row seeding than for between row seeding at the zero and half fertiliser rates. Although the Mn increases are interesting, overall plant Mn concentrations at this site are very high. Neither concentrations nor total uptake of Cu and Zn were ever enhanced by seeding wheat on the row. Note that statistical analyses of the data in Table 2 is not complete.

Table 3. Effects of row position and banded fertiliser rates at seeding on wheat yields and associated whole-plant and grain parameters at harvest (Binnu, 2005)

<table>
<thead>
<tr>
<th>Fertility treatment (MAP)</th>
<th>Row position</th>
<th>Machine yield (kg/ha)</th>
<th>Hand yield (kg/ha)</th>
<th>Biomass yield (kg/ha)</th>
<th>Harvest index (ratio)</th>
<th>Good head #/m²</th>
<th>Seed weight (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>On-row</td>
<td>2319 c*&lt;br&gt;Between</td>
<td>2597 abc</td>
<td>2689 b&lt;br&gt;5099 b</td>
<td>0.51&lt;br&gt;53.3 ab</td>
<td>167.7 c&lt;br&gt;46.3 ab</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>2733 a&lt;br&gt;2819 a</td>
<td>3263 a&lt;br&gt;3383 a</td>
<td>6107 ab&lt;br&gt;6764 a</td>
<td>0.50&lt;br&gt;50.9 b</td>
<td>210.9 a&lt;br&gt;45.8 ab</td>
<td></td>
</tr>
<tr>
<td>Half-rate</td>
<td>On-row</td>
<td>2464 bc&lt;br&gt;2536 abc</td>
<td>2835 a&lt;br&gt;2819 ab</td>
<td>5540 ab&lt;br&gt;6764 a</td>
<td>0.51&lt;br&gt;51.0 c</td>
<td>189.8 abc&lt;br&gt;45.3 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>2781 a&lt;br&gt;3383 a</td>
<td>3983 a&lt;br&gt;6764 a</td>
<td>6107 ab&lt;br&gt;6764 a</td>
<td>0.50&lt;br&gt;50.9 b</td>
<td>210.9 a&lt;br&gt;45.8 ab</td>
<td></td>
</tr>
<tr>
<td>Full-rate</td>
<td>On-row</td>
<td>2835 a&lt;br&gt;3383 a</td>
<td>2819 ab&lt;br&gt;5540 ab</td>
<td>5664 a&lt;br&gt;6764 a</td>
<td>0.50&lt;br&gt;50.9 b</td>
<td>210.9 a&lt;br&gt;45.8 ab</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>2781 a&lt;br&gt;3383 a</td>
<td>3983 a&lt;br&gt;6764 a</td>
<td>6107 ab&lt;br&gt;6764 a</td>
<td>0.50&lt;br&gt;50.9 b</td>
<td>210.9 a&lt;br&gt;45.8 ab</td>
<td></td>
</tr>
<tr>
<td>Mean of 3</td>
<td>On-row</td>
<td>2439 b&lt;br&gt;2439 b</td>
<td>2721 b&lt;br&gt;2721 b</td>
<td>5298 b&lt;br&gt;5298 b</td>
<td>0.51&lt;br&gt;51.0 c</td>
<td>172.0 b&lt;br&gt;46.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>2733 a&lt;br&gt;3171 a</td>
<td>3171 a&lt;br&gt;6167 a</td>
<td>6167 a&lt;br&gt;6167 a</td>
<td>0.51&lt;br&gt;51.0 c</td>
<td>205.1 a&lt;br&gt;45.6</td>
<td></td>
</tr>
</tbody>
</table>
* Letters that are different from each other in the same column indicate that their respective means are significantly different according to a protected LSD test (P=0.05).

Both grain and total biomass yields were significantly higher (when averaged for the 3 fertiliser rates) for between-row than for on-row planting (Table 3). Trends for yield increases associated with between-row seeding were evident, but not significant, at all 3 MAP rates (Table 3). Both grain and total biomass yields increased rather linearly with the rate of fertiliser application (Table 3), and there was no indication that placement of wheat rows on former wheat rows resulted in any reduction in the optimum MAP rate required. Most of the yield increase with between-row planting can be attributed to higher head numbers (Table 3) which may likely have resulted both from higher head number per plant and an overall improvement in plant establishment consistency when wheat was seeded between the stubble from former rows. Grain quality parameters were similar for between- and on-row systems (Vyn et al. 2006).

Mullewa location

Wheat plots (Wyalkatchem) were planted 25 May 2005 with an RTK-guided DBS tyne seeder in 30 cm row widths. Barley crop yield in 2004 was approximately 2.5 t/ha. The study consisted of 4 treatments: Two MAP fertiliser (‘Summit Zinc Star’) rates of 75 kg/ha (full rate) and 38 kg/ha (half rate) with in-row and between-row seeding. Individual plot width matched the air seeder (18 m); plots were over 1500 m long. No residue bunching from seeding was evident, and plant establishment looked ideal. Nitrogen fertilisers were applied before and after sowing: ammonium sulfate at 200 kg/ha (April) and urea at 100 kg/ha (July). Plant sampling was similar to Binnu, but harvest sub-areas were 1.8 m² each (six 30 cm rows).

Exchangeable K concentrations were higher for the in-row sample (Table 4) as expected. Available P levels were similar for in-row and between-row sampling positions, but these samples were only taken to a 10 cm depth. Higher Zn concentrations were also observed in-row. More intensive sampling (depths and replications) is recommended to validate the row position effects on P status in low P soils.

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Crop Updates is a partnership between the Department of Agriculture, Western Australia and the Grains Research & Development Corporation
Plant number and head number at flowering were slightly (i.e. 5%) lower with on-row planting (Vyn et al. 2006), suggesting that presence of the cereal stubble was a negative factor in either seed placement or survival of young seedlings. A much larger reduction in plant population with wheat after wheat has also been observed in Southern Australia (McCallum, 2005) with higher levels of residue cover. Whole plant dry weights were not affected by either the fertility or the row position treatments. Plant concentrations of P and Zn at flowering were higher for wheat planted on the old row versus those planted between the old row at the half rate of MAP application, but not with the full rate of MAP application (Vyn et al. 2006). Plant concentrations of K were consistently higher for on-row versus between-row planting. Both biomass and grain yields were significantly increased by on-row versus between-row seeding (Table 5), but the most obvious advantage with on-row seeding occurred at the highest MAP fertility rate. On-row seeding did not result in any reductions in wheat head density. One wonders what the yield advantage might have been for on-row seeding with no MAP application, because soil available P concentrations were only 20 ppm.

Table 5. Effects of row position and banded fertiliser rates at seeding on wheat grain yields and associated whole-plant and grain quality parameters at harvest (Mullewa, 2005)

<table>
<thead>
<tr>
<th>Fertility treatment</th>
<th>Row position</th>
<th>Hand yield (kg/ha)</th>
<th>Biomass yield (kg/ha)</th>
<th>Good head #/m²</th>
<th>Seed wt. (mg)</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half-rate</td>
<td>On-row</td>
<td>2820 a*</td>
<td>6196 ab</td>
<td>253.1</td>
<td>47.6</td>
<td>2.24</td>
<td>0.29</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>2852 a</td>
<td>6121 b</td>
<td>265.9</td>
<td>47.8</td>
<td>2.23</td>
<td>0.31</td>
<td>0.38</td>
</tr>
<tr>
<td>Full-rate</td>
<td>On-row</td>
<td>2930 a</td>
<td>6503 a</td>
<td>257.0</td>
<td>48.5</td>
<td>2.17</td>
<td>0.31</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>2536 b</td>
<td>5926 b</td>
<td>256.1</td>
<td>47.8</td>
<td>2.18</td>
<td>0.29</td>
<td>0.36</td>
</tr>
<tr>
<td>Mean of 3</td>
<td>On-row</td>
<td>2875 a</td>
<td>6349 a</td>
<td>255.1</td>
<td>48.1</td>
<td>2.20</td>
<td>0.30</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>2694 b</td>
<td>6023 b</td>
<td>261.0</td>
<td>47.8</td>
<td>2.20</td>
<td>0.30</td>
<td>0.37</td>
</tr>
</tbody>
</table>

* Letters that are different from each other in the same column indicate that their respective means are significantly different according to a protected LSD test (P = 0.05).

The favourable influence of on-row positioning on wheat yields at this location (Table 5) contrasts directly with the wheat yield reductions observed at the Binnu location (Table 3). Although some of the differences in response might be due to barley as a prior crop instead of wheat, the major advantage with on-row seeding at the Mullewa location was that on-row seeding did not negatively affect plant population (Vyn et al. 2006) or the final head number (Table 5). Neither row position nor MAP fertility rate had any impact on nutrient composition in wheat grain or wheat straw (Vyn et al. 2006).

**Pindar location**

Soil pH was low (5.2). Wyalkatchem wheat was seeded at 50 kg/ha on 30 May 2005, with an RTK-guided DBS tyne air seeder in 30 cm row widths. Rows were planted either on or between the wheat rows from 2004. Wheat crop yield in 2004 was approximately 0.5 t/ha due to drought, and wheat stubble did not interfere with seeding. Individual plots were 15m wide and 100 m in length. Three rates of 0, 25 and 50 kg/ha of a MAP-based fertiliser composed of 8 per cent N, 17.6 per cent P, 0.5 per cent Zn, and 0.5 per cent Cu were applied. Soil and plant sampling were similar to Mullewa. Both avail. P (75 vs. 40 ppm) and exch. K (200 vs. 155 ppm) concentrations were higher for in-row samples than for between-row samples taken in March 2005.

Wheat grain and biomass yields were not significantly affected by row position or by fertility application rate (Table 6). In the Control fertiliser treatment, wheat biomass yields were about 300 kg/ha higher, and wheat grain yields were about 100 kg/ha higher, when wheat was seeded on the old rows rather than between the old rows. Wheat yields were not improved further by MAP fertiliser application in either on-row or between-row seeding. Harvest index was low (42%) and overall biomass at harvest was lower than at flowering. The most profitable system for the farmer in this dry environment for 2005 was to apply no P fertiliser and seed on the old rows. Although average N, P and K
concentrations in the grain were unaffected by row position, grain P concentrations were highest with between-row seeding at the full rate.

Table 6. Effects of row position and banded fertiliser rates on wheat yields and associated whole-plant and grain quality parameters at harvest (Pindar, 2005)

<table>
<thead>
<tr>
<th>Fertility treatment</th>
<th>Row position</th>
<th>Hand-yield kg/ha</th>
<th>Biomass yield (kg/ha)</th>
<th>Total head #/m²</th>
<th>Seed wt. (mg)</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>On-row</td>
<td>1157</td>
<td>2777</td>
<td>174.0</td>
<td>37.0</td>
<td>2.32</td>
<td>0.203 ab*</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>1056</td>
<td>2470</td>
<td>178.0</td>
<td>38.2</td>
<td>2.37</td>
<td>0.197 b</td>
<td>0.44</td>
</tr>
<tr>
<td>Half-rate</td>
<td>On-row</td>
<td>1124</td>
<td>2619</td>
<td>191.0</td>
<td>38.2</td>
<td>2.24</td>
<td>0.197 b</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>1159</td>
<td>2553</td>
<td>193.0</td>
<td>37.0</td>
<td>2.42</td>
<td>0.214 ab</td>
<td>0.45</td>
</tr>
<tr>
<td>Full-rate</td>
<td>On-row</td>
<td>1121</td>
<td>2731</td>
<td>188.3</td>
<td>36.5</td>
<td>2.53</td>
<td>0.228 ab</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>1158</td>
<td>2817</td>
<td>190.3</td>
<td>36.5</td>
<td>2.47</td>
<td>0.241 a</td>
<td>0.49</td>
</tr>
<tr>
<td>Mean of 3</td>
<td>On-row</td>
<td>1134</td>
<td>2709</td>
<td>184.4</td>
<td>37.6</td>
<td>2.36</td>
<td>0.209</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Between</td>
<td>1124</td>
<td>2592</td>
<td>187.1</td>
<td>36.8</td>
<td>2.42</td>
<td>0.217</td>
<td>0.46</td>
</tr>
</tbody>
</table>

* Letters that are different from each other in the same column indicate that their respective means are significantly different according to a protected LSD test (P = 0.05).

CONCLUSIONS

Soil exchangeable K concentrations prior to seeding wheat were consistently higher for samples taken in versus between the old crop rows. On-row seeding increased wheat grain and biomass yields at least 7 per cent at one location (Mullewa), had no effect on wheat yields at a second location (Pindar), and reduced wheat yields 11-14 per cent at a third location (Binnu), relative to between-row seeding systems. Maintaining wheat plant and head density were key to successful on-row seeding systems in these low-rainfall environments in the Northern Agricultural Region. Although there were early-season benefits in plant nutrient uptake following on-row seeding at reduced MAP fertiliser rates, there was no conclusive yield or grain nutrient composition evidence that MAP fertiliser rates could be lowered further with on-row versus between-row seeding. There is more potential for fertiliser efficiency gains with RTK seeding on former crop rows when wheat follows a prior crop other than wheat, or when wheat is seeded in wider row width systems than those in this study. Future studies should involve soils with lower available P concentrations.

KEY WORDS

automatic guidance, RTK precision, wheat, row position, phosphorus fertility, nutrient uptake, low rainfall

ACKNOWLEDGMENTS

Research Fellowship funding from the Organization of Economic Cooperation and Development (OECD, AGR/PROG Contract JA00030987) enabled Dr T. Vyn to conduct this research on his sabbatical leave from Purdue University, in conjunction with Dr P. Blackwell of DAWA. Financial support for local expenses was provided by DAWA (Nutrient Management Initiative). In-kind support was received from CSBP Ltd (plant analyses, coordinated via Dr Steve Loss, Kwinana, WA) and United Farmers Cooperative. Cooperating farmers were Russell Carson; Binnu, Matt Freeman; Mullewa and Mike Kerkmans; Pindar. Technical assistance from Stewart Edgecombe and Dale Spencer.

REFERENCES


Paper reviewed by: Andrew Blake
Assessing the sustainability of high production systems (Avon Agricultural Systems Project)

Jeff Russell and James Fisher, Department of Agriculture, WA; Roy Murray-Prior and Deb Pritchard, Muresk Institute; Mike Collins, ex WANTFA, Northam

KEY MESSAGES

A project has commenced to test the hypothesis that ‘High production farming systems are sustainable in the Avon valley’. An outline of the first two season’s progress is described with discussion for future activities at the site.

AIMS

Staff from the Department of Agriculture, Curtin University and the Western Australian No-Tillage Farmers Association are involved in a collaborative project to assess the sustainability of high production farming systems in the Avon District. To answer the following questions:

1. What are the limits to potential yield/production?
2. What are the consequences of high production farming on other aspects and components of the system?
3. What are the impacts of specific management options?

METHOD

Paddock 30 at Muresk was selected to investigate the practical elements of a high production cropping system. It met criteria covering accessibility, had a recent continuous cropping history and detailed records of paddock operations and yield mapping. As this paddock had a recent history of continuous cropping and was likely to have built up a grass weed seed bank, TT canola was grown in 2004 as a cleaning crop to set the paddock up for 2005.

‘Tramline’ technology was used to determine if this management practice is suitable to the Avon Valley and one which could meet the aims of the project. Existing machinery used by Muresk was modified through upgrades as they occur in the normal course of farm operations. This would be in keeping with many of the existing farming operations used in the Avon Valley district and so serve as a demonstration site to neighbouring farmers as to how to go about similar transitions.

In January 2005 a geophysical survey of paddock 30 was conducted by Geoforce. Terrain, EM31, EM38 and radiometric images were produced. Detailed soil testing had been conducted at a number of sites (Figure 1) in the paddock during 2002 by Georgina Warren as part of the CPSTOF project to develop ‘Collaborative planning support tools for optimising farming systems’, which was financed by the Australian Research Council (ARC-Linkage program, LP0219752). These sites plus others were sampled in detail in March 2005 to make up 33 study locations within the paddock.

Procedures were put in place for 2005 to incorporate more data collection while at the same time, use the paddock as a resource within Muresk’s teaching program. Students undertaking practical field work activities on Paddock 30 contributed to the collection of baseline information required of the paddock in helping to ascertain soil properties, weed dynamics on the paddock and agronomic measures from the 33 locations preselected within the paddock.

RESULTS

The total paddock area is 98 ha with 94 ha. The paddock has a slope mainly down to the north with a slight area sloping down on the south western edge. A water way also runs down to the northwest end of the paddock. Soils are mixed, light loam on the western edge with the balance being loam to clay. Contour banks had been placed up the slope at the southern and south eastern parts of the paddock. These were removed in April 2005. Rock heaps are also more prominent on the upslope areas of this southern half of the paddock. Tramlines were placed to run northwest–southeast down the longest slope.
DISCUSSION

Using the site for the demonstration purposes of implementing a ‘tramling’ system in a manner most likely to be adopted by neighbouring growers has progressed. The stepwise modification, transition and upgrading of machinery is a more realistic and pragmatic approach similar to that which is used by growers.

Background information on the paddock has been collected thanks to records held by Muresk and these are currently being documented in greater detail to give a general overview of the history of the paddock. The detailed soils data collected by Warren will serve as a useful benchmark upon which to match changes to soil properties in future years. Muresk has been collecting yield data maps of paddocks over the last 5−6 years. These data also be used for future implementation of ‘site specific’ agronomy being established on the paddock and demonstration and evaluation of variable rate technology for cropping systems in this environment.

Benchmarking progress on Paddock 30 with that of existing paddocks on the Muresk property can also be done to assist in the evaluation process of implementing the tramline system and crop agronomic practices selected to push the system. This with archived paddock data on input costs and incomes can be used to analyse efficiency gains and costs with the implementation of a new system.

The geophysical data will assist in the understanding of agronomic performance across the paddock and for implementation of future studies to measure environmental impacts.

KEY WORDS
high productivity farming systems, sustainability, tramlining, Avon Valley

ACKNOWLEDGMENTS

John Eaton (Farm Manager) and the 2005 1st Year students at Muresk; Boekeman machinery.

Project No.: 67F Central Farming Systems
Paper reviewed by: Linda Leonard
The application of precision agriculture techniques to assess the effectiveness of raised beds on saline land in WA

Derk Bakker¹, Greg Hamilton², Rob Hetherington¹, Andrew Van Burgel¹ and Cliff Spann³, Department of Agriculture, Western Australia
¹Albany, ²Perth and ³Mt Barker

KEY MESSAGES

The application of raised beds on waterlogged saline land improves grain yield. More specifically, using spatial distribution techniques it was found that significant scope exists to improve the grain yield in areas not affected by salinity. Using the same techniques it was also found that raised beds did not reduce the impact of salinity on crop productivity. A novel spatial technique was developed and used to assess the pasture composition in relation to salinity but no particular soil management treatment was detected that maintained the composition.

AIM

Due to the extensiveness of salinity and waterlogging in many paddocks the effectiveness of raised beds was assessed with spatial techniques common to precision agriculture. Some results of this approach are presented in this paper.

Background

Significant areas of the Western Australian Wheatbelt experience elevated levels of soil salinity particularly in lower lying areas. The increase in soil salinity caused by rising ground water tables, has severely altered the farming options in those areas. Historically these areas produced good yields but are now excluded from cropping and are used exclusively for grazing with little scope for improved pastures except perhaps for the utilisation of saltbush. Transient waterlogging has now also been recognised as a major factor contributing to the poor productivity of these areas.

For several years, research into the application of raised beds to alleviate waterlogging has shown that yield increases can be obtained with the current farming system. The impact of raised beds on waterlogged and saline land has not been clear and has been the subject of a research project funded by the Department of Agriculture, Western Australia (DAWA), the Grains Research of Development Corporation (GRDC) and the CRC for Plant Based Management of Dryland Salinity.

Aspects associated with raised beds thought to be beneficial in the cultivation of saline land are: i) the ability of raised beds to leach salts from the root zone; ii) increased soil cultivation limits the capillary rise in spring and reduces the re-salinisation of the root zone; and iii) an increase in the runoff from the beds reduces the accession of the ground water, which will have a positive long-term effect on the watertable.

METHODS

Three large experimental areas (about 60 ha) located in the South Western part of WA were selected on the basis of the range of salinities, the susceptibility to waterlogging, and their representation of significant portions of the landscape. The initial salinity distribution was established through an electromagnetic (EM38) survey and the topography assessed with a Beeline® DGPS system. The electrical conductivity (ECa) obtained with an EM38 is a very good predictor of salinity to a depth of 60-70 cm. Based on the survey information an experimental layout was determined and shallow surface drains and treatments were installed in 2002. The treatments consisted of a cropping and a pasture area with raised beds (RB) made following a deep soil cultivation and an annual soil loosening, no-till beds (NT) made without any prior soil cultivation or annual soil loosening and a control (C). Each treatment was replicated four times with an average plot size of 2 to 3 ha. The choice of crop and pasture composition varied from site to site and was determined by the growers. Changes to the salinity distribution were captured in subsequent salinity surveys carried out each year during the winter after seeding and after each harvest. At harvest time the spatial distribution of the
grain yield was recorded with a yield monitor and a DGPS. The gross plot yields were obtained by weighing the header empty and full using large roll-on/roll-off weighing platforms. Biomass estimates of the pasture and the crop were derived from digital multi-spectral images, obtained in late September or early October but it is beyond the scope of this paper to present any data.

The salinity and the yield were not obtained in exactly the same position and because the yield was obtained at a higher resolution, an interpolated calculated yield was related to each measured salinity point using GIS software. In order to extract the salinity effect on the yield other factors such as, for example, waterlogging, soil nutrition and weeds had to be excluded. This was done using the approach of relative yield which is calculated as the yield at each point within a plot relative to the average yield in that plot unaffected by salinity. All the data points were separated into the three treatments, C, RB and NT, sorted in ascending order, split into groups of 50 data points each and the average calculated of each group. The averages were used in the presentation.

The pasture composition was assessed during the EM38 surveys in a novel way using seven potentiometers each representing a species including bare ground. During the survey the position of the potentiometer was changed to reflect the composition, i.e. a pure rye grass stand would result in the RG potentiometer fully open and the rest closed. The same logger logging the EM38 logged the position of the potentiometers.

RESULTS AND DISCUSSION

The results presented are limited to one site (Woodanilling) only because the sites did not vary greatly in the way they performed and the type of relevant issues.

In Figure 1 the salinity distribution at two different times is presented.

![Salinity Distribution at Two Different Times at Woodanilling](image)

**Figure 1.** Salinity distribution (ECa, mS/m) at Woodanilling in April 2002 and 2004.

A salinity level of > 300 mS/m severely affects crop growth. From the figure it is clear that several areas had such high salinities but no major change was detected in the size of those areas by April 2004.

The relative yield as well as the yield in 2004 in relation to salinity is presented in Figure 2.
Figure 2. Relative yield as a function of salinity for the control (C), raised beds (RB) and the no-till beds (NT) (A) and the absolute yield (B).

No difference is present between the treatments in the salinity effect on the relative yield (Figure 2A) since the slope of the three regression lines is identical. There is little difference in the salt movement between the raised beds, the no-till beds and the control (no data presented here). All three treatments had significant salt leaching during the winter months and re-salinisation during the summer hence no difference in yield-salinity relationship.

When the yield vs salinity relationship is presented (Figure 2B) a strong salinity effect appears to be present. The yield in the beds remained constant until a level of about 80 mS/m after which the yield declined rapidly. What appeared to be a salinity effect was really caused by other factors affecting the yield in various plots as presented in the next section.

For a given salinity there was a great difference in the yield across plots as presented in Figure 3.

Figure 3. Yield as a function of salinity separated in the plots for the control (A), the no-till beds (B) and the raised beds (C).

Little difference was found between the plots in the control (Figure 3a). All were affected by waterlogging and weeds to a point that salinity did not affect the productivity. In the no-till beds NT1 was the most productive plot, followed by NT3, NT4 and NT5. Plot NT1 has the largest depth to the ground water, the best nutrition, the least exposed to waterlogging and very few weeds while the other plots were more affected by those factors. The productivity of the raised beds varied also greatly. Good yields were achieved in RB2 which was well drained, had good soil nutrition, and few weeds despite some moderately salinities, i.e. up to 130 mS/m while the other plots suffered from, to various degrees, a poorer soil nutrition, weed control, overall drainage as well as a coarse grey sand-over-clay duplex soil which limits the yield.
Assuming that below 120 mS/m the yield potential is not affected by salinity the potential to improve yields by better drainage, fertiliser application and weed management is considerable (i.e. 2 t/ha).

**Pasture composition**

The pasture composition was expressed as a presence of rye grass and cape weed, the first a sign of a healthy pasture and the latter evidence of a poorer pasture. The composition was determined in September 2003 and again in July 2005 and is presented in Figure 4.

![Rye Grass Sept 2003](image1)

![Rye Grass July 2005](image2)

![Cape Weed Sept 2003](image3)

![Cape Weed July 2005](image4)

**Salinity Distribution and Pasture Composition**

**Rye Grass and Cape Weed**

**September 2003 and July 2005**

Figure 4. Salinity distribution and pasture composition changes over two years along a transect at Woodanilling. 1 = Solid stand and 0 = nothing present.

A severe degradation of the pasture occurred between 2003 and 2005. In September 2003 the pasture had not yet been grazed and the rye grass grew prolifically. This grass almost entirely disappeared after two years of intermittent grazing while the presence of cape weed showed the reverse. While the rye grass seems to survive in the areas with a low salinity there was no obvious treatment effect and raised beds while providing very good surface drainage did not halt the decline of the pasture. At times waterlogging did seem to have a positive effect on the pasture with pockets of clover established in the wettest areas. It should be mentioned that grazing of the pasture has been less than ideal and it is recognised that with some more intensive and timely grazing the pasture composition could be improved. There is a lot of visual evidence that indicate that stock losses are higher on the beds than on the flat as it was found that sheep lying in the furrows were sometimes not able to get up again and died of de-hydration.

**CONCLUSIONS**

The introduction of raised beds to waterlogged saline land increased the farming systems options available. The alleviation of waterlogging greatly improved the yield, but high salinity, weeds, poor soil fertility and soil type limited the yield. Using the spatial distribution of salinity and yield, and the approach of relative yield, salinity effects were separated from other confounding effects resulting in little difference between the three treatments in the yield-salinity relationship. The implementation of raised beds did not improve pasture growth or helped to maintain pasture composition. Due to the stock losses experienced on raised beds, surface drainage to improve pasture production will require other means.
KEYWORDS
raised beds, salinity, waterlogging, yield mapping, EM38 mapping

ACKNOWLEDGEMENTS
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