Crop Updates 2000 Cereals - part 4

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Response to subsoil acidity of wheat genotypes differing in Al-tolerance

C. Tang, Z. Rengel, E. Diatloff and B. McGann, Soil Science and Plant Nutrition/CLIMA, University of Western Australia

KEY MESSAGE
Liming and selection of tolerant cultivars provide solutions to the subsoil acidity problem.

INTRODUCTION
Subsoil acidity with high levels of toxic Al is a major limiting factor in crop production in the Western Australian wheatbelt. Liming is a common practice to ameliorate topsoil acidity but is inefficient in amelioration of subsoil acidity within the time scale and with economic effectiveness required because of the slow movement of lime down the soil profile. Subsoil acidity will impair root growth of sensitive crops and hence reduce water and nutrient uptake, particularly in the late part of the season. Crop cultivars differ in their susceptibility to Al toxicity in acid soils. Selection of tolerant cultivars may provide an alternative way to cope with the subsoil acidity problem. Here we report a field trial along with a glasshouse soil column study which examined the effect of subsoil acidity on the yield of two isogenic wheat genotypes differing only in Al-tolerance.

METHODS
A field trial was conducted on a sand over gravel at Wongan Hills (Peter Sadler, Leahurst Farms - 15 km east of Wongan Hills). The trial used large strips of lime (25 m x 1 km) applied at 0 and 2.5 t/ha in 1984. Two distinct soil acidity profiles had been established under the limed and unlimed strips (Figure 1).

![Figure 1. Soil pH (a) and soil Al concentration (b) profiles of the field trial site at Wongan Hills.](attachment:figure1.png)

By applying lime (1.5 t/ha in 1999) we ameliorated the topsoil acidity in the portion of the unlimed strip. Hence three soil acidity profiles were created:

1. Acid topsoil over shallow subsurface acidity (old unlimed strip).
2. Newly limed topsoil over shallow subsurface acidity.
3. Ameliorated topsoil and subsurface acidity (old limed strip).
The two genotypes were sown in five replicates over each of the soil profiles. These genotypes are isogenic (more than 95% similarity in their genome) wheat lines ET8 (Al-tolerant) and ES8 (Al-sensitive) which are almost identical in their genetic background to cv Egret (Egret = Al-sensitive). The trial was sown on 24 June, and received 150 kg/ha of superphosphate Cu, Mo and Zn, 100 kg/ha of KCl and 100 kg/ha of urea. Due to the late sowing and late maturity of the genotypes, grain filling occurred during the dry part of the season, resulting in decreased yields overall.

RESULTS

The average yield of the Al-tolerant genotype (ET8 – 0.99 t/ha) was significantly higher than that of the Al-sensitive genotype (ES8 – 0.87 t/ha) (Table 1). There was an overall 14% yield increase by growing the Al-tolerant genotype, mostly due to much better performance (41%) of ET8 over ES8 in the soil profile with limed topsoil, but acidic subsurface soil. This yield difference also indicates that Al toxicity is a major yield-limiting factor at the trial site because the wheat genotypes ET8 and ES8 differ only in their tolerance to Al toxicity.

The isogenic lines tested here represent the extremely valuable genetic material for identifying potential contribution of Al tolerance to preventing yield losses in an Al-toxic soil. In addition, Al tolerance of modern, well-adapted wheat cultivars (as opposed to old cultivar Egret) can be improved by transferring tolerant genes that exist in ET8.

Table 1. Grain yield (t/ha) of Al-sensitive (ES8) and Al-tolerant (ET8) wheat genotypes grown on the field trial site at Wongan Hills in the 1999 season. Values are means ± SE

<table>
<thead>
<tr>
<th>Soil profile</th>
<th>ES8</th>
<th>ET8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Acid topsoil over shallow subsurface acidity.</td>
<td>0.82 ± 0.08</td>
<td>0.85 ± 0.11</td>
</tr>
<tr>
<td>2. Newly limed topsoil over shallow subsurface acidity.</td>
<td>0.78 ± 0.05</td>
<td>1.10 ± 0.03</td>
</tr>
<tr>
<td>3. Ameliorated subsurface acidity due to surface applied lime at 2.5 t/ha in 1984.</td>
<td>1.02 ± 0.02</td>
<td>1.03 ± 0.06</td>
</tr>
<tr>
<td>Average =</td>
<td>0.87</td>
<td>0.99</td>
</tr>
</tbody>
</table>

The results in Table 1 also showed: 1) The Al-sensitive genotype ES8 did not respond to topsoil liming applied before sowing. By contrast, there was a 29% increase in the grain yield of ET8 due to this lime application. 2) Wheat genotypes produced 21% (ES8) and 24% (ET8) higher yield due to the lime applied 15 years ago. This indicates that the benefits of liming can last at least 15 years after initial application at 2.5 t/ha.

It is interesting to note that there were no differences in the yield between the two wheat genotypes in either the fully acidic soil profile (1) or in the ameliorated soil profile (3) (Table 1). This indicates that: 1) liming is more beneficial than using Al-tolerant wheat genotypes, but 2) using Al-tolerant genotypes as opposed to Al-sensitive ones can provide early response to liming (compare 1 and 2) and is beneficial when subsurface acidity is present (compare 1 and 3).

A more detailed glasshouse study using reconstructed soil columns examined the effect of subsoil acidity on the growth of these two wheat genotypes. The soils were collected from the field trial site at Wongan Hill. The reconstructed soil profiles contained the same topsoil (0-10 cm) from the limed strip and different subsoil (below 10 cm): one from 15-25 cm of the unlimed and the other from 15-25 cm of the limed strip. The results showed that subsoil acidity decreased the yield of ES8 (Al-sensitive) by 44% and of ET8 (Al-tolerant) by 12%. The ET8 line proliferated more roots than ES8 in the acid subsoil layer (Figure 2).
Figure 2. Root distribution of Al-tolerant and Al-sensitive wheat genotypes grown in soil column with a limed topsoil (0-10 cm) and limed or acid subsoil (below 10 cm). Horizontal bars indicate SE.

CONCLUSION
- Al-tolerant wheat genotype yields higher than Al-sensitive genotype when the topsoil is limed and subsoil acidic.
- Al-tolerant wheat genotype proliferates more roots in the acid subsoil than Al-sensitive genotype.
- The benefits of liming may last at least 15 years after initial application at 2.5 t/ha.

KEY WORDS
al-tolerance, genotypic variation, root proliferation, subsoil acidity

GRDC Project No.: UWA 259
Application of molecular markers in Barley Improvement

Mehmet Cakir¹, Nick Galwey¹ and David Poulsen²

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KEY MESSAGES

The use of molecular markers in plant breeding is well underway. Though they are expensive to develop, molecular markers open the possibility of reliable and rapid selection for a wide range of traits. In many cases marker-based selection will eventually be more efficient and cost-effective than evaluation of plants in the field. Marker-based selection has particular potential for the genetic improvement of traits that must be painstakingly evaluated after harvest, such as malting quality in barley.

The objective of this study is to generate and identify molecular markers to be used in marker-assisted breeding for disease resistance, quality, and agronomic traits in barley. Molecular markers such as RFLPs (Restriction Fragment Length Polymorphisms), AFLPs (Amplified Fragment Length Polymorphisms), and SSRs (Simple Sequence Repeats) are being used. Major traits of interest are scald resistance, net blotch, stripe rust, basic vegetative period, plant height, time to maturity, grain size, malt extract, alpha amylase activity and grain yield. This process requires the construction of a mapping population with the parents that differ for the desired traits and fingerprinting of the progeny lines with the markers. Depending on the size of the population and the genetics of a trait a full population analysis or a bulk segregant analysis will be used, with the DNA markers, to identify significant chromosomal regions so called ‘Quantitative Trait Loci’.

AIMS

To construct linkage maps of DNA markers including RFLPs, SSRs, and AFLPs in barley crosses segregating for important traits.

To identify markers that are strongly linked to (co-segregate with) the traits.

To validate putative markers on different populations.

MATERIALS AND METHODS

Populations and field trials

Populations were constructed from crosses among varieties that are widely used throughout Australia. Currently a dihaploid (DH) population with 65 lines from the cross Tallon × Kaputar is being analysed with bulked segregant analysis, that is, bulking the samples from individuals that show extreme phenotypic expression of a trait. For example for a disease resistance, DNA samples from resistant lines are mixed in a bulk, and those from susceptible lines in a second bulk. These two samples are then assayed with available DNA markers. Any difference in presence and absence of a band between the two samples indicates the co-segregation of the marker with the trait.

DH lines were grown in replicated trials in seven sites for two years in five states including two Western Australian sites. Phenotypic data have been subjected to a biometrical spatial analysis to minimise error variation, and used in the construction of the bulks.
MOLECULAR ANALYSIS

DNA from each sample was isolated and viewed on an agarose gel. RFLP analysis of genomic DNA was carried out using 72 probes with an average of three restriction enzymes each. Seventeen primer pairs for SSR markers were tested.

RESULTS

In the RFLP analysis, 52 probes corresponding to 98 probe enzyme combinations were polymorphic between the two parents. Parents were also polymorphic with 9 of the 17 SSR markers (Figure 1) that were used thus far. Once the construction of the bulks is completed these polymorphic markers will be assayed for them along with AFLP markers. For AFLP markers, bulk samples and parents will be assayed at the same time.

Figure 1. SSR profiles of parental lines and some of the DH lines. Lanes: M: DNA fragment size marker, K: Kaputar, T: Tallon, 1 to 5 DH lines, C: control with no DNA.

CONCLUSIONS

DNA markers have already been demonstrated to be useful tools in marker-assisted selection (MAS) of a number of crops including barley. Western Australian Barley Breeding Program is using polymerase chain reaction-based (PRC-based) markers in MAS for β-amylase activity and resistance to Barley Yellow Dwarf Virus. The same strategy is being used in South Australia for boron tolerance in barley using RFLP-based markers. In the United States MAS has paid good dividends to breeders of soybean for resistance to cyst nematode.

The current project has already demonstrated a high level of polymorphism between the parental lines. Further screenings will continue with additional parental varieties that are planned to be used in population construction.

GRDC PROJECT

UA 423

PAPER REVIEW BY

Dr Nick Galwey
Implementation of molecular markers for wheat improvement in the Western Region

M. Carter¹, A. Briney¹, R. Wilson², R.H. Potter¹ and M.G.K. Jones¹

¹ Western Australian State Agricultural Biotechnology Centre, Murdoch University
² Crop Industries, Agriculture Western Australia

KEY MESSAGE
Selections for noodle quality and flour colour in wheat are now being made on single seedlings rather than growing large plots. This is made possible by the use of molecular markers linked to the genes that control these traits. This process has the potential to improve the efficiency of wheat breeding.

AIMS
Wheat breeding is a cost effective approach to variety improvement, but breeders must provide continuous improvements in yield, quality and disease resistance to be competitive on the world market. Breeders must also respond to new demands for sustainable production, quality related to specific end uses and international competition. Molecular biology has now reached a stage where increased understanding of the genes that underlie agronomic characters, and the development of new techniques to identify them, are becoming available, and should be used to help wheat breeders achieve their goals more efficiently. In particular, molecular marker assisted selection is a powerful tool that makes it possible to test varieties for quality and disease characteristics on a single seed or 1 cm of leaf tissue. The advantages of such genetic selection is that selection is not influenced by climatic variations, soil types or nutrition, so once a genetic trait is fixed it is permanent. Specific advantages of molecular marker assisted selection over existing assays include:

• accuracy of results;
• speed and ease of tests;
• need for small amounts of leaf tissues or single seeds;
• assay at seedling stage, enabling larger populations of segregating lines to be screened so that undesirable lines can be removed at an early stage.

The PCR test is both more rapid, more accurate and simpler to carry out than previous tests, it presents a more cost-effective screen with the potential for automation.

The aim of this project is to implement the application of molecular markers of high priority to benefit the Western Region wheat breeding program. The target markers have been selected by the breeders, such that breeding requirements are the driving force for marker development.

METHOD
Approximately 2 cm (0.05 g) of leaf tissue was taken from wheat lines provided by Agriculture Western Australia. DNA was extracted from this leaf tissue and the samples amplified using the appropriate PCR primers. The initial wheat varieties used to test the designed primers were rated for their noodle quality and flour colour by Agriculture Western Australia. The flour colour PCR primers were developed and obtained from Dr Garry Parker, Flinders University, South Australia. Once the PCR tests were validated on the wheat varieties they were used for the routine implementation of the molecular markers on advanced breeding lines and doubled haploid populations.
RESULTS

Figure 1 displays the results of the PCR test for GBSS 4A gene (noodle quality). The absence of a PCR band at 260 base pairs correlates with the null 4A status of the genotype. This is an example of a dominant molecular marker (i.e., unable to score heterozygotes). Figure 2 displays the results for the flour colour PCR test, the presence of a 37 bp band correlates with the Schomburgk allele indicating yellow flour and the presence of a 67 bp band correlates with the Yarralinka allele indicating white flour.

![Figure 1](image1.png)
![Figure 2](image2.png)

**CONCLUSION**

In this project it is envisaged that approximately 7 molecular markers of top priority to the Western Wheat Breeding Program will be generated. These will all be established for implementation by efficient high throughput routine screening of breeders germplasm. The primary outcomes of the work will be to increase the accuracy, number, speed and efficiency of screening of agronomic traits for breeders. Combined with doubled haploid technology, the use of molecular markers will speed up the selection process for breeders in the Western Region. In turn, this will help lead to production of improved noodle and other wheat varieties, and to maintain the success of the wheat production and export from the Western Region.

To date, the GBSS PCR test has been routinely implemented for all of the required germplasm of Agriculture Western Australia noodle breeding program, including over 2000 normal lines and approximately 1570 doubled haploid lines. The flour colour PCR test has been positively validated on Western Australian breeding lines that segregate for this characteristic. This marker is now available to be implemented on the required germplasm in the Western Region breeding program.

**Current marker development**

Future work includes the development and implementation of other traits that affect grain quality and yields including that of Late maturing alpha amylase (LMAA), disease resistance (Sr2, VPM) and boron and aluminium tolerance. These are either being developed by AFLP analysis on advanced breeding crosses developed by Agriculture Western Australia (LMAA), or as molecular markers obtained nationally or internationally and validated on the Western Region germplasm.
GRDC Project No.: GRDC UMU55
Paper reviewed by: Dr Rob Potter
Performance in 1999 of recently released wheat varieties in Western Australia
Robin Wilson, Iain Barclay, Robyn McLean, Dean Diepeveen and Robert Loughman, Agriculture Western Australia

INTRODUCTION
1999 was a record wheat production year in Western Australia. However widespread and early leaf rust affected the crops, as did stem rust in some areas. Rain at harvest caused problems in central and southern areas of the state. This resulted in some downgrading. Strong adoption of the new varieties released from Agriculture Western Australia (AGWEST) occurred in 1999. About 68% of the wheat grown in Western Australia in 1999 was from varieties bred in Western Australia. Westonia and Arrino were each grown on about 10% of the area in 1999.

YIELD
The rate of genetic gain for yield in the past five years has ranged from 2% pa for APW to 1% pa for AH.

• Westonia, Brookton and Cunderdin recorded good yields in Western Australia in 1999 and were similar to the long-term performance.

The yield performance of some recently released varieties sometimes differed to the long-term results.

• Some performed better than their long term average as a result of having some rust resistance. These were Carnamah, Camm, Nyabing and Calingiri.

• Although Arrino was adversely affected by the leaf rust, it still yielded better or similar to Eradu.

• Ajana was not up to its previous very high yields probably because of leaf rust.

RUST
Some adjustment of rust rating of varieties was necessary in the light of experiences in the 1999 season.

• Prior to this season Arrino was thought to be moderately susceptible to leaf rust, but was clearly susceptible.

• Westonia, Arrino and Calingiri must be regarded as susceptible to stem rust.

• Calingiri proved to be more resistant to leaf rust than previous data had indicated. Given the summer rainfall we have experienced, growers should ensure that they have sufficient rust resistant varieties in their program, or provision for fungicide sprays. It should be noted that the varieties Carnamah, Cunderdin and Perenjori are now able to be traded freely farmer to farmer. This should help in the availability of rust resistant wheats for 2000.

SPROUTING
Westonia and Carnamah appear to be more susceptible to sprouting based on grower experience in the 1999 harvest, very much protracted by unseasonal rain. They join Brookton and Cunderdin that were identified in 1998. This tendency to sprout may limit the use of these varieties.

GRDC Project No.: DAW 516 and SAW 499
Outlook for prices and implications for rotations

Ross Kingwell¹, Michael O’Connell¹, Simone Blennerhasset¹

¹ Agriculture Western Australia
² University of Western Australia

KEY MESSAGE

Wheat prices are forecast to improve during 2000, malting barley prices are likely to remain firm, yet the prices of many other major crops, including canola, are likely to remain depressed. Responding to these prices will require graingrowers to be careful about a range of farm management decisions.

AIMS

(i) Provide information on canola prices.
(ii) Highlight consequences for rotation selection and farm incomes.

METHOD

(i) Review current knowledge and views about crop price movements, in particular focus on canola.
(ii) Use representative farm models and sensitivity analysis to show possible impacts of changes in prices on farm incomes and land use.
(iii) Describe the ramifications and limitations of findings.

RESULTS

Commodity price movements

Wheat: The final pool price of the 1999 ASW 10 wheat crop is likely to be around $175/tonne or 3 per cent lower than in 1998/9. During 2000 wheat prices are forecast to improve as production falls and stocks tighten. The pool price of the ASW 10 wheat for the 2000 season is around $190 per tonne.

Feed grains: Large world supplies are expected to maintain the downward pressure on feed grain prices in 1999/2000, continuing some of the lowest prices in over 20 years. However, malting barley prices are expected to remain firm at around $190 per tonne for first grade malting barley.

Lupins: Lupin prices are forecast to remain low in 2000, averaging around $155 per tonne.

Canola: In December last year ABARE suggested that Australian canola prices for the 1999 crop would fall by 16 per cent to average $288 per tonne and Agriculture Western Australia was suggesting a gross price of $350 per tonne for the 2000 crop. However, in light of more recent information, the gross price for canola in the 2000 season may be closer to $315 per tonne.

Field peas: Their prices in 1999/2000 are forecast to average $222/tonne.

Chick peas: Their prices in 1999/2000 are forecast to rise slightly to average $384/tonne.
Modelling the impacts of price movements

Representative farm models of the southern and eastern agricultural regions of Western Australia were used to examine the possible impacts on farm profits and rotations of changes in commodity prices, in particular changes in canola prices. The farm models considered the impact of forecast price changes, assuming the 2000 season is average. These models describe the resources, biology, agronomy, enterprise and rotation options available to a representative farm in these two regions. It is possible to conduct sensitivity analysis with these models to assess the robustness of findings.

Impacts of changes in prices

<table>
<thead>
<tr>
<th>Prices in 1999 (base case)</th>
<th>Eastern wheatbelt region</th>
<th>South-Coast region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farm profit</td>
<td>Change in area of</td>
</tr>
<tr>
<td></td>
<td>$'000</td>
<td>Wheat</td>
</tr>
<tr>
<td>Wheat</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Forecast prices for 2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>2000 prices (+ low canola)</td>
<td>41</td>
<td>↑</td>
</tr>
<tr>
<td>2000 prices (+ high canola)</td>
<td>35</td>
<td>↑</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>↑</td>
</tr>
</tbody>
</table>
Modelling results point to an increase in the area sown to wheat this season. Although the level of farm profit in the south-coast region is sensitive to changes in the price of canola, the optimal area sown to canola appears to be far less sensitive. Associated with the changes in relative prices are also some changes in the areas sown to lupins, barley and faba beans. Overall farmers will benefit from the forecast increase in wheat prices of the 2000 crop, yet if the 2000 average season is average then farm incomes will be an historical low.

**CONCLUSION**

Wheat prices are forecast to improve during 2000, malting barley prices are likely to remain firm, yet the prices of many other major crops, including canola, are likely to remain depressed. Responding to these prices will require graingrowers to be careful about a range of farm management decisions. Capital expenditures, in particular, should be reviewed. Sound financial and technical management of enterprises are essential to improve profit prospects this season.

**KEY WORDS**

crop prices, rotations
Price Risk Management and the Western Australian Grain producer

Benjamin Michael Tiller, Muresk Institute of Agriculture

EXECUTIVE SUMMARY
The marketing environment of the Australian grain producer has seen some comprehensive changes in the past decade. Repeal of the government guaranteed minimum price (GMP) and the deregulation of the domestic trading of wheat in 1989 has exposed the grain producer to greater price volatility but has also increased the range of marketing alternatives available. Additionally, a more diverse range of price risk management tools has been introduced into the market which, when used correctly, can minimise the price risk a producer encounters and stabilise or increase average farm returns. However, producers’ utilising these tools are in the minority and it appears that the bulk of producers are willing to speculate on spot prices. This research aimed to identify why this is the case whilst also quantifying the current level and future use of price risk management tools.

A structured cross-sectional telephone survey was used to interview 100 grain producer’s located across 42 shires of the Western Australian wheatbelt. Their responses were then analysed using a combination of descriptive statistics and bivariate tests for independence. The results proved both interesting and provoking.

Despite current season usage for forward contracts, futures, options, the AWB Basis Pool, and OTC products being below previous state and national averages, forecast usage for all tools except OTC products is extremely strong. Within five years, respondents wishing to minimise their price risk exposure indicated that 57 percent will be using forward contracts, 37 percent will be using futures contracts, 46 percent will use options on futures, and 29 percent will use the AWB Basis Pool. This represents a dramatic increase from current levels and one which should provide the risk management provision industry a busy schedule.

The bivariate data analysis revealed that the probability of producers using futures increases as producers’ scale of farming operations increases. That is, those producing higher tonnages of wheat are more inclined to be using the tool in the next five years. Additionally, those producers who involve themselves with a farm improvement group are also more inclined to be using futures in the short term.

However, on reflection, the high usage figures forecast could well be overstated. The fundamental reasons for the slow adoption of these tools thus far has been producers’ lack of knowledge and understanding of the tools’ structure and operation and a strong perception that there is a lack of relative advantage in using the tools when compared to the national export pool system. These concerns are still present with half of respondents claiming they still do not understand the tools’ operation and one third rejecting their use in favour of the pool.

For such a rapid increase to occur, vast and concerted educational programmes must take place within the wheatbelt region to provide the reassurance the majority of producers require. Ultimately, the responsibility for these programmes must fall on the commercial sector as increased producer usage will provide industry growth and subsequent commercial profit taking.

Paper reviewed by: Christine Storer, Honours supervisor, Muresk Institute of Agriculture
Can we forecast wheat yields in Western Australia?

Senthold Asseng\(^1\), Holger Meinke\(^2\), and Bill Bowden\(^3\)

\(^1\) CSIRO Plant Industry
\(^2\) APSRU/DPI
\(^3\) Agriculture Western Australia

INTRODUCTION

Any management decision in wheat farming associated with higher inputs (e.g. N fertiliser and deep ripping on sandy soils) can be risky, since results in terms of yield increase vary from season to season and with different rainfall regions. Field experiments are often limited to few locations and seasons and often do not represent the whole scale of possible outcomes. To sample the effects of climatic variability and associated management responses adequately may require many decades of experimentation, particularly in areas where such variability is high. In contrast to real field experiments a validated simulation model allows studies of interactions of seasonal variability and specific management practices. These results supply a wide range of possibilities for soil types and rainfall zones, depending on the particular season and allow the construction of probability distributions.

METHOD

A wheat module of the Agricultural Production Systems Simulator (APSIM) (McCown \textit{et al.} 1996 Agric. Syst.) has been rigorously tested against field measurements and used in various studies under a large range of growing conditions (Probert \textit{et al.} 1995 AJEA; Probert \textit{et al.} 1998 Agric. Syst.; Asseng \textit{et al.} 2000 Europ. J. Agron.) and in particular in the Mediterranean climatic regions of Western Australia (Asseng \textit{et al.} 1998a AJAR; Asseng \textit{et al.} 1998b FCR). With this model, wheat yields have been estimated using historical climate records (>80 years) for different rainfall zones, soil types, and very low input (after a previous wheat crop and with up to 30 kg N/ha of fertiliser applied) and high input (additional N-fertiliser and deep ripping). The simulation results have been used to assess the effect of high inputs on grain yield across seasons and rainfall locations.

RESULTS

According to the simulations, increasing inputs from a very low level of input in Western Australian agriculture can increase wheat yields on average in all rainfall zones and in particular in the medium to high rainfall regions (Table 1). Yield increases might be as large as four times the low-input average yield depending on the season. However, yields might only response marginally to higher inputs or even decrease in a poor season. Hence, increasing inputs without knowledge about the season ahead increases production risks.

<table>
<thead>
<tr>
<th>Location</th>
<th>Average annual rainfall (mm)</th>
<th>Yield increase, absolute (t/ha) and relative to low-input-mean (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Maximum</td>
</tr>
<tr>
<td>Moora</td>
<td>461</td>
<td>1.8 (133%)</td>
<td>4.6 (349%)</td>
</tr>
<tr>
<td>Wongan Hills</td>
<td>391</td>
<td>1.5 (135%)</td>
<td>4.6 (409%)</td>
</tr>
<tr>
<td>Merredin</td>
<td>311</td>
<td>1.2 (216%)</td>
<td>2.5 (475%)</td>
</tr>
</tbody>
</table>

\(^A\) Moora and Wongan Hills: from low input (30 kg N/ha) to high input (deep ripping and 90 kg N/ha); Merredin: from low input (nil N) to high input (deep ripping and 30 kg N/ha).

Physically based relationships between an index of the ocean/atmosphere El Niño/Southern Oscillation phenomenon and future rainfall amount and their temporal distribution exist in many
parts of the world, including Western Australia (Stone et al. 1996 Nature). The statistical forecasting systems based on the SOI (Southern Oscillation Index) allows historical rainfall records to be grouped into analogue years for poor, average or good rainfall seasons, based on the SOI around sowing in April-May (Stone et al. 1996 Nature). Applying this system to the simulated yields (Hammer et al. 1996 AJAR), which integrates not only the amount but also the effectiveness of in-season rainfall, results in a range of possible wheat yields and not just a single, categorical forecast (Table 2). Such knowledge can be used for crop management decisions and so increase profits and reduce risks (Meinke and Hochman, 2000 Kluwer Academic Publishers). For example, in a season with the SOI phase II in April-May, the chance of achieving a better than average ('good') grain yield is 64% and the chance for the largest possible return from high inputs is therefore best (Figure 1 and Table 2).

Table 2. Probabilities of yields for the five SOI phases in April-May being below 33% (poor), between 33-66% (average) and above 66% (good) of the probability distribution derived from all years of an 87-year simulation for a wheat crop grown on a sandy soil at Wongan Hills with deep ripping and 90 kg N/ha

<table>
<thead>
<tr>
<th>SOI phase</th>
<th>Good (%)</th>
<th>Average (%)</th>
<th>Poor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>15</td>
<td>33</td>
<td>52</td>
</tr>
<tr>
<td>II</td>
<td>64</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>III</td>
<td>24</td>
<td>35</td>
<td>41</td>
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<td>IV</td>
<td>35</td>
<td>35</td>
<td>30</td>
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<tr>
<td>V</td>
<td>19</td>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td>No skillA</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
</tbody>
</table>

A With no predictable knowledge of the coming season.

In contrast, in the SOI phase I in April-May, the yield prospects are poor with a 52% chance of achieving a yield in the ‘poor’ yield-range and an only 15% probability of achieving a yield in the ‘good’ yield-range (based on the yield distribution from all years of an 87-year simulation). Therefore the chance for a positive return in a SOI phase I from high inputs would be small (Figure 1 and
Table 2).

Figure 1. Probabilities of exceeding a given yield level for a wheat crop grown at Wongan Hills with deep ripping and 90 kg N/ha derived from all years of a 87-year simulation (______). Probabilities of exceeding a given yield level from groups of years associated with the SOI phase II (______) and the SOI phase I (______).
CONCLUSION
When combining long-term simulation results with the SOI climate forecasting system, a defined range of possible yields in relation to inputs can be predicted, which varies according to the SOI phase in April-May, however the forecast of a specific outcome is not possible. Thus, the information must be used in a risk management context (e.g. costs of inputs and outputs).

KEY WORDS
wheat, grain yield, yield forecast, SOI

GRDC Project No.: CSP 246WR
Paper reviewed by: Holger Meinke and Bill Bowden
On-farm testing, the quiet revolution continues

Jeff Russell\textsuperscript{1}, Ivan Lee\textsuperscript{2}

\textsuperscript{1} Agriculture Western Australia, Northam
\textsuperscript{2} Farmer Kunjin TopCrop group, Corrigin

KEY MESSAGE

The impending release of the ‘Test as you grow’ kit was communicated at last year’s Crop Updates. During the 1999 season the inherent principles of the kit were refined and further developed. This work continues to show that:

- Broadscale on-farm testing value adds to the variety evaluation information.
- Collaborative research and development between farmers and agribusiness partners value adds to the information being produced.

This paper presents a case study of on-farm testing for variety evaluation conducted during the 1999 season.

BACKGROUND

Intensive research to aid the development of agronomic packages and varietal comparisons through the Crop Variety Testing (CVT) program are conducted every year throughout the state. Getting the best from the many new varieties on offer and assessing the effectiveness of the agronomic packages is the basis of the On-farm testing program.

On-farm testing is gaining popularity throughout the state. The ‘Test as you grow’ kit was launched last season and is undergoing refinement for general release next year. On-farm testing allows growers to develop and assess management packages for varieties in line with particular farming systems.

METHODS

Farm scale variety comparisons were conducted by members of the Kunjin TopCrop group in a similar geographical location to intensive smaller scale CVT sites established by Agritech. This is the second season of such collaborative work with members of the TopCrop group, Agritech (Lamond Burgess and Assoc. in 1998) and Agriculture Western Australia.

The four farm scale sites contained a limited number of varieties suitable for the soil type and paddock rotation. A common variety ‘Tincurrin’ was used as a benchmark variety around which the other varieties are compared. Only a limited number of varieties, between 5 to 10, are selected for any particular on-farm test. At these sites the benchmark variety is sown every third plot while each other variety is replicated twice.

The CVT site contained some 24 varieties in a randomised block design and was replicated three times. There were also 2 times of sowing at 1 June and 14 June 1999 respectively.

RESULTS

Examples of the data sets obtained from the intensive small plot CVT site for the first time of sowing is shown in Tables 1. Full details of this and the second time of sowing can be found on Agritech’s web site on the Internet. An example is given of one of the farm scale sites (Table 2) that included varieties from within the CVT site.

At the CVT site significant yield differences were seen by many varieties over the standard Tincurrin. These varieties also indicated large economic gains. A number of these varieties when compared to
Tincurrin in the farm scale comparison, however, do not reflect as great a difference. In general their performance is not as good as at the CVT site.
Table 1. Wheat variety yield and economic analysis of the first time of sowing CVT site

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield kg/ha</th>
<th>Wheat Grade</th>
<th>Gross Income $/ha</th>
<th>Variety</th>
<th>Yield kg/ha</th>
<th>Wheat Grade</th>
<th>Gross Income $/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calingiri</td>
<td>3,017</td>
<td>ASWN</td>
<td>$582.52</td>
<td>Arrino</td>
<td>2,647</td>
<td>ASWN</td>
<td>$497.55</td>
</tr>
<tr>
<td>RAC873</td>
<td>3,175</td>
<td>APW</td>
<td>$579.69</td>
<td>Perenjori</td>
<td>2,691</td>
<td>APW</td>
<td>$496.70</td>
</tr>
<tr>
<td>RAC868</td>
<td>3,066</td>
<td>APW</td>
<td>$558.26</td>
<td>Machete</td>
<td>2,767</td>
<td>APW</td>
<td>$494.13</td>
</tr>
<tr>
<td>Carnamah</td>
<td>3,121</td>
<td>APW</td>
<td>$557.35</td>
<td>Nyabing</td>
<td>2,723</td>
<td>ASW</td>
<td>$483.55</td>
</tr>
<tr>
<td>Cunderdin</td>
<td>3,115</td>
<td>APW</td>
<td>$551.60</td>
<td>Ajana</td>
<td>2,778</td>
<td>ASW</td>
<td>$480.82</td>
</tr>
<tr>
<td>Westonia</td>
<td>3,110</td>
<td>APW</td>
<td>$550.72</td>
<td>Tamaroi</td>
<td>1,906</td>
<td>ADR1</td>
<td>$478.13</td>
</tr>
<tr>
<td>Camm</td>
<td>2,958</td>
<td>APW</td>
<td>$540.07</td>
<td>Stiletto</td>
<td>2,576</td>
<td>APW</td>
<td>$466.46</td>
</tr>
<tr>
<td>Brookton</td>
<td>3,094</td>
<td>APW</td>
<td>$535.51</td>
<td>Cascades</td>
<td>2,587</td>
<td>ASW</td>
<td>$459.40</td>
</tr>
<tr>
<td>Cadoux</td>
<td>2,729</td>
<td>ASWN</td>
<td>$526.92</td>
<td>Amery</td>
<td>2,544</td>
<td>APW</td>
<td>$455.58</td>
</tr>
<tr>
<td>Datatine</td>
<td>3,268</td>
<td>SOFT2</td>
<td>$523.14</td>
<td>Kalgarin</td>
<td>2,549</td>
<td>APW</td>
<td>$448.83</td>
</tr>
<tr>
<td>WAWHT 2151</td>
<td>2,919</td>
<td>APW</td>
<td>$521.28</td>
<td>Tincurrin</td>
<td>2,505</td>
<td>SOFT</td>
<td>$428.56</td>
</tr>
<tr>
<td>H45</td>
<td>2,761</td>
<td>APW</td>
<td>$505.48</td>
<td>Currawong</td>
<td>3,143</td>
<td>FEED</td>
<td>$424.56</td>
</tr>
</tbody>
</table>

LSD = 245 kg/ha (P=0.05), CV = 5.26%

Table 2. On-farm test comparing wheat variety yields and qualities at Ivan Lee’s, Corrigin

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield kg/ha</th>
<th>Protein %</th>
<th>Screening%</th>
<th>Specific weight</th>
<th>Staining %</th>
<th>Wheat Grade</th>
<th>Gross Income $/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datatine</td>
<td>4,884</td>
<td>8.3</td>
<td>1.94</td>
<td>79.24</td>
<td>3.5</td>
<td>Soft</td>
<td>$845.32</td>
</tr>
<tr>
<td>Calingiri</td>
<td>4,304</td>
<td>9.7</td>
<td>1.68</td>
<td>82.83</td>
<td>ASWN</td>
<td>$757.85</td>
<td></td>
</tr>
<tr>
<td>Tincurrin</td>
<td>4,351</td>
<td>8.2</td>
<td>1.98</td>
<td>78.92</td>
<td>2.5</td>
<td>Soft</td>
<td>$753.07</td>
</tr>
<tr>
<td>Brookton</td>
<td>4,602</td>
<td>8.8</td>
<td>2.91</td>
<td>79.84</td>
<td>ASW</td>
<td>$745.89</td>
<td></td>
</tr>
<tr>
<td>Arrino</td>
<td>3,896</td>
<td>10.1</td>
<td>1.10</td>
<td>80.09</td>
<td>ASWN</td>
<td>$736.66</td>
<td></td>
</tr>
<tr>
<td>Westonia</td>
<td>4,646</td>
<td>9.8</td>
<td>2.47</td>
<td>82.54</td>
<td>GP1</td>
<td>$729.79</td>
<td></td>
</tr>
<tr>
<td>Carnamah</td>
<td>4,319</td>
<td>9.6</td>
<td>2.16</td>
<td>82.07</td>
<td>ASW</td>
<td>$717.30</td>
<td></td>
</tr>
<tr>
<td>Cadoux</td>
<td>3,978</td>
<td>9.6</td>
<td>1.54</td>
<td>79.80</td>
<td>ASWN</td>
<td>$684.53</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSIONS

This is the second season of results to be collected. All of the data have yet to be analysed at the time of printing for all sites. Yield alone is not the primary determinant of choice for variety selection. Quality characteristics play a major role in the selection process. The control variety Tincurrin generally performed well as in the previous year in the on-farm test, as have some other soft wheat varieties at this and the other sites.
While small plot intensive CVT sites are able to give an indication of the relative performance of a variety, it is necessary to conduct on-farm tests to assess varieties more specifically suited to individual farming systems and the associated environment. Such tests are more relevant the further away from the CVT site and the more distinct the environment varies from the CVT site.

This work highlights the importance of all sectors of the industry working together to produce a series of on-farm tests that provide valid results so that informed decision making is able to be performed by growers regarding variety selection.

ACKNOWLEDGMENTS

The On-farm testing project acknowledges the support of GRDC, Agritech, Farmanco, the Biometrics Unit at Agriculture Western Australia and the support of farmers of the Kunjin TopCrop group.

GRDC Project No.: DAW599
CD-ROM tool for growers and advisers: Managing on-farm grain storage – effective practices for the delivery of quality assured products

Clare Johnson¹, Chris Newman²

¹ Quality Wheat CRC Ltd
² Production Resource Protection Services, Agriculture Western Australia

KEY MESSAGE

Quality Wheat CRC has developed a CD-ROM resource for growers and advisers, titled, 'Managing on-farm grain storage - effective practices for the delivery of quality assured products'.

The need for a resource

The question advisers most often receive from growers who store grain on farm is, “I’ve got weevils and I have to deliver my grain tomorrow. What should I do?” Unfortunately, they will lose the sale as they have not planned and maintained their grain in good enough condition to meet this opportunity. As more growers are opting for on-farm storage of grain for seed, feed, or to increase their marketing flexibility, there is the need to provide sound advice to maintain the quality of the commodity. Best practice includes emphasis on hygiene, regular monitoring, and the safe use of chemicals suitable for the pests in question, in line with local state regulations. This will safeguard growers’ profits, the safety of grain handlers and the food safety of the end products.

To meet this need, Quality Wheat CRC has developed a CD-ROM, 'Managing on-farm grain storage - effective practices for the delivery of quality assured products'. The launch was held in Wagga in September 1999 to coincide with Henty Field Days, and was attended by key industry members with an interest in grain storage and QA.

Many organisations and individuals willingly contributed material to ensure production of a comprehensive, up-to-date resource for the industry. Where relevant web sites already existed, hotlinks were added to take readers to them, for example there are links to the Agriculture Western Australia PestWeb insect identification and phosphine resistance study sites. Prior to release, experts across the industry reviewed the CD, and their comments and suggested improvements were incorporated.

Storage and transport important for food safety and QA

Grain storage and transport are important control points to meet the food safety quality requirements of end users. Levels of chemical residues and toxins, stones, animal material and insects, and bacteria and moulds in the grain need to be controlled. The CD will be a great aid to growers’ planning by increasing awareness of quality assurance issues, from the farm to the end user. A risk management process based on HACCP principles is suggested, and as national guidelines develop, updates will be available through the 'Updates on-line' Internet site accessible from the CD.

SCOPE

The CD features practical information on subjects such as:

• control of insects, mould and flour quality;
• keeping risk down with good hygiene;
• meeting market residue requirements;
• inspecting stored grain;
• choosing the right protectant for the pest;
safe and effective use of grain protectants;
advice on dosage and half-life of protectants;
choosing and maintaining machinery and storage structures;
making storage structures airtight;
maintaining seals;
economics;
market information and industry contacts;
receiving standards and regulatory information;
where to get training;
a summary of RTCA competencies, with site link;
hotlinks to on-line updates and other relevant sites;

RECENT RESEARCH ON AERATION BENEFITS

The CD also contains outcomes of QWCRC research, which has shown that if grain is aerated soon after harvest and maintained at 20°C or lower (and 12.5% moisture or less), the processing quality of the flour will then be stable for at least a full year. This benefit of aeration, in addition to those already known, namely, reduction of insect and mould problems by controlling moisture and temperature, has been welcomed by the milling and baking industries. The partners of Quality Wheat CRC support aerated storage and are considering making it a requirement when setting purchase contracts. The advantages include a reduced need for quality testing if quality is more predictable following storage, reduced exposure to pesticides and improved product specifications.

Farm chemical safety

Phosphine resistance has been receiving a lot of attention over the past year, and the CD provides contact details for courses in the correct use of this and other farm chemicals. Advisers and growers can obtain the most current information by using the hotlink to the updates site accessible over the Internet.

Workshop development

Information on RTCA competencies is also provided, and quizzes are incorporated throughout the CD for growers to check their understanding of each section, and to help advisers with workshop development. There is also a spreadsheet to help determine whether on-farm storage would be profitable to each grower, depending on their individual circumstances. Quality Wheat CRC is working with Topcrop to develop TopActive modules and on-farm demonstrations based on the content.

Availability and enquiries

The CD is available, non-exclusively, through Graintec, Ph: 07 4638 7677, graintec@icr.com.au, Rural Connect, Ph: 1800 11 00 44, ruralconnect@ozemail.com.au, and Tocal College, Ph: 1800 025 520, tocal@agric.nsw.gov.au, for a recommended retail price of $35.00. Distribution and wholesale enquiries should be directed to Alan Ellis, Business Manager, QWCRC, Ph: 02 9490 8488. For other enquiries and updates, or to participate in workshop development, contact Clare Johnson, Education and Training, QWCRC, Ph: 02 9490 8476.

Further information on the ‘Great Grains’ on-farm QA system is available on Ph: 1800 226 125 and information on the ‘Graincare’ system is available on Ph: 02 6273 3000. GRDC is working toward integrated development of QA on farm.

KEYWORDS

storage, aeration, insect, training

Paper reviewed by: Dr W.G. Rathmell, Quality Wheat CRC
The Internet as a tool for managing grain insects
Robert Emery, Romolo Tassone and Ernestos Kostas,
Agriculture Western Australia

INTRODUCTION
Western Australia is heavily reliant on sealed storage and phosphine fumigation for grain insect control both on-farm and in the central handling system. This has enabled all grain exports since 1990 (approximately 60 Mt) to be achieved without the use of contact insecticides at any stage during storage. This places Western Australian in the unique position of being able to take advantage of burgeoning markets for residue-free grain.

Reliance on phosphine, both on-farm and in the central handling system has its drawbacks particularly with respect to resistance. It is of paramount importance that phosphine be protected from resistance development in grain insects. Last year, three strains of grain insects were detected in the eastern states with resistance levels approaching that found in developing countries and which could result in control failures. Monitoring farms for resistance and integrated pest management is the key to protecting the Western Australian grain industry. Agriculture Western Australia has carried this out for the last 20 years.

Integrated pest management continues to become more complex as new pests arise, pesticides are released or regulated and resistance inevitably develops. The Stored Grain Protection project can be used as a model for what can be achieved through digital delivery of pest management information.

The advantages are by no means restricted to researchers, farmers will be major beneficiaries of the Internet revolution given their relative remoteness. The Internet will provide them with access to the same extensive, dynamically updated information resources used by government, industry and researchers.

Although currently only 17 percent of Australian farmers have access to the Internet, this figure will grow rapidly as rural communication initiatives are realised. We believe that it is incumbent upon us to ensure that quality pest management information is available right now so that farmers arriving on the Internet will be met by a valuable resource.

DISCUSSION
Agriculture Western Australia’s Stored Grain Protection project first became involved in the digital delivery of information in 1996 with the development of the Australian Grain Insect Resistance Database (AGIRD). This database was built at Agriculture Western Australia to hold the results of bioassays conducted around Australia as part of the GRDC funded national project on stored grain protection. This collaborative project involved Queensland Department of Primary Industry and New South Wales Agriculture.

Resistance researchers around the world have been recommending the development of national resistance databases for some years however Australian Grain Insect Resistance Database, hosted by Agriculture Western Australia, is the first successful online implementation.

AGIRD currently holds results from 17,000 assays on 13,000 insect strains, from 5,100 sites around Australia. It underpins the development of integrated pest management plans for grain insect control in Australia. It is used daily by researchers and bulk handlers around the country.

The AGIRD webpages have aroused considerable international interest over the last four years with both FAO Information on Postharvest Web and the US National Integrated Pest Management websites providing links to AGIRD. With the renewal of the GRDC project DAW615 to 2002, it
seemed appropriate to expand the website to provide information for farmers on grain insect biology, control and storage practices.
This information comes in the form of:

- Database-driven identification keys for grain pests; this is a database driven basic key to identify grain insects and provides description, lifecycle, damage and control information.
- Downloadable multi-language screensavers; this initiative draws international attention to Western Australia’s thorough approach to minimising grain insect infestation in export grain.
- Continuously updated frequently asked questions; these address the most common queries received from grain growers. This section will be updated continually as issues are raised through our contact with grain growers.
- A range of information reports and extension documents; these are articles and links demonstrating good grain storage practices, insect identification, biology and control information in a web page layout.
- A publicly accessible discussion web; this is a forum for the grain industry to participate in online dialogue.

Figure 1. The Stored Grain Protection screensaver home page.

The website is also delivered on CD-ROM for the 70 percent of farmers that have a computer but no Internet access. The CD is a snapshot of the website at the time of production and uses the same tools and information as the website. This allows farmers to familiarise themselves with the layout of the website and hypertext interface without the costs associated with being online enabling to target sites of interest when they eventually connected to the Internet. Once farmers are aware of the quality and availability of web information we are hopeful that farmers will get connected to take advantage of dynamic, continuously updated pest management information on the web.

The grain pest management webpages are available from: http://www.agric.wa.gov.au:7000/ento/grain1.htm the next release of the CD-ROM will be publicised in the rural press.

ACKNOWLEDGEMENT
We acknowledge the financial support of GRDC Development, maintenance and safe use of grain storage chemicals project and component collaborators, Dr Pat Collins, Queensland Department of Primary Industries and Dr Barry Wallbank, New South Wales Agriculture.

GRDC Project No.: DAW615
Summer crop update and agronomic considerations
Graeme Ralph, Pioneer Hi-Bred Australia Pty Ltd

KEY CONSIDERATIONS IN THE CHOICE OF SUMMER CROP

Why summer crop?
Typical reasons for growing a summer crop (i.e. grain sorghum, forage sorghum, sunflower, or lucerne) are; Replace ‘missed’ cereal crop; Rotation to control ‘resistant’ weeds; Fill summer feed gaps for livestock; or more likely, as part of a whole farm program for water-table control, and salinity management. The reasons that lead you to growing a summer crop may dictate the choice of crop.

Other factors that impact crop choice
Soil type and depth of friable topsoil will impact crop choice, as will the, ability to handle the summer crop stubble. Waterlogging may limit both crop choice and sowing time. Another major factor is the availability of end markets for grain or feed produced by the summer crop. While there is a large potential local demand for grain sorghum by the poultry and beef industries, markets for sunflower grain are more limited in tonnage and forward contracts should be obtained before growing a sunflower crop. Forage sorghum and lucerne will be easier choices for farms with livestock operations as all production can be utilised on-farm, and soil type/moisture availability are not as limiting a factor in the use of these crops.

Crop choice situations and preferences
Replace ‘missed’ cereal crop with a summer crop for cash flow and return to cereals next winter. Sunflowers are the preferred choice as they can be planted in early spring, harvested mid summer, and the stubble breaks down quickly and is easily handled. Grain or forage sorghums are the other choices, but must be ‘sprayed out’ to control stubble regrowth in the following crop.

Herbicide resistance situations traditionally require a winter fallow. Summer cropping allows a pre-Spring fallow spray for control of problem weeds with alternative herbicides, and allows a flexible sowing time. Two consecutive summer crops are needed for good control. Lucerne is the preferred choice for farms with livestock, with grain or forage sorghum, followed by sunflower an alternative for grain-only farms.

Waterlogging is harder to manage than a rising water table and can’t be solved by winter cropping. A summer crop is needed to remove moisture during non-recharge periods. The major issue is to handle the stubble from the summer crop if cereals are to follow in autumn. Wide rows simplify stubble management. Forage or grain sorghums are the best options, as sunflowers do not tolerate ‘wet feet’ during establishment.

Water table control, Salinity management, are long term programs that require perennial crops (e.g., lucerne) and tap root crops (e.g. sunflowers) in the crop rotation

Need to understand the difference between a water table and waterlogging. Lucerne and sunflowers love a water table but don’t like to be waterlogged. Need to address the source of the water table and the saline water recharge areas, not the areas with the symptom.

To be successful, place the appropriate crop in the relevant area of the landscape. The degree and depth of salinity will dictate crop suitability.
**AGRONOMIC KEYS TO SUMMER CROP SUCCESS**

*Soil type and available depth*

Grain crops need 1 metre of friable sub-soil for adequate moisture reserves if grain fill is to be maximised. Hard pans limit the growth of all crops, especially sunflower lucerne taproots. If hard pans or shallow soils are present, forage sorghum is the best option.

*Soil fertility and weed control*

Do not grow summer crops if you aren’t prepared to feed them. Their fertilizer requirements are similar to a good wheat crop, with nitrogen the biggest input cost, and essential for good sorghum growth. Similarly, good weed (and in particular, grass) control is essential if grain sorghum and sunflower crops are to be successful.

*Row width*

Wide row spacing is needed to regulate the availability of moisture throughout the life of the crop. Wide rows are needed even for waterlogged fields if grain crops are to be successful. Row width dictates reliability of yield, and the goal of any dryland summer crop in Western Australia should be reliable yield - not maximum yield. Wider rows are even an advantage in forage sorghum crops, as they reduce trampling losses by approximately 50%.

Recommended row widths for grain crops are:

- One metre spacing, single skip rows in favorable moisture situations  
  i.e. for yields of 3 to 5 tonne/ha sorghum, 0.3 tonne and higher/ha sunflowers
- One metre spacing with double skip rows in marginal moisture situations  
  i.e. sorghum yields of < 3 tonne/ha, sunflower yields < 0.3 tonne/ha

Row widths of less than 1 metre (i.e. 75 cm spacing) are only for maximum moisture removal in waterlogged situations, and then only with forage sorghum crops.

*Plant populations*

Plant population is not as important as row spacing in determining crop yield. Population within the row determines tillering, but does not dictate final yield. Head size is the major determinant of grain yield. Trials have proven a yield advantage for wide row spacing and skip rows in grain sorghum crops up to 5 tonne per hectare yield level. Above this yield level, moisture availability and in-crop rainfall allows 1 metre or closer row spacing to maximise grain yield.

Recommended Plant Populations are:

- Sunflower = 30,000 plants/ha established
- G. Sorghum = 50,000 plants/ha established
- Forage = 100,000 plants/ha established

*Hybrid selection*

Limited potential for in-crop rainfall in most areas of Western Australia indicates that growers should select hybrids that have the following key characteristics:

- Forage Sorghum – conventional sorghum-sudangrass hybrid with good ‘cool soil’ tolerance, good regrowth after grazing or rain, and fine stems if needed for sheep.
- Grain Sorghum – early maturity, very good standability and stress resistance.
- Sunflowers – mid season maturity with proven stress resistance.

**SUMMARY**

Over the next decade summer crops will become a regular part of most Western Australian farm programs as growers tackle salinity and water table issues. These guidelines should provide growers with a good starting point for the profitable integration of summer crops into their own farm situation.
The effect of tree windbreaks on grain yield in the medium and low rainfall areas in Western Australia

Robert Sudmeyer, David Hall and Harvey Jones, Agriculture Western Australia, Esperance

KEY MESSAGE

The principle benefit of providing shelter is reduced physical damage of crops during severe wind events. With appropriate design and management, windbreaks can improve farm productivity in windy areas. Microclimate changes in the lee of field windbreaks are generally too small to have a significant impact on crop yield.

AIMS

Limited Australian research suggests microclimate changes in windbreak systems can increase grain yield by up to 20%. However the paucity of Australian information has been identified as a constraint to the adoption of farming systems incorporating windbreaks. The aim of this experiment was to quantify changes in microclimate and crop growth in the medium and low rainfall areas of the Western Australian wheatbelt.

METHODS

Microclimate, soil water content, wind erosion and crop growth was quantified in a Maritime pine (Pinus pinaster) windbreak system near Esperance. Crop yield in the lee of windbreaks was also quantified for several crops over 64 field years in the medium and low rainfall areas of the Western Australian wheatbelt between 1994 and 1997. The effect on crop yield of severing (pruning) lateral Maritime pine roots extending into the crop was evaluated.

RESULTS

Microclimate

In the tree windbreak system, windspeed was reduced by up to 47% when the wind was perpendicular to the windbreak. However changes in the prevailing wind direction meant that over the whole growing season, windrun was reduced by 20-34% within an area extending 6 times the height of the windbreak (H) and by less than 10% more than 12 H from the windbreaks. Within 10 H of the windbreaks, relative humidity was generally increased and potential evaporation decreased compared to unsheltered conditions, the differences were generally within ±5-10% of unsheltered values. Average temperature over the growing season increased by 0.1 C where windspeed was most reduced, but this increase was too small to affect rates of crop development.

Soil water

Measurements of soil water content indicated that shelter reduced evaporation from bare soil in some years, but that after crops become established there was no difference in the soil moisture content of sheltered and unsheltered soil. Soil water content, duration of waterlogging and recharge were always less within two times the height of the trees (2 H) than further away. Pruning tree roots increased soil water content within 2 H.

Wind erosion

Reductions in soil movement in shelter were larger and extended further from the trees than changes in microclimate. The reasons for this were twofold. Firstly, 58% of annual soil movement occurred in June and July when the soil was cultivated and winds were strong and predominantly from the northwest and west, the windbreaks were orientated to provide most shelter from these winds. Secondly, small reductions in windspeed can significantly reduce the erosivity of wind since erosivity is
proportional to windspeed. Consequently reducing annual windrun at 3 H by 25% reduced soil movement over the same period by 49% compared to unsheltered conditions and wind erosion was reduced for a distance of 30 H.

**Crop growth**

The survey of windbreak sheltered crops showed that windbreaks significantly improved yield when crops were exposed to wind erosion and sandblasting, slightly improved yield in years with below average rainfall, but did not improve yield in years with average rainfall and no wind erosion (Figure 1). Yield improvements in windbreak systems in years with low rainfall may be due to shelter reducing low level wind erosion and evaporation from the soil under the sparse crops in these years. The magnitude of yield changes depended on crop type (lupins benefited more from shelter than cereals), the degree of shelter (windbreak orientation) and edaphic and climatic conditions. Regression analysis using long term rainfall records and assuming no wind erosion suggested that the yield of sheltered crops (1-20 H) may be slightly increased in low rainfall areas (> 350 mm annual rainfall) but decreased in medium and higher rainfall areas (> 450 mm).

When windbreaks are unmanaged crop yield is invariably reduced within 3 H of the trees, making it uneconomic to crop within 1-1.5 H. Below ground competition from the trees for water appears to be the most likely reason for this. There was no clear evidence of the trees reducing nutrient levels in the soil or competing with the crops for nutrients and shading appeared to have little effect on yield. Regression analysis suggested the width of the competition zone increased with windbreak age and as rainfall decreased.

Pruning lateral tree roots where the roots were confined close to the soil surface improved crop yield enough to make cropping within 0.5 H economical for at least three seasons after root pruning. On deeper soils where roots were not confined close to the surface root pruning was less effective.

Economic modeling showed that in situations where crop damage is unlikely, microclimate modification in windbreak systems will not improve net grain yields or farm profitability. However in situations where unsheltered crops suffer severe wind damage in four years over the 35 year life of a windbreak then appropriately designed and managed windbreaks (widely spaced (30 H), root pruned, three rows wide) can increase net grain yields and profitability.

![Graph](image)

**Figure 1.** Average crop yield relative to open conditions (20-30 H) in the Esperance District in a dry year (1994), throughout the wheatbelt in years receiving average rainfall (1995, 1996 and 1997) and in a year with severe wind erosion (1996 in the Jerdacuttup area).
CONCLUSIONS

Microclimate changes in tree windbreak systems have little impact on crop yield except in very dry years. However reduced wind damage, particularly sandblasting of establishing crops, in shelter can significantly improve yields. Competition from the trees for water significantly reduces crop yield within 3 H, however it is possible to reduce competition by pruning the tree roots. Economic analysis showed appropriately designed and managed windbreak systems can increase crop productivity and farm profitability if unsheltered crops suffer severe wind damage 3–4 times over the 35 year life of a windbreak. Indeed if the environmental and possible timber production benefits of windbreaks are considered along with the ‘insurance’ benefits, farmers faced with the need to plant trees on large parts of their farms should be encouraged to consider establishing windbreaks.

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