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Crop Updates 2007 - Farming Systems

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Compiled and edited by Doug Arbrecht

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ACKNOWLEDGEMENTS

Thank you to those who contributed to the development of the farming systems component of the 2007 Crop Updates program. Papers covering current research and a wide range of issues likely to be topical in season 2007 have been prepared and reviewed to a tight deadline – the effort of contributors and reviewers is gratefully acknowledged.

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Doug Abrecht
FARMING SYSTEMS CONVENOR

Quality Assurance and industry stewardship

David Jeffries, Better Farm IQ Manager, Cooperative Bulk Handling

KEY MESSAGES

Attitudes towards responsible industry stewardship within the grains industry must begin to change if we hope to maintain our current market position. Chemical residues, questionable pest control strategies, varietal purity and the potential for the introduction of GM crops demand a greater recognition of the market impacts of even the smallest mistakes. Currently, new import legislation and chemical residue testing regimes are highlighting to our overseas customers that our clean and green image is just a mirage. Quality Assurance cannot, nor should it have to police this issue and end product testing is neither an efficient or cost effective alternative to mitigate the risk. As industry professionals we need to understand what has been entrusted to our care and work together to safeguard our reputation and livelihood.

DISCUSSION

In the Western Australian grains industry, Quality Assurance cannot and will not have a meaningful existence without appropriate industry stewardship to back it up. In many other countries, over-regulated QA programs have tried to take on the role of policing the industry, catching people out and effectively forcing honest producers to become good liars. Quality Assurance should only be used to prove what responsible industry stewardship has already achieved.

Industry stewardship carries with it the responsibility of proactively looking after your industry, not because you are forced to or legislated to, but because it is valuable. Industry stewardship is defined as the careful and responsible management of something entrusted to one's care. What has been entrusted to your care?

On 6 September 2006 a Quality Assured grower from the Esperance area made a call to the manager of the Better Farm IQ Program, an on farm Quality Assurance program run and managed by Cooperative Bulk Handling. He openly stated that he had purchased a large quantity of 2,4-D Ester and intended to breach the APVMA restrictions by using it to control summer weeds. As a direct result the industry was motivated to submit a permit application to cover its use during the summer months.

The grower could have lied, he could have falsified his QA records, but he didn't. Was this action motivated by compliance with his QA system or was it industry stewardship?

On 10 July another grower called his Integrated Quality Coordinator (IQC) to let him know that he had applied Propyzamide / Kerb to his Canola and Peas. This knowledge allowed key players in the grains industry to work together to determine whether the application would result in a breach the Maximum Residue Levels (MRLs).

The grower had knowingly done something that was illegal and yet he still called his QA auditor to let him know. Was this criminal an industry steward?

A wool producer from Doodlakine called his IQC to inquire about refurbishing a sheep dip that had historically contained arsenic based products. A bit of cooperative research, a couple of coats of bondcrete and $32 later, the grower had his answer and the confidence that he could use his old dip without the fear of arsenic residues on his wool.

Who was the industry steward?

A trucking contractor who was carting wheat for a Quality Assured grower called his CBH area manager to query what he needed to do to clean out his truck after carting fertiliser that had been treated with uptake (flutriafol). As a direct result, and with the generous support of Cropcare, CSBP, Marley's Transport and CBH operations, a full scale trial was conducted which demonstrated that flutriafol residues would exceed the MRL if the truck was not washed out after carting treated fertiliser.

Who was the industry steward?

In all cases, the industry steward was the person who put up their hand and raised the issue. In all cases, records could have been falsified, QA auditors duped and the potential risk simply passed on undetected to the next person in the supply chain, but at what cost? Our clean and green image and continued access to the highest paying world markets are at stake unless the industry as a whole begins to better understand the potential consequences of getting it wrong. Even with this level of cooperation with our growers, we are still a long way off where we need to be as an industry. Stewardship is the careful and responsible management of something entrusted to one's care, what has been entrusted to your care?

As a grain handling and marketing company, the CBH Group have been entrusted with ensuring that the WA grains industry is well placed to compete in a rapidly evolving global market. The implementation of an industry wide QA program is a necessary and responsible step to ensure we are ready to take on the world.

It may not be a popular move, but a quick look at what our competitors are doing clearly shows a trend towards on farm Quality Assurance, the Canadian On Farm Food Safety System, Eurepgap combinable crops, BRC technical standard, GMP 13, Grain Safe out of America and UK assured malt out of the UK, to name but a few of the many systems currently in circulation. Grain buyers in China, Japan and Korea are already buying quality assured or identity preserved grain from our global competitors.

From a market access perspective, inquiries regarding Quality Assured grain, traceability and chemical use patterns have increased significantly in the last year. AWB is seeking traceable grain, ABB is requesting quality assured malting barley, Kirin breweries gave us less than two weeks notice to prepare for a supply chain audit including grower’s production records and several Japanese customers have requested complete lists of chemicals applied to WA crops.

As a company, we recognised that Quality Assurance and traceability systems in the grains industry will soon become a ticket to the game. What was also recognised was that an industry which could demonstrate that it was responsibly managing its own affairs would be far less likely to come under the scrutiny of the regulators. We have all seen what happens when an industry avoids dealing with an issue. The legislators, government or customers move in and force unreasonable change. Look at mulesing, live export, animal welfare, sheep crossing, Occupational health and Safety, vehicle overloading. The horticulture industry revolted against industry managed on-farm QA programs and is now stuck with multiple QA programs and multiple audits to satisfy their different customers.

Restrictions on the use of Endosulfan and Ester are just the tip of the iceberg when it comes to legislating farming practices. The Biosecurity and Agriculture Management Bill and the proposed restriction on access to chemicals proposed by the Council of Australian Governments (COAG) will soon impact on the livelihood of every grower in the state. The swiftness and impact of this legislation has only been exacerbated by industry practices that have resulted in the detection of illegal residues in overseas markets no less than five times in the last year alone.

Many of you reading this will be aware of issues which have the potential to negatively impact on the reputation of an industry which has, in part, been entrusted to your care. I can assure you without a shadow of a doubt, that if our industry does not deal with issues such as off label chemical use and a seemingly blatant disregard for withholding periods and registered uses we will all be forced to deal with higher costs and harsher legislation.

Our grain has never before been under the scrutiny that is now under. Some importing governments are now testing for almost 800 chemicals, 762 of which have not been tested for in the past. The industry cost of testing one sample from every stack in the state is almost 1.5 million dollars, is akin to looking for a needle in a haystack, and provides no avenue to deal with the source of the residue. Testing one sample from every grower would cost the industry almost 8.5 million and one sample of each grain type from every grower would be over 42 million dollars, and that is just one issue. If the industry needs to rely on random testing to police this and other emerging issues, it will fail.

CONCLUSION

The implementation of the Better Farm IQ program has helped, but it is designed to demonstrate compliance to customers, not hunt out deceit amongst growers and the industry. Spray records can be easily falsified and QA auditors duped, does that point to a problem with QA or with the industry? At times it seems the industry is working against each other. We need more industry stewards, more truck drivers, growers, chemical manufacturers, farm advisors and agronomists willing to put up their hand and take on the tough issues. To raise the awareness and drive a necessary change before something or someone forces us to.

As an industry, should we continue to ignore these issues and wait for the inevitable media hyped overseas contamination to occur, or should we take steps to responsibly manage that which has been entrusted to our care?

Who will be the industry steward?

KEY WORDS

Western Australia, grain, chemical residues, industry stewardship, Quality Assurance

Paper reviewed by: Peter Portmann, Roslyn Jettner, (CBH)

Sothis: *Trifolium dasyurum* (Eastern star clover)

A. Loi, B.J. Nutt and **C.K. Revell**, Department of Agriculture and Food, Western Australia

KEY MESSAGE

Trifolium dasyurum Sothis is the first cultivar of eastern star clover released to world agriculture. *Sothis* germinates very late in the season compared to traditional pasture legumes and weeds. The delay in germination allows the use of non-selective herbicides or intensive grazing after the break of season for a long period of time (3-6 weeks) to obtain > 90% control of troublesome crop weeds. Although slow to germinate, Sothis can grow rapidly in late winter/spring and produce a productive legume-dominant pasture for grazing or forage conservation. Sothis is suitable for use on acid and alkaline fine textured soils in low to medium rainfall areas (325-450 mm).

AGRONOMIC CHARACTERISTICS

Sothis was originally collected at Naxos Island (Greece) and introduce to Australia in 1995. Later, intensive hard seed studies were conducted by Dr Loi and Mr Nutt, which lead to the discovery of the particular delayed germination strategy of Sothis. Subsequent experiments were designed to highlight the potential benefits this species could provide in allowing control of herbicide-resistant weeds in current and emerging Mediterranean farming systems.

Sothis is an early-mid maturing cultivar, flowering approximately 100 days after emergence from a mid May sowing in Perth, Western Australia. It is suited to regions with 300 to 500 mm annual rainfall with a Mediterranean rainfall distribution pattern and can be grown on acidic and alkaline sandy-loam and loamy soils. Seed needs to be inoculated with inoculant Group C for clovers.

Field experimentation in Western Australia has shown that herbage production in spring of ungrazed Sothis may range from 4.1 to 5.6 t/ha and seed yields from 310 to 663 kg/ha (Table 1). It has good forage quality in terms of dry matter digestibility (71%) and crude protein generally varies between 20 and 25% at the start of flowering (Norman *et al*. 2005).

Table 1. Spring herbage yield (t ha^{-1}) and seed yield (kg ha^{-1}) in the year of establishment (1998) at two sites in Western Australia

Legume species	Herbage yield				Seed yield			
	Cunderdin		Mingenew		Cunderdin		Mingenew	
	t ha^{-1}	SE	t ha^{-1}	SE	kg ha^{-1}	SE	kg ha^{-1}	SE
T. dasyurum cv. Sothis	5.6	1.3	4.1	0.7	663	191	310	5
B. pelecinus cv. Casbah	4.3	0.3	4.9	1.3	439	148	568	224
M. polymorpha cv. Santiago	5.8	0.5	4.9	0.2	502	335	665	109
M. truncatula cv. Caliph	6.5	0.2	3.8	0.5	648	121	582	62
O. sativus cv. Cadiz	4.3	0.6	5.8	0.3	357*	147	38*	20
T. glanduliferum cv. Prima	4.9	0.5	4.1	0.3	367	125	427	145
T. michelianum cv. Frontier	5.1	0.4	5.1	0.7	237	47	168	43
T. subterraneum cv. Dalkeith	4.0	0.05	4.6	0.1	201	36	252	40

Sothis is an hardseeded clover and its variation in percentage of hard seed compared to other pasture legumes is shown in Table 2. Species generally differ in their progress of softening during the summer period. Sothis usually softens more rapidly in the second 90 day period, unlike *T. subterraneum* cv. Dalkeith and *T. michelianum* cv. Frontier, which generally soften rapidly over the first 90 days remaining exposed to false breaks.

Table 2. Individual seed weight (mg), and seed softening (%hard seed) of *T. dasyurum* Sothis and a range of annual pasture legumes in the field over one summer at Perth, Western Australia (initial test January 1999, final test first of July 1999)

Legume species	Seed size (mg)	Hard seed levels					
		Initial (0 days)		Mid autumn (90 days)		Final (180 days)	
		%	SE	%	SE	%	SE
T. dasyurum cv. Sothis	6.2	89	1.3	82	2.0	67	3.0
B. pelecinus cv. Casbah	1.2	99	0.2	90	4.5	86	5.4
M. polymorpha cv. Santiago	3.6	69	4.0	75	5.1	61	5.6
M. truncatula cv. Caliph	3.7	98	2.0	88	2.5	82	2.9
T. glanduliferum cv. Prima	0.7	98	0.5	60	5.6	56	3.6
T. michelianum cv. Frontier	0.7	86	7.7	15	6.1	4	1.3
T. subterraneum cv. Dalkeith	6.7	79	1.9	18	1.0	14	3.0

The levels of hard seed of Sothis combined with observations of seedling regeneration (Table 3) suggest that it is likely to be suited to self-regenerating ley systems or short-term phase farming systems (where it needs to be resown at the beginning of each pasture phase).

Table 3. Seedling regeneration (plants m^{-2}) in second year (1999) and after a crop (2000) at Cunderdin Western Australia (standard errors in brackets)

Species	1/4/99	28/5/99	1/7/99	2/2/00	10/5/00	30/6/00
	Plant/m^2	Plant/m^2	Plant/m^2	Plant/m^2	Plant/m^2	Plant/m^2
cv. Sothis	271 (74)	258 (73)	1433 (273)	17 (8)	306 (207)	1552 (87)
cv. Santiago	300 (53)	579 (151)	0	172 (54)	272 (126)	0
cv. Frontier	967 (270)	1942 (509)	0	29 (8)	56 (36)	0
cv. Dalkeith	3225 (503)	2475 (135)	0	233 (32)	219 (22)	0

In regenerating pastures, the peculiar delayed germination of Sothis (Table 3) is a useful tool in controlling herbicide-resistant weeds. Its long period of delayed germination allows the use of non-selective herbicides at the break of the season for a period of up to 8 weeks (3-6 weeks preferable) to control > 90% of the weeds without compromising future legume production. Table 4 summaries the plant densities after the spray treatment. The density of Sothis was only moderately reduced by the herbicide treatment compared to subterranean clover (35% reduction compared to 97%). Weed densities were also substantially reduced after the herbicide treatment, particularly the herb component and were similar for both pasture legumes. The ability to control weeds early in the growing season is critical. However, delayed sowing to allow consecutive knockdowns with non-selective herbicides usually compromises successful pasture establishment and may limit the winter production of the legume, decreasing biomass and seed yield. The yield penalty from late sowing of Sothis appears to be much less than for current pasture legume species.

Table 4. Modified from (Loi *et al.* 2006): Plant densities of *T. dasyurum*, Dalkeith subterranean clover and weeds in unsprayed and sprayed treatments (standard errors in parenthesis)

	Sown legume plants/m^2	Grasses plants/m^2	Herbs plants/m^2
Sothis unsprayed	**722 (135)**	**6325 (3615)**	**3548 (939)**
Sothis sprayed	**475 (84)**	**165 (32)**	**0 (0)**
Dalkeith unsprayed	**5160 (992)**	**5295 (3152)**	**3682 (443)**
Dalkeith sprayed	**161 (30)**	**145 (61)**	**4 (3)**

CONCLUSION

Innovation in pasture plant improvement can make a substantial contribution towards addressing some of the major threats to agricultural systems. The strategic use of non-selective herbicide in regenerating pasture containing *Sothis* significantly reduced weed density whilst still retaining a high legume density. The delayed germination in *Sothis* offers farmers an important opportunity to control weeds during the pasture phase compared to traditional pasture legumes that germinate rapidly at the break of season.

KEY WORDS

annual pasture legume, delay germination, seed bank, weed control

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Poor performing patches of the paddock – to ameliorate or live with the low yield?

Yvette Oliver[1], Michael Robertson[1], Bill Bowden[2], Kit Leake[3] and **Ashley Bonser[3]**, CSIRO Sustainable Ecosystems[1], Department of Food and Agriculture, Western Australia[2], Kellerberrin Farmer[3]

KEY MESSAGES

- Poor performing patches of the paddocks can be located with farmer knowledge and precision agriculture (PA) tools.
- By target sampling soils and identifying soil constraints, it may be possible to determine the basis for low yields. Soil type and soil constraints are likely to affect the plant available water capacity (PAWC).
- Knowledge of PAWC can be used to determine the yield potential over different seasons.
- The decision to ameliorate depends on the opportunity to alter the constraint (e.g. liming for acidity) and the economic viability determined from improved yield potential based on increased PAWC.
- If the constraint cannot be fixed (e.g. shallow soil) or it is not economically viable to fix, then farmers need to “live with the low yield” and alter their management of these low yielding regions.

AIMS

To describe a process so farmers and consultants can identify the location and causes of variability in yield within (or between) paddocks using PA tools and targeted soil sampling. This is achieved by measuring soil properties and using the soil plant available water capacity as an indicator of yield potential. This information may be used to determine whether there is potential for amelioration in low yielding areas. This process has been trialled with farmer groups in the wheatbelt and we report on one case study to illustrate the process.

METHOD

A field day with the Kellerberrin Demonstration Group in October 2006 used precision agriculture (PA) tools to target soil sampling to help define the relationship between soils and crop performance across paddocks. Yield mapping is the most commonly tool of PA, but most farmers in the Kellerberrin region are not yield mapping, so other precision agriculture tools which map spatial variability of crop growth and soil properties were used. The farmers knowledge of the paddock was added to the PA data to provide understanding of the management and history of these paddocks.

At two of Kit Leake’s paddocks, NDVI, an indicator of biomass, was used to define areas of low, medium and high production (Silverfox Solutions Pty Ltd). Paddock 1 was 65 hectares and paddock 2 was 58 hectares. They have been in cereal-lupin/canola rotations with pasture in 2003, with paddock 1 limed with 1 t/ha in 1997 and 2003 and paddock 2 limed with 1 t/ha in 1996 and 1 t/ha dolomite in 2003. The biomass performance analysis used the NDVI over cereal years (paddock 1 using 1997, 1999, 2001, 2002, 2004, and paddock 2 using 1995, 1998, 1999, 2001, 2002, 2004) to determine the variation in biomass performance and its consistency over time, i.e. a poor performing area performed poorly relative to other areas in the paddock in most years.

At Ashley Bonser’s site, two paddocks were geophysically surveyed using an EM38 and gamma radiometrics (data from the Wallatin-O’Brien CDI). These data were used to target soil sampling in two different soil types. The paddocks are both approximately 45 hectares and are currently under wheat-pasture rotations with some years in chickpeas or barley.

Targeted soil sampling was able to define the soil type, soil texture, rooting depth, soil constraints (pH and EC) to estimate plant available water capacity (PAWC). Soil pits were dug in high, medium and low performing areas of Kit Leake’s paddock (Figure 2). In Ashley Bonser’s paddocks, soil cores were

dug in areas without salinity but differing gamma radiometric signal (Figure 3a,b). The estimate of PAWC was based on averages from previously measured PAWC profiles at unconstrained sites around WA (Table 1) but need to be adjusted for other soils and gravel content. It is still advised to measure PAWC at your site using methods from Soil Matters Handbook (Dalgliesh and Foale 1998).

Through APSIM modelling, the PAWC was related to potential yield in different seasons using 100 years of the Kellerberrin climate record and a range of PAWC values from 40 mm to 150 mm (Figure 1).

At each site the soil constraints, management issues, PAWC, yield potential and potential benefits from amelioration were discussed with Kit and Ashley and the others in the group.

Table 1. Estimated PAWC (mm) to a rooting depth for different soil texture classes (as defined by CSBP). Data are averages from measured PAWC profiles

Depth (cm)	Sand ~0.4 mm/cm	Loamy sand ~0.7 mm/cm	Loam ~0.9 mm/cm	Clay loam ~1.2 mm/cm	Clay ~1.4 mm/cm	Heavy clay ~1.8 mm/cm
30	10	20	30	35	45	55
50	20	30	45	55	70	85
75	30	45	60	75	95	120
100	40	60	75	95	115	150
150	60	80	110	130	155	195
200	80	105	130	155	180	225
250	100	125	150	180	200	250

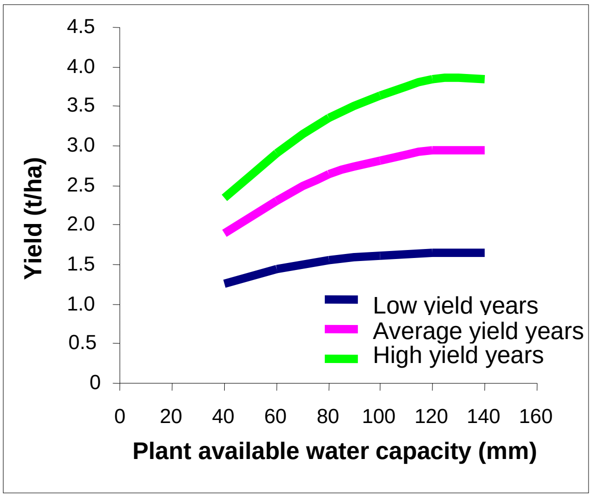


Figure 1. APSIM modelled relationship between plant available water capacity (PAWC) and potential yield using 100 years of rainfall for Kellerberrin rainfall station and a range of soils with PAWC which range from 40 mm to 150 mm, with the results grouped in low, medium and high yielding years

RESULTS

Using biomass analysis to target low yielding areas

At Kit Leake's paddocks the NDVI biomass performance analysis matched Kit's knowledge of how these paddocks performed in the past and also how they were performing in 2006. Low yielding areas occupied 28% of the paddocks (red on Figure 2), with 32% average yielding (green on Figure 2) and 40% high yielding (blue on Figure 2). These paddocks have a consistency of 70%, i.e. in 70% of years a poor performing part of the paddock has lower yield than other areas of the paddock.

In the low performing area, (L) (Figure 2), the crop had a low plant density, low tiller density and some nitrogen deficiency. The soil pit was a yellow loamy sand with an acidic layer at 0.2-0.4 m with a pH (water) of 4.5-4.9. There was little visual evidence of roots below 0.5m and the soil was wet soil

below 0.5 m which confirmed the roots were not able to penetrate past the acid layer. The PAWC was estimated from the soil texture and rooting depth as only 30 mm would yield less than 1 t/ha in a poor season and 2 t/ha in a good season (Figure 1).

The average performing area, M (Figure 2), was a gravelly loamy sand (~50% gravel) without any pH constraint. The roots were visually evident to 1.2 m with a dry soil profile to this depth but the roots may be able to penetrate deeper with a better season than 2006. The gravel soils also have higher leaching capacity than the loamy sands and nutrients may quickly leach from the root zone. The PAWC was estimated as 60 mm due to the gravel reducing the ability of the loamy sand to hold water, which gives a yield estimate of 1.3 t/ha in a poor year and 2.7 t/ha in a good year (Figure 1).

The high performing site (H on Figure 2) had a yellow sandy loam, which was similar to the low yielding site. This site had a hardpan, which was evident when the pit was dug, and was just starting to become acidic (pH water = 4.9) at 0.2 m. This site has not been ripped for 22 years or more but had lime in 1996 and dolomite in 2003. The roots were still able to penetrate this hardpan and were present below 1.2 m despite the acidic layer. The PAWC was estimated at greater than 100 mm which could yield 1.5 t/ha in a poor year and 3.5 t/ha in a good year (Figure 1).

Ameliorating the acidity in Kit's low yielding sites can increase the rooting depth which will increase the PAWC from 30 mm to 100 mm. This increase in PAWC could increase the yield potential by 0.4 t/ha-1.5 t/ha, depending on the season, which will require additional nutrient inputs. Or inversely at the high yielding site, if amelioration does not occur it could eventually lose 0.4 t/ha-1.5 t/ha. There were no options to ameliorate to average performing area the gravely loamy sand. In this instance it is best to match nutrients to the yield potential, in other words live with the average/low yield.

With this knowledge Kit was going to look at the cost/benefits of ameliorating the low yielding site, but decided to rip and lime the high yielding site to prevent further degradation of the soil. Kit will attempt to match fertiliser to yield potential to increase his overall returns in the future.

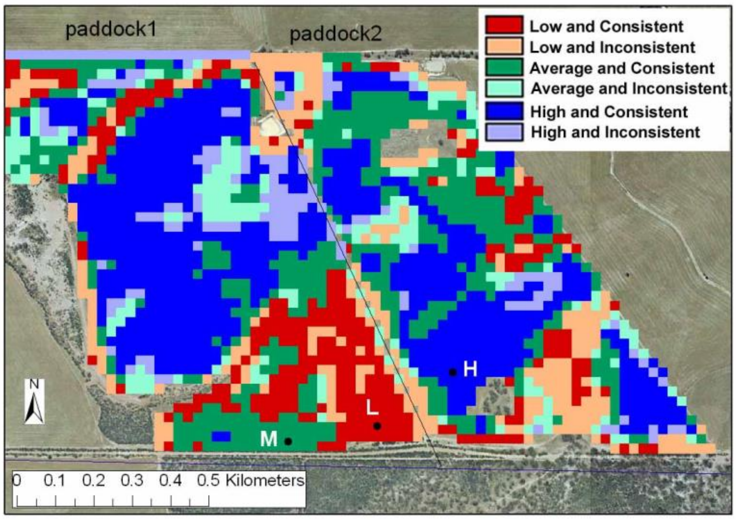
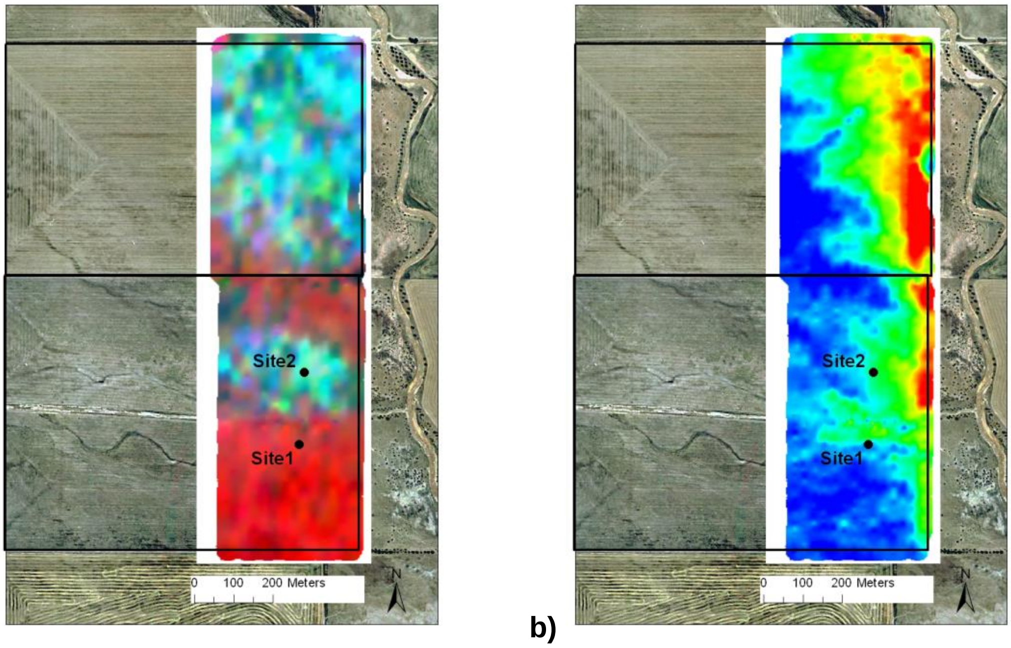


Figure 2. Kit Leake's paddock with the location of the soil pits (L,M,H) based on the biomass performance analysis to determine the high (blue), medium (green) and low yielding (red) areas and their consistency of performance over time (the pale colours are inconsistent in their performance).

Using geophysics to target different soil types

At Ashley Bonser's site, geophysical surveys of Electromagnetic induction (EM) and gamma radiometrics were used to target soil sampling in two different soil types, site 1 and site 2. The gamma radiometric ternary image (Figure 3) indicates the different soil types with the red having higher potassium minerals in the soil often associated with granites (Cook *et al.* 1996). In the EM survey (Figure 3b) the red/yellow colours have high electric conductivity, which in this case relates to saline areas adjacent to a valley-floor creek. Ashley knew the two parts of the paddock had different yield potentials and behaved differently in different seasons.

Site 1 was coarse sand over clay (at 0.8 m) with roots to 1.2 m and an estimated PAWC of 70 mm, and site 2 was a heavy clay also with roots to 1.2 m with the PAWC was estimated 120 mm. Field test of EC and pH suggested growth at the sites was not constrained by soil acidity or salinity. With the average to high PAWC in these soils, the yield difference is approximately a 0.05 to 0.5 t/ha (depending on season, Figure 2) which would suggest a single management strategy. However from discussion with Ashley, the seasons with dry finishes cause the coarse sandy duplex to 'fall over'. This is related to the 0.8 m of coarse sand only holding 35 mm water which may not be enough water to overcome drought periods late in the season when the crop is filling grain. Therefore different management strategies are required for each soil type.



a) b)

Figure 3a. Ashley Bonser's paddocks with the location of the two soil sampling sites overlayed on the ternary image from the gamma radiometric survey (a) and EM survey (b).

CONCLUSION

On poor performing patches in paddocks, most farmers would first try to increase the yield by adding extra inputs rather than reduce inputs. By understanding why an area is poor farmers can make an informed choice about ameliorating the site or to "stop throwing good money after bad" and live with the low yield.

Spatial data in precision agriculture is more than a yield map. Other tools exist, including NDVI, NDVI biomass analysis, gamma radiometrics and electromagnetic surveys. Incorporating these PA tools with farmer knowledge can determine the location and boundary of the poor performing parts of paddocks. Soil sampling in poor performing locations can then determine the possible soil constraint, PAWC and how the soil constraints affect the yield potential.

Management decisions for inputs for these paddocks can now be informed by knowledge of the location of differential crop performance and how this relates to soil type, PAWC and season. This leads to improved management of inputs within or between paddocks and allows understanding of benefits from amelioration or how to best live with the low yield by managing to the yield potential.

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KEY WORDS

Plant Available Water Capacity (PAWC), precision agriculture, spatial variability

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What evidence is there that PA can pay?

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KEY MESSAGES

- One of the chief reasons for low adoption of PA is the reluctance of farmers to invest many thousands of dollars in PA without knowing if the technology will return a profit.
- Typical gross margin increases required to offset the PA technology costs can be calculated for different regions in WA at $3-10/ha.
- Evidence from nutrient response curves and within-paddock yield variation, strip trials and commercial practice would suggest that benefits to variable rate fertiliser management in WA vary from $5 to > $60/ha, with a long-term average in commercial conditions of $15-20/ha.

BACKGROUND

In commercial practice in Australia the implementation of precision agriculture (PA) encompasses the use of vehicle guidance to reduce overlap in application of agricultural chemicals, reduced traffic associated with tramlining to reduce compaction and operator fatigue, shielded spraying of pesticides in row crops, yield monitoring, variable rate technology (VRT) for application of agricultural chemicals, especially fertiliser and within-paddock zone management for agricultural operations. All of these activities have in common the use of spatially-aware technologies made possible through the use of global positioning systems (GPS).

The commercial benefits of guidance, tramlining and shielded spraying are well understood and growers in WA are taking up these technologies in greater numbers. However, there has been less uptake by growers of 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, and this paper will focus on the economics of zone management.

One of the chief reasons for low adoption of PA is the reluctance of farmers to invest many thousands of dollars in PA without knowing if the technology will return a profit. Early PA adopters are often moving into systems based on high cost 2 cm accurate GPS auto-steer systems with capital costs ca. $60,000. To potential adopters this seems too expensive and they question the application of PA to their farming system. The early adopters often crop large areas (above 3000 ha) which means highly accurate auto-steer 2 cm systems are a good investment based on 10% savings in inputs from less overlap. GPS costs can range from $800 to $60,000 depending on what accuracy is most appropriate for the operation. Highly accurate GPS systems are not an essential piece of equipment for variable rate technology.

In this paper we examine the evidence that economic returns can be generated from zone management on WA grain farms. Our evidence comes from three sources: (1) the economics of nutrient response curves and differences in crop yield potential among zones; (2) results of on-farm strip trials comparing variable and uniform management; and (3) commercial benefits reaped at the whole-farm scale by users of VRT.

FINANCIAL CONSIDERATIONS

Typical gross margin increases required to offset the PA technology costs can be calculated for different regions in WA according to statistics of cropped area on farms. Grain growing properties in the northern agricultural areas of WA average 3,600 ha, of which about 1,700 ha is cropped each year. In the eastern agricultural area, average farm size is about 5,000 ha with just over 1,700 ha under crop each year. Given these farm sizes, the range of gross margin increases required to break even from investment in PA is less than $5/ha depending on the level of investment and assuming that benefits accrue over the entire cropping program on the farm starting at year two after equipment purchase and persist through a 10 year period. Average farm size in the central agricultural area and the mallee and sandplain country of WA is similar at about 2,300–2,600 ha. About 1,000 ha of this land is cropped each year. For these areas, the break-even gross margin will be $3-6/ha depending upon the size of the investment. Of course all growers are expecting to more than just break even with the investment in PA and want to see sizable returns on their investment. What evidence is there that this can happen?

EVIDENCE FOR THE ECONOMICS OF PA

Profit increases from zone management can come from the achievement of higher yields with higher input where the value of the extra yield outweighs the cost of the extra fertiliser, or where the cost savings in fertiliser input exceed the reduced value of the yield either through the achievement of the same yield but with less fertiliser or a lower yield with less input.

There are three main sources of evidence: From theoretical calculations based on differences in crop yield potential among zones; from on-farm strip trials, and in commercial practice where VRT is applied at paddock scale across a farming enterprise.

Theoretical calculations

We have examined the relationship between within-field yield variation and economic advantages for zone management, and the impact of variation in size of management zones, costs and prices, and soil fertility status. We found that the biggest gains were to be made in fields with the widest differences in yield potential. This is because yield potential (defined as the yield limited only by water) is the major determinant of crop nutritional requirements. The advantages gained through zone management were seen mostly via higher rates of fertiliser on medium and high yielding zones, and to a lesser extent as lower rates, and thus cost savings, on low yielding zones. Additional benefits would accrue if zone differences in starting soil fertility co-occur with differences in yield potential particularly where high starting fertility occurs on low yielding zones. For the range of cases for VRT on wheat the potential economic benefits to WA growers ranged from < $5/ha to over $40/ha.

On-farm trials

While theoretical calculations of the economic benefits of zone management abound, there are few documented cases of on-farm benefits. Growers experimenting with zone management often use strip trials across management zones to compare the returns from uniform and variable nutrient application. Table 1 shows on-farm trial results, collected by DAFWA under commercial conditions from Casuarinas district near Geraldton, of matching fertiliser inputs to zone potential, where, based on past performance recorded by yield maps, paddocks were divided into three zones with low, medium or high potential. The advantage of applying low, medium or high rates of fertiliser to zones of low, medium or high potential over the baseline strategy of applying a medium rate to the whole field varied from $29 to $63/ha.

Table 1. Wheat grain yield (t/ha) and gross margin ($/ha) per zone in each of three seasons at a farm in the northern sandplain of WA. The percentage area of each zone in Paddock A was 21% low, 28% medium and 51% high and in Paddock B was 20% low, 35% medium and 45% high. Gross margins were determined using input costs, yield and grain quality and premium grain prices for the year. Shaded cells are the maximum gross margin for each zone within a season

Zone	Fertiliser input	Paddock A				Paddock B	
		Yield (t/ha)		Gross margin ($/ha)		Yield (t/ha)	Gross margin ($/ha)
		2002	2004	2002	2004	2005	2005
Low	Low	1.5	2.2	105	188	2.8	236
	Medium	1.7	2.0	38	88	3.5	345
	High	1.7	2.2	-26	60	4.2	429
Medium	Low	2.1	2.3	248	209	3.2	311
	Medium	3.6	2.7	303	223	3.6	362
	High	3.7	3.4	238	285	4.5	483
High	Low	2.4	2.4	254	242	3.5	387
	Medium	3.6	3.0	320	275	4.5	549
	High	4.3	3.8	398	357	5.4	661
Advantage of matching input to long-term zone potential vs. medium rate across field.				56	63		29

In 2002, the optimal practice was to match fertiliser rates to the long-term zone potential. In 2004 on the medium zone it would have been best to apply a high rate rather than a medium rate and so benefits of matching inputs to zone potential were less than if the optimum for that season was applied. In 2005, applying high rates on all zones would have been best, so the advantages of matching fertiliser rates to the long-term zone potential were less than the optimum in all three zones. These results show that the economic benefits of zone management derived from theoretical estimates are not always achievable in commercial practice due to seasonal influences enhancing or diluting the benefits of matching fertiliser to zone potential through the impact on yield potential, as with any nutritional management.

Commercial practice

For growers that have been conducting zone management over whole paddocks and have also been yield monitoring and keeping records of fertiliser rates used on each zone, an estimate can be made of the commercial advantage of zone management. We have done this for a range of paddocks over a number of seasons on two farms: David Forrester at Casaurinas and David Fulwood at Cunderdin). Only the results for Forrester are given here, and similar results were found for Fulwood.

In order to calculate the benefit of variable rate fertiliser application, some estimate had to be made of yield on each of the three zones if uniform management had been applied rather than variable rate. It was assumed that under uniform management the yield of the medium zone was the same as under VRT. After discussion with growers it was decided to assume that the yield of the high zone under uniform management was the average of that in the medium zone and that in the high zone under variable rate. Hence, the higher yield under variable rate on the high zone were assumed to be due to this zone being nutrient-limited and hence the benefits of more fertiliser applied was to increase yield. For the low zone the assumption was that the yield was unchanged from the variable rate situation and hence less fertiliser was applied for the same yield. David Forrester insisted that yields were on the whole higher in the low zone under variable rate and he put this down to less ‘haying off’ and better grain quality (less screenings), hence we assumed yields to be 10% higher in the low zone under VRT.

David is a long-time practitioner of zone management and the experience from his farm provides a good long-term guide to the profitability of VRT. David and Christina Forrester farm 3,400 ha at Mullewa in the northern WA grainbelt. About 2600 ha are cropped each year and the yellow sand plain and white sand over gravel or clay soils are under a six year wheat–lupin rotation, with the occasional crop of canola or barley. This is followed by a three-year pasture phase of Cadiz clover. Their average growing season rainfall is 336 mm and average wheat yields are about 3 t/ha. They also run approximately 2,000 sheep.

Unlike many other practitioners of variable rate management in WA, David does not use autosteer or tramlining. However, he does use guidance for his spraying operations with an autoboom. His main reasons for not venturing into tramlining and autosteer is that at this stage it would require a large capital outlay to change his machinery over to a compatible wheel spacing. He does not rule out the possibility of converting to a tramlining system sometime in the future “when the time is right”.

David began yield mapping in 1997 and started varying rates of fertiliser to paddock zones on the farm the following year. Before 1997 David was conscious of trying to raise the poor performing zones in paddocks through high rates of fertiliser under the belief that poor performance was largely due to nutrient limitations. Since moving to variable rate he has seen that lower, rather than higher, rates on such areas are more cost effective and agronomically sensible. Zones have been defined on the basis of soil type and the native vegetation and he has been gradually refining the zones as more yield mapping is done. Biomass imagery was used from Silverfox a few years ago to confirm the zone boundaries, but David has stuck largely to his original zone definitions, and these have been more or less fixed for the last four seasons. Most paddocks have three zones (low, medium and high yield potential) with some paddocks having four. Fertiliser rate maps are produced from preceding year’s yield maps, with drought years being discounted.

In the early years of variable rate David was tentatively varying rates by 10% above and below the paddock average for the high and low zones respectively. However, since 2000 he has varied rates more strongly. Cereals and lupins receive similar rates of starter fertiliser (60, 90 and 120 kg product/ha for low, medium and high zones, respectively). Potash is applied at 60, 80 and 100 kg/ha of muriate of potash. Urea is applied to cereals at rates of 50, 70, and 90 kg/ha of urea and in good

seasons this is topped up with 10, 20 and 30 kg /ha of urea + S. David occasionally varies these rates if the soil test indicates that this is needed. He has also experimented with applying more on the medium zones and less on the high zones to see if productivity differences are related to nutrient deficiencies, but most of the time this has not turned out to be the case.

An estimate was made of the benefits of variable rates of N, P and K on ninecropping paddocks, where yields maps were collected during 1997-2005. The average yield in each fertiliser zone was determined using the boundaries of the zones overlaid on yield maps. Gross margins were then calculated using actual fertiliser rates, standard prices and other variable costs and the assumptions outlined above for the yield under uniform management.

Across the 24 wheat paddock x season combinations, the difference between the yield from the high and low zone ranged from 400 kg/ha in the most uniform situations to 2,100 kg/ha in the most variable situation with the mean being just over 1,000 kg/ha. The benefit to variable rate varied from -$15/ha to +$50/ha, with an average of $14/ha. Across the 21 lupin paddocks x season combinations, the difference between the yield from the high and low zone ranged from 300 kg/ha in the most uniform situations to 1700 kg/ha in the most variable situation with the mean being just over 800 kg/ha. The benefit to variable rate varied from $1/ha to +$42/ha, with an average of $19/ha.

The season influence on returns can best be seen in Table 2 where returns tended to be lower in 1999, 2002 and for wheat in 2004 and 2005. An analysis of climatic conditions in those seasons will reveal as to why returns were lower than in other seasons.

Table 2. Mean increase in paddock gross margin ($/ha) due to variable rate fertiliser application by crop type on David Forrester's farm

Crop	Season									
	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Barley	13								34	23
Lupins	10	17			14	12	12	22	30	19
Wheat	25	26	5	19	22	8	16	9	7	14
Mean	16	23	5	19	18	9	13	13	27	16

The example paddocks chosen give on average a $16/ha benefit to variable rate over the paddocks and crops examined. If this benefit is extrapolated over the entire cropping program of 2,600 ha then annual benefits are calculated at $41,600. The NPV over a 10 year timeframe comes to $297,164 in 2006. On the basis of the evidence presented here variable rate fertiliser management is making more than a large enough return to justify the investment made.

CONCLUSIONS

Evidence from nutrient response curves and within-paddock yield variation, strip trials and commercial practice would suggest that benefits to variable rate fertiliser management in WA vary from $5 to >$60/ha, with a long-term average in commercial conditions of $15-20/ha. These gains are well over that required to break even for a typical investment in VRT technology. Further evidence needs to be collected in other agro-climatic zones of the WA wheatbelt to see if such gains can be widely expected.

KEY WORDS

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

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Paper reviewed by: Yvette Oliver, CSIRO

The journey is great, but does PA pay?

Garren Knell, ConsultAg; **Alison Slade**, Department of Agriculture and Food, Western Australia, CFIG

KEY MESSAGES

Variable results were achieved in 2006 when matching fertiliser inputs to productivity zones. Results ranged from an increase in paddock returns of $2,700 to a loss of $4,500 compared to a blanket application of fertiliser.

After eight trials over four years it remains unclear if the adoption VRT and applying fertiliser according to the performance of each productivity zone is likely to generate significant profits when compared to blanket applications of fertiliser in the Corrigin district. The information gathered in the process does however allow farmers to better understand their paddocks and their crops fertiliser requirements to assist in making profitable fertiliser decisions.

Where soils have a high nutrition status (N, P, K, S) and low reactive iron there is scope for farmers to significantly reduce fertiliser inputs in the short term and still achieve profitable grain yields.

AIMS

To better match fertiliser inputs to productivity zones to increase whole paddock profitability.

To document and evaluate a practical procedure utilising tools and services that are readily available for zoning paddocks and matching fertiliser inputs to productivity zones.

METHOD

Zoning paddocks and estimating crop nutrition requirements

The Corrigin Farm Improvement Group in conjunction with ConsultAg and DAFWA conducted five trials looking at Precision Agriculture and Variable Rate Technology. Summarised within this paper are two trials from 2006. The rest of the trials performed in a similar manner. Paddocks were zoned using Silverfox's biomass imagery analysis. The analysis incorporated biomass data from five seasons of crop performance. This produces a biomass stability map. The biomass stability map identifies zones in the paddock that consistently show poor, average or good performance. This is a useful tool in precision agriculture because it also helps to identify those areas which are unstable in their performance through time.

Target yields for each productivity zone were set using the biomass images and farmer experience.

Soil testing was undertaken in each zone at a depth of 0-10 cm and 10-20 cm. The Nulogic crop nutrition model was used to generate the fertiliser requirements to achieve the target yield in each productivity zone. Target yields were reviewed post emergence due to the late break to the season and low rainfall. Where target yields were lowered the nitrogen requirements were amended to reflect the change in target yields.

The sites were tissue tested in August to evaluate nutrient uptake and to ensure that there were no trace element deficiencies that would influence the trial results. The paddocks were also flown by Air Agronomics to assess crop biomass in response to the nutrition treatments.

Trial designs

The paddocks were sown with the farmer's air seeder so that a seeding run would pass through at least two of the productivity zones but usually through all three. The plots were a full air seeder width wide and yield was measured with a weigh trailer from a minimum plot length of 100m in each zone.

Trial designs were a fully randomised design with three replications. In paddocks where the zone size was not large enough for three replications, two replications were used but two header cuts were taken down the length of each plot to provide four data points for each treatment.

Economic calculations

All financial calculations used 2006 list fertiliser prices. The grain prices were calculated individually for each treatment using the December 2006 AWB golden rewards premiums and discounts. The prices were then converted back to a farm gate price. The calculated returns for each treatment represent gross income minus fertiliser and application cost.

RESULTS

Example 1 – N. and G. Turner, Corrigin 2006

The trial paddock is a sandplain soil type ranging from loamy sand to deep white sand and was located high in the landscape. The paddock grew lupins in 2004 and Calingiri wheat in 2005 and 2006.

The paddock was ungrazed over summer and the stubble was burnt in late autumn prior to sowing. The paddock received *266 mm* of rain during January, February and March. It was a dry winter and the crop received *180 mm* of growing season rainfall.

Soil tests indicated that the site had relatively high phosphate levels and low to ideal reactive iron levels (see Table 1). This meant that the site was unlikely to be responsive to phosphate. The soil nitrogen levels were low and the paddock was wheat on wheat and the site was expected to be responsive to nitrogen. Table 2 shows the target yield for each productivity zone and the recommended rate of nitrogen and phosphate to achieve the target yield.

Table 1. Soil test results

Productivity zone	pH (CaCl)	Organic carbon	Nitrate nitrogen	Ammonium nitrogen	Phosphorus (Colwell)	Reactive iron	Potassium (Colwell)
Poor	4.8	0.46	8	1	21	127	34
Average	5.2	1.76	8	2	33	682	102
Good	5.5	1.37	17	1	23	488	81

Note: Sub soil data not included.

Table 2. Fertiliser recommendation to achieve target yield

Fertiliser treatment	Target yield $t.ha^{-1}$	Phosphate kg/ha	Nitrogen kg/ha	Potassium kg/ha	Cost $/ha
Low	1	5	11	3.5	$27
Medium	2	10	30	6.7	$59
High	3	10	65	6.7	$96

Grain yield and economics

All three productivity zones yielded very well, exceeding target yields by between 0.5-1 $t.ha^{-1}$ (Table 3). The zones performed as expected with the highest yield in the good, average and poor zones 3.65, 2.89 and 2.2 $t.ha^{-1}$ respectively.

The highest yield and returns in the poor productivity zone were achieved with the medium fertiliser input. This is not surprising given the grain yields were at least 1 $t.ha^{-1}$ greater than the target yield.

In the average productivity zone the medium and high input treatments achieved similar yields and grain quality, however the additional costs of the high input treatment meant that it generated lower returns (Figure 1). All three treatments failed to make ASWN quality because of low protein.

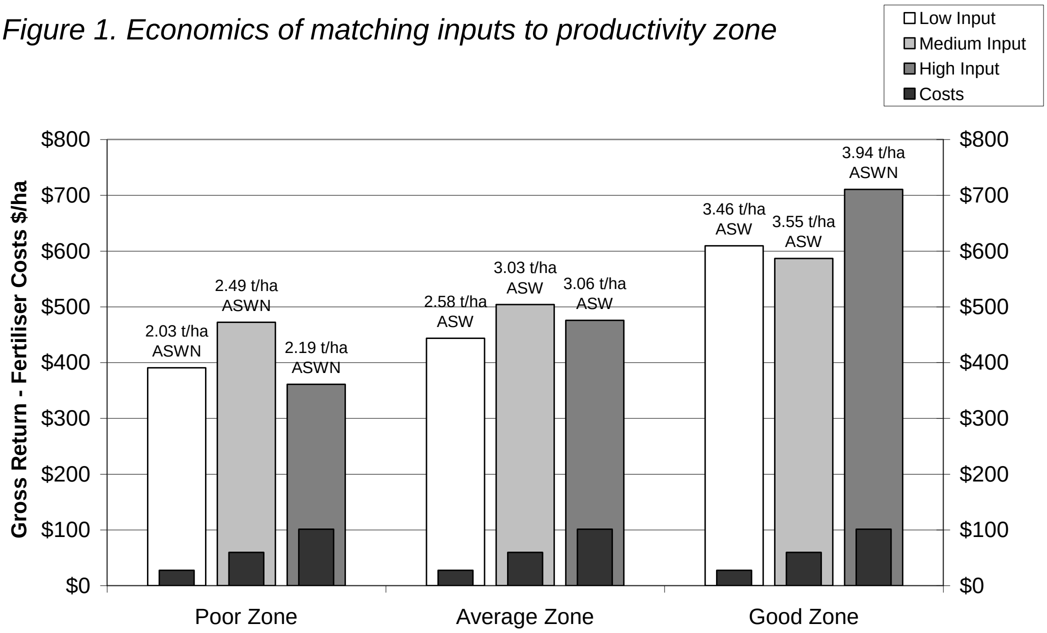
Table 3. Grain yield, quality and price of each fertiliser treatment in poor, average and good productivity zones

	Input	Yield t.ha	Hect wt	Screenings	Protein	Moisture	Pay grade	Price $/T
Poor zone	Low	2.03	82.1	3.2%	9.5%	10.0%	ASWN	$206.0
	Medium	2.49	81.5	3.2%	10.1%	10.0%	ASWN	$213.5
	High	2.19	81.5	3.0%	9.8%	10.0%	ASWN	$211.0
Average zone	Low	2.58	81.5	1.8%	8.9%	10.0%	ASW	$182.5
	Medium	3.03	82.1	1.7%	9.1%	9.9%	ASW	$186.0
	High	3.06	81.6	2.5%	9.4%	9.9%	ASW	$188.5
Good zone	Low	3.46	80	3.2%	9.2%	9.9%	ASW	$184.0
	Medium	3.55	81	2.2%	8.9%	9.9%	ASW	$182.0
	High	3.94	80	3.2%	9.5%	9.8%	ASWN	$206.0

In the good productivity zone the high input treatment achieved the highest yield and returns (Figure 3). The returns were further improved by the high input treatment achieving ASWN where as the medium and low inputs were down graded to ASW because of low protein.

Figure 1 shows the gross return minus fertiliser cost for the low, medium and high inputs in the good, average and poor productivity zones. The black bars represent fertiliser expenditure.

Figure 1. Economics of matching inputs to productivity zone



Zone management vs blanket treatment

To calculate the benefit or cost of managing this paddock according to productivity zone we extrapolated the findings across the whole paddock according to the areas of each zone in the paddock (Table 4). In this example VRT assumes fertiliser rates based on target yield in a zone; good (high), average (medium) and poor (low). The unstable areas of the paddock that fluctuate in performance from year to year were included in the average productivity zone.

This shows that in 2006, there would have been a net benefit of $2,693 in this paddock from matching fertiliser inputs to productivity zones (VRT) compared to applying the medium treatment as a blanket across the whole paddock. While this additional income is a step in the right direction it only represents a 5% increase in returns. Given the financial and time costs involved in setting up a VRT system many farmers would want a substantially greater increase in returns than 5% to warrant adoption.

If the whole paddock was blanketed with the high input treatments there would only be a $740 benefit compared to the medium input in 2006. This is a small additional return given the extra financial risk associated with spending an extra $37/ha on fertiliser. In an average or poor season the high input treatment would be highly unprofitable.

Table 4. Cost or benefit of matching fertiliser inputs to productivity zones

	ha	Low	Medium	High	VRT
Poor	10	$3,910	$4,720	$3,610	$3,910
Average	59	$26,137	$29,736	$28,084	$29,736
Good	31	$18,879	$18,197	$21,700	$21,700
Total		**$48,926**	**$52,653**	**$53,394**	**$55,346**
Difference from medium input		-$3,727	$0	$741	$2,693

Example 2 – P and A Groves Yotting 2006

The paddock was sown to lupins in 2005 and Calingiri wheat in 2006.

The paddock received around *260 mm* of rain during January, February and March. It was a dry winter and short spring and the crop received approximately *180 mm* of growing season rainfall.

Soil tests indicated that the site had high phosphate levels and low to ideal reactive iron levels (see Table 5). This means that the site was unlikely to be very responsive to phosphate. The soil nitrogen levels were not high. This was surprising considering the previous legume crop and mineralisation from summer rain. There may have been some leaching of nitrate from the soil surface.

Table 5. Soil test results

Productivity zone	pH (CaCl)	Organic carbon	Nitrate nitrogen	Ammonium nitrogen	Phosphorus (Colwell)	Reactive iron	Potassium (Colwell)
Poor	4.9	0.74	36	5	31	326	87
Good	4.6	0.4	11	1	27	451	87

Note: Sub soil data not included.

Table 6 shows the target yield for each productivity zone and the recommended rate of nitrogen and phosphate to achieve the target yield. The soil tests indicated that there was no additional phosphate or nitrogen required to achieve the 2T target yield in the low zone.

Table 6. Fertiliser recommendation to achieve target yield

Fertiliser treatment	Target yield $t.ha^{-1}$	Phosphate kg/ha	Nitrogen kg/ha	Cost $/ha
Low	2	0	0	0
Medium	3	5	15	$30
High	4	10	55	$91

Grain yield and economics

The paddock was high yielding, especially given the dry season, however the zones did not perform as predicted. The poor performing zone was the highest yielding with an average yield of 3.06 t/ha (Table 7, Figure 2). It is not clear why this occurred and will require further investigation. The average production zone achieved the lowest yield (2.6 t/ha) and the good zone achieved the median yield (2.87 t.ha).

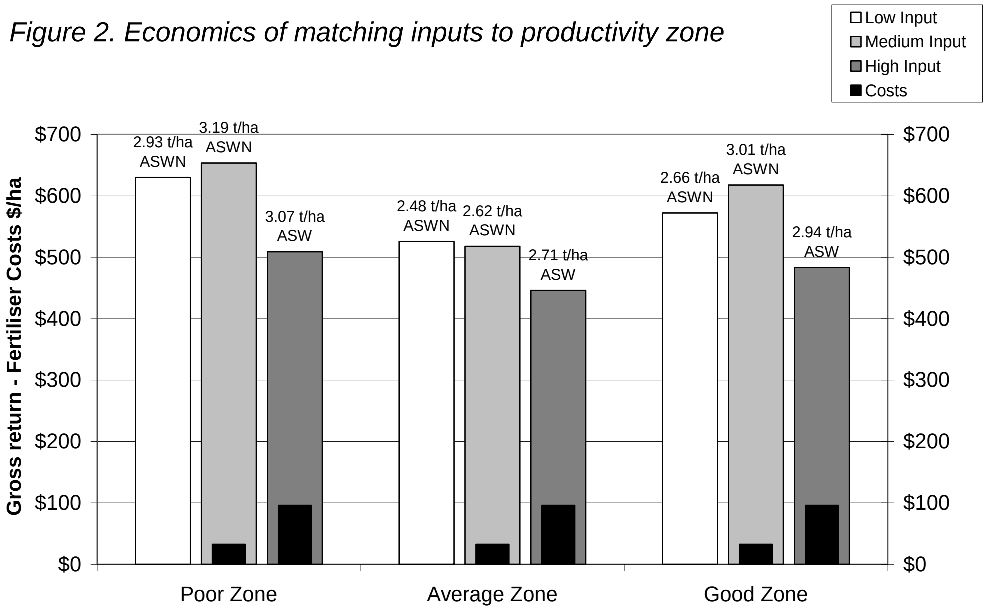
Table 7. Grain yield, quality and price of each fertiliser treatment in poor, average and good productivity zones

	Input	Yield t.ha	Hect wt	Screenings	Protein	Moisture	Pay grade	Price $/t
Poor zone	Low	2.93	80.9	2.4%	10.2%	10.1%	ASWN	$215
	Medium	3.19	81.2	2.1%	10.1%	10.1%	ASWN	$215
	High	3.07	78.0	5.0%	11.9%	10.1%	ASW	$197
Average zone	Low	2.48	80.6	2.7%	11.0%	10.3%	ASWN	$212
	Medium	2.62	80.6	2.9%	11.4%	10.2%	ASWN	$210
	High	2.71	79.0	3.8%	12.2%	10.2%	ASW	$200
Good zone	Low	2.66	81.2	2.4%	10.4%	10.3%	ASWN	$215
	Medium	3.01	81.1	2.1%	10.4%	10.2%	ASWN	$216
	High	2.94	78.1	4.5%	11.8%	10.2%	ASW	$197

Across all zones the medium input treatment achieved the greatest returns except in the average zone where it had equivalent returns to the low input treatment (Figure 2). The low and medium input treatments were able to achieve ASWN quality in all zones, however the high input treatment was discounted to ASW due to high protein. This is not surprising given the high nitrogen supply and sharp finish to the season. If a AH or APW variety had been grown the high input treatments would have received a protein premium rather than a discount and would have increased the returns. The grain yield failed to respond to the additional nitrogen and phosphate applied in the high input treatments and in most cases it suffered a yield penalty as well as grain quality discounts (Table 7).

The low input treatment exceeded the target yield (2 t/ha) in all productivity zones (average yield 2.69 t/ha). This is an exceptional yield to achieve across all 3 zones given there was no applied fertiliser.

Figure 2. Economics of matching inputs to productivity zone



Note: No costs associated with low input as no fertiliser used.

Zone management vs blanket treatment

To calculate the benefit or cost of managing this paddock according to productivity zones we extrapolated the findings across the whole paddock according to the areas of each zone in the paddock (Table 8).

If the paddock was sown using VRT and nutrition was applied according to predicted zone performance there would have been a net loss of $4,494 (8%) in this 105 ha paddock compared to a blanked application of the medium input (Table 8).

The most profitable management option for this paddock would have been a blanket application of medium inputs (fertiliser cost $30/ha). The blanked application of low input treatment (nil fertiliser) generated the next best returns which were only $1,186 less or a 2% reduction in income for nil fertiliser expenditure. This is a surprising result and it is pleasing to know that fertiliser inputs can be reduced (in the short term) without significantly compromising yield where soil nutrition levels are high (N, P,K,S) and reactive iron levels are low.

Results would have been different if there had been a better finish to the season; however the site still achieved above 5 and 10 yr average yield for the district.

Table 8. Cost or benefit of matching fertiliser inputs to productivity zones

	ha	Low	Medium	High	VRT
Poor	10.5	$6,615	$6,857	$5,345	$6,615
Average	63	$33,138	$32,634	$28,098	$32,634
Good	31.5	$18,018	$19,467	$15,215	$15,215
Total	**105**	**$57,771**	**$58,958**	**$48,657**	**$54,464**
Difference from medium		-$1,186	$0	-$10,300	-$4,494

CONCLUSION

The Corrigin Farm Improvement Group (CFIG) has replicated these types of trials more than eight times over four years with similar results and as yet it is unclear if the adoption of VRT and applying fertiliser according to the performance of each productivity zone is likely to generate significant profits when compared to blanket applications of fertiliser in the Corrigin district.

The information gathered in the process does however allow farmers a better understanding of their paddocks and the crops fertiliser requirements to assist in making profitable fertiliser decisions.

In most situations there are trends or small increases in profit that suggest that zone management may have merits, however the seasonal variability in yields (wet, dry, drought, frost) seems to prevent the treatments achieving their full response.

Our previous trials have indicated that zone management to ameliorate soils and correcting potassium deficiencies can be highly profitable.

It would appear logical to use VRT to assist growers to play the season with post emergent applications of nitrogen. The paddock could be sown with blanket nutrition and if there is an above average season addition nitrogen could be applied to the higher yielding zones in the paddock. CFIG will focus on this in the final year of the project.

KEY WORDS

zone management, precision agriculture, VRT, nutrition, profitability

ACKNOWLEDGMENTS

Corrigin Farm Improvement Group and participating farmers, GRDC, James Easton CSBP.

Project No.: CFIG 00002

Paper reviewed by: Michael Odea, Summit Fertilisers

2007 Seasonal outlook

David Stephens and **Michael Meuleners**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

The end of 2006 saw mature El Niño conditions established in the eastern equatorial Pacific. Most ocean-atmosphere models suggest that the Pacific should remain warm in the short-term with a gradually return to neutral conditions by mid-year. The DAFWA analogue year selection system has a more optimistic outlook, suggesting that there is a high chance of La Niña conditions developing by the middle of the year. In terms of wheatbelt rainfall, the analogues suggest that average to above average rainfall is likely over summer and at least average rainfall is likely between May and October. The system skill at predicting growing season rainfall at this time of the year is greatest for the central and southern WA wheatbelt. However, to the northwest of WA there has been a recent trend towards warmer sea surface temperature (SST). If this trend contributes to a stronger SST gradient to the northwest of WA, enhanced northwest cloudband activity could develop and contribute to above average growing season rainfall.

The lesson from 2006 is that trends in SST in this region need to be closely followed. Farmers should also pay attention to the high soil moisture reserves in the south-eastern wheatbelt, disease risk and sowing opportunities in major management decisions. If a La Niña develops there is a reasonable chance grain (fuel) prices could remain high as a La Niña is generally related to drier (colder) conditions in North America, southern South America and parts of southern Europe.

AIMS

This paper aims to review broadscale weather patterns and summarise implications for the 2007 cropping season, i.e. May-October.

METHOD

Possible seasonal scenarios for 2007 are developed using several approaches. These are ocean/atmosphere indicators in the Australian/Pacific region; a review of the main forecast model predictions; and, the outlook from a forecasting system being developed at DAFWA. Pressure indices are combined with SST in the eastern Pacific (Nino-3 region), to form the basis of a 'big picture' monitoring of the ocean/atmosphere pattern. An experimental computer program called ESS (ENSO Sequence System) applies weights to the importance of these indices through the year and uses pattern matching to select the most similar combination of indices from past years, called analogue years. ESS is the first step forward to provide better long-lead rainfall outlooks. Future developments will add local and regional influences to this experimental system to create a new rainfall outlook system. Research undertaken at DAFWA and the University of New South Wales has found that an enhanced SST gradient (cool in south Indian Ocean, warm near Indonesia) is positively related to growing season rainfall in the wheatbelt. Details of the indices used in ESS, and monthly updates of the analogues are available on DAFWA's climate website www.agric.wa.gov.au/climate in the ENSO Technical Summary.

RESULTS

A reduced SST gradient to the northwest of Australia and strong high pressures over Australia were the major contributing factors to drought conditions in 2006. At the end of 2006 mature El Niño conditions were in place. However, this pattern began to breakdown in early 2007 with a strengthening of the North and South Pacific highs and associated trade winds. For the first time in eight months below normal pressures were consistently recorded in the Western Australian region and heavy rains from a decaying cyclone brought flooding to the Esperance region.

The majority of twelve commonly used ENSO forecasting models are indicating a gradual cooling back to neutral conditions in the eastern equatorial Pacific later in the year. It must be noted though that March to June is known as the predictability barrier and predictive skill of the models across these months is at its lowest.

DAFWA climate indices also indicate a similar, but more dramatic cooling in the next six months. In late 2006, the El Niño Prediction Index (EPI) was +0.96, which suggests that neutral to La Niña conditions are possible later in 2007. Based on preliminary data for January, ESS currently selects the three La Niña years: 1964, 1970 and 1995, and the two neutral years 1952 and 1978. The three La Niña years generally had average to above average rainfall (1964 above average, 1995 average to above average, and 1978 average to below average), while the two neutral years had average to below average rainfall in the main growing season. With strengthening trade winds and a rising MeanSOI, a transition to weak La Niña conditions looks most likely in the eastern Pacific by the end of 2007.

In late 2006 and early 2007, the SSTs were warming to the northwest of Australia and cooling to the west of Perth. If the trend to an enhanced SST gradient in the Indian Ocean persists into late autumn this should assist cloud-band activity and moisture inflow from the northwest. The confidence in an average to above average forecast for the growing season will increase if a La Niña develops in the Pacific and an enhanced SST gradient develops in the Indian Ocean SST pattern. If neutral conditions become established in the Pacific the outlook would indicate average to below average rainfall is more likely. A La Niña could also contribute to high grain (fuel) prices as the weather in these years is generally related to drier (colder) conditions in North America, southern South America and parts of southern Europe.

CONCLUSION

Recent trends in broad-scale indicators suggest that El Niño conditions have peaked and have started to break down. DAFWA analogues suggest that there is a high chance of La Niña conditions becoming established by mid-year. Overall, the DAFWA indices suggest that a more optimistic approach to decision-making is recommended in 2006 and confidence in this assessment would be enhanced if a La Niña develops. Summer rains have already begun accumulating soil moisture reserves in the eastern and south-eastern regions of the wheatbelt. Disease risk becomes a more critical factor in seasons with better rainfall. Farmers should respond to stored soil moisture and the timing of opening rains, but also pay close attention to updates of seasonal forecasts and SSTs to the north of Australia.

KEY WORDS

forecasting, rainfall, weather, climate, outlook

ACKNOWLEDGMENTS

Funding for research has been kindly provided by the GRDC (Project DAW00087). Summary of climate models from the following websites: http://www.bom.gov.au/climate/ahead/ENSO-summary.shtml and http://iri.columbia.edu/climate/ENSO/currentinfo/SST_table.html).

Paper reviewed by: Ian Foster and Meredith Fairbanks

Towards building farmer capacity to better manage climate risk

David Beard and **Nicolyn Short**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

The current use of climate risk management (CRM) information and tools by farmers in WA is limited, with most farmers at the initial awareness/interest stage of the adoption pathway. There is however a significant central core of farmers who are embracing this technology. Consultants and advisors are generally at a more advanced level of knowledge and understanding than the majority of the farming community. There is substantial interest by farmers in learning more about CRM. Learning preferences of farmers indicate that a mix of extension methods is appropriate, encompassing web based and hard copy information delivery, training workshops and farmer group activities orientated around in-season management. Ongoing input and support from farmer advisory services is also an essential part of the extension mix.

A two year DAFWA project entitled AcCLIMATise is utilising these results with the objective of building WA farmer and advisor capacity in CRM.

AIMS

Farm earnings are two to three more times sensitive to production than they are to price and climate variability is the biggest factor impacting on production. It follows that farmer's effectiveness in managing climate variability is critical to their profitability and sustainability as farm businesses. Anecdotal evidence has suggested that there may be a relatively low uptake of available CRM information and tools by WA farmers.

In this paper we describe a climate risk needs analysis of WA grain and livestock producers, and people in the supply network providing advisory services. A summary of selected results is presented, with a specific focus on the level of adoption of CRM.

The needs analysis was undertaken as an integral part of AcCLIMATise – 'Building effective climate risk management in the WA grainbelt'. This part of the project was designed to establish current knowledge, attitudes, skills, aspirations and practices (KASAP) of both farmers and their advisors, enabling the design and implementation of a program of activity aimed at building their CRM capacity.

METHOD

The needs analysis included two key elements:

Consultant/advisor survey[1]

A survey of selected 'independent' consultants (13) and agribusiness staff (7) was undertaken using a structured questionnaire comprising 43 questions (by D. Hamilton, DAFWA). The purpose was to establish key decision points for their farmer clients in the cropping year and also to understand how advisors currently access climate risk information, their access preferences, use of decision support tools and understanding of climate risk terminology.

Farmer survey

Implementation of a needs survey, targeted at cropping and livestock farmers across the WA wheatbelt, commenced in March 2006 and was completed in September 2006. A random sample of about 200 wheatbelt farmers, from all agricultural regions, were interviewed on a face to face basis utilising a structured questionnaire comprising 54 questions. The questions probed the current level of farmers KASA in relation to CRM behaviour and practice.

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[1] For brevity the term advisors is used in this paper to describe the survey respondents.

RESULTS

Use of climate information or tools to make decisions

The farmer survey found that many WA farmers do not use historical climate information, do not regularly access climate outlook/forecast information and the large majority do not use climate risk decision support tools. While the advisory services situation is better, over a third of advisors surveyed did not regularly use climate outlooks and forecasts and about two thirds did not use decision support tools (Table 1).

Table 1. Farmers and advisors use of climate information

Category	Farmers	Advisors
Those not accessing historical climatic information.	**54%**	**Not surveyed**
Those not regularly accessing climate outlook/forecast information.	**43%**	**35%**
Those not using climate risk decision support tools.	**94%**	**65%**

Of those farmers that **do** use historical climate information, only 25% stated that they use that information to assist in making farm management decisions, with many of the remainder using the data primarily to identify patterns, trends and even for reassurance, providing a background against which they can then make their decisions.

Table 2 sets out how those farmers using climate forecasts or outlook information (57% of the total), actually use that data. Broadly consistent with their use of historical climate information just over a quarter (and 17% of all farmers surveyed) use the data to assist in making farm management decisions with many of the balance using it as background, reference and for general interest.

Table 2. How farmers use climate forecasts or seasonal outlook information

Assist farm management decisions	Back-ground information/ reference	Interest	Reliability problem	Short term decision making	Do not base management decisions on it	Other
29%	25%	21%	8%	4%	4%	5%

Climate information access

Farmers were asked several questions relating to the way in which they currently access climate information, their preferences in the future and their sources. For comparison, and to distinguish between the two types of information, they were also asked about current sources of weather information. For this purpose weather was defined as referring to climatic conditions which may occur in the ensuing two weeks.

The web emerges as a major means of accessing climate information with 94% of those surveyed having web access, and of those with web access 86% currently using it to access weather information and 50% for climate information. In response to a further question relating to their preferences for receiving/accessing climate information, electronic access was again the most highly preferred followed by print and broadcast media. A similar question of advisors also highlighted electronic access as being very important.

Knowledge of climate risk terminology

Farmers with a good knowledge of climate terminology were in the minority (Table 3). While self assessed knowledge of climate terminology was generally good for advisors, there are some areas where knowledge is poor, e.g. knowledge of terms such as SST, GESS, ENSO. A short test of respondent understanding of some basic climate risk concepts also revealed that six of the 20 advisor respondents were confused about the meaning of a simple climate risk probability statement.

Table 3. Farmers with working or superior knowledge of climate terminology

How would you rate your current knowledge or understanding of the following?	% farmers with working or superior knowledge
Median rainfall	38
El Niño, La Niña, ENSO	26
Analogue year, Sea Surface Temperature (SST), decile	21
Using climate information or climate forecast to adjust areas cropped	19
Seasonal climate forecasting and how it is derived	19

Learning interests and preferences

The large majority (76%) of farmers have an interest in learning more about CRM. Learning preferences are strongly orientated towards access to written information either in hard copy or web based form (Table 4). Over 40% of surveyed farmers indicated a preference for learning in a more structured workshop environment and 36% indicated a preference for an 'action learning' approach, working with a group of other farmers locally to 'play the season'. Advisory services also play an important role with over 25% specifying this option.

Table 4. Farmer learning preferences

Learning preference	%
Reading material	**59**
Access to web based information	**50**
Formal workshops	**41**
Work with group of people locally to play the season	**36**
More information from your advisor	**26**
Other	**1**

CONCLUSION

Farmers and adoption

Several authors have defined the process by which farmers adopt a new idea, practice or innovation, commencing with awareness when a farmer hears about an idea or practice but does not have any detailed information, the interest stage where the farmers sees that the practice might be relevant and seeks more information, the evaluation stage where the farmer weighs up its advantages and disadvantages. At the trial adoption stage the farmer decides to try the innovation. When the trial is finished, the farmer makes a decision to adopt or reject the innovation. Finally following adoption it is important that the innovation be monitored for service and to identify unanticipated problems.

There are several indicators that point to the likelihood that many WA farmers are either at the early awareness/interest stage of the adoption process, or alternatively haven't even reached that stage:

- The low number of surveyed farmers using climate information to minimise losses in bad years or maximise gains in good years.
- The majority not accessing historical climate information for their area.
- Many not using seasonal forecasts or climate outlooks.
- Most farmers not using climate related computer packages to assist in making property management decisions.
- A generally low level of understanding of climate risk terminology.
- The 25% of farmers who believe that seasonal changes are a fact of life and there is nothing that they can do about it in a farm management context.

However on the positive side there are a significant proportion of farmers who are clearly well down the adoption pathway – the 17% of all farmers surveyed who stated that they use climate outlooks and forecast information to assist in making management decisions. Another major positive is the stated desire by the large majority of farmers surveyed to improve their knowledge and understanding of CRM.

While the majority of the advisory profession are leading farmers in terms of their use of climate risk information and tools, there is still a proportion that are not using the technology, particularly in the decision support area. In addition there are some apparent gaps in advisor knowledge and understanding.

Implications for extension

There are significant implications in these results for the mix and content of extension methods needed to improve the adoption of CRM by WA farmers.

Written material, whether in hard copy or web based form is important. It follows that information providers need to think their way very carefully through what information is currently being provided, the format of that information, the outcomes they are expecting to achieve, and most importantly the target audience particularly in relation to their relative position on the adoption continuum. There is a clear need for the provision of some form of structured workshops for the many farmers willing to invest their time in this type of activity and the extension mix must include an action learning component where farmers can learn from each other through the trialling of CRM information and tools.

The central core of farmers who are already actively embracing the technology are clearly pivotal and must be specifically recognised in any program of extension activity, both in terms of their needs and the services they demand, and also in terms of the leadership and example they provide to the rest of the farming community.

Similarly there is a clear need for consultants and advisors to be targeted, but it is important to recognise their generally different positioning on the adoption pathway, and their different learning needs.

In conclusion, the needs analysis has enabled an assessment of the distribution of farmers along the pathway from initial awareness through to final adoption of CRM information and tools being offered by various organisations. It also provides the means for a critical evaluation of the effectiveness of the content and delivery of CRM information and tools, and in the case of the Department of Agriculture and Food, WA, through the AcCLIMATise project is already assisting in establishing some clear directions for current and future service delivery.

KEY WORDS

climate risk, farm management, extension

ACKNOWLEDGMENTS

Thanks to all the farmers and advisors who participated in the surveys, the AcCLIMATise team for their dedication and support, and the various funders of the project including DAFWA.

Paper reviewed by: Meredith Fairbanks, DAFWA

A NAR farmers view of his farming system in 2015

Rob Grima, Department of Agriculture and Food, Western Australia, Geraldton

KEY MESSAGES

- Farmers have a clear view of constraints to their current system, and threats to their profitability.
- Intended management of perceived threats varied enormously between growers.

AIMS

The aim of this survey was to gather information from northern agricultural region (NAR) growers relating to:

1. their current enterprise mix;
2. their perceived threats to their enterprise;
3. intended changes to their enterprise due to these threats.

METHOD

Fifty one growers from across the NAR were surveyed as part of an NLP project titled 'Long term sustainability of medium rainfall sand plain farming systems'. The survey was conducted via local grower groups including Northern Agri Group, Mingenew Irwin Group Yuna Farm Improvement Group and West Mullewa. Data pertaining to their current enterprise mix reflected the 2005 season. The survey attempted to benchmark their knowledge, skills, attitude and practices in relation to their farming system by asking them to:

- define their current enterprise mix;
- quantify their land use patterns from 10 years ago to now, and projections for 10 years time;
- quantify their current stock numbers;
- describe the main threats to their enterprise;
- define limitations to changing their enterprise mix.

RESULTS

Table 1 shows survey respondents on average were approximately 45 years of age. An aging farming population appears to exist with only three respondents being below 30 years of age while almost half were older than 50 years. Farm size averages 4,280 ha, of which 68% is cropped. A further breakdown of land use and its change over time is shown in Table 2.

There is very little fundamental change from 10 years ago to now, and similarly for the next 10 years. However, within some categories there are massive increases comparative to the area of land they currently occupy. On average, respondents suggested total cropped area will reduce slightly in the future.

When broken down it appears canola area is to increase slightly with cereal area reduced significantly. The reduction in crop means an increase in pasture. Within non cropped areas there are massive fluctuations. Perennial species and improved annuals have similarly large increases in land use with a massive drop in volunteer unimproved pasture. This analysis does not show if this improved pasture will be sown fodder cereals or annual legumes.

Stock numbers varied widely between farms. For the farms that carried stock there were on average an equivalent of 5500 DSE during the winter period. This assumes that both sheep and cattle were late pregnant or lactating during this period and at their greatest DSE rating. This sum therefore equates to 4 DSE/ha on average for these farms. However the actual adult animal stock number is 3,280 per farm, and 2.4/ha. Almost all respondents that had stock carried sheep, while only 10 had cattle. Seven had no stock at all. Twenty-three respondents said they employed trading stock at least occasionally, but only 11 of these were on an annual basis.

Respondents were asked to identify threats to their current farming system. The top responses were cost price squeeze, climate variability, weeds/herbicide resistance, and government/policy. The last threat was widely referenced to include all bodies that growers are required to deal with inclusive of all levels of government, grain handling and marketing, and production/business regulation.

Respondents were also asked if there were any impediments to increasing their stock numbers, and what were they. Forty-one answered “yes”, while only five answered “no”. The top ranking constraints to increasing stock numbers were not fitting the farming system, erosion, profit, and climate. To explain the first response, growers currently employing a static self replacing flock with a moderate to high cropping percentage expressed a major conflict between increasing their stock numbers and maintaining their cropping focus. The view suggests carrying capacity is limited by the length of our summer/autumn, as well as a usually distinct lack of feed due to efforts to reduce weeds for the vital cropping phase.

Table 1. Average information from respondents

Average age of farmer (yrs)	45 years
Average rainfall (mm)	367 (170-475)
Average farm size (ha)	4280 (668-18000)
Average % cropped	68
Average DSE carried ∞	5535
Resistant weeds present and no. of respondents	Radish – 27, Ryegrass – 40
Weed that influences management the most	Ryegrass
Average sheep weaning %	93

Table 2. Land use change from 2005 to 2015 prediction

	1995	2005	2015	% change
% Crop	66.2	67.8	65.4	-2.4
Wheat %	40.5	45.9	42.0	-3.9
Lupin %	23.0	18.6	18.8	+0.2
Canola %	2.7	3.2	4.6	+1.4@
Volunteer pasture	17.8	16.2	7.5	-8.7@
Improved pasture ^	10.1	12.5	16.5	+4.0
Perennial	0.1	1.1	5.7	+4.6@

@ Whilst absolute numbers for these areas is small in 2015, they have extremely large changes compared to 2005 figures, e.g. perennial pasture increases by 400%.
* Non crop means land that is not cropped and also not utilised for grazing.
^ Includes both legumes and grazing fodder.
∞ Winter grazing DSE assuming pregnant/lactating. Number excludes non stock farms.

DISCUSSION

The response to this farming system survey covered almost 220,000 ha of agricultural land. In general, respondents seemed to have a clear view on the major threats to their current enterprise and profitability.

Land use changes

Potential changes in land use on average offer very little deviation from the current enterprise mixes observed. However this does not reflect the massive changes on any individual farm. Only three respondents currently with stock believe they will move to a complete cropping regime. Conversely one grower currently at 50% crop believes he will be 100% stock oriented in 10 years time. Respondents also believe there will be a slight overall reduction in cereal crops. The majority of individual growers who carried this view for their farm were from the lower end of the rainfall spectrum, or those who had poorer sandy soils. This suggests parts of their farm are not routinely producing a profitable cereal crop. In almost all cases they believed an increase in improved and/or perennial pastures was going to occupy that land.

The increase in improved and perennial pasture areas by more than 60% over current levels comes at the expense of both cereal crops and volunteer unimproved pasture. Growers have in the past only considered legumes as improved pasture but recent research in the NAR has highlighted grazing cereals and perennials as viable alternatives. Whilst this system has not been fully integrated within our environment and soil types, anecdotal evidence from case studies suggests that it does offer more scope to increase stock numbers than current pasture systems. As discussed, most growers implement a self replacing flock with only a handful of growers serious about trading animals for the

sole purpose of fattening. Under this self replacing system the autumn feed gap governs stock numbers. Perennials offer some relief at this time, and grazing cereals appear to provide feed faster once the season has broken in the NAR reducing the deferred grazing period.

Stock in the system

There was a wide discrepancy between growers stocking rates' with growers appearing to operate well below their potential. At every rainfall zone the highest stocking rate recorded was routinely two to five times greater than the lowest stocking rate despite similar soil types and enterprise mix. These differences may occur for several reasons including a sole cropping focus, labour restrictions or no current desire to maximise their potential grazing. To maintain profitability growers who intend to increase total stock number may need to increase stocking rate per hectare. This can be achieved in a variety of methods including utilising some trading animals, sowing more suitable pastures and attributing time on the pasture/livestock enterprise. To be implemented successfully this all requires investment, and that is the challenge for those growers attempting to lower their cereal plantings.

Threats to current system

Cost price squeeze is a phenomenon known for many decades, and ranked as the biggest threat to current businesses. Many growers to date have attempted to overcome this with increasing their production efficiency. Today many industry representatives believe leading growers have optimised their agronomic efficiency, and little more gains can be made in profit by focussing on this in the future. However many growers are yet to optimise their business efficiency.

Respondents ranked climate variability as their second highest threat. A simplistic analysis may suggest this was due to the pressures of the 2006 season. However a deeper analysis offers an alternative view. Medium rainfall farmers currently have a business system that requires a moderate annual grain tonnage harvest and does not function efficiently with massive fluctuations between years. After fairly static seasons during the '90s yields have fluctuated significantly over the last five years. This has reduced the ability of these businesses to annually service their debt and fixed costs. Climate change or 'drought' may be a major thereat to growers, but it is more likely the fluctuating seasons that has created uncertainty for them and questioned their future. Whether this seasonal fluctuation will persist remains a key concern, and businesses will need to adapt to remain viable. Enterprises wishing to move more into livestock will need to manage these unpredictable seasons. The reliance on static self replacing flocks makes it difficult to manipulate through such changes and other strategies may need to be considered.

Respondents feel weeds and herbicide resistance are a major threat to their current farming system which is little surprise given the historical cropping focus in the NAR. However it was not the top response and paradoxically growers suggest they feel they have learnt from previous mistakes and will be able to overcome potential impediments of this regard. Only 25% of respondents believed numbers of their major weed will increase under their current management, leaving 75% with no such concerns. Continued reliance on trifluralin for ryegrass and 2,4-D for radish may render these herbicides useless. Alternative herbicides and/or cultural control methods will most likely be developed, but it is the cost of these alternatives that will put pressure on the farming system. Prudent agronomic and business management during such times will help ensure sustainability.

Several respondents who indicated they would embark on large changes to their enterprise mix have been selected for further investigation over time. These will provide useful case studies for other growers wanting to investigate alternative opportunities.

KEY WORDS

survey, enterprise mix, threats

ACKNOWLEDGMENTS

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Paper reviewed by: Andrew Blake and Caroline Peek

Biofuels opportunities in Australia

Ingrid Richardson, Food and Agribusiness Research, Rabobank

KEY MESSAGES

This paper will explore the agricultural, social, political and legislative environment that is necessary for the development of the biofuels segment in Australia.

Motivation: What is driving the growing interest in biofuels?

The buzz about biofuels in the media, in political circles and at bowsers around Australia has changed from a murmur to a roar as the price of crude oil has risen steeply through 2005 and 2006. Both ethanol and biodiesel have generated public interest as possible alternative fuel sources to crude oil. In a 2005 report, the federal government's Biofuel Taskforce identified a number of potential benefits that may result from the development of a biofuels sector in Australia, including, amongst others:

- improved urban air quality;
- reduced greenhouse gas emissions;
- assisting the Australian economy – either through import substitution or encouraging the development of a new industry;
- improved energy security;
- regional development.

Source: Report of the Biofuels Taskforce to the Prime Minister, August 2005.

Of all these factors, regional development is identified as the single strongest driver of biofuel development in Australia. In order to encourage this nascent industry, the federal government has set a production target of 350 million litres (ML) of biofuels by 2010. Current production and use levels of biofuels are miniscule, approximately < 1%. If the 350 ML target is met, this will equate to approximately < 2% of Australia's fuel requirements being supplied by biofuels. Compared with other countries around the globe, the level of government support provided to the Australian biofuels sector is restrained – both in terms of assistance to encourage production increases and policy to encourage consumption.

Many overseas countries have adopted policies to encourage the production and/or use of biofuels. Without exception, the development of biofuel production has required government assistance. This assistance has been provided through a range of mechanisms, which include, amongst others, fuel tax reductions or rebates, capital grants for plant development, and mandated use levels. The justification given for adopting these policies is generally in line with the reasons cited in Australia. In some countries it is particularly important to highlight the magnitude of regional and agricultural support provided by biofuel development policies.

Agriculture and biofuels: What is the relationship?

From an investment perspective, the price that biofuels can be produced at and sold for will drive development. In spite of high oil prices, any investment in biofuels in Australia, or overseas, remains heavily exposed to the policy and feedstock supply environment in which the facility is operating. The most commonly discussed feedstocks for ethanol in Australia are grains – chiefly, wheat, sorghum and feed barley – and sugar or molasses. For biodiesel, plants are being developed based on tallow, recycled oils, imported palm oil and canola. Feedstocks account for the largest proportion of total costs of biofuel production. As a rule of thumb, feedstocks account for 60-75% of ethanol production and 80-90% of biodiesel production. Consequently, in analysing the competitiveness of biofuels production, it is essential to discuss the availability and cost of various feedstocks in Australia. Traditionally, Australia has been a solid exporter of many agricultural commodities, including those commodities which could be used as feedstocks. Therefore, theoretically, a domestic biofuels industry has the potential to change this export focus fundamentally. However, agricultural production in Australia can be extremely volatile. This volatility in production does lead to corresponding volatility in prices. A self-sustaining biofuels industry would need to be able to manage the price volatility that is inherent in agricultural production while continuing to sustain production and maintain prices at competitive levels.

Legislation: Where is Australia positioned?

Currently, the sale of biofuels in Australia is essentially fuel-tax free due to a system which the fuel tax of 38.143¢/L is levied and then rebated. This system of tax-and-rebate is applicable until 1 July 2011 after which point, a fuel tax will be incrementally applied. From 2015/16, biofuels will receive a 50% discount on the tax applied for fuels sold in the private vehicle market. This effectively means that biofuels can be sold at a higher price with the 50% tax discount acting as a subsidy. The system of fuel taxes in Australia is complex and is currently being simplified and reformed. In June 2006, the Senate passed further legislation relating to tax reform that will have implications for the biofuels sector in Australia by removing some of the more advantageous measures that were previously in place.

As is the situation with the fuel-tax rebates, there will be continuing market liberalisation and a reduction of support mechanisms for biofuel production after 1 July 2011. From this date the effective import restrictions for fuel ethanol that are currently in place will be removed. This change is likely to result in increased competition for domestic producers as imports from low-cost ethanol producing countries such as Brazil are able to enter Australia.

From a demand-side perspective, the Australian government has chosen to shy away from imposing mandates on the level of biofuel to be used in fuel. This is a policy which has proved particularly popular in the EU, US and Brazil as a means of ensuring a market for biofuels through the creation of compulsory demand. At this juncture, it looks unlikely that the coalition government will support a biofuels inclusion mandate.

Consumer acceptance

Biofuels have an image problem with motorists in Australia. Consumer wariness of ethanol stems from public debate in 2002 and 2003 regarding the safety of ethanol blending rates. The Australian government initially advocated a 20% ethanol blend in 2002; however, car, boat and lawn mower manufacturers disputed this. Following further research, in April 2003, the government released a report that confirmed that blends of 20% were potentially harmful for (unmodified) vehicles. As a result of this public confusion, consumers have been focused on the mechanical safety aspects of ethanol and consequently demand for biofuel blended fuels has been lacklustre. According to some major oil companies, consumers are unlikely to alter their views without a concerted education campaign.

CONCLUSION

The viability of the biofuels industry in Australia will depend upon the relative costs of biofuel production as compared to the price of petroleum-based fuels in the transport fuel market. With oil prices rising and remaining at high levels, the relative prices of biofuels begin to look more attractive. However, the competitiveness of biofuel production will also depend on the availability of cheap and plentiful feedstocks. Several studies suggest that there is a limit on the availability of cheap feedstocks in Australia. The Australian biofuels industry is best described as an infant industry. In many countries around the world biofuels are booming – private investment is strong, government support is solid. In contrast, in Australia, biofuels producers are operating with a greater degree of uncertainty about biofuel support policies and a lower level of support. Consequently, lessons in biofuel industry development from the EU and US do not translate easily to Australian market conditions.

The role of groundwater depth on the hydrological benefits of lucerne and the subsequent recharge values

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KEY MESSAGES

- Lucerne reduced recharge and lowered groundwater levels under the whole hillside. These positive effects occurred despite having very saline groundwater (25,000 mg/L) and high initial groundwater levels (0.5 m and 1.6 m below soil surface).
- The time lag (in months) between rainfall and its impact on groundwater increased as lucerne became effective and groundwater levels dropped.
- The increased time lag resulted in a longer period for roots of lucerne and soil profile to absorb excess rainfall and reduce recharge.
- Lucerne intercepted more of the rainfall as saline watertable dropped.
- The exploration zone of lucerne's roots extended into the depths previously occupied by saline groundwater.
- Rainfall had low impact on groundwater, during the cropping phase that followed the lucerne.
- The maximum hydrological impacts of lucerne was realised during the first four to five years.
- The selected model is offered for carrying similar analysis.

The source of funding: Department of Agriculture and Food, Western Australia, SCRIPT and contribution by the landholder.

AIMS

Abstract

Introduction

An increasing area of cleared land in Western Australia is becoming affected by secondary dryland salinity to some extent. The cause of this salinity is excessive recharge under traditional agriculture, leading to rising groundwater levels. To effectively reduce land and water salinity, a deep-rooted perennial is needed to mimic the temporal and spatial extent and distribution of leaf area that existed prior to clearing.

Lucerne (*Medicago sativa*), which has deep roots, can dry a significant depth of the soil profile and create storage for excess rainfall within its own phase and in subsequent cropping phase. Lucerne fits into the broadacre-grain growing section of Australian farming systems and. It is becoming an integral part of farming practices. Lucerne has advantages in providing beneficial inputs to the crop phase (N fixation, disease suppression, soil structure improvement and weed control). Previous studies have shown that the effectiveness of lucerne as a salinity control measure is dependant on landform and groundwater flow system (Ferdowsian *et al.* 2002).

This paper explores the recharge processes operating during 15 years of crop-lucerne-crop-lucerne periods in a phase farming system. We present data showing lucerne lowered groundwater levels in four different landforms along the whole hillside and under unfavourable conditions. The sites had very saline groundwater (25,000 mg/L) that was close to soil surface (0.5 m and 1.6 m below soil surface), high sodium chloride chemistry and high groundwater levels.

The paper quantifies groundwater level decline changes in during various stages of two lucerne phases lucerne and during cropping growth phases. Itand shows that as groundwater levels drop, lucerne becomes more effective in reducing or preventing recharge. It demonstrates that the beneficial impact of lucerne extend beyond its life span and into cropping phase that follows. Finally, the paper attempts to quantify and separate the effects of rainfall from the effects of lucerne using the HARTT method of hydrograph analysis (Ferdowsian *et al.* 2001).

METHOD

Site selection

The selected site is in the Jerramungup District (Figure 1; 119°11′ E, 33°36′ S) on the south coast of Western Australia. The area has hot summers (December-February) and cold winters (May-September). The average annual rainfall is 400 mm. Sixty per cent of the annual precipitation falls during the cereal growing season (May to October). A 70 ha paddock was selected in 1990. It includes the whole hillside, which is 1200 m long. Groundwater has a local-scale flow system and groundwater levels conform to local topography. This is the typical groundwater flow system in most of the agricultural areas.

The paddock was cleared in 1964 and cropped continuously until 1992 when it was sown to lucerne. Lucerne grew together with annual pastures in winter and on its own in summer between 1992 and 1998. A cereal crop was grown in 1998 and grew together with some surviving lucerne plants. Between 1999 and 2001 lupins and after that cereals, replaced both plant types. Lucerne was replanted in June 2002.

Groundwater monitoring

Two observation bores were drilled in 1988. Bore GB1 was drilled in the mid-slope, approximately 300 m upslope of an expanding saline seep. The second bore (GB2) was located in the lower-slope in the same paddock. Bore GB2 was approximately 30 m upslope of the same saline seep. The depth to groundwater was measured once every 3 months (65 records over 15 years).

Evaluation method and statistical analysis

The HARTT (Hydrograph Analysis Rainfall and Time Trends) method (Ferdowsian *et al.* 2001) was used to supplement the standard empirical analysis of hydrographs. This model is appropriate for cases where there is no major change in land use during the period of analysis. To include the impacts of changes in land use, we define two types of dummy variables. The use of dummy variables is explained by Ferdowsian and Pannell (2001).

RESULTS AND DISCUSSION

Table 1, 2 and 3 show the statistical regression results, including all the terms, which had significant impact on groundwater levels. The selected models fitted the data extremely well, explaining > 95 % of variation in groundwater levels (Table 1). All selected variables were statistically significant. The fitted graphs followed the actual data very well (Figure 1 for GB1 and GB2).

Table 1. Statistical analysis results after excluding the non-significant terms

Note: The two R^2 figures show very high explanatory power of the model. Intercept is approximately equal to the initial depth to groundwater.

Parameters	GB1; Mid-slope	GB2; Lower-slope
R^2	0.99	0.95
Intercept	-2.54	-0.660

Underlying trend in groundwater levels and effects of treatments

During the first cropping phase (prior to growing lucerne, May 1990-July 1992), groundwater levels under the mid-slope were rising (GB1; Table 2). During the same period, there was no statistically significant rise in groundwater levels in GB2. This is not surprising since with such a shallow

watertable (0.25 to 0.7 m below soil surface), there would be significant discharge at the site (or nearby areas) to offset any ongoing recharge.

Lucerne was shown to reduce groundwater levels. Its impact changed with the stages of its growth. The highest rate of groundwater level drop was associated with the second stage in its growth period (Table 2). The estimated net effect of lucerne during the three stages of the first phase was up to 2.7 m reduction in groundwater levels over 80 months. The 2.7 m reduction was in addition to 0.7 m reduction due to lower than average rainfall.

Table 2. Trends (m/month) in groundwater levels during various stages of lucerne phases as well as during cropping phases. Note: The negative figures indicate the falling trends in groundwater levels while the positive figures show the rising trends

Parameters	GB1; Mid-slope	GB2; Lower-slope
First cropping phase (pre-lucerne period; 31 months)	0.010	n/s
First stage in phase-1 lucerne (30 months)	-0.035	-0.060
Second stage in phase-1 lucerne (23 month)	-0.057	-0.040
Third stage in phase-1 lucerne (25 months)	-0.012	n/s
Second cropping phase (after lucerne; 28 months)	0.020	0.042
Second lucerne phase (33 months)	-0.027	-0.049

N/S = Not significant; they were removed from the model.

Groundwater levels rose after lucerne and during the second cropping phase. The rate of rise was 0.02 m/month in mid-slope and 0.04 m/month in the lower-slope. The trend in groundwater levels, during 34 months of the second lucerne phase was a drop of only 0.86 m in mid-slope and twice that in the lower-slope.

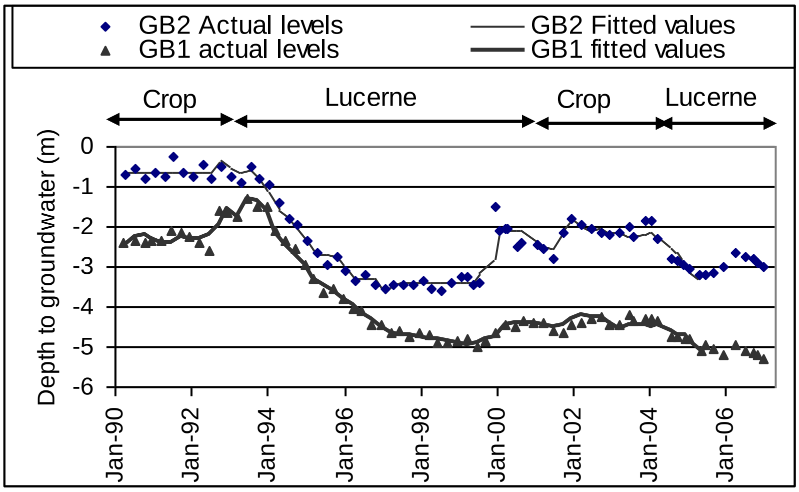

Figure 1. Groundwater level changes in relation to treatment in GB1 and GB2.

Effects of rainfall on groundwater levels

During the first cropping phase (prior to growing lucerne), rainfall had significant impact on groundwater levels in GB1 (mid-slope; Table 3), where the levels were > 1.6 m below the soil surface. During the same cropping phase, excessive rainfall had very little or no impact on groundwater level in GB2 (Table 3). This is because the profile was full of water and there was little or no storage capacity to hold more water.

The situation changed as lucerne lowered watertable (Table 3):

- At first (during the first stage of phase-1 lucerne), the impact of rainfall increased as sufficient storage capacity was developed.
- As lucerne matured the impact of rainfall on groundwater was reduced.
- Very little or no portion of rainfall managed to bypass the root zone of matured lucerne and have an impact on groundwater levels.

Three incidences of > 80 mm/month rainfall occurred during the last stages of lucerne in phase-1. Despite these high rainfalls, no significant impacts on groundwater levels were observed. This indicates that very little or no recharge occurred in these stages.

Table 3. Impact of rainfall (m/mm) on groundwater levels

Parameters	GB1; Mid-slope	GB2; Lower-slope
First cropping phase (pre-lucerne period; 31 months)	**0.002**	**n/s**
First stage in phase-1 lucerne (30 months)	**0.004**	**0.002**
Second stage in phase-1 lucerne (23 month)	**n/s**	**0.003**
Third stage in phase-1 lucerne (25 months)	**n/s**	**n/s**
Second cropping phase (after lucerne; 28 months)	**0.0015**	**0.0045**
Second lucerne phase (33 months)	**0.002**	**0.004**

N/S = Not significant; they were removed from the model.

The time lag (in months) between rainfall and its impact on groundwater

At the mid-slope position (GB1), the lengths of the time lags increased from one month to three months, as lucerne became effective and groundwater levels dropped from 1.6 m to 5 m below soil surface. The increased time lag implies that there will be longer periods for lucerne roots and for the dry soil profile to absorb moisture and reduce recharge. In the lower-slope (GB2), the lengths of the time lag between rainfall and its impact on groundwater remain the same (one month). This was despite groundwater levels dropping from 0.5 m to 3 m.

CONCLUSION

- The selected model fitted the data extremely well, explaining > 95% of variation in groundwater levels. All selected variables were statistically significant.
- In most of the landscape, the time lag (in months) between rainfall and its impact on groundwater increased from one month to three months, as lucerne became effective and groundwater levels dropped.
- Lucerne reduced recharge and lowered groundwater levels in the whole toposequence (from top of the hill to lower-slopes).
- The hydrological impacts of lucerne was realised during the first four to five years.
- Lucerne intercepted more of the rainfall as saline watertable dropped.
- The exploration zone of lucerne's roots extended into the depths previously occupied by saline groundwater.
- The estimated net effect of lucerne during the first and second phases was up 0.034 m per month reduction in groundwater levels.
- These positive effects occurred despite having very saline groundwater (25,000 mg/L) and high initial groundwater levels (0.5 m and 1.6 m below soil surface).
- Little recharge occurred during the cropping phase that followed the lucerne.

KEY WORDS

lucerne, recharge, groundwater, salinity

Paper reviewed by: Dr Sally Peltzer, Department of Agriculture and Food, Western Australia, Albany

Subsoil constraints to crop production in the high rainfall zone of Western Australia

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KEY MESSAGES

When deciding where to crop, farmers require an understanding of subsoil physical and chemical limitations including those induced by farming practices, and of the distribution of these limitations.

To date, most research in the high rainfall zone (HRZ) has focused on management strategies; sowing date, cultivars, pest and disease control and nutrition, rather than inherent and induced soil limitations.

Yield modelling based on observed soil types highlights that insufficient soil moisture storage capacity is an important limitation to achieving high yields despite higher seasonal rainfall.

AIMS

This work aimed to clarify the nature, extent and distribution of subsoil constraints to cropping in the HRZ of WA, in order to direct future research towards those constraints.

METHOD

Figure 1. Location of the HRZ shires in WA.

Thirty soil pits were dug with a backhoe to a maximum depth of 1.6 m depending on the presence of impenetrable layers. Site coordinates were recorded using a GPS and comprehensive soil profile descriptions were made in the field using the terminology of the Australian Soil and Land Survey Handbook (McDonald *et al.* 1990). Plant Available Water Capacity (PAWC) was estimated using the formula provided in the Soil Guide (Moore 2004). Subsoil compaction and naturally occurring strong subsoils were assessed by visual appearance and soil strength. Each soil was classified according to 'Soil Groups of Western Australia' (Schoknecht 2005) and the soils were cross referenced against the DAFWA soils maps to confirm their consistency with the soil mapping. The Van Gool and Vernon (2005) model, which is based on the French and Schultz equation with yield adjustments based on land capability mapping and temperature, was used to show the distribution of yield potential.

Four of the 30 soils were selected for modelling wheat yield potential using the Agricultural Production Systems Simulator (APSIM) to assess the effects of low PAWC in a high rainfall environment. The model was run with 105 seasonal climate records for each of the four soils at Williams, Kojonup, Boyup Brook and Frankland. Simulated PAWC for each soil reflected field estimates as determined by the capacity of the soil to store water and crop observed rooting depth.

RESULTS

The 30 sampled soil profiles represent a third of the HRZ area (Table 1). The most notable omission from the sampling was the grey deep sandy duplex (17.5%) which is similar to the yellow/brown deep sandy duplex soil. Most of the remaining soils individually represent less than 2% of the HRZ.

Table 1. Soil groups observed in the HRZ

Soil	Extent
Duplex sandy gravel	**9.7%**
Yellow/Brown deep sandy duplex **(Grey deep sandy duplex)**	**5.3%** **(17.5%)**
Loamy gravel	**5.1%**
Deep sandy gravel	**4.0%**
Shallow gravel	**3.3%**
Yellow/Brown shallow sandy duplex	**2.1%**
Red shallow loamy duplex	**1.5%**
Yellow/Brown shallow loamy duplex	**1.4%**
Red shallow sandy duplex	**0.8%**

Eight subsoil constraints plus one surface constraint were identified. All of these manifest themselves by the soil not holding sufficient moisture because of the coarse or gravelly texture, or a subsoil constraint denying root access to moisture at depth, or both.

1. Coarse texture

Despite their depth, the water holding capacity of the coarse sands and gravels is low, consequently the frequency of rainfall events and distribution of moisture within the profile has a great impact on yield. In the early part of the season, root elongation may not keep up with drainage and some of the moisture and nutrients may be lost below the root zone. A third of the soils were sandy soils that typically contain gravel and have poor potassium and nitrogen holding capacity.

2. Shallow depth

'Shallow' refers to soils with a depth of < 80 cm, or a duplex soil with < 30 cm of light textured topsoil over a heavier textured, poorly structured subsoil (duplex soils). Many duplex soils have developed on gneiss or granite creating a massive clayey material so that subsoils have little or no structural development. The subsoils are poorly explored by roots so that these profiles are effectively truncated.

3. Coarse textures and shallow depths

In the HRZ, duplex soils with upper soil horizons of very coarse sand and ironstone (laterite) gravels are very common. These soils present two constraints to plant growth – a coarse upper layer that holds very little water and a dense lower layer that crop roots and water cannot readily penetrate.

4. Low nutrient holding capacity

This soil problem is common in sandy textured soils. Nitrogen and potassium leaching, combined with a low PAWC, severely limit the potential of these soils. A critical question is whether root elongation keeps pace with nutrient leaching.

5. *Poor structure*

Poor subsoil structure impedes root growth and water infiltration and may result in perched soil water or waterlogging. Over half of the soils exhibited poor subsoil structure, although often not until 80 cm or deeper in the profile where it has less potential to reduce crop performance. Poor subsoil structure at shallow depth was generally associated with the sandy or loamy duplex soils while deeper examples were generally in saprolite or ferricrete.

6. *Waterlogging*

Impermeable subsoil clay layers prevent through-drainage, allowing waterlogged and anaerobic conditions to develop within what would otherwise be the root zone. This condition was identified by gleyed (blue/grey) colours in the clay layer and by the paler and greyer colours in the sandy layer above the clay.

7. *Compaction*

Subsoil compaction was only observed at one site, a yellow/brown shallow loamy duplex. This apparent absence of subsoil compaction may be because the soils that are most susceptible, the sandy earths, represent only 1.7% of HRZ soils. It may also be that cropping is relatively new to the region and smaller machinery is used in comparison with the wheatbelt.

8. *Low pH*

Contrary to expectations, a low subsoil pH < 4.8 ($CaCl_2$) was only observed in four of the thirty profiles. With the introduction of cropping or increased cropping frequency this may increase with an accompanying increase in lime requirement. Soils with a low pH < 4.8 require lime applications now to prevent future yield losses caused by ongoing subsurface soil acidification.

9. *Water repellence*

Water repellence was widespread due to the very coarse texture of many surface soils and the long history of pasture allowing the accumulation of organic matter. While not strictly a subsoil problem, it becomes a subsoil problem because of uneven wetting of the soil profile at depth. Surprisingly, water repellence may persist through winter contributing to the inefficient use of rainfall by crops.

Overall low PAWC was the most common constraint. Two thirds of the soils including the duplex sandy gravels, shallow gravels, deep sandy gravels and duplex soils had low (< 70 mm) or very low (< 35 mm) estimated PAWC.

The APSIM simulation modelling showed that despite the longer growing seasons of the HRZ, there was still a marked dependence of yield on soil moisture holding capacity (Table 2). There appear to be sufficient dry periods to affect yields, particularly on the low PAWC soils. Simulated yields only reflect those constraints that may limit PAWC, other constraints such as acidity and waterlogging were not included in the simulation, though they can act through their effect on rooting depth and, therefore, PAWC. Observed crop rooting depths were 50 cm for the yellow/brown shallow loamy duplex, 70 cm for the duplex sandy gravel and 140 cm for the loamy gravel and yellow/brown deep sandy duplex.

Table 2. PAWC impact on simulated decile 5 wheat yields for 105 years (1900-2005) of climate data using APSIM at four sites in the HRZ data

Soil type	PAWC (mm)	Simulated decile five wheat yield (t/ha)			
		Williams Apr./Oct. rainfall = 458 mm	Kojonup Apr./Oct. rainfall = 447 mm	Boyup Brook Apr./Oct. rainfall = 569 mm	Frankland Apr./Oct. rainfall = 579 mm
Duplex sandy gravel	15	1.7	1.9	2.2	3.8
Yellow/ brown deep sandy duplex	42	2.6	2.8	3.2	5.2
Loamy gravel	61	3.0	3.2	4.0	7.0
Yellow /brown shallow loamy duplex	145	5.0	6.2	7.5	10.0

CONCLUSION

Farmers require knowledge of the soils on their farms so that they can decide which areas to crop. It is often necessary to dig soil pits to identify subsoil constraints. Methods are required for quickly identifying or predicting subsoil constraints over entire farms or catchments. Extension of the DAFWA soil maps and field days that focus on the suitability and management of soils for cropping is recommended.

Modelling results show that, despite relatively high rainfall, cropping in the HRZ needs to be targeted towards those soils which have high PAWC or to those which will have a high PAWC once the subsoil constraint has been removed. Split or post seeding applications of N are required to overcome high N leaching in the deep coarse textured soils.

Further modelling and research is required to evaluate amelioration of inherent and induced subsoil soil constraints including soil acidity, subsurface waterlogging, subsoil compaction, poor subsoil structure, nutrient leaching and effects of water repellence. Calibration of crop yield modelling for the HRZ requires field trials on dominant soil types and the modelling could also be improved with better methods for determining rainfall runoff.

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KEY WORDS

soil types, subsoil constraints, PAWC

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Prospects for lucerne in the WA wheatbelt

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KEY MESSAGES

- There are significant opportunities for greater areas to be sown to lucerne in the WA wheatbelt due to recovery of commodity prices for livestock products, the need for more profitable enterprises with declining terms of trade for grain production, and more options to deal with herbicide-resistant weeds
- Regions with the best prospects for high percentages of the farm under lucerne are those in medium to high rainfall agro-ecological zones, with a high percentage of suitable soils and with only minor technical constraints.
- Producers who will benefit most from the greater adoption of lucerne are those who adapt their existing livestock systems to lucerne's specific grazing management requirements. Even in low rainfall regions lucerne provides an opportunity to reduce the level of risk associated with annual cropping systems.

AIMS

Lucerne is currently our most promising perennial pasture for the wheatbelt. However, its widespread use will depend on its profitable use in farming systems, suitability to soils and climate, as well as its ability to control recharge to groundwater. The CRC for Plant-Base Management for Dryland Salinity has recently reviewed the prospects for widespread use of lucerne in the wheatbelt (*Robertson, M. 2006. Lucerne prospects: Drivers for widespread adoption of lucerne for profit and salinity management*). In this paper we provide an extract of that publication and define the scope for widespread profitable use of lucerne in WA mixed faming systems.

Lucerne in cropping rotations

Lucerne has been widely grown as a permanent pasture for many years, but by far its largest potential for expansion is its integration within a cropping rotation. Successful use of lucerne in an integrated cropping system requires producers to: 1. maximise the use and benefits of the lucerne pasture phase to livestock enterprises; 2. optimise the positive benefits flowing from the pasture phase to subsequent crops (for example, nitrogen fixation, weed and disease management); 3. manage the potential costs and impacts of lucerne on following crops (for example, effective establishment and removal strategies and competition for water); and 4. manage additional workload and lifestyle preferences.

The benefits of lucerne-based pastures compared to annual-based pastures in cropping systems are summarised in Table 1.

Key factors that will determine whether lucerne can be successfully employed on a given farm, and therefore whether the benefits listed in Table 1 can be captured, will depend upon: (1) suitability of lucerne to the local climate and soils; (2) farm enterprise mix and livestock system; (3) salinity risk and ability to control groundwater rise; and (4) impacts on the cropping system.

Table 1. Impact of lucerne when integrated into a cropping system compared to an annual-based system

Impact	Crops growing in phase with annual pastures	Crops growing in phase with lucerne
Cropping operations		
Pasture termination	Not required	Required
In-crop weed control	More herbicide-resistant grass weeds	Fewer herbicide-resistant grass weeds
Grain yield	Soil water supply less likely to limit grain yields	Soil water supply more likely to limit first year crop yields
Summer weeds	More opportunity for summer weed invasion	Less opportunity for summer weed invasion
Pasture establishment	Less costly	More costly
Livestock operations		
Stocking rates	Lower, especially in drier environments	Higher, especially in drier environments
Grazing management	Set-stocking	Rotational with infrastructure costs (fencing/watering)
Ewe joining dates	Early to mid-summer	Late summer to mid-autumn
Lambing dates	Autumn/winter	Winter/spring
Weaning dates	Early spring/mid-spring	Late spring/early summer
Shearing dates	Spring	Summer
Supplementary feeding	More summer/autumn feeding but greater winter feed supply	Less summer/autumn feeding but less winter feed supply
Farm economics		
Livestock returns	Lower supply of lambs to over-supplied markets; grass seed penalties	Increased supply of late season lambs
Cropping returns	Slightly higher – less impact on subsequent crops	Slightly lower in first year after lucerne if dry conditions

Areas suitable for lucerne production

Keeping in mind the optimum conditions for lucerne (Table 2), its suitability has been assessed for the WA wheatbelt. For all the agricultural land in WA the area considered moderately to highly suitable for lucerne production is about 7.8 Mha, about 42% of the total. The current area under lucerne (2002 estimate) in WA is only 171,000 ha which suggests a significant potential for expansion, varying between regions. Most lucerne is currently grown in the Central Wheatbelt, South West and South Coast (see Figure 1), although many producers also grow lucerne successfully in lower rainfall areas. GRDC Zones not considered here (the WA Northern and WA Eastern) are less suitable, mostly due to low rainfall, but lucerne could play a niche role in the valley floors.

Table 2. Suitability criteria for lucerne

Criterion	High	Moderate	Low	Very low
Soil pH_{Ca}	>5.5	5.0-5.5	4.5-5.0	<4.5
Rooting depth (mm)	>800	500-800	300-500	<300
Soil water storage (mm)	>70	35-70	–	<35
Rainfall (mm/yr)	>450	350-450	250-350	<250

Maximising profitability of lucerne

Producers are most likely to adopt lucerne if it is profitable. We have assessed the profitability of lucerne for selected regions using whole farm models, such as MIDAS, configured to represent a typical farm within a region, with its soils, crop and pasture sequences, livestock production, costs, prices and availability of labour and capital. While results are representative of the various regions with typical farm system configurations, there will naturally be variations from farm-to-farm within each region. The whole-farm economic analyses highlight some key messages:

- **Benefits to incorporation of lucerne into the farming system can be sizable** (see Table 3)**.** Changes in livestock enterprise from wool to prime lambs deliver the full economic benefit from increased lucerne (Figure 2). Changes to lambing date, a higher lambing percentage and the use of crossbreds are all characteristic of more profitable systems. The demand for supplementary feeding varies, in some cases increasing, while in others it decreases.

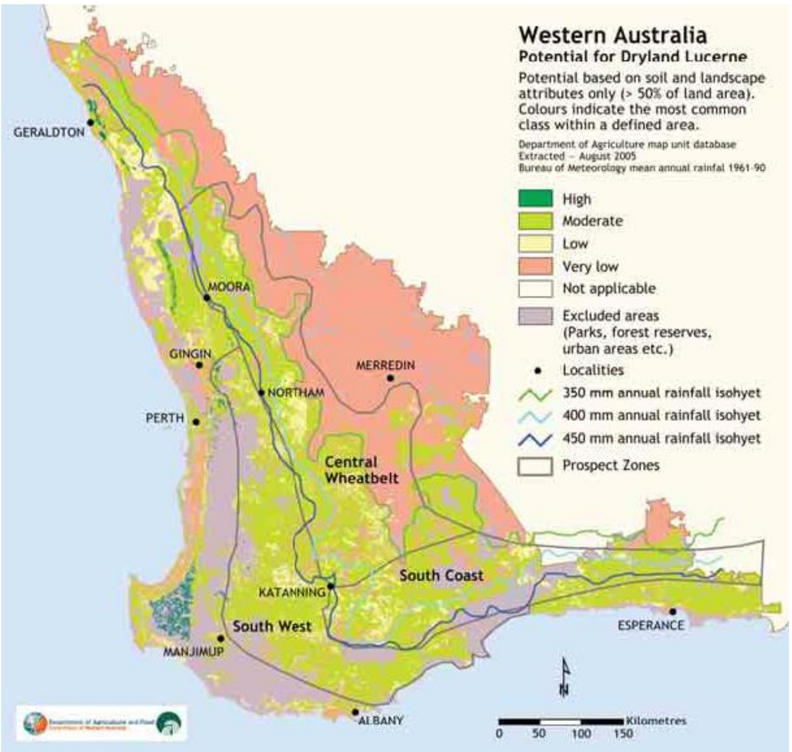

Figure 1. Potential for dryland lucerne in WA.

- **For a given farming system there is an optimum area of lucerne that maximises whole-farm profit.** The size of this area varies from region-to-region, due to differences in rainfall, climate and soils (Figure 2). It also varies from farm-to-farm depending on the soil type mix, animal enterprise, occurrence of herbicide-resistant weeds and producer expertise. Beyond this optimum area, profit decreases with each additional hectare of lucerne, because the opportunity cost of not growing something else exceeds the benefit from the additional hectare. So, while some lucerne is good, more is not necessarily better. In some cases the decrease in profit is small; meaning lucerne beyond the optimum might be grown if improved leakage control is a priority.

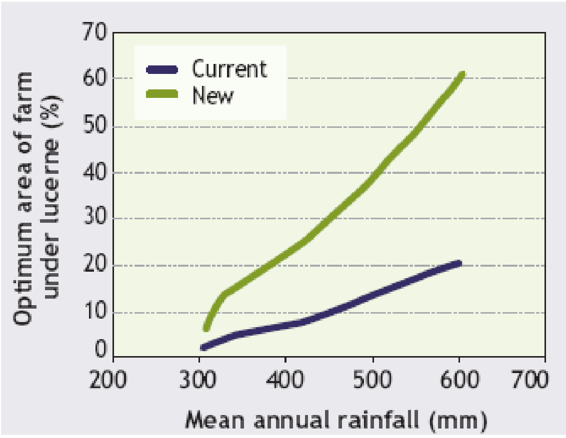

Figure 2. Optimum lucerne area for a mixed crop and livestock enterprise increases with rainfall. Modelled 'current' system (self replacing ewe flock) compared with 'new' system (prime lamb production) and grass mixtures where applicable.

- **Small changes in lucerne production or profitability per hectare will have minimal impact on the optimum area.** This is because the fixed costs of lucerne production are closely related to the area planted, and generally much greater than any variation in profit due to changes in productivity.

- **In marginal areas the slight increase in farm profit from lucerne might not warrant adoption.** In some cases management considerations and the costs of transition involving reduced return on crop infrastructure and new investment in livestock infrastructure are too great an impediment. But if lucerne can ameliorate soils previously unsuitable for cropping (for example, due to waterlogging or salinity) then increases in profit from improved crop production will justify greater areas of lucerne. Some producers believe that while lucerne may not improve overall profitability it forms a risk management tool in low rainfall environments.

Impact on salinity

As a summer-active perennial, lucerne can significantly reduce groundwater recharge with a root system that grows deeper into the soil, creating a zone of dry soil beyond the penetration depth of annuals during a single growing season. The extent to which lucerne can create a dry soil buffer varies, but in general the buffer increases with lucerne age and is greater for heavier-textured soils. In some landscapes, lucerne can impact on hillside seeps within the region as groundwater flow systems are often local, meaning salinity is within the control of producers with small-scale seeps. But until lucerne areas approach 50% of the landscape, or are better targeted in areas of risk, their impact in valleys is likely to be localised and the benefit restricted to delaying the impact of salinity.

Table 3. Summary of drivers influencing the adoption of lucerne in three WA wheatbelt regions

	Central Wheatbelt WA	South West WA	South Coast WA
Area of agricultural land (Mha)	5.2	4.0	3.4
Mean annual rainfall (mm)	350-450	450-650	325-450
Area moderate-highly suitable for lucerne on basis of soils and climate (%)	48	65	63
Expected increase in salt-affected land	High	High	High
Potential impact of lucerne on local groundwater levels if widely grown	Low	Medium	High
Economically-optimum area of lucerne on typical mixed farms[1] (%)	4-30	15-30	18-25
Increase in whole-farm profitability from 0 to optimum lucerne area	$28,000 (prime lambs) $6,000 (prime lambs and wool)	$95,000 (prime lambs) $65,000 (prime lambs and wool) $20,000 (wool)	$50,000 (prime lambs) $35,000 (prime lambs) and wool) $20,000 (wool)
Major managerial constraints to greater adoption of lucerne	Poor profitability compared with cropping, high establishment costs or lack of confidence	Lack of confidence and knowledge in integrating lucerne into cropping systems	Poor profitability compared with cropping, unreliable summer production
Overall prospects for widespread adoption of lucerne	✔	✔✔	✔✔✔

[1] range depends on the type of livestock enterprise employed [2] N/a – information not available

Regional constraints and opportunities

Across the WA wheatbelt the need and potential for widespread lucerne adoption varies markedly. Regions within the State differ in terms of the profitability of lucerne on mixed farms, the size of the salinity threat, the impact on rising groundwater of reduced recharge, and the obstacles to integrating lucerne into existing farming systems (Table 3). In all regions there is significant potential for salinity to spread. On typical mixed farms of the region, lucerne could be grown across 5–30% of farm area depending upon the livestock enterprises. Adoption at these levels requires confidence and knowledge regarding the integration of lucerne into cropping systems, increased livestock numbers and improved profitability compared with cropping. Using lucerne to help manage herbicide-resistant weeds, along with the reduced risk in frost-prone landscapes such as valley floors, are key future drivers for adoption in all regions.

KEY WORDS

lucerne, livestock, salinity, economics, grazing management

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Paper reviewed by: Lindsay Bell

Nitrous oxide emissions from a cropped soil in the Western Australian grainbelt

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KEY MESSAGES

Nitrous oxide (N_2O) 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. There are no reliable data on the contribution of the Western Australian grain production to N_2O emissions.

The Department of Agriculture and Food, WA, in collaboration with The University of Western Australia, commenced measuring N_2O 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.

Daily emissions ranged from -1.8–7.3 g N_2O-N ha^{-1} day^{-1}, culminating in an annual loss of 0.11 and 0.09 kg N_2O-N ha^{-1} from the +N (100 kg N ha^{-1} yr^{-1}) and 0N treatment (0 kg N ha^{-1} yr^{-1}), respectively. Annual emissions represented 0.02% of the N fertiliser applied. Daily losses were not affected by the application of N fertiliser, and were greatest following summer rainfall events.

Preliminary results indicate N_2O emissions from cropped soils in the Western Australian grainbelt will be low under typical N application rates and frequency of applications.

INTRODUCTION

Nitrous oxide emissions from the earth's surface to the surrounding atmosphere are increasing (Bouwman, 1990). Although N_2O 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, N_2O is stable for about 120 years and contributes to the greenhouse effect; while in the stratosphere, N_2O 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% of the increase in N_2O emissions to the atmosphere, with the increase linked to a global increase in N fertiliser use (Bouwman, 1990). Soil microbial activity is the main source of N_2O from agricultural soils (Firestone and Davidson, 1989)). Nitrifying microbes convert soil ammonium to nitrate under aerobic conditions. Likewise, denitrifiers reduce nitrogen oxides (e.g. nitrate) to N_2, when there is sufficient nitrate and available carbon, generally in anaerobic microsites in the soil. In both cases, incomplete conversion results in the formation of N_2O.

Much of our understanding of agricultural N_2O 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. Extrapolating findings from overseas studies to the south-western Australian grainbelt is not appropriate due to differences in N fertiliser management (type, rate and application method), soils and climates, i.e. factors demonstrated to influence agricultural emissions (Stehfest and Bouwman, 2006). Consequently, the aim of the following study was to acquire a unique, long-term (> 1 year) data set of N_2O emissions from a rain-fed, cropped soil in a semi arid region and to investigate the relationship between N_2O emissions and other soil and environmental parameters. In the following paper we report N_2O emissions measured from May 2005 to May 2006 from a site cropped to wheat in the central grainbelt of Western Australia.

METHOD

Soil and study site

Nitrous oxide emissions 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 and forms part of a cereal-lupin rotation. The surface soil (0–100 mm) has a pH of 5.9 (1:5 soil : 0.01 M $CaCl_2$ extract), electrical conductivity of 139 µS cm^{-1} (1:5 soil : water extract), cation exchange capacity of 3.3 cmol (+) kg dry $soil^{-1}$, C content of 9.81 mg kg^{-1}, N content of 0.85 mg kg^{-1} and a bulk density of 1.42 g cm^{-3}. The area experiences a Mediterranean-type climate, with an annual rainfall of 368 mm, and mean daily maximum air temperature of 34.1°C (January), and mean daily minimum air temperature of 6.0°C (August).

Experimental design and approach

A completely randomised plot design with three replicates was employed at the site, with plots measuring 141 m^2. The treatments consisted of either plus N fertiliser (+N) or no N fertiliser (i.e. control, 0Nl). In the +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 six weeks after seeding). The N application rate was based on site history (rotation and yield) and soil chemical composition. In addition, both N treatments received 15 kg P ha^{-1} at seeding as 'Superphosphate CuZnMo'®.

Soil, plant and environmental measurements

Nitrous oxide emission measurements commenced on the 19 May 2005, with wheat (cv. Carnamah) sown on the 1 June 2005. Emissions were measured in each treatment plot up to six times per day using soil chambers (one per plot) connected to a fully automated system that enabled simultaneous determination of N_2O and CO_2 emissions. Briefly, the system consisted of a gas chromatograph fitted with a ^{63}Ni electron capture detector for N_2O analysis, an infra-red analyses for CO_2 analysis, an automated sampling unit for collecting and distributing gas samples, and six chambers (one per treatment plot). Chambers (500 mm x 500 mm, varying height depending on crop height) were placed on metal bases inserted into the ground (100 mm), and fitted with a top that could be automatically opened and closed. Four bases were located in each treatment plot to enable the chambers to be moved to a new position every week so as to minimise the effect of chambers on soil properties and plant growth. 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 N_2O emissions, a number of soil, plant and climatic and variables were be measured to assist in the explanation of N_2O emissions. These included soil mineral N (nitrate + ammonium), soil water-filled pore space (WFPS), rainfall and plant growth parameters (not presented). Carbon dioxide and methane concentrations in the chambers were also measured but are not reported here.

Data analysis

All data were statistically analysed using Genstat (2002). A general linear model (using completely randomised design) was used to determine whether fertiliser rate affected measured parameters. Post-hoc pair-wise comparisons of means were made using lsd (significance level of 5%).

RESULTS

Environmental conditions

A total of 358 mm fell at the study site from the 19 May 2005 to the 18 May 2006, of which 210 mm fell during the wheat growing season (April-October). The amount of rain that fell during the growing season was 81 % of the growing season mean for the 30 year period 1974-2003. Historically the region is characterised by warm dry summers and mild wet winters; however during this study, the summer was marked with a series of summer thunderstorm events that resulted in 152 mm rainfall (42% of the total rainfall) (Figure 1). Much of the summer rainfall resulted from six events between the 2 January and the 6 February 2006, and which ranged from 8.6-55 mm day^{-1}. Mean daily air temperature for the study period was 16.4°C. The minimum hourly air temperature (-3.6°C) was recorded in July 2005, while the maximum hourly temperature (42.7°C) was recorded in December 2005 (Figure 1). Average daily soil temperatures in the surface 50 mm ranged from 8-33°C, with temperatures lowest during July 2005 (mid-winter) and greatest in January 2006.

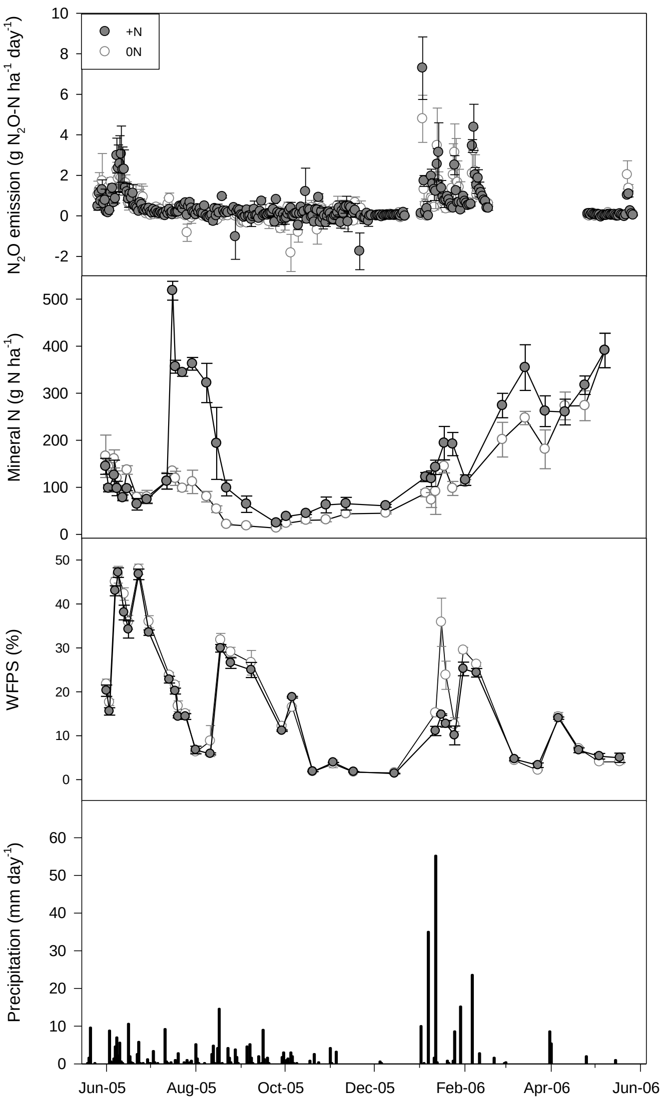

Figure 1. Daily N_2O emissions, soil mineral N, water-filled pore space (WFPS) and precipitation with time at a cropped site at Cunderdin, Australia (19 May 2005-18 May 2006).

Seasonal variability of N_2O emissions

Nitrous oxide emissions were highly temporally variable, with daily emissions ranging from -1.8-7.3 g N_2O-N ha^{-1} day^{-1}. Losses were not affected by the application of N fertiliser. Greatest losses occurred from both N treatments immediately following planting, and following summer rainfall events (Figure 1). At all other times emissions were low (< 1 g N_2O-N ha^{-1} day^{-1}) and less than the detection limit. Following seeding, N_2O emissions peaked (3 g N_2O-N ha^{-1} day^{-1}) after 7 to 10 days, and then returned to baseline emissions (< 1 g N_2O-N ha^{-1} day^{-1}) within 15 days. These losses coincided with elevated soil WFPS (following 'opening' rains) and mineral N concentrations (predominately soil nitrate; Figure 1). Nitrous oxide emissions following summer rainfall events were as high as 7.3 g N_2O-N ha^{-1} day^{-1} for the +N treatment and 4.8 g N_2O-N ha^{-1} day^{-1} for the 0N treatment. The greatest daily losses occurred following the first of the summer rainfall events. During summer, elevated N_2O emissions coincided with increased WFPS and soil mineral N concentrations (predominately soil nitrate; Figure 1); plus surface soil temperatures often greater than 30°C (data not shown).

Annual N_2O emission

The total amount of N lost emitted as N_2O after one year was 0.11 kg N_2O-N ha^{-1} for +N treatment and 0.09 kg N_2O-N ha^{-1} for the 0N treatment; however these losses were not statistically different. If it is assumed that the annual N_2O emission varied between N treatments, then 0.02% of fertiliser N applied was emitted as N_2O.

FUTURE WORK

Quantifying annual N_2O emissions accurately requires intensive and continuous measurements over an extended period of time (e.g. > 2 years), therefore we will continue the study for at least a further 12 months. Developing models that predict N_2O emissions from agricultural soils from easily measurable soil, climatic and crop parameters may provide an alternative to measuring emissions. Consequently, data collected from the study will be used to test the suitability of a N_2O simulation model (Water and Nitrogen Management Model, WNMM) (Li, 2002) for predicting N_2O emissions from Western Australian grainbelt soils.

CONCLUSION

Findings from one year of measurements indicate that N_2O emissions from cropped soils in the Western Australian grainbelt will be low under typical N application rates and frequency of applications. Episodic rainfall events may result in significant, short-term N_2O emissions.

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KEY WORDS

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

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Managing seasonal risk is an important part of farm management but is highly complex and therefore needs a 'horses for courses' approach

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KEY MESSAGES

- Recent seasonal variation highlights the need for farmers to manage seasonal variability.
- Predicting crop yield is the key to managing seasonal variability.
- There are tools/methods available that can help predict likely crop yield.
- The bulk of the expenditure on a crop is committed at seeding – thus this is the time when such a prediction is most useful.
- At seeding the bulk of the rain which will contribute to final crop yield is still to come – thus the range of possible crop yields is at its greatest.
- Yield predicting tools/methods were of extra value in 2006 due to the abnormally late and dry start across the NAR, which for many followed significant summer rain. The tools, when combined with calculations of crop breakeven yields, helped farmers decide just how late is too late to sow!
- The Horses for Courses project has tested a range of tools with Mingenew-Irwin Group members – their feedback over 3 contrasting seasons confirms that managing seasonal variability is important and that decision support tools/improved methods can improve the final outcome.

AIMS

1. To compare a range of decision support tools.
2. To figure if use of the tools can lead to better management of climatic risk.
3. If so how do they or their outputs need to be packaged or presented.

METHOD

Test sites and bulletins to Mingenew-Irwin Group (MIG) members

Over the 2004, 2005 and 2006 seasons 11 sites were run whereby soil, agronomy and climate (rainfall) data was collected. This data was used by several tools to: a) forecast likely crop yield; and b) predict nitrogen requirements of the crop. The tools used were the Yield Prophet, Potential Yield Calculator (PYCAL), NULogic (CSBP nutrient tool) and Select Your Nitrogen (SYN).

Each month from April to September the outputs of the tools along with Seasonal Climate Outlook information from the DAFWA ENSO Sequence System, Bureau of Meteorology and phase of the SOI were included in a bulletin which went to all MIG members. Also included in the bulletin was some interpretation of just what the information meant for each of the 11 sites.

Performance of the tools

At the end of each year the outputs of the yield tools were compared with the actual crop yield to allow an evaluation of the performance of each tool. This information not only allowed evaluation but, if there were significant discrepancies, it often also led to alterations to the way the tools were set up or being run.

Member surveys

At the start of the project (2004) a sample of MIG members were surveyed to establish how they made a wide range of crop management decisions. At the end of the project the same members were surveyed again to establish if they, as a result of their involvement in the project, now went about making crop management decisions any differently.

Also at the end of the project the wider MIG membership was surveyed to determine the impact of the project and also what their views were on managing seasonal variability after some involvement in the Horses for Courses project.

RESULTS

This paper focuses mostly on the yield forecasting tools but also touches on the use of seasonal climate outlooks. Both are the critical factors when considering management of seasonal variability. The results are also focused on feedback from the MIG farmer membership.

How MIG members make crop management decisions

A total of 22 growers from the Mingenew-Irwin Group in **June 2004** were asked to complete a questionnaire that asked them how they make crop management decisions in relation to seasonal variability.

The survey highlighted the following points:

- Most farmers use a range of information sources when deciding to vary inputs to their cropping program. Fertiliser is the main crop input varied and often this is done with a target yield in mind. More fertiliser is applied in response to favourable seasonal conditions but there is a suggestion that farmers are less likely to vary rates downwards in poor seasons.
- There are a range of methods used to derive target yields, and on average three sources of information were used in coming up with a target yield. Summer rainfall (and subsoil moisture at the start of the season), conditions at the start of the season and rainfall to date are all used to formulate target yields. About half of the respondents varied the target yield as the season unfolded.
- Nitrogen is the key fertiliser input being varied in response to season, with a significant minority ‘playing the season’ in response to unfolding conditions. Post-seeding N is applied in both granular and liquid form and there is a clear reluctance to applying N beyond late tillering. When asked how they determine what rate of N they require in a paddock the most popular answers were: advice from an agronomist (59%), past use pattern (50%), fertiliser rep (36%), computer based models (i.e. SYN, Nulogic) (23%) and 32% said they would use a mix of methods. The most influential factors used when deciding on rates of N were yield potential followed by crop history then soil test results.
- MIG growers are well aware of seasonal climate outlooks, are accessing them via a variety of means, and using them to make management decisions. Of the seasonal climate forecasts available, 62% said they paid attention to ones from DAFWA, 81% to the Bureau of Meteorology and 29% to others like internet sites. Of those that pay attention to climate outlooks, 50% just keep an eye on them, while 41% use them to make management decisions.
- A forecast of yield potential was most valuable early in the season for budgeting and planning, fertiliser management at sowing and weed management. Some decisions are not varied as a function of estimates of yield potential. The majority indicated that they would be more likely to base tactical decisions on estimates of yield potential if they had access to quantitative (e.g. t/ha) yield forecasts. However, there is a healthy scepticism about being asked to pay for such information, as there are doubts about accuracy and reliability.

Crop expenditure – when does a farmer commit?

The survey responses say a great deal about when the critical crop decision points are. When considering how to manage seasonal variation one needs to consider the reality of when crop expenditure is committed. The questionnaire showed for most farmers **the decision to sow** a paddock **commits** them to the following operating expenses:

- Seed.
- Herbicides (as once planted the majority of wheat crops no matter the yield potential will be sprayed for weeds).
- At seeding fertiliser.
- Fuel (seeding, spraying and harvesting).
- Labour (seeding, spraying and harvesting).
- Depreciation of plant/equipment.
- Crop insurance.
- Interest on seasonal finance required.

Crop operating expenses often available to be **varied during the season** include:

- extra fertiliser (mostly nitrogen and sulphur).
- fuel and labour (extra fertiliser spreading/spraying).
- fungicides.

Understanding this is important because it has implications on several components of managing seasonal variation.

- Playing the season – a straight forward strategy based around the theory of holding back crop inputs until the latest possible time so as to gain as much knowledge of the season without compromising crop yield. Understanding what expenses are effectively committed at seeding makes one realise that playing the season is valuable but for many lower rainfall farmers leaves very little to vary once the season is underway.
- Does a yield forecasting tool/method need to be highly precise? The first thing that needs to be understood about yield predictions at this early stage of the season (i.e. sowing) is that the bulk of the growing season rain is usually still to fall. Thus the range of crop yields that can be expected is substantial at this time. With this in mind we suggest that being precise in terms of the ability of the tool is over rated – simply because the range of yields possible from this time will always be substantial due to the uncertainty of the amount of rain to come.

The tools – yield forecasting/predicting

The Horses for Courses project really focused on two tools / methods of yield forecasting. These tools are the Yield Prophet and PYCAL (or 'back of the envelope'). PYCAL was modified during the life of the project such that it really just makes using a modified 'French-Schulz' water use efficiency equation simple and integrated with historical rainfall information. This 'back of the envelope' method, as it has become known through the project, is based on the historical water use efficiency (WUE) of a site/soil type.

Table 1. Comparison of Yield Prophet and PYCAL on a number of issues

Issue	Yield Prophet	PYCAL
Short description	Uses a daily time-step crop-soil simulation model (APSIM).	A calculator to estimate potential yield from rainfall records.
What can I use it for?	Estimates the likely range of yield and grain protein outcomes for a given season as a function of climate conditions to date, sowing date, soil type, cultivar, distribution of soil water and N at sowing, applied fertiliser N, irrigation.	Estimates the likely range of yield outcomes for a given season as a function of rainfall conditions to date, summer rainfall, and soil type.
How does it account for 'soil type'?	Soil types vary in terms of their plant available water capacity (PAWC).	Soil types vary in terms of their water use efficiency.
What information do I need to run it?	Knowledge of the PAWC of the soil type in the paddock, rainfall to date, distribution of soil water and N down the soil profile at sowing, sowing date, cultivar.	Knowledge of the long-term WUE of the paddock, rainfall to date, summer rainfall.

Table 1 continued …

Issue	Yield Prophet	PYCAL
How do I get hold of the model?	Use of Yield Prophet is licensed through the Birchip Cropping Group. There is an annual fee of $500 (2006).	PYCAL costs $44 from DAFWA.
Computing requirements	Access to the internet is required to run YP.	A personal computer is all that is required.
Strengths	Can deal with "what ifs" like topdressing decisions. Accounts for the distribution of rainfall during the season. Accounts for the distribution of soil water and N in the profile at the start of the season. Accounts for sowing date and cultivar effects.	Total summer and in-season rainfall is all that is needed. No internet connection required. Based on local 'calibration' to past paddocks yields.
Weaknesses	Requires detailed knowledge of soils or a reliable estimate (PAWC and starting soil water and N).	No accounting for distribution of rainfall within the season. No accounting for N effects, cultivar and sowing date. No accounting for runoff or leaching.

Over the three seasons (2004-06) the tools have proven to mostly work effectively. Table 2 shows the performance of the tools in 2006 when many were questioning their ability to cope with such a late sowing and very low rainfall amounts.

Table 2. Yield Prophet and PYCAL performance in 2006 at all project sites

Site		Yield Prophet	PYCAL	Actual yield
Property	Rain (GSR)	Final	Final	Site (t/ha)
C. Gillam (clay)	127 mm	0.7	0.7	0.6
Forward (sand)	164 mm	1.1	1.0	1.5
D. Heitman (yellow sand)	144 mm	1.6	1.0	1.5
A. Pearse (yellow sand)**	136 mm	1.0	1.0	2.3
Holmes (red loam)*	142 mm	2.6	1.3	2.3
Spencer (clay)	128 mm	0.4	0.9	0.6
K. & B. Heitman (red loam)	139 mm	1.0	1.2	1.3

* Yield was higher at this site due to summer rain and earlier sowing opportunity than the rest.
** Site also sown earlier (31 May).

DISCUSSION

Where and when is yield forecasting most relevant?

There is no doubt that certain farming regions/districts can benefit more than others from yield forecasting and the general playing the season approach. Specifically the wider the range of possible yields the greater the application.

In Western Australia this generally means the heavier the soil type and the lower the rainfall.

Farmer members of the Mingenew-Irwin Group farming sandier soils in the western part of the district have reported that Horses for Courses generated yield predictions have often told them what they already know (2004 and 2005). They have also reported that farming for the average in the early part of the season is a good strategy. This is because yields achieved do not necessarily vary greatly from a dry season to a wet. It is distribution of rainfall that is of most importance.

Of courses these same farmers are often interested in yield predictions in the middle to latter part of the season as they attempt to maximise crop profitability via late nitrogen applications, fungicides, etc. Playing the season is something numerous of them do on an annual basis.

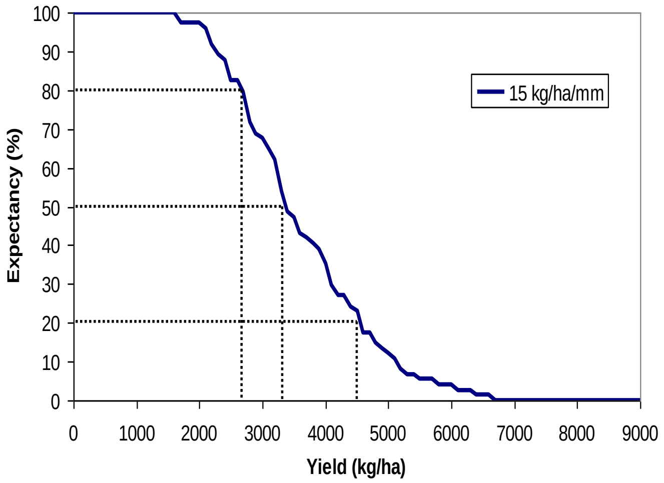
The 2006 season showed for most of these same farmers that even in the most reliable of areas it is possible for an extremely late break cum drought! This ‘one in a hundred’ type of season though did show one thing about yield forecasting. Tools such as the Yield Prophet and PYCAL could at least put some rigor into yield calculations in such extreme circumstances – of particular value were forecasts at or before seeding when everyone was asking the same question “how late is too late to sow a crop?” For some this was further complicated by higher than average levels of stored moisture from summer rains. Provided there was a good understanding of a crop’s breakeven yield (with fertiliser and possibly other costs lowered) the tools helped many farmers with the decision to sow or not!

Higher rainfall regions probably have less to gain with regards yield forecasting than the lower rainfall regions as in all but the most extreme of seasons they will sow a crop. Thus they commit to a substantial proportion of their operating costs in 95% of seasons although it is these farms that stand to gain more from playing the season.

Higher rainfall farmers also report that they are not so interested in saving a few dollars on input costs in poor seasons but of more interest is maximising crop profitability in the average to above average seasons. We suspect that this highlights their general business profitability and stability as well.

How does a farmer respond?

A yield forecast really needs to be expressed in terms of probabilities because of the unknown amount of rain to come and the impact this has on likely crop yield. The questionnaire showed that most farmers are comfortable with target yields being expressed in probabilistic terms. Thus a yield forecast will usually look something like this.



Graph 1. ‘French-Schulz’ based yield forecast in 2005.

The problem a farmer then has is how to respond. Obviously factors such as aversion to risk and financial position will impact on the response.

The above chart indicates that the site has the potential to yield as high as 6.0 t/ha and as low as approximately 2.0 t/ha. The difference in N required to reach 2 t v 6 t is approximately 150 kg or $150. The question for the farmer is where do I aim?

Logic says that the natural place to aim is at 3.2 t/ha because this is where, based on historical rainfall, there is a 50:50 chance of achievement. In 2006 though if a user had aimed at the 50 percentile then they would have been quite wrong as rainfall failed to rise above the decile 1 line or 90 percentile.

Now this is where a climate outlook that a user can have confidence in would help. If such an outlook points towards below average rainfall then the user can factor this into their thinking. Certainly this was the case as 2006 unfolded – at no point during June/July did any of the outlooks suggest anything better than average. Most were indicating rainfall for the season from that point to be most likely

below average. Obviously what made 2006 challenging was that the NAR received the lowest growing season total on record. There is big difference between 'lowest on record' and 'below average'!

Difficulties that need to be acknowledged when considering the response to the yield forecast:

- Which climate outlooks have skill and when. When do I factor into the yield equation and when do I not?
- Is my visual assessment of the crop fitting with the yield calculation?
- Where will be my best return on investment?
- Which strategy comes with an acceptable level of risk?

Understanding the principles of yield forecasting

The general principles of crop yield forecasting are quite simple and it is our belief that once a skilled farmer has these well embedded in his/her head then sound crop management decisions can be made without the use of complex tools.

For example at seeding the critical information at a farmers disposal that needs to be processed includes, in order of importance:

1. The date (i.e. seeding date – is it optimal?).
2. The amount of rain at the break (soil moisture that is being sown into).
3. Weather forecast (i.e. is more rain coming in the next few days?).
4. Stored soil moisture (summer/autumn rain).
5. Climate outlook (i.e. are there any strong signals worth factoring into the equation?).

If the above are carefully considered in conjunction with historical yields and experience then a skilled farmer will usually have a fair understanding of what the chances of achieving a certain yield are because for a skilled and experienced farmer past experience will guide him/her quite effectively.

Where this approach breaks down and certainly where effective tools can really be of benefit is where:

- There is a clear lack of historical performance (i.e. cropping and management skill is questionable, something is constraining crop yield, the farm is new to the manager, etc.).
- There is a lack of experience (new or young farmer).
- Extreme circumstances, e.g. very late break, substantial summer rain has fallen, etc.

It's Horses for Courses

Because the needs of individual farmer's change with experience, location, attitude, profitability, etc. so does the decision on the correct tool, method and approach vary.

The Horses for Courses project has shown that tools from the simple to the complex can add value to crop management decisions. Yield forecasting, calculating N requirements and factoring in seasonal climate outlooks are all possible and all can have an impact if applied properly. But ultimately it is up to the farmer and probably his/her adviser to decide which horse suits their course.

KEY WORDS

yield forecasting, climate variability, Yield Prophet, PYCAL, seasonal climate outlook

ACKNOWLEDGMENTS

Managing Climate Variability Program for funding the Horses for Courses project. MIG and MIG members, DAFWA, CSIRO, Elders for their vital contributions.

Project No.: MIG1

Paper reviewed by: Richard Quinlan, Planfarm

Novel use application of clopyralid in lupins

John Peirce[1], Senior Research Officer and **Brad Rayner[2]**, Senior Technical Officer, Department of Agriculture and Food, Western Australia; [1]South Perth and [2]Vasse Research Centre

KEY MESSAGES

- Clopyralid has activity on cape weed, skeleton weed and some thistles.
- Clopyralid is registered for use in cereal crops but not registered for use in lupins.
- Albus lupins will not tolerate clopyralid but several narrow leaf varieties will tolerate up to 450 mL/ha pre-sowing and 100 mL/ha post-emergent.
- Further research is required to indicate potential to use clopyralid pre-sowing and also post-emergent to control/suppress blue lupins, albus varieties of lupins, cape weed, thistles and skeleton weed in narrow leaf lupins.

AIMS

To evaluate the herbicide tolerance of narrow leaf lupins to clopyralid.

METHOD

A split plot design having three replications in both the main and sub plots was used for the trial at the Eradu Sandplain Research Anex in 2005. The site was burnt on 5 April. Pre-sowing treatments clopyralid (300 g a.i.) of 0, 150, 300 and 450 mL/ha were applied to the main plots on 20 April 2005. Spray.Seed® 1 L/ha and simazine 2 L/ha were applied over the entire trial on 6 May. Narrow leaf lupin Mandelup were sown at 100 kg/ha with 100 kg superphosphate on 16 May 2005 using bulk seeding equipment fitted with press wheels. Crop maintenance included dimethoate 800 mL on 25 May and applications of 150 mL/ha Brodal® plus 0.5 L simazine on 14 June. Further grass weed control was carried out on 27 June using Fusilade® 70 mL, Select® 250 mL and Hasten® 500 mL/ha. Post emergent applications of clopyralid at 0, 50, 75 and 100 mL/ha were applied to the sub plots at two different times 22 June and 19 July 2005. Additional insect control was carried out with the trial treated with Dimethoate 800 mL and Fastac Duo® 300 mL/ha to control aphids and other pests in early and late September. Plots were machine harvested in November.

RESULTS

The narrow leaf lupin Mandelup tolerated up to 450 mL/ha of clopyralid pre-sowing and post-emergent applications up to 100 mL without showing any significant yield losses (Table 1). No measurements were taken but observations noted that clopyralid also was more damaging on the blue (sandplain) lupins contaminating the trial site.

CONCLUSION

Work carried out by Dhammu and Nicholson and reported in crop updates 2006 (Weed Updates pp. 79-83 and 87-89) confirmed the tolerance of narrow leaf lupins to clopyralid and also the susceptibility of the albus lupins. The gap in tolerance would indicate the possibility of controlling or suppressing the albus and the cosentinii varieties (blue lupins) growing in narrow leaf (angustifolius) lupin crops as well as many other weeds such as capeweed and some thistles susceptible to clopyralid.

In addition the use of clopyralid in lupins has another benefit in the eradication of skeleton weed. This weed causes significant yield loses in cereals and its density increases dramatically, probably because of nitrogen fixation, when the weed infests lupins. The weed is currently under an eradication program in Western Australia and clopyralid is used extensively where large infestations of skeleton weed are found in cereals. If it can be used in the lupin as well as the cereal phase it will contribute greatly toward the possibility of eradication as currently there are no herbicides registered for use against skeleton weed in Western Australia.

Table 1. Effect of clopyralid on yield (t/ha) of narrow leaf lupins treated pre-sowing and post emergence

Post-emergent		Pre-sowing Clopyralid mL/ha				Post em averages
Clopyralid mL/ha	Application time	150	300	450	Nil	
50	22 June 2005	2.44	2.41	2.43	2.52	2.45
75		2.37	2.26	2.33	2.22	2.30
100		2.39	2.17	2.22	2.24	2.25
Nil		2.43	2.33	2.35	2.20	2.33
50	19 July 2005	2.31	2.35	2.35	2.22	2.31
75		2.33	2.26	2.22	2.28	2.27
100		2.35	2.24	2.30	2.24	2.28
Nil		2.30	2.28	2.33	2.26	2.29
Pre-sowing averages		2.37	2.29	2.32	2.27	

lsd (0.05)
Pre treatments – 0.09
Post treatments – 0.16

KEY WORDS

narrow leaf lupins, blue (sandplain) lupins, skeleton weed, clopyralid tolerance

ACKNOWLEDGMENTS

Grateful acknowledgement of funding from the Skeleton weed Eradication Trust Fund.

Project No.: ???

Paper reviewed by: Dr Aik Cheam

Long season wheat on the South Coast – Feed and grain in a dry year – a 2006 case study

Sandy White, Department of Agriculture and Food, Western Australia, Jerramungup

KEY MESSAGES

- Climate change is predicted to increase the variability of rainfall distribution throughout the season on the south coast and cause a higher proportion to fall outside of the April to October growing season.
- This poses some challenges for conventional annual varieties of crops and pastures. Farmers on the south coast are already managing this change with pastures by growing perennials such as lucerne.
- In the crop phase, out of season rainfall can be utilised to establish early sown long season wheats to provide useful winter feed to livestock and produce acceptable yields of quality grain. This tactic proved a sound economic strategy in the dry year of 2006 for the Willison's, who farm at North Gairdner.

BACKGROUND

Dual purpose winter wheats have been grown in the Eastern States to utilise soil moisture and provide valuable winter feed when pasture growth is reduced by cold conditions. Improved varieties with increased resistance to disease, especially rust, have meant these wheats have application along the south coast of WA to utilise out of growing season rainfall in the crop phase and provide winter feed to the sheep enterprise. In order to test suitability of a range of varieties to the south coast environment a long season wheat Crop Variety Testing Trial was sown in early April 2005 south of Jerramungup. This was featured as part of the Fitzgerald Biosphere Group's (FBG) Trials Tour that year with a very enthusiastic Mohammed Amjad extolling the virtues of long season wheat in his presentation at the trial. Neighbouring farmers Ray, Lyn and Brett Willison were impressed by the performance of Wedgetail wheat in this trial and obtained seed to plant 18 ha in early April 2006. The seed was purchased from local farmer Barry Porter, who has experience with growing long season wheat in NSW and provided advice on grazing management. The paddock was sown on moisture stored from substantial rain received in mid January and follow up rain received on 1 April.

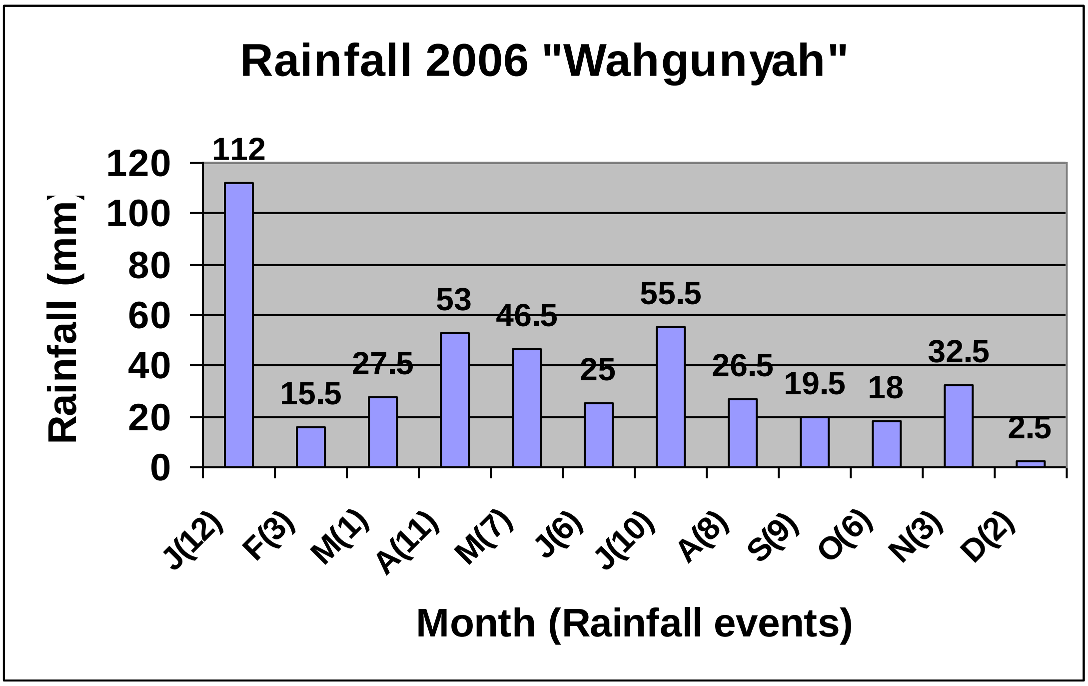
Willison's grazed the paddock heavily for approximately two weeks in both June and July with ewes and lambs. These sheep would otherwise have received supplementary feeding during this time as pasture quantity was limited during a dry winter. After the July grazing the crop was left to develop normally and was featured at the FBG's Trials Tour on 18 October when it was at the milky dough stage. The crop was harvested in November and yielded 1.9 t/ha of APW quality. Willison's plan to plant at least two maximum 40 ha paddocks of Wedgetail in 2007 as they are pleased with it's performance under heavy grazing this year and are confident of a reasonable yield between 1.5-2 t/ha in dry conditions. They view long season wheat as an ideal system to complement their sheep enterprise by utilising summer rain to fill a winter feed deficit and still continue to grow grain on that paddock. It can also be used as a tool to control some weeds in crop to reduce reliance on herbicides.

CROP PRODUCTION DETAILS

Variety	**Wedgetail**
Paddock history	**2004 Oats, 2005 Pasture**
Paddock area	**18 ha**
Sowing date	**4/4/2006**
Seed treatment	**Armour®**
Sowing rate	**48 kg**
Fertiliser	**100 kg/ha Agstar Extra® at sowing** **60 kg/ha Urea 30/7/06 (after final grazing)**
Knockdown	**Roundup® 1 L/ha, Glean® 15 g/ha**
Post emergents	**Monza® 25 g/ha 30/4/2006 then Hoegrass® 1 L/ha 10/5/2006**
Fungicide	**125 mL Folicur® 22/9/2006 aerial spray**
Harvest	**24/11/2006**
Yield	**1.9 t/ha**
Quality	**APW, Protein 11.5%, Screenings 2.35%, Hectolitre weight 78.32**

After sowing on 4 April, 13 rainfall events of no more than 2.5 mm were recorded until the 24 May when 37 mm fell. Early crop growth was held back by lack of effective rain then grew well after the May rain. Barley grass and ryegrass were controlled with Monza® in late April then Hoegrass® in mid May as the paddock was not intended for cropping in 2006 and had not been spray topped in 2005.

RAINFALL



Rainfall in 2006 totalled 434 mm, just below the average of 450 mm. Growing season rainfall (April to October) was 244 mm over 57 days. The highest recordings were 12.5 mm and 22 mm falling on 1 and 2 April and 37 mm recorded on 24 May (first effective rainfall after sowing). During the growing season only 14 recordings totalled more than 5 mm and 5 recordings more than 10 mm.

Out of growing season rainfall was 190 mm, or 44% of total rainfall. Most of this fell in January to March, the highest recordings being 55 mm and 25 mm falling on the 13 and 14 January respectively, followed by 27.5 mm on 2 March. 29.5 mm fell on 29 November, although a dry spring had preceded this. Luckily this meant harvest was completed before this rain.

GRAZING

Long season or winter wheats such as Wedgetail are able to withstand grazing and still produce grain yield as their shoot apex remains in the vegetative phase until their vernalisation requirement is met, it will then switch to the reproductive phase to develop and produce grain. The Willison's first grazed the crop on 12 June with 330 ewes and 340 lambs just after lamb marking. The crop was at a late tillering stage and 25 cm in height. This mob was removed on 30 June when the crop had been grazed to about 5 cm in height, giving 19 days of grazing at the equivalent of 40 DSE's/ha for this period (based on 2.2 DSE's per ewe at the 6 week stage of lactation). The crop was grazed again from the 17-29 July for 13 days with 519 ewes and 538 lambs at an equivalent of 49 DSE's during this period (based on a ewe in late lactation at 1.7 DSE). Crop height was reduced to 2 cm at the second grazing to try and achieve more even flowering and grain fill across the whole paddock.

During June and July 2006 pastures were suffering from lack of rain and several frosts that had reduced dry matter production considerably. Many pastures in the district were struggling to achieve 1000 kg DM/ha despite early autumn rains simply due to the state wide problem of lack of winter rainfall. 80 mm fell over this period in 16 rainfall events, the greatest being 13 mm on 22 June. As a result, Willison's were still supplementary feeding lactating ewes through winter. The paddock of Wedgetail proved to be a cost saver in terms of reduced grain fed and allowed a pasture paddock to be spelled to increase dry matter to provide more feed on offer when sheep returned. The supplementary feed requirement was also reduced for ewes returning to this spelled paddock.

Alternatively, the winter grazed pasture area is temporarily increased allowing either higher stocking rates during good seasons or more feed on offer to other mobs when feed is limited. This ultimately has a positive effect on profitability of the sheep enterprise.

Benefit summary

	Sheep	Tonnes feed saved (ewes @ 750 g/h/day 25% lupins 75% oats mix)	Total cost saving (Lupins $250/t, Oats $200/t)	Cost saving per hectare Wedgetail
1st grazing – 19 days	**330 ewes, 340 lambs**	**4.7 t**	**$999**	**$55.50**
2nd grazing – 13 days	**519 ewes, 538 lambs**	**5 t**	**$1,062**	**$59.00**
Total – 32 days		**9.7 t**	**$2,061**	**$114.50 (plus value of extra FOO available on return to pdk)**

THE FUTURE

Willison's will plant two paddocks of Wedgetail on canola stubble this year given adequate summer rain to provide stored soil moisture for good establishment. 37 mm had already fallen in early January. Paddocks selected will be no more than 40 ha to allow for even grazing and to suit preferred mob size. Larger paddocks can be grazed either with larger mobs or strip grazed where practical but this is not a preferred option. Sowing rate will be increased to 55 kg/ha next year to slightly increase plant density. Sowing time is aimed at late March to early April as this achieves the best results with grazing and final yield. Other growers in the area are keen to try Wedgetail as they were impressed by the 2006 results.

KEY WORDS

long season wheat, Wedgetail, grazing

ACKNOWLEDGMENTS

Ray, Lyn and Brett Willison, Barry Porter

Paper reviewed by: Leanne Bee, Department of Agriculture and Food, Western Australia, Jerramungup

Wheat yield response to potassium and the residual value of PKS fertiliser drilled at different depths

Paul Damon[1], Bill Bowden[2], Qifu Ma[1] and **Zed Rengel[1]**; Faculty of Natural and Agricultural Sciences, The University of Western Australia[1], Department of Agriculture and Food, Western Australia[2]

KEY MESSAGES

- Depth of fertiliser placement can affect the capacity of a wheat crop to take up nutrients and produce grain.
- Split application (half drilled at 7 cm depth and half drilled at 18 cm depth) of a compound (PKS) fertiliser in the preceding season appeared to increase plant growth and grain yield compared to drilling all fertiliser at either 7 cm or 18 cm depth.
- Application of K (MoP top dressed) appeared to increase the yield response to the residual value of fertiliser placed at different depths in the preceding season for a single trial at a K-responsive site.
- Inadequate soil K levels may limit the capacity of wheat crops to make best use of background soil fertility.

AIMS

To assess the effect of:

1. The residual value to wheat in the following year of fertiliser (PKS) placed at different depths.
2. Response of wheat to K applied as MoP (broadcast four weeks after sowing) where the residual value of fertiliser drilled in the previous year may differ due to depth of placement.

METHOD

The site was located near Corrigin, Western Australia with mean annual rainfall of 355 mm and mean seasonal rainfall of 253 mm (May to October). The month of May (prior to sowing) had a rainfall of 10.2 mm, and it was dry in the early (sowing to late July) and late growth season (mid September to final harvest). In contrast, 73.6 mm rainfall was recorded from late July to mid September, which was equivalent to 84% of total rainfall (87.5 mm) over the whole period of plant growth. The soil was a loamy sand with the following nutrient levels (mg/kg) 26 P, 54 K and 18 S at 0-10 cm; 7 P, 22 K and 8 S at 10-20 cm; and 5 P, 39 K and 4 S at 20-30 cm. Soil pH_{ca} was 5.0 at 0-10 cm, 4.7 at 10-20 cm and 5.4 at 20-30 cm, i.e. a minimal effect of soil acidity. In the previous season, wheat cv. Wyalkatchem was grown.

The experiment was laid out as a randomised plot design for the residual depth of fertiliser treatments. There were three replicates of these 2005 treatments. The fertiliser treatments (residual) were applied in 2005 as a compound granular product delivering (kg/ha) 19.3 P, 10.9 K, 15.9 S, 0.2 Cu and 0.3 Zn drilled below the seed. The treatments were: 1. no fertiliser (control); 2. fertiliser at 7 cm (shallow); 3. fertiliser at 18 cm (deep); and 4. half of fertiliser at 7 cm and half at 18 cm (split). In the 2006 season, wheat cv Wyalkatchem was sown across the trial area on 6 June with no additional fertiliser applied at sowing. A basal dressing of 50 kg N/ha was applied as urea, within four weeks of seeding. Potassium was applied as Muriate of Potash (KCl), broadcast at 50 kg K/ha four weeks after sowing in a 2 m wide strip across all plots. Plots were 1.4 m wide with eight rows at a row space of 17.5 cm.

Plots were sampled for aboveground plant parts five weeks after sowing and every three weeks thereafter until maturity. For the first and second samplings, shoots of 20 or 30 average-sized plants per plot were sampled, with quadrants taken for all other samplings. Plant samples were dried, weighed and analysed for K and P content after digestion in a mixture of nitric/perchloric acids. Uptake of K and P was calculated as the product of the nutrient concentration and the total dry weight of shoots. Mature plant samples were weighed, threshed and grain was collected. Treatment effects for the residual depth of fertiliser placement were assessed as the percentage difference from the control treatment for the nil K and K fertilised strip treatments.

RESULTS

Fertiliser (PKS) drilled beneath seed in the previous year increased shoot weight and grain yield at maturity of wheat plants relative to the control (no fertiliser drilled) for the shallow and split fertiliser placements. The split fertiliser placement consistently produced the highest shoot weight for the routine samplings and the highest shoot weight and grain yield at maturity (although the differences were not statistically significant). Fertiliser drilled 18 cm below seed in the previous year did not significantly increase grain yield or shoot weight compared to no fertiliser.

Application of K at 50 kg/ha four weeks after sowing increased grain yield, shoot weight, 1000-grain weight, number of heads per hectare, and harvest index (= grain yield/total shoot weight) at maturity and increased shoot weight during the routine samplings. Averaged across all residual placement treatments, there was a 28% response to K application for grain yield. The concentration and total amount of K in shoots was increased by the application of K. In contrast, K application did not increase uptake of P for any of the fertiliser placement treatments, but reduced the concentration of P in shoots.

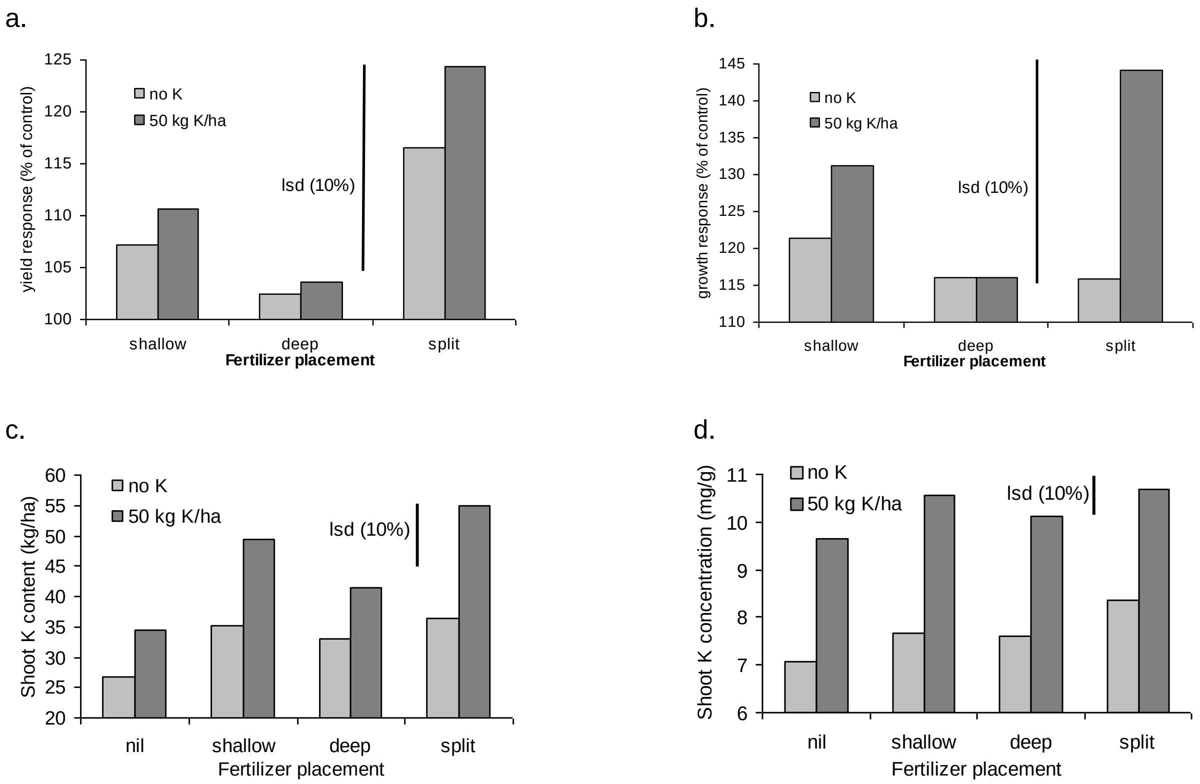


Figure 1. The relative response to the residual value of a compound (PKS) fertiliser applied in the previous year of: a) grain yield at maturity; and b) shoot weight at the grain filling stage (Zadoks 7) and absolute values for: c) K content (kg/ha); and d) K concentration (mg/g = kg/t) of shoots at the grain filling stage (Zadoks 7) of wheat (cv. Wyalkatchem) grown on a loamy sand soil near Corrigin, Western Australia. Compound fertiliser treatments were drilled below the seed for wheat (cv. Wyalkatchem) in the previous year at 7 cm depth (shallow), at 18 cm depth (deep) or half at 7 cm and half at 18 cm depth (split). Relative responses were calculated as the per cent improvement from the control treatment, where no compound fertiliser was applied, with or without MoP applied for the 50 kg/ha and nil K treatments respectively.

The key effect of K application was a consistent trend of greater response to the residual value of fertiliser placement where K was applied (Figure 1a, b). The effect of K application on the magnitude of the response to the residual value of fertiliser placement was generally not statistically significant, but was consistent across all blocks and sampling dates. Application of K four weeks after sowing appeared to increase the magnitude of the response to the best treatment for residual value: split placement.

By increasing the shoot K concentration for all treatments (Figure 1d), K application appeared to increase the capacity of wheat to capitalise on the residual value of fertiliser, depending on the depth of placement. The large response of shoot K concentration to K application corresponded to smaller, but significant responses in terms of shoot growth, and grain yield.

Seasonal and site-specific factors may have contributed to the responses observed in the present trial, and continued work is warranted to further assess the trends observed in this trial under the 'Nutrient Management Initiative'.

ACKNOWLEDGMENTS

The work was conducted in collaboration between the Faculty of Natural and Agricultural Sciences, The University of WA and the Department of Agriculture and Food, WA as part of the GRDC funded 'Nutrient Management Initiative'. Tim Hilder and Reg Lunt were responsible for much of the planning and implementation of the trial work. We appreciate the assistance of Des Hickey, the farmer, for allowing access to the trial site.

Project No.: UWA00084

Paper reviewed by: Bill Bowden

Saltbush as a sponge for summer rain

Ed Barrett-Lennard and **Meir Altman**, Department of Agriculture and Food, Western Australia, South Perth and CRC for Plant-based Management of Dryland Salinity

KEY MESSAGES

Rows of saltbush can be a valuable asset in wheatbelt areas in reducing the risk of waterlogging, especially after summer rain, which is considered more and more likely if climate change predictions are confirmed.

AIMS

To determine whether rows of old man saltbush can act as 'biological drains' lowering watertables and ensuring the growth of high quality understorey plants.

METHOD

The 'Wheel' saltbush experiment has been planted at four locations: Wubin (property of Keith Carter), Meckering (Colin Pearce), Yealering (Chris Walton) and Pingaring (Michael Lloyd). At each site, the old man saltbush clone 'Eyres Green' (gift of the Topline Plant Company in South Australia) was planted in rows intersecting each other (like the spokes of a wheel) at 30 degree angles in early September 2003. Plants were 2 m apart in the rows and each row is 75 m long

At monthly intervals we have been measuring the effects of the plants at 0, 3, 6 and 12 m distance from the saltbush on groundwater levels (measured with 3 m deep piezometers) and soil moisture (measured using the neutron moisture meter). In addition, we are measuring plant volumes because as water becomes more limiting on the site, the plants at the centre of the wheel will grow more slowly than those at the margins.

RESULTS

Rainfall

The rain that fell at each site from June 2004 to October 2006 decreased in the order Yealering (953 mm) > Meckering (840 mm) > Pingaring (800 mm) > Wubin (666 mm). A substantial proportion (47-58%) fell from June to September. However there was an especially wet period in the summer of 2005-06 and about 150–180 mm of rain (17-23% of the total) fell in January and February 2006.

Growth

The growth of this saltbush clone has been strongly affected by the soil conditions (Figure 1). The differences in growth between the sites appear to be primarily due to differences in soil texture (Table 1). Canopy volumes expanded faster with time at Meckering than at any other site, and by the end of the experiment volumes at Meckering were about twice those at Wubin and Pingaring, and these were about twice those at Yealering.

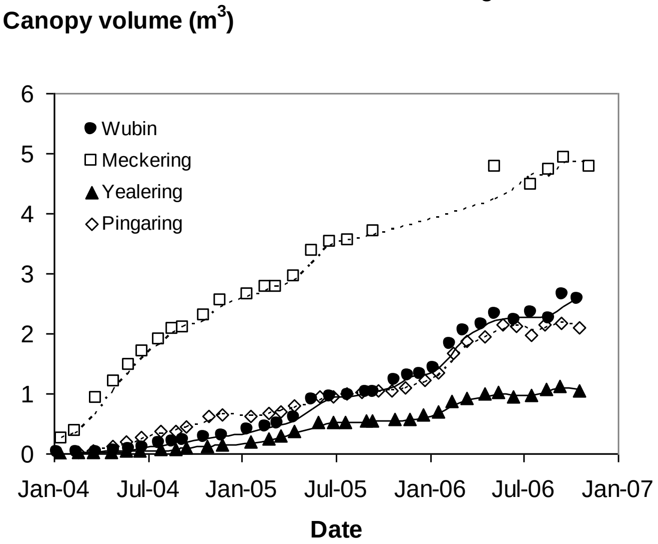


Figure 1. Change in geometric mean canopy volume with time. Each point is the geometric mean of 144 plants. Lines of best fit are two period moving averages.

Table 1. Summary of site conditions at the four locations of the wheel experiment

Site	Watertable depth median (m)	Salinity of groundwater (% seawater)	Texture
Meckering	**1.0**	**31**	**Deep duplex**
Pingaring	**2.0**	**96**	**Loam**
Wubin	**1.8**	**89**	**Shallow duplex**
Yealering	**0.9**	**27**	**Clay**

Water use by single rows of saltbushes

We are considering proofs that saltbushes use groundwater, and because of the greater density of plants, this use is greater at the centre than the periphery of the wheels.

- *Soil beneath rows of saltbushes has lower moisture content than adjacent soil away from the saltbush rows*. Figure 2 shows the pattern of difference in neutron counts and total stored water over the upper 2 m of the soil profile between saltbush rows and 6 m away. These data show that to some degree, the soils beneath rows of saltbush became drier at all sites in summer compared to winter. However, the effect only persisted at Wubin, the site with the combination of most drying conditions in summer (data not presented) and deepest watertables (Table 1). In summer 2004-05, soils were up to 100 mm drier at Wubin, but only 25-31 mm drier at the other three sites. In the 2005-06 summer, the maximum effects were no greater (23–99 mm), presumably because of the high rainfall in January-February 2006.
- *Soil beneath rows of saltbushes has deeper watertables than adjacent soil away from the saltbush*. Effects of the single rows of saltbush on stored soil moisture were quite subtle and clearest in summer. In January-February 2005, the average differences in the depths of watertable beneath the single rows of saltbushes compared to 6 m away were: 3.4 cm (Wubin), 1.3 cm (Yealering), 2.3 cm (Meckering) and 3.1 cm (Pingaring). Although all plants were larger in January-February 2006, we were not able to detect greater effects because of the exceptionally high rainfall that occurred in those months. Further measurements of watertable difference are being made this summer.
- *Salt accumulates in the root-zone beneath the rows of saltbushes*. All plants (including halophytes) take up water faster than salt; this leads to an accumulation of salt in the root-zone. We have completed the first round of drilling (August-September 2006) for the calibration of our neutron moisture meter data. Analysis of the collected soil samples shows clear evidence of salt accumulation in the root-zone at the two sites with the less saline shallow groundwater (Table 1), Meckering and Yealering (Figure 3). Salt concentrations ($EC_{1:5}$) increased beneath the saltbush rows at depths less than 100 cm. At Yealering the greatest increases (0.3-0.6 dS/m) occurred at 0-60 cm, whereas at Meckering greatest increases in salinity (0.5 dS/m) occurred at 40-80 cm depth (Figure 3). We expect greater differences in salt concentration to develop this summer.

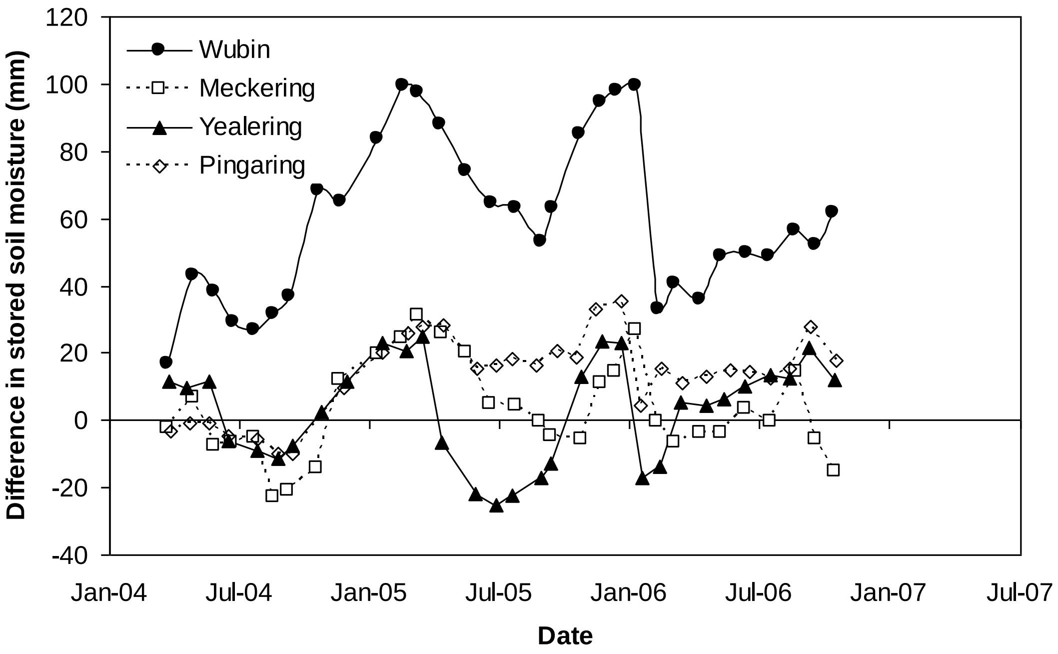


Figure 2. Estimated differences in stored soil moisture between saltbush rows and adjacent areas 6 m way. Each point is the mean of six replicates.

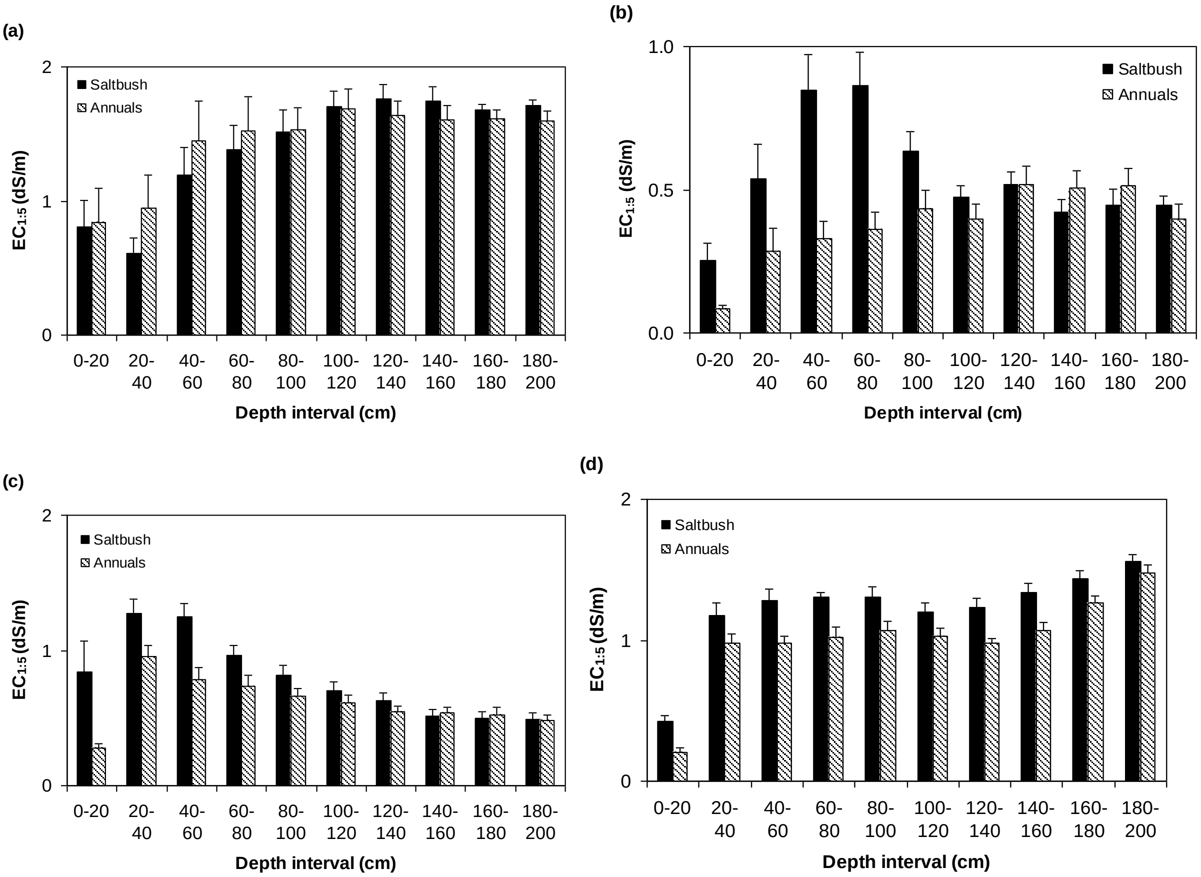


Figure 3. Salt concentrations ($EC_{1:5}$ values) in winter 2006 down the soil profile at (a) Wubin, (b) Meckering, (c) Yealering and (d) Pingaring. Soil cores were taken either in the saltbush row ('saltbush') or 6 m away ('annuals'). Each value is the mean ± sem of 12 values (6 locations, 2 replicates per bore).

CONCLUSION

These data show that even single rows of saltbush are able to use soil moisture and at least partly control groundwater. The level of water use beneath single rows of saltbush after two years is relatively slight (30-100 mm). However, there may be further use of groundwater as the saltbushes continue to grow. (We have observed about 200 mm of dryness beneath denser commercially managed stands in the Lake Grace area.)

The ability of plants to dry out soil profiles will depend on the depth of the watertable (upper soil profiles can be dried if watertables are around 2 m deep), the salinity of the groundwater (water use will decrease as groundwater salinity exceeds that of seawater), and the dryness of the summer.

The water use by the saltbush system could be very substantial when bulked up over large areas. For example 100 mm of water use over a hectare amounts to one million litres of water. Water use on this scale should help to decrease the severity of waterlogging, and lower watertables enough to grow less salt and waterlogging-tolerant annual legumes (such as burr medic and balansa clover) as higher value understorey species.

Warning needs to be given to farmers seeking to use saltbush stands as an alternative to drainage. The saltbushes mainly use groundwater during summer. They may therefore need to be combined with surface water management structures (like W-drains) if waterlogging and flooding is to be avoided in winter.

KEY WORDS

saltbush, watertable, waterlogging, groundwater, understorey

ACKNOWLEDGEMENTS

This trial is part of the Sustainable Grazing on Saline Lands (SGSL) WA2 project and has been supported by Australian Wool Innovation Ltd. We are deeply indebted to our host farmers – Keith Cater (Wubin), Colin Pearce (Meckering), Chris Walton (Yealering) and Michael Lloyd (Pingaring).

Building strong working relationships between grower groups and their industry partners

Tracey M. Gianatti, Grower Group Alliance

KEY MESSAGES

- The key benefits of grower, researcher and industry collaboration were: Greater access to grower group members, improved communication and feedback between all partners, and more efficient use of shared resources.
- Constraints of collaborative projects included: A research environment constrained by rules and reporting, poor communication between partners and a complexity in transaction costs.
- Practical ways of building strong working relationships included: Establish personal contact with partners, create joint management committees and resource the planning phase for new projects.

INTRODUCTION

The Grower Group Alliance (GGA) is a Grains Research and Development Corporation (GRDC) funded project which began in 2002. The project aims to support grower groups to provide their members with access to the latest information and research, and creates opportunities to establish collaborative projects between grower groups across the state. There are currently a total of 41 recognised grower groups in the wheatbelt of WA with a combined membership of over 2500 growers.

Each year, the Grower Group Alliance organises a one day 'Grower and Researcher' Forum to allow its members to interact and discuss current research and development issues. The aims of the GGA Forum are to:

1. improve communication within the GGA network to deliver better information to its members;
2. establish collaborative partnerships between grower groups, researchers and industry partners.

Previous forums have: Compiled grower group priorities for research; identified research gaps in regards to soil health, livestock, and cropping pests and diseases; and explored the communication networks used to share information between grower groups and researchers.

Participants include growers and staff members from the 16 grower group members of the GGA together with scientists from eight research institutions (Department of Agriculture and Food, CSIRO, CRC for Plant-based Management of Dryland Salinity, Centre for Legumes in Mediterranean Agriculture, WA Herbicide Resistance Initiative, University of Western Australia, Murdoch University and Curtin University). Funding partners, consultants and representatives from agribusiness, banking and fertiliser companies (collectively called industry partners) also attend in recognition of the increasingly important role they play in research projects. Regional catchment councils with expertise in natural resource management were involved for the first time in 2006. Approximately 60 people attend each year.

In 2006, the Forum examined three ma questions: 1) "What are the benefits of grower groups, research organisations and industry working together?"; 2) "What are the constraints?" and 3) "What do we need to do to build strong working relationships between grower groups and their industry partners?" Findings from this workshop are outlined in the paper together with recommendations for how grower groups and their industry partners could improve their future working relationships.

METHOD

The responses from the two focus questions were achieved through facilitated discussion groups. Participants were allocated into carefully selected groups of eight to ensure representation from all organisations invited to the forum. A brainstorming process was used to generate responses to the questions. All ideas were treated as valid contributions to the discussion and 'piggy backing' of ideas on each other was encouraged. Answers were written by a scribe onto butchers paper and pinned on a wall for other groups to read. After discussing the first question, new groups were formed with a

different mix of people to tackle the second question. At the end of the session, each table was asked to contribute one answer to each question for discussion in a summary session.

RESULTS

Question 1

"What are the benefits of grower groups, research organisations and industry working together?" A summary of the results is presented in Table 1.

Table 1. The key benefits of grower groups, research organisations and industry working together

Benefits
Greater access to target audience through increased exposure to grower group members.
Improved information flow and feedback between all partners.
Ensures the research is relevant to growers and the local farming system.
More efficient use and sharing of resources.
Builds trust and ownership between partners to accelerate adoption.
Increased networking opportunities and sharing of ideas.

Question 2

"What are the constraints of grower groups, research organisations and industry working together?" A summary of the results is presented in Table 2.

Table 2. The key constraints of grower groups, research organisations and industry working together

Constraints
Research environment is constrained by rules, regulations and reporting.
Ownership of knowledge in collaborative projects.
Poor communication between partners.
Recognising different levels of rigour in research (trials verses demonstrations).
Scarce amount of time and resources for all partners.
Complexity in transaction costs make it difficult to meet stakeholders needs.

Question 3

"What do we need to do to build strong working relationships between grower groups and their industry partners?" A summary of the key recommendations are listed in Table 3.

Table 3. The key recommendations to build strong working relationships between grower groups, research organisations and their industry partners (listed by category)

Recommendations	
Communication	- Encourage open communication between all parties. - Use a common language. - Establish personal contact with at least one person from each partner organisation.
Resources	- Resource the planning phase for new projects. - Formalise partnership arrangements to meet expectations.
Relevance	- Increase industry understanding of the conditions on-farm today.
Ownership	- Joint management committees for collaborative projects. - Cultivate positive attitudes to collaboration and full sharing of ideas.
Trust/respect	- Show mutual benefits to develop trust and understanding.
Social	- Make it fun, enjoyable and interesting.

DISCUSSION

Question 1 – Benefits of working together

The benefits of growers, researchers and industry working together could be categorised under six main headings. These were: Access to farmers, information flows, relevance, resources, ownership, and social factors.

In terms of access benefits (Table 1), researchers working with a grower group have improved interaction with numerous group members compared to working with individual farmers. Local advice and identification of field sites are also more readily available. When communicating research results, grower groups are able to organise events which increases researcher exposure. This also encourages interaction with those group members who don't always participate in on-farm activities.

A significant benefit of growers and researchers working in partnership is vastly improved information flow. Information can be targeted and relevant, and flow between all collaborators. In particular, one grower stressed:

> "It is vitally important that industry partners become more aware of grower group activities (and visa versa), so that information can be shared to prevent reinvention of the wheel".

Direct involvement of growers allows for a more rapid change in research priorities and the gathering of constructive feedback can lead to development of research with increased relevance to the farming community. Once results are generated, partnerships ensure faster communication and adoption of results by growers. Researchers benefit as grower groups are very good at breaking down information into simple, easy to understand format, and placing it in context to improve local relevance for their members.

More efficient use of shared resources is a large benefit of different organisations working together. Linkages increase efficiency through a reduction in overlapping of research efforts, costs and information flows. An example of where this is already occurring is the Mingenew-Irwin Group 'Horses for Courses' project which has five organisations working together.

Having two or more partners creates a critical mass to pool ideas. An increase in diversity and skills can then lead to more innovative ideas. When implementing these ideas, multiple project partners can spread the risks of innovating and improve the success rate of new projects.

Collaborative projects are beneficial as they build trust and ownership between farmers, researchers and their industry partners. Working alongside each other, project partners are able to appreciate the work being done by each other. Additional benefits can be gained by taking time to develop clear roles for each partner, allowing each to stay focused on their core purpose. Grower ownership of projects can help direct where their R&D levies are spent through placing emphasis on their local research priorities.

Socially, collaborative projects allow exposure and interaction with a variety of people which benefits all project partners. New projects can bring outside opportunities to rural communities providing a focus for social networking, shared skills and knowledge.

Question 2 – Constraints of working together

Alongside the many benefits of collaborative projects, there are also constraints which impede progress. These can be categorised under the headings of rules, ownership, rigour and resources (Table 2).

Collaborative projects are often constrained by the expectations of different project partners. A key comment from many researchers was that:

> "Growers need to understand that the research environment is constrained by rules, regulations and reporting. There are internal and external guidelines, and funding bodies have a large influence over what research is done".

In large organisations, there is often a lack of flexibility and a set process of obtaining funding must be followed. Researchers need to understand that a grower's priority is farming, and the timing of certain farm operations cannot be compromised. Scientists have administrative duties and often need to write research papers to progress their careers. Industry partners have their own constraints related to creating a return for shareholders.

In projects with more than one partner, a common question is "who owns the knowledge"? Complexity in transaction costs add an additional barrier which makes it difficult to meet stakeholders needs. Other ownership constraints include; burnout for farmer 'champion' or grower group, changes in farm ownership, and a lack of 'corporate memory'. This means that preserving results for future use is of paramount importance and may need to be resourced in project budgets. Partners must have respect for each other and be prepared to make concessions.

The lack of differentiation in the levels of rigour in research, e.g. trials verses demonstrations is a common constraint. Growers and researchers need to be clear about the aims of the work, and recognise the limits of the planned research. Appropriate trial sites need to be chosen and both the farmer and their employees must understand the importance of maintaining scientific rigour in a trial.

The lack of labour, skills, funding and infrastructure are enormous issues. In addition, short project timeframes and funding cycles means it is difficult to complete long term research projects. The turnover of staff in grower groups, DAFWA, and other research organisations decreases the continuity of people and skills creating extra constraints. Grower groups also have life cycles of enthusiasm.

Question 3 – Building strong working relationships

The second question discussed at the GGA Forum focused on the practical aspects of building better relationships between growers, researchers and industry (Table 2). A common result from the discussion groups was that open communication between all project partners needs to be encouraged. A way to improve this was to be proactive about establishing personal contact with at least one person from each potential partner organisation. Using a common language, with layman terms as appropriate, was also a suggestion for improvement.

In new projects, a dynamic communication plan to engage end users should be established for the life of the project. Time should also be invested in the beginning to develop a clear statement of each partner's goals. In established collaborative projects, awareness and interaction should be maintained between project partners through regular communication. Growers were eager to emphasise that:

> "Project partners must be willing to share all knowledge and results – especially including negative results from trials. This may need prior agreement that all results will be published (unless the trial is a true 'stuff up')".

The GGA Forum was cited as an effective way to encourage interaction and networking, as well as an opportunity to gain constructive feedback on project progress. The coordinators role is valuable as it aids the formation of linkages to make things happen.

Accessing resources to fund collaborative projects is a perennial issue. The discussion groups placed emphasis on ensuring collaborative projects involving grower groups are funded by R&D corporations. In addition, projects need to be funded with longer timeframes to help ensure continuity of staff and expertise in both grower groups and research institutions. A practical suggestion was that a per cent of research dollars be allocated to groups in the budget when they are a lead partner in a research project.

Constraints associated with labour, skill and time may be addressed by allocating resources in the planning phase of new projects. All partners should be involved in the planning stage as it takes time to establish roles and understand each partners contribution to the project. Clear contracts may need to be designed and abided by. To identify appropriate grower group partners, the 'capability' of groups need to be understood. Key questions are:

> "What are the interests/strengths/core objectives of each group?"
>
> "What can they deliver that is useful to researchers?"

To maintain the relevance of research trials, growers recommended that researchers and industry personnel increase their understanding of the conditions on-farm today. Through improved communication with groups, researchers could establish their credibility and profile in the farming community. In turn, researchers stressed that trial results will not always be practical and generate instant profit. The two groups must work together for mutual benefit.

Ownership of collaborative projects could be improved through agreement and clarification of goals between partners. A practical way to implement this is to formalise partnership arrangements and expectations. Joint management committees for projects could provide clear guidelines and ensure a willingness to share outcomes.

CONCLUSION

Successful collaboration depends on mutual trust, mutual benefits and sufficient resources, underpinned by good communication. Trust and respect between grower groups and their research and industry partners is to be encouraged through shared experiences. Strong project leadership with a farmer 'champion' from groups will encourage relevant research. Ensuring project and relationship flexibility will help to deliver benefits for all parties involved. Finally, including aspects of social networking that is interesting, enjoyable and dynamic will improve partner relationships.

KEY WORDS

grower groups, partnerships, collaboration, communication

ACKNOWLEDGMENTS

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To graze or not to graze – the question of tactical grazing of cereal crops

Lindsay Bell and **Michael Robertson**, CSIRO Sustainable Ecosystems, Floreat WA

KEY MESSAGES

On poorer soils in low rainfall environments, sacrificial grazing of cereal crops can sometimes be more profitable than continuing to harvest the crop. Tactical decisions to graze crops can improve profitability, particularly if low grain yields or prices are expected and livestock prices are favourable.

BACKGROUND/CONTEXT

In the 2006 season, with low yield expectations, many farmers were faced with a decision about the most valuable use of their wheat crops. While some farmers may have chosen to 'open the gate and let the sheep in', others finish livestock on their cereal crops more often, integrating the additional benefits of weed control.

AIMS

This study aimed to investigate the frequency with which wheat crops have more value for grazing than for grain production in the northern wheatbelt of Western Australia. It was intended to identify circumstances where this commonly occurs and to provide some guidelines on the potential for strategic and tactical use of cereal crops as a forage source.

METHOD

Simulation approach and assumptions

The APSIM Wheat module was used to predict seasonal variability in wheat biomass and grain production based on 116 years of historical meteorological data. A full factorial was investigated of four locations in the northern wheatbelt, differing in long-term average rainfall (Badgingarra, 575 mm; Mingenew, 400 mm; Binnu, 360 mm; and Dalwallinu, 300 mm), and three soils differing in waterholding capacity (PAWC); a shallow gravel with 40 mm PAWC, a yellow sand with 90 mm PAWC and a red loam with 148 mm PAWC (Figure 1). Specific simulation details were: wheat cv. Wyalkatchem was sown between 15 May and 30 June after 10 mm of rain was received over three days to achieve 150 plants/m^2; high rates of nitrogen (120 kg N at sowing and 100 kg N at 42 days after sowing) were applied to prevent N stress; and initial levels of soil water and mineral nitrogen were reset to crop lower limit and to base nitrogen levels on 1 January to ensure the same starting levels for each year of the simulation.

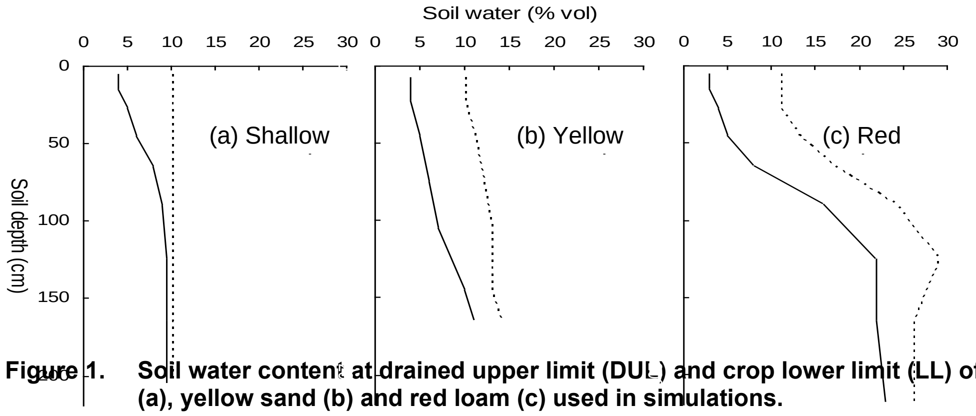

Figure 1. Soil water content at drained upper limit (DUL) and crop lower limit (LL) of the shallow gravel (a), yellow sand (b) and red loam (c) used in simulations.

Estimating grazing and grain value

The values of grain and grazing options were estimated from the APSIM outputs for grain yield at harvest and green biomass at 100 days after sowing, approximately flowering and expected maximum metabolisable DM (Equations 1 and 2). The standard assumption for grain price were $220 per tonne (five year WA average for APW) and harvesting cost of $ 35/ha. Grazing value was calculated based on assumptions of utilisation of the wheat crop, livestock production and price. Standard assumptions were a live weight price (LWP) of $1.7/kg (three year WA average for trade steers or lambs), feed conversion rate (FCR) of 0.1 kg of liveweight/kg of forage consumed and utilisation rate (U) of 50% of the standing forage at 100 DAS. Since the decision whether or not to graze the wheat crop was taken after sowing, costs for the grain or grazing options were assumed to be equal. Equal transaction and transport costs for grain and livestock were also assumed.

(1) Grain value ($/ha) = (grain yield × price) – harvesting cost

(2) Grazing value ($/ha) = biomass × U × FCR × LWP

Sensitivity analysis of different price scenarios was investigated for the two enterprises, expressed as grain price per tonne to livestock price per 100 kg LW (i.e. standard assumptions produce a relative price ratio of 1.3). Different animal feed conversion rates were also investigated to represent different livestock operations or forage qualities.

RESULTS

As expected, higher grain yields were simulated in the higher rainfall environments and on the better soils with greater water holding capacity. Grain yields were most consistent but low on poorest soil, while variation in biomass at 100 days after sowing was largest on the poorest soils particularly in lower rainfall environments. This indicates in these environments there are a number of years when large amounts of biomass are not effectively converted to grain yield.

Table 1. Mean, decile 1 and decile 9 grain yield (t/ha) and biomass at 100 days after sowing (t/ha) over 116 years of simulations by APSIM at four locations in the northern wheatbelt on three soils varying in PAWC

Data	Location	Mean			Decile 1 – Decile 9		
		Red loam	Yellow sand	Shallow gravel	Red loam	Yellow sand	Shallow gravel
Final yield (t/ha)	Badgingarra	4.14	5.61	2.04	3.20 - 4.86	4.70 - 6.52	1.38 - 2.72
	Mingenew	4.05	3.36	1.59	3.06 - 4.84	1.94 - 4.6	0.94 - 2.21
	Binnu	4.10	3.14	1.38	2.77 - 5.07	1.7 - 4.66	0.76 - 2.10
	Dalwallinu	3.45	2.31	1.16	2.17 - 4.73	0.82 - 3.76	0.57 - 1.81
Green biomass at 100 DAS (t/ha)	Badgingarra	5.67	5.34	3.76	4.77 - 6.62	4.49 - 6.23	2.62 - 4.83
	Mingenew	6.27	5.8	3.23	5.32 - 7.13	4.29 - 6.82	2.02 - 4.47
	Binnu	6.79	6.05	2.99	5.61 - 7.77	4.14 - 7.77	1.90 - 4.33
	Dalwallinu	5.69	4.83	2.82	4.67 - 6.62	2.7 - 6.30	1.43 - 4.21

Table 2 presents the proportion of years when grazing of crop biomass had greater value than carrying on to harvest grain. Grazing was less profitable than grain at the higher rainfall environments and on the better soil types. In situations where grain is most profitable in > 80% of years there is little economic penalty in focusing on grain production. Meanwhile, at the lower rainfall environments on poorer soil types, grazing had greater value quite frequently, especially at Binnu on shallow gravel and at Dalwallinu on yellow sand and shallow gravel (Table 2). In these circumstances there appears to be considerable merit in utilising cereal crops as a forage source. However, as grain production is still more profitable in 25-70% of years, the average profitability of employing either grain or grazing solely in these circumstances is significantly lower than the optimum case where the best choice is made each year (Table 3). Thus, some ability to make in-season tactical decisions when to graze or continue through to harvest would be valuable.

Table 2. Proportion of years when grazing has greater value than grain production from wheat at four locations in the northern wheatbelt on three soils varying in PAWC (using standard price assumptions)

Site	Soil		
	Red loam	Yellow sand	Shallow gravel
Badgingarra	0.00	0.00	0.21
Mingenew	0.03	0.15	0.31
Binnu	0.06	0.28	0.49
Dalwallinu	0.11	0.47	0.69

Table 3. Average difference between the best option each year ($/ha/year, using standard price assumptions) and a choice of grazing or grain production only, or tactical grazing in years when final grain yield is known to be less than the predicted critical yield for situations where grazing is frequently more profitable

Location	Soil	Graze only	Grain only	Tactically graze below critical yield	Predicted critical yield (t/ha)
Binnu	Yellow sand	-159	-17	-7	2.11
Dalwallinu	Yellow sand	-95	-34	-5	1.86
Mingenew	Shallow gravel	-58	-18	-9	1.22
Binnu	Shallow gravel	-40	-24	-7	1.24
Dalwallinu	Shallow gravel	-18	-38	-12	1.45

The relative value of grain and grazing was closely related to the final grain yield achieved, with grazing favoured in low yielding years (Figure 2). Below a certain final grain yield, grazing would be expected to be the most profitable option and greater value could be attained if farmers tactically graze their crops when their grain yield expectations are below this value. If a choice is made to graze the crop when final yield is known to be less than the critical yield then the average profitability can be improved (Table 3). In addition, in these dry and low yielding years, less forage from other sources is likely to be produced and cereal crops could add a valuable feed source for livestock. Obviously in-season decisions would not have perfect knowledge of final grain yield, as in this analysis, but the use of prediction tools, such as Yield Prophet®, could enable greater confidence about this decision.

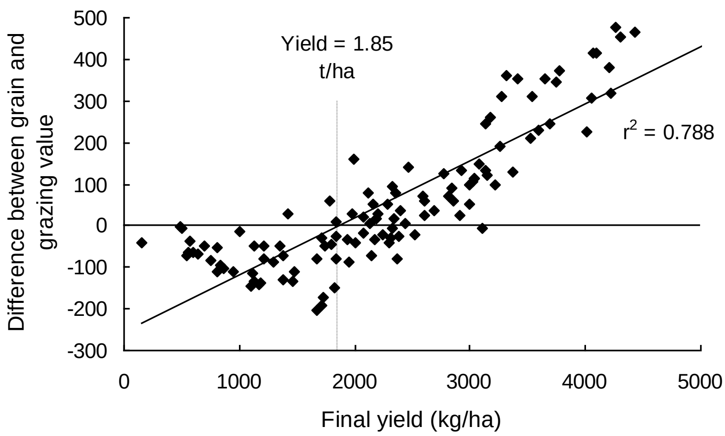

Figure 2. Relationship between simulated final grain yield and the difference between grain and grazing value at Dalwallinu on yellow sand. Dotted line depicts the critical yield where the most profitable enterprise changes between grazing and grain production.

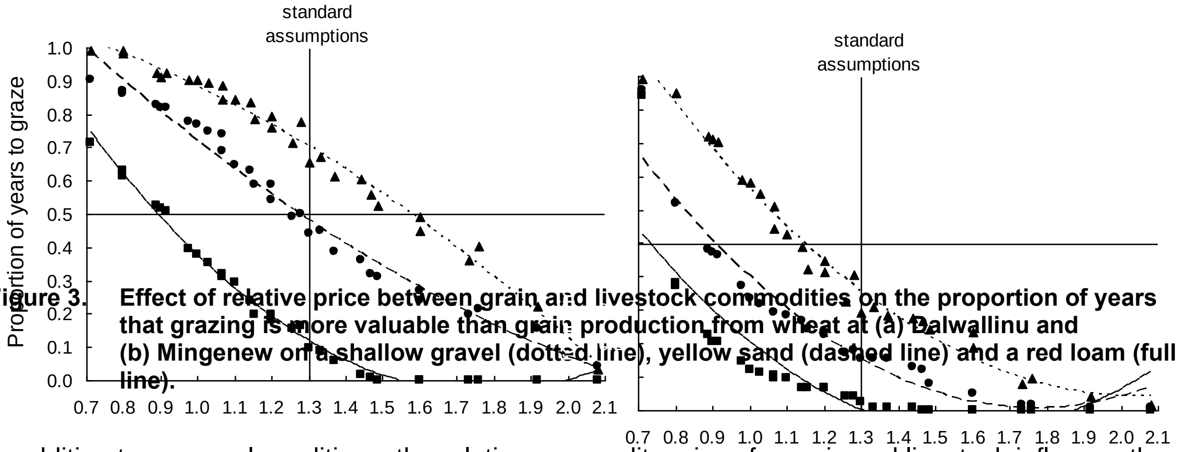

Figure 3. Effect of relative price between grain and livestock commodities on the proportion of years that grazing is more valuable than grain production from wheat at (a) Dalwallinu and (b) Mingenew on a shallow gravel (dotted line), yellow sand (dashed line) and a red loam (full line).

In addition to seasonal conditions, the relative commodity prices for grain and livestock influence the proportion of years where either enterprise is most profitable (Figure 3). Obviously as grain prices are relatively higher than livestock prices (i.e. ratio > 1.0) then grain production is more often profitable, and *vice versa*. Variations from the standard assumptions (i.e. a relative commodity price of 1.3) greatly impact on the frequency that grazing in most profitable. For example, a change to a relative commodity price of 1.0 (e.g. $200/t grain and $2/kg LW) adjusts the frequency that grazing is more profitable from < 3% to 12% of years on a red loam, from 15% to 34% of years on a yellow sand, and from 31% to 68% of years on a shallow gravel at Mingenew. Thus, the commodity prices are an important aspect of any decision to graze a cereal crop.

The standard assumptions for livestock performance or feed conversion rates in this analysis are based on typical growth rates of yearling cattle (300 kg LW) on pasture (MLA More Beef from Pastures Manual). Figure 4 addresses the impact of variations of feed conversion rates, as this is likely to vary depending on class of livestock used and the phenological stage and quality of the forage.

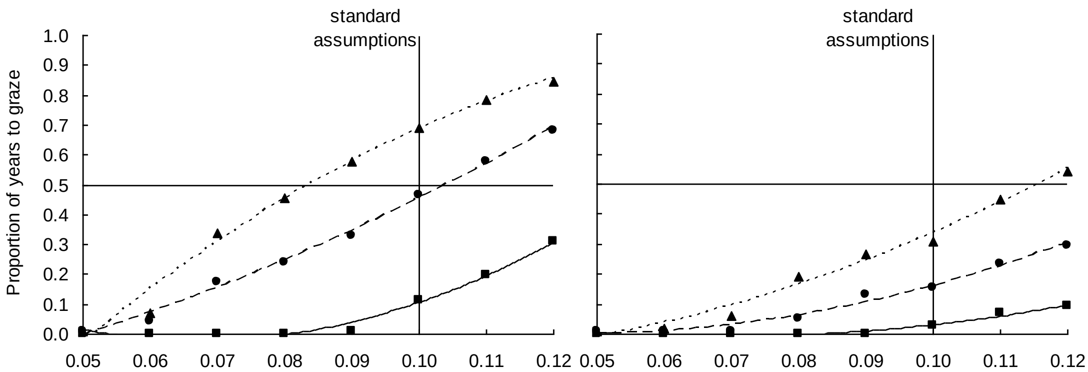

Figure 4. Sensitivity of the relative profitability of grain and grazing of wheat to different feed conversion rates that might be expected from different classes of livestock or forage qualities at Dalwallinu (a) and Mingenew (b) on a shallow gravel (dotted line), yellow sand (dashed line) and a red loam (full line).

CONCLUSIONS

While this analysis suggests there may be some capacity to profit from tactically grazing cereal crops, this may be limited by the capacity to obtain or manage livestock to utilise the additional forage. Issues regarding validation of livestock performance and grazing management remain to be resolved.

KEY WORDS

forage crops, grain and graze, dual purpose wheat, livestock, economics

ACKNOWLEDGEMENTS

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Project No.: CSE41 – National Grain and Graze – Whole-farm feedbase distribution and utilisation to reduce risk and maximise the sustainability of mixed farming systems.

Paper reviewed by: Dr Andrew Moore, CSIRO Plant Industries, Canberra

Can legume pastures and sheep replace lupins?

Ben Webb and **Caroline Peek**, Department of Agriculture and Food, Western Australia, Geraldton

KEY MESSAGES

- Self regenerating legume pastures grown in rotation with wheat can be more profitable than a wheat lupin rotation where lupin yields are low and input costs have been increased to manage herbicide resistance.
- Increasing stocking rate, lamb price, grain yield and quality and lowering input costs are the main profit drivers of medium rainfall sandplain farms that are including pastures in their system.

AIMS

The wheat lupin rotation has found itself under pressure where lupin yields are often low and increasingly more expensive to grow due to herbicide resistance. One option many farmers are considering is increasing their stock numbers. This helps to diversify their income, take advantage of high meat prices, manage herbicide resistance and maintains a legume in the rotation. This comes with many questions including how many sheep are needed to remain profitable, what impact will the pasture phase have on weed numbers and nitrogen levels and what percentage of the farm to crop. This paper examines the impact these changes have on the cumulative financial position (CFP) over a 10 year period using a case study farm business.

A grower from the medium rainfall zone near Geraldton realised that the traditional wheat lupin rotation is no longer profitable on his farm. Increasing fertiliser costs and herbicide resistance are driving up input costs and making his low yielding lupin crops unprofitable. The grower decided to shift towards a legume based pasture and cereal rotation. This way he could keep his wheat area up, use the sheep to help control herbicide resistant weeds and reduce fertiliser costs due to the nitrogen fixed by the pasture. With the new system the grower hopes to crop 50% of his area to wheat or barley and run sheep on the other 50%. The grower realised that although this system was more profitable than the traditional wheat lupin system it was still falling short of his financial goals. The grower and his agronomist decided that an analysis of the system would lead to a better understanding of the profit drivers and would help him to make some decisions regarding the future. This paper describes an economic analysis of the options that the grower wanted to explore using the STEP model.

METHOD

The analysis was conducted using the STEP (Simulated Transitional Economic Planning) model over a 10 year time frame. STEP is a computerised series of whole farm annual financial budgets using real farm data to investigate the progressive annual cash flow consequences of changing the enterprise mix. The main output is annual surplus deficit and the cumulative addition of the surplus deficit to result in cumulative financial position (CFP). The model takes into account the cost price squeeze by increasing costs at 3% per annum and returns at 2% per annum. A discount rate of 7% was applied to the 10 year cumulative financial position so it can be compared in today’s terms. It should be noted that the CFP is calculated net of the grower paying himself a wage, and repayments of interest and principal.

The results of the analyses should only be used as a guide to compare relative differences between the different systems and to explore what are the main profit drivers in each system. Changes in land price are not included in the calculations.

The grower supplied rotation, production and input cost details from his sand plain farm located in the Northern agricultural region in the low medium rainfall zone. Average financial data from BankWest benchmarks was used to estimate capital and fixed costs. Other assumptions included an average farm gate price for wheat, barley and lupins of $180/tonne, $50 per head for whether lambs, $25 for cast for age ewes and 500¢ kg of clean wool.

The grower also hopes the legume pasture will increase his wheat yields from 2.5 to 2.7 t/ha and help control herbicide resistant weeds, resulting in reduced costs. He also hopes to improve wheat quality to attract an extra $14 per tonne.

The analyses

- The traditional system including low stocking rate, a merino flock, lupins and growing APW wheat.
- A wheat pasture system with two stocking rates and reduced fertiliser input costs.
- Examining the sensitivity of the system to main profit drivers including stocking rate, wheat yield and quality.

The grower grows his hard seeded yellow serradella Santorini seed on another higher rainfall property but for this analysis we assumed that it cost him $60 ha in serradella seed costs.

Table 1 shows a summary of the systems analysed in this paper. These systems include a wheat lupin rotation, a serradella wheat rotation with two winter grazed stocking rates.

Table 1. A summary of sheep numbers, stocking rates and areas of crop and pasture

System	Wheat ha	Lupin ha	Pasture ha	Merino numbers	DSE/ha
Wheat lupin	1,800	1,800	300	1,300	5
Serradella wheat 5 DSE	1,950	0	1,950	7,800	5
Serradella wheat 7 DSE	1,950	0	1,950	11,000	7

RESULTS

Table 2. The impact of yield, wheat price, and DSE on the 10 year Cumulative Financial Position (CFP)

System	Wheat yield t/ha	Lupin yield t/ha	Stocking rate/ha	CFP Farm gate wheat price $180/t	CFP Farm gate wheat price $194/t
Wheat lupin	2.5	1.3	5	-$390,000	$149,000
Serradella wheat 5 DSE	2.5		5	$225,000	$818,000
Serradella wheat 7 DSE	2.5		7	$723,000	$1,314,000
High wheat yield after serradella	2.7		5	$830,000	$1,469,000

Table 2 shows that wheat yield, price and stocking rate are big profit drivers.

The CFP of the traditional wheat lupin rotation is negative due to the low lupin yields (1.3 t/ha) and high input costs due to herbicide resistance and higher fertiliser rates. The analysis suggests that the system that the farmer is currently moving towards is more profitable than the traditional wheat lupin system. With a CFP of about $225,000 over 10 years the case study grower was aware that this system was still not making a lot of profit. The farmer believes that the legume pasture may increase protein and lift yield due to the fixed nitrogen. If he is able to achieve hard wheat and get a $14 per t bonus, his CFP will be increased by a good margin to $818,000. A similar result occurs if wheat yields can be lifted by 200 kg per ha and quality remains the same. If both quality and yield can be lifted the CFP improves substantially to $1,469,000. The table also highlights that if stocking rate can be increased that this will also have a big influence on CFP.

Threats to the system

There are several emerging threats to this system. The 2006 season highlighted the importance of planning for unpredictable seasons. Farms with large numbers of livestock are vulnerable to wind erosion and high feeding costs if rainfall is low. This is particularly evident where the majority of the flock are breeding stock and lack the flexibility of trading stock. The case study farm sold all the lambs

and reduced the ewe number by 10-15%. Much of the farm was not cropped and the sheep were run across the whole farm. Pasture production was good in 2005 and the serradella stubble together with a small germination in 2006 has protected the paddocks from significant wind erosion, despite some grazing pressure.

Weed control

There are not a lot of herbicide options for weed control in serradella pastures. Doublegee and radish control in serradella pasture can need the use of the more expensive herbicides. These herbicides can also contribute to resistance development. Stock numbers have to be sufficient during the spring period to control weed seed set. Stock numbers are often limited by the potential to carry then through the summer and autumn period. The case study flock will need a small amount of rebuilding and green/brown manuring, slashing and the purchasing of trade stock could be among several options being considered to control weeds in some paddocks if stock numbers are not sufficient in 2007.

The farmer has recently purchased a slasher to help control radish seed set; this was not included in the analysis. Doublegee control is more of a problem because of its prostrate growth habit. The farmer is currently using selective herbicides. Once Santorini is established it is hoped to make use of its delayed germination and to get an early knockdown of doublegee when the opportunity arises. Some paddocks were sown in 2006 and although germination was very late it is thought that enough seed of the hard seeded Santorini was set. Yelbeni is a very short season variety and could be useful in these systems.

CONCLUSION

The wheat pasture system can be more profitable than the traditional wheat lupin rotation where lupin yields are routinely low and input costs high. The profitability of the pasture wheat system is strongly influenced by the ability of the pasture phase to reduce costs and increase wheat yield and quality. Stocking rate is also a strong profit. This paper highlights how sensitive medium rainfall sandplain farms are to yield, quality, stocking rate and input costs. A small change in one of these can have large ramifications over a 10 year period. The 2006 season also highlighted the need to consider ramifications that seasonal unpredictability can have when moving into a livestock system. This system is based on a static self replacing lamb flock but other more flexible options may need to be considered and further analysis needs to be done.

KEY WORDS

pasture, serradella, wheat, profit drivers, economic analysis, STEP, stocking rate.

ACKNOWLEDGMENTS

Thanks to the case study grower for sharing the production details of his business and Peter Eliott-Lockhart, Elders Agronomist, Geraldton for his help with providing information.

Project No.:	Northern Region Farming System Project 69F and NLP/NACC Project 053064-01 Long term sustainability of profitable medium rainfall farming systems
Paper reviewed by:	Andrew Blake

EverGraze – livestock and perennial pasture performance during a drought year

Paul Sanford, Department of Agriculture and Food, Western Australia, Albany and CRC for Plant-based Management of Dryland Salinity

KEY MESSAGES

In a drought year perennial pastures can provide valuable green feed with limited moisture. Preliminary observations suggest that rotational grazing is crucial to maintaining tall fescue, lucerne, chicory, setaria and panic plant density under drought conditions. Perennials have the potential to improve farm profit, control groundwater recharge, reduce soil erosion and provide valuable green feed in drought years.

AIMS

To provide evidence that a perennial based prime lamb production system is 50% more profitable while improving environmental outcomes e.g. significant reductions in groundwater recharge. The system is based on a farm that is 70% pasture and 30% crop on the south coast of WA. EverGraze is a partnership between the CRC for Plant Based Management of Dryland Salinity, Meat and Livestock Australia and Australian Wool Innovation delivering new grazing systems nationally.

METHOD

Comprehensive modelling suggests that Merino prime lamb production based on summer-active perennials and high-performance meat genetics could substantially increase profit while reducing groundwater recharge. In 2005 a 60 hectare site was chosen in the Albany Eastern Hinterland at Wellstead and sown to tall fescue (16 ha, eight paddocks), lucerne (8 ha, four paddocks), kikuyu (18 ha, two paddocks), setaria/panic (3 ha, one paddock) and chicory (15 ha, four paddocks) in spring.

The site consists of 0.5 m of sand over gravel and clay. Soil pH ($CaCl_2$) in the top 10 cm is 5.0, available P 13 ppm, available K 54 ppm and available S 5 ppm. In spring 2005 superphosphate was applied at 100 kg/ha across the whole trial and 50 kg/ha of urea applied to lucerne to alleviate N deficiency. In spring 2006 super:potash 2:1 was applied to the whole trial and 100 kg/ha urea to the chicory to increase spring growth.

In February 2006, 393 Merinotech ewes were delivered to the site and joined to Poll Dorset rams in March. All pasture types were rotationally grazed with the exception of kikuyu.

Measurements commenced in early 2006 and comprise of frequent assessment of pasture and livestock. An adjoining annual pasture is also assessed for comparative purposes.

RESULTS

The following results are preliminary.

In a below-average rainfall year the system performed well. The target of 104% weaning (from MIDAS) was exceeded by 15%, however could have been higher if the level of mismothering had been reduced. The goal was to finish the lambs on pasture, however without adequate feed the lambs were weaned and sent to agistment at Esperance Downs Research Station.

Ewe condition score was maintained at three or better, however this required feeding just over 30 kg of supplement per dry sheep equivalent, 17 kg higher than the economic optimum based on MIDAS simulations.

Perennial plant persistence was good under rotational grazing; however the lack of rainfall and low pasture growth meant feeding of ewes recommenced in mid-November 2006.

The site has a long-term annual rainfall of 500-550 mm with an average of 25% of rainfall falling outside the growing season. Season 2006 was very dry and from January to October the site only received 278 mm, 154 mm down on the long-term average of 432 mm.

The stocking rate was 6.5 ewes/ha or 12 dse/ha averaged over the year, while most local producers are running about 8 dse/ha. Grazing management mostly consisted of short intensive grazes with medium to long rests.

As a result of the dry season, pasture growth rates were below 20 kg DM/ha/day for most of the year only reaching a maximum of around 50 kg DM/ha in spring on some pasture types, e.g. kikuyu. Peak spring growth rates in a normal year are typically 80 to 100 kg DM/ha/day. Average feed on offer is shown in Figure 1. Pasture availability reflected the lack of soil moisture and subsequent poor pasture growth, rarely exceeding 1400 kg DM/ha. The normally reliable spring pasture flush did not eventuate.

Competition for moisture was intense with subterranean clover and other annuals competing poorly against the perennials.

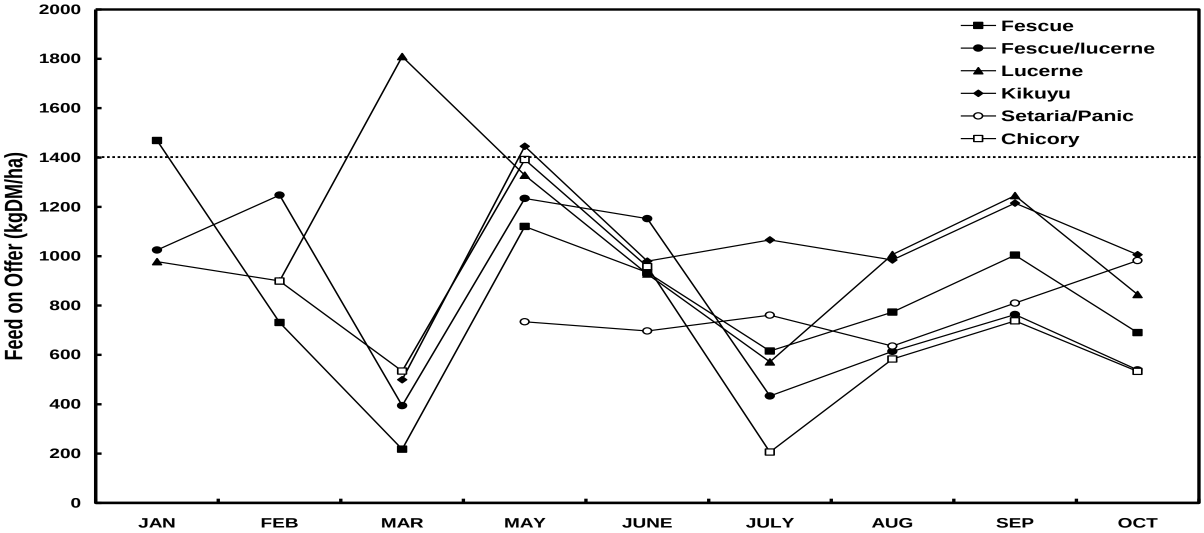

Figure 1. Average feed on offer across tall fescue, tall fescue/lucerne, lucerne, kikuyu, setaria/panic and chicory pastures.

While the scanning of ewes revealed a potential lambing of 164%, approximately 46 lambs were lost between scanning and lambing. Of those born, 132 lambs were lost mainly due mismothering and birthing difficulties, resulting in weaning of 119%, 15% more than the target set by MIDAS but below the more ambitious goal of 130%.

The liveweight and condition scores of ewes over the season are shown in Figure 2.

Pellets and lupins were fed to all ewes in April and May and just the twin-bearing ewes in August and September. Total for this period was 62 kg of supplement per head or just over 30 kg/DSE which is more than double the 13 kg/DSE/yr maximum suggested by the economic modelling. Feeding of ewes recommenced in the second week of November.

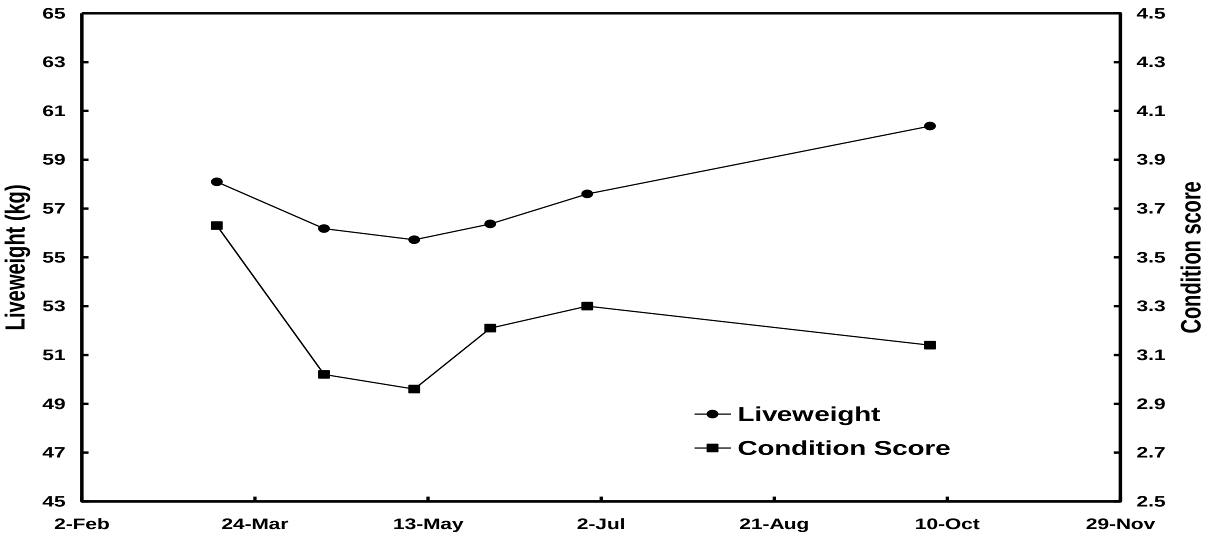

Figure 2. Liveweight (kg) and condition score of ewes.

CONCLUSION

While this year has been challenging it has provided us with an opportunity to understand how a perennial system performs in a drought year. However until further modelling analysis is completed it is not possible to rigorously compare the performance of this farming system to one based on annual pasture. Preliminary observations demonstrate that the perennial pastures maintained high plant density in a very dry year under rotational grazing and provided green feed in response to rain. Unfortunately the extreme lack of moisture resulted in poor pasture yields and sheep were fed more supplement than predicted. While lambing percentages exceeded the goal of 104% they could have been higher if the level of mismothering had been reduced.

KEY WORDS

perennial pastures, rotational grazing, kikuyu, chicory, lucerne, tall fescue, ewes, lambing

ACKNOWLEDGMENTS

Rodney and Bernadette O'Meara for providing the trial site. The WA EverGraze project team, Jeremy Ryan, Paula Coombe, Eric Dobbe and Elysha McCready. Funding support from Meat & Livestock Australia and Australian Wool Innovation.

Crop survival in challenging times

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KEY MESSAGES

Poor autumn rainfall has made crop establishment difficult in recent seasons, especially in 2006 in many northern and eastern areas of the WA wheatbelt. The crop which was established was often faced with periods of low rainfall, high temperatures and strong winds to induce drought stress which would reduce yield and grain quality. This paper sets out some guiding principles of seeder design, seed priming and water injection to help growers and advisors develop technical strategies which may reduce risks of poor establishment with poor autumn rains; especially after February to April rain greater than about 50 mm and development of marginal soil moisture conditions. The paper also makes suggestions to reduce risks of drought stress reducing yield and quality of the established crop. Warnings are provided about key problems of excessive seed depth and successful management of grass weeds in cereals. Some technical strategies are suggested to help reduce these problems.

THE VALUE OF DISC SEEDERS IN MINIMISING SOIL DRYING

Collins and Dale (1998) showed clear benefits of a disc opener for crop establishment in marginal moisture conditions. In April 1997 a field experiment with a randomised complete block design was set up at Merredin Research Station on Norpa grey sand. Three reduced tillage openers; a Triple disc with attached presswheel, a Knife point, and Inverted T point (both without a presswheel or harrow); and one conventional opener, a Full cut point (without a presswheel or harrow) were used to sow wheat (cv. Halberd) at low moisture soil content.

The Triple disc conserved the most moisture at 0-40 mm in the 14 days after seeding (Figure 1). It also conserved the most moisture at 40-80 mm together with the Full cut point. Crop establishment followed the same pattern as soil moisture, with more rapid emergence occurring with the disc opener than the knife point or direct drilling. From this experiment it could be expected that a Triple Disc opener is likely to be more effective than the other openers tested at conserving soil moisture. Experiments to evaluate disc openers and knife point openers for lupin establishment in marginal moisture conditions (Blackwell and Parker, 2003) provide more evidence of reduced risk of crop establishment when using disc designs. Lupins were sown into a dry sand layer over moist sand with either a double disc opener with presswheels or a knife point opener with presswheels. Plant emergence was more rapid with the double disc opener than with knife points in the subsequent five days after sowing without rain.

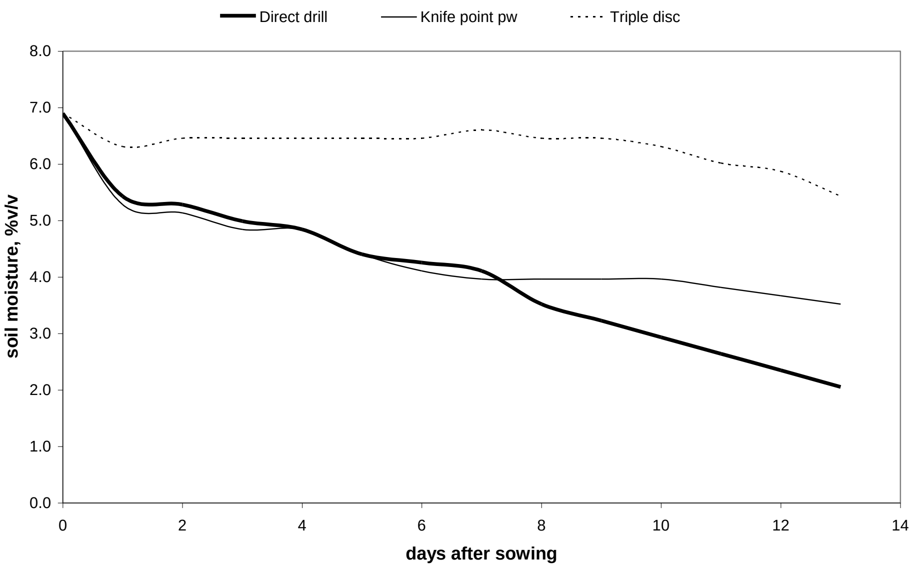

Figure 1. Topsoil drying 0-40 mm after sowing wheat with three different types of soil openers.

The deductions from these experiments supports grower and agronomist experience and observations of better and more reliable crop establishment by double and single disc openers, compared to knife points, when topsoil moisture is marginal and there is very little following rain in the 10-14 days after seeding. However, it is still possible to have too little moisture, too little following rain and too strong evaporation after seeding, despite using disc openers and a crop may perish.

THE VALUE OF SEED SOAKING (PRIMING) IN LOW SOIL MOISTURE

Scarce soil moisture reserves in relatively dry topsoil can be conserved if the water requirements for seed imbibition for germination are not provided by the soil. Water to initiate germination can be met from another source when seed is soaked for a sufficient period, then dried, before planting. Saikia *et al.* (2006) showed the mean time for 50% emergence at about 20°C of six Indian wheat cultivars was reduced to one third, from six days to two days, by soaking seed in water for 12 h prior to sowing. Yield benefit from priming in these trials averaged 12% but constituted an extra 236 kg/ha grain at little or no cost. Laboratory studies by Sharma (2000) showed that 17 h soaking of wheat seed in good quality water at about 20ºC can imbibe the seed, but avoid emergence of the coleoptile but more recent studies with other sources of wheat seed have found more rapid imbibition (optimum six to seven hours). The time for sufficient imbibition may depend positively on the adsorbing surface are of the seeds compared to the volume of seed requiring moisture; thus smaller seed size will imbibe more rapidly. If the coleoptile is exposed, it may be damaged when being delivered through the seeding machinery.

The variation of sprouting time during seed soaking in the above lab tests encourages the use of on-farm checking of the soaking time for each seed batch. The imbibition rate is largely influenced by crop species, seed size and temperature. Soaking needs of different species (wheat, barley, grain legumes and oilseeds) is relatively poorly studied, as well as any possible for surfactant to overcome resistance to imbibition by seed oil contents. A brief method of checking seed soaking time is explained below.

Soak 500g of seed in a water jug containing one litre of water. Stir the seed every two hours and try denting imbibed seed with thumb nail on a 1-5 scale. Do it on 10 seeds drawn after stirring, record the data on a sheet and calculate average. The optimum soaking time should correspond to the stage when you can dent the seed with medium force, i.e. an average score of three (may be two, but not four). If the seed can be dented fairly easily, it is too wet and if you can only peel the seed coat, it is bit too early and may not bring desired benefits.

For further details please contact Darshan Sharma at dsharma@agric.wa.gov.au.

One farmer experience in the Geraldton district in 2006 was encouraging; seed priming resulted in the best farm yield of 0.7-1.0 t/ha. This was associated with better crop establishment by seed priming.

THE VALUE OF WATER INJECTION TO MINIMISE SOIL MOISTURE NEEDS

Water injection supplies water to the seed placement zone while the seed is being planted; this reduces the demand for water of imbibition from relatively dry soil. It may be a more convenient technique than seed soaking and has had relatively more research, partly due to the use of water as a carrier of pesticides, nutrients and herbicides. Hauser (1986) used field tests of water applied to the seed furrow at rates of 0, 18, 38 and 59 mL/m furrow to improve seedling emergence. Seeds were sown using a drill with double disc openers with gauge wheels on each side and dual, angled, rear presswheels. Water was applied on top of the seed before the furrow was closed from between the disc openers. Fifty-nine millimetre water/m row length applied in the seed furrow doubled the number of grass plants established. The practice was successful on clay and sandy soils. Less success than this has been reported for larger seeds, from sorghum to wheat and often on clay soils without use of disc openers (e.g. Radford and Nielsen, 1985). Noori *et al.* (1985) provide the most encouraging results of water injection for wheat. Water injection into dry soil in the Pacific North West at rates of 20-60 mL/m of row provided yield increases of 4 to 33%.

Calculation of possible water injection requirements

Some basic calculations of possible volumes of water required per hectare can be made using the data of Sharma (2001) and known soil water retention properties. If it is assumed that the zone of water adsorption around the seed can be simplified to a cylinder, then the required water rate can be

calculated:-Injected water (L/ha) = water to imbibe seed + water to bring soil zone to field capacity = (seed rate (kg/ha) x % saturation of seed at imbibition) + (soil zone volume x soil water content at field capacity) .... 1.

The amount required can vary due to soil texture and amounts can be very large, e.g. the 50 L/m of row for 180 mm row spacing is 2500 L/ha; this would limit the practical farm use to small areas. A more encouraging analysis comes from the amount of water needed to change volumetric water content by a few per cent, which may be more appropriate to small changes required to re-moisten soil after drying following summer or early autumn rain. Figure 2 is an analysis which uses the notional radius of a tube of wetted soil at sowing depth, compared to the amount of water required to change the water content by a known, and small, amount.

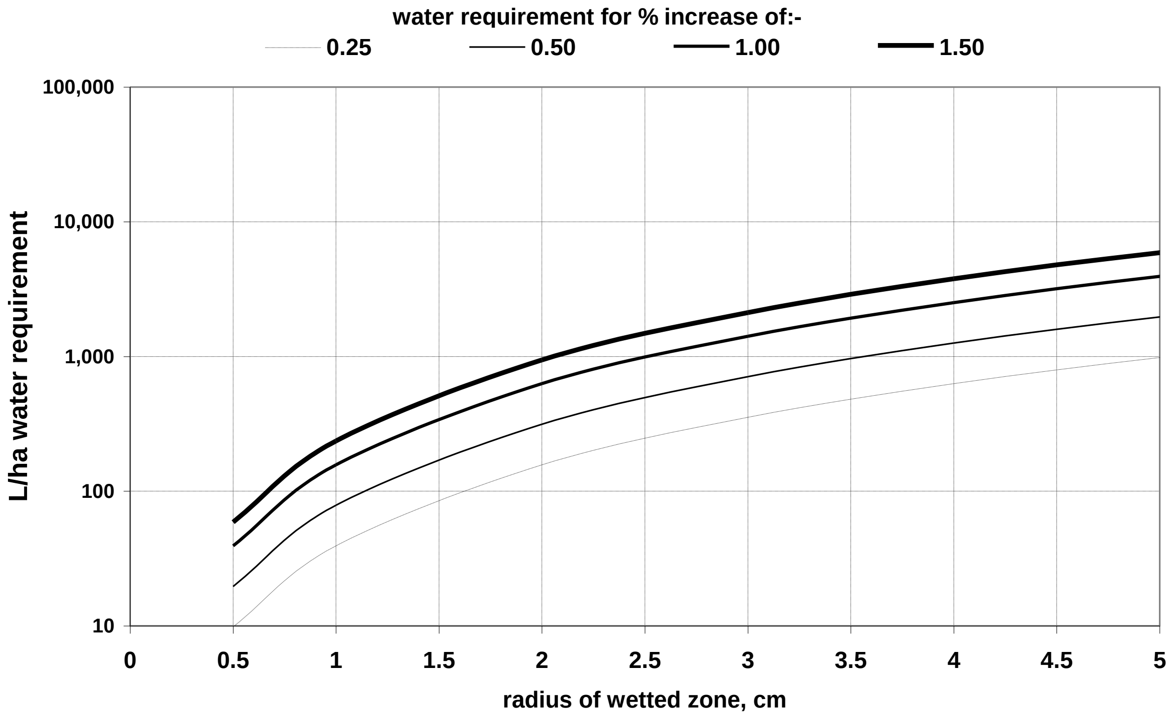

Figure 2. An estimate of the rate of water injection required to increase volumetric water content for by small percentages (range of 0.25 to 1.5%) in different radii of soil in the seed zone.

From this analysis there is a suggestion that water rates of about 60 L/ha can increase water content by about 1% v/v when a zone of about 1 cm diameter (0.5 cm radius) is wetted. This may explain why some growers in the northern agricultural region have reported yield benefits to such water rates applied through a liquid injection system into dry soil. The change in soil moisture may have just been enough to make enough water available to the germinating plant. If water injection is combined with seed priming, the amounts of water applied would be less, but the seeding rate would also have to increase by about 75% to accommodate the water in the seed for the same plant population. This may be more achievable in lower rainfall areas where lower seed rates are more commonly used.

MOIST SOIL DELVING TO INCREASE SOIL MOISTURE IN THE SEED ZONE

When the soil is sandy textured, it may be more practical, with a tined seeder, to use moist soil delving with deep winged points to lift moist subsoil into the seed zone and enable less risky establishment of crops with the existing subsoil moisture. More details of moist soil delving are shown in Blackwell and Parker (2003).

REDUCED DROUGHT STRESS; LOWER PLANT DENSITIES AND WIDE ROWS

Moisture supply to crops suffering mid season drought stress on shallow soils after early sowing and good early growth can be reduced by very wide rows and lower seed rates (Blackwell *et al.* 2006).

Trials in 2006 have found that less benefit and even yield loss can occur for wide rows and late sowings, especially on pasture without sown fertiliser (Glasfurd, 2007). Yield improvements to wider rows can be achieved by ribbon sowing (Blackwell *et al*. 2007), and presumably by paired rows with disc openers. Some growers are looking at wide row cereal sowing as an economic alternative to spray fallow by using shield sprayers to control grasses between wide rows.

CONCLUSIONS

Reduced risk of crop failure in a dry autumn after summer or early autumn rains of 50 mm or more should be achievable by:

1. Use of disc seeders instead of points to reduce soil drying.
2. Combinations of seed priming and water injection at rates of about 50 L/ha. With appropriate testing of priming time and some development of practical seed drying equipment. Perhaps rotary seed graders or augers could be adapted to dry primed grain to allow easy passage through an air seeder (Doug Abrecht and Lindsay Olman; pers. comm.). The practicality of drying primed seed needs investigating.
3. The use of low seed rates and wide (skip) rows for early sowing to minimise the drought stress risk for the established crop. Late sowing (June/July) should maintain normal row spacings unless it is part of a grass weed control strategy using shielded sprayers instead of chemical fallow.

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Paper reviewed by: Stephen Davies

Soil health constraints to production potential – a precision guided project

Frank D'Emden, Department of Agriculture and Food, Western Australia, Esperance and **David Hall**, Department of Agriculture and Food, Western Australia, Esperance

KEY MESSAGES

Yield variability across paddocks is one of the driving forces in the development of precision agriculture applications. Variable rate technology is being adopted by growers for fertiliser and gypsum applications, with rate decisions being based on yield maps and soil conductivity readings. Soil conductivity is one indicator that can provide guidelines for variable rate gypsum application on alkaline, sodic subsoils (Quenten Knight, pers. comm.). Infra-red technology is also being adopted by some growers and provides spatial data for variable rate nitrogen application.

Tailoring inputs to requirements is an important consideration in profit maximisation. In some cases, changes to land use on particularly difficult soil types may need to be considered. However, understanding the underlying soil constraints to yield potential and the relevant amelioration requirements is needed to further develop input optimisation and inform optimal land use decisions.

AIMS

This paper describes the development of a farmer driven project delivered through collaboration between the Department of Agriculture and Food, WA, the Esperance Regional Forum and the University of WA.

The primary goal of this project is to gain a better understanding of the soil health constraints to the potential productivity of soils in the Neridup catchment. Fourteen growers have selected paddocks with significant yield variability that cannot be explained solely by known factors such as waterlogging, pH or water repellence. Identifying which soil parameters (chemical, physical and biological) explain most of the variation in crop yields will be a key outcome from this project.

It is envisaged that the process used in this project will be extended to growers in the Young River catchment.

METHOD

Four layers of data will be used to identify up to seven soil sampling sites in each paddock: Yield-monitor and biomass imagery data (averaged over four years) on respective cropping and pasture paddocks; 2 cm digital elevation maps (DEM); Electromagnetic (EM) induction (apparent electroconductivity (EC_a) used as a proxy for soil salinity, sodicity and clay content) and regional soil landscape maps.

Site selection

Regional soil landscape maps will provide the initial, broadscale overview of how the paddock lies in the landscape and the types of soils that are expected to be observed in the paddock. Yield monitoring data and biomass imagery will be used to identify areas of consistently low productivity, with DEM information to be used to identify areas prone to waterlogging. Following the methods used in previous studies (Lesch *et al*. 2005) and current local applications, EM data will be used to further pinpoint sampling sites by providing indications of clay content.

Soil sampling and analysis

Soils will be sampled at 0-10 cm, 10-20 cm, 20-30 cm and 30-60 cm depth intervals. Analyses will be conducted to determine the biological, chemical and physical status of the samples. Biological factors will include microbial biomass carbon (MBC), MB C/N ratio, biological N supply, microbial activity, organic carbon, total C, labile C and disease status. Chemical factors will include cation exchange

capacity, EC, pH, macronutrients (i.e. N, P, K and S) and trace elements, Aluminium, Boron and P retention. Physical factors will include soil texture (% sand, silt and clay), plant available water, soil strength and bulk density.

Data analysis

Principle components analyses (PCA) and multiple regression will initially be employed to determine the significance of relationships between soil characteristics. PCA is a technique for simplifying a dataset, by reducing complex datasets with multiple units (e.g. EC_a, pH, mg/Kg, %OC etc) to lower dimensions for analysis. Subset regression will then be employed to determine the significance of different combinations (subsets) of soil characteristics on yield. For example, on low-lying clay-dominant mallee soil types, a small subset of characteristics (e.g. EC_a, subsoil pH and boron) may be significantly influencing yield, while on deep sandy soils it may be a small subset of different characteristics.

In order to illustrate the processes to be employed within the Neridup catchment, principle component analysis and multiple regression analysis between grain yields and a range of soil and geophysical parameters was performed for a sand plain paddock at Condingup. The 50 ha paddock is bounded by mature trees. From fifty points within the paddock crop yields and a range of chemical, physical and biological parameters were measured.

RESULTS

Principle component analysis biplots were used to initially assess the interrelationships between the various soil parameters and wheat yields (Figure 1). The vectors which are orientated in the same direction are likely to be positively correlated (YLD, trees_m, etc.). Conversely vectors in opposite directions are likely to be highly negatively correlated (i.e. MBC, U). Parameters which are oriented at 90 degrees to each other are unlikely to be correlated.(i.e. YLD, TC, etc.).

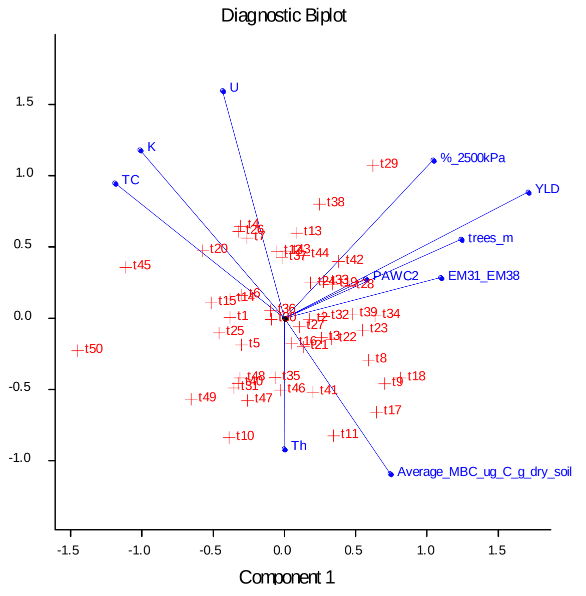

Figure 1. Biplot of soil and wheat yield parameters. The variable include (1) Wheat yield: YLD, (2) Plant available water: PAWC2, (3) Distance from trees – tree_m, (4) ECa: EM31-EM38, (5) Depth at which soil strength exceeds 2.5 MPa:- %_2500, (6) Microbial biomass: MBC, (7) Potassium isotopes: K, (8) Total Counts: TC, (9) Uranium isotopes: U and (10) Thorium: Th.

From the above plot those vectors orientated in a similar direction to crop yield (YLD) are soil strength (%_2500), plant available water (PAWC2), distance from trees (trees_m) and EM31-EM38.

Using multiple regression, four of the nine parameters measured were significantly correlated with wheat yield. These parameters explained 69% of the variation in wheat yields and are listed in (Table 1). The variable listed in Table 1 are the same as those determined using the Principle component analysis biplot.

Table 1. Multiple regression analysis between wheat grain yield and soil/biological parameters. Significance levels and date measured are included

Soil parameter	Estimate	Probability/significance	Date measured
Grain yield t/ha			2004
Distance from trees (m)	7.83	< 0.001	2004
Plant available water (mm)	58.82	< 0.001	2005
ECa (EM31-EM38) mS/m	378	0.001	1998
Soil strength. Depth at which strength exceeds 2.5 MPa	2.98	0.021	2005
Constant	-3,964	< 0.001	

It is clear from the above analysis that soil water was the key limitation to crop yields given that plant available water, distance from trees and soil strength explained 62% of the variation in crop yields. Seasonal conditions in 2004 were dry (Decile 2) hence a high correlation between crop yields and parameters which affect soil water availability is to be expected. Management options including root pruning of neighbouring trees and an investigation of deep ripping within the paddock would appear to be logical recommendations. Given that 40 % of the paddock exceeded the rainfall limited yield potential for 2004, it is unlikely that disease, weeds and nutrient deficiencies were a major limitation.

ECa (EM31-EM38) and crop yields were significantly correlated but explained only 6% of the total variation in yield. The specific mechanism for this correlation is not clear. ECa is a measure of the soils bulk electrical conductivity to depths ranging from 1 m (EM38) to 3 m (EM31). Subtracting EM38 from EM31 values focuses more on subsoil soil conductivity rather than topsoil. Salt, water and clay content will affect the ECa measurement and in combination will affect water availability to plants. This parameter may be useful in characterising the potential productivity of sandplain soils particularly where the depth to clay exceeds 1 m. However, further research is required to confirm the validity of this parameter.

CONCLUSION

Soil fertility (physical, chemical and biological) is fundamental to improved crop yields. Understanding which components of fertility are driving crop yields empowers land managers to make changes which will improve the profitability and sustainability of their farming system.

The use of statistical procedures for interpreting soils data is presented. The use of PCA and multiple regression is useful for determining the relationships between soil properties and crop yields. Based on this information presented, soil water availability, root growth and subsoil conditions have a large impact on crop yields. Recommendations for soil amelioration on consistently under performing areas can therefore be made as can directions for future research.

KEY WORDS

soil health, precision agriculture, land use change, soil amelioration

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Paper reviewed by: Andrew Van Burgel

A review of pest and disease occurrence in 2006

Mangano, G.P. and **Severtson, D.L.**, Department of Agriculture and Food, Western Australia (DAFWA)

KEY MESSAGES

Reports of pest and disease occurrence and their geographical distribution within the WA grainbelt are provided by contributors to the PestFax service throughout the growing season. The collation of this information into a recently developed database has provided a summary of the 2005 and 2006 reports. This review provides an opportunity for awareness, discussion and ongoing evaluation of changing pest and disease status under the influence of important factors such as seasonal variation/ climate change and varying farming systems.

Diseases with frequent occurrence and widespread distribution in 2006 were wheat stem rust, stripe rust and the new detection of Wheat streak mosaic virus (WSMV). The incidence of leaf spot diseases was less than previous seasons.

Invertebrate pests, including redlegged earth mites, cutworm, cockchafers, adult vegetable beetles, canola aphids and locusts, were reported in 2006 to be at damaging levels and above those recorded in 2005.

BACKGROUND

PestFax is an interactive information service on the diseases and pests which threaten crops and pastures throughout the grainbelt of WA. Weekly news updates during the growing season provide broadacre agribusiness with information on the plant diseases and insect pests which are currently posing a risk to crops and pastures. A large network of field agronomists, consultants, farmers and industry specialists provide weekly input. This in turn encourages researchers to respond to industry needs for information. This interactive input ensures that current pest and disease alerts, together with the best diagnostic and control methods, are provided to farmers and industry.

PestFax is able to alert all major cropping industry personnel of infrequent or unusual pest occurrence and to pass on research findings at a time of the season when it is required and most likely to be applied. Information on new or suspected biosecurity threats can be rapidly circulated allowing farmers and industry representatives to survey, identify and respond quickly to new challenges.

Seasonal variations can encourage a larger than expected effect from irregular or less well known diseases or pest species. Farmers can be alerted to these situations and have the opportunity to inspect crops and take the necessary control measures as required. The PestFax service provides an avenue for regular information on beneficial organisms, integrated pest management options and general pest and disease information not readily available through other information outlets.

Limitations

- Reports to PestFax of pest and disease incidence and regional distribution is solely from voluntary input and therefore relies on the good will of readers and participants. Reports are often limited to visually obvious symptoms (e.g. rust disease or caterpillars chewing crops) and are usually not as comprehensive on more obscure symptoms such as root lesion nematodes mild blackleg cankers and some viral diseases. Specific pests or diseases of less widely grown crops (e.g. some pulse crops) may not be reported as frequently as others. This does not indicate that the disorder is any less serious.
- Reports are often most reliable for the first seasonal appearance of a pest organism and less frequently reported when a pest or disease is commonplace in a locality.
- Reports are infrequently confirmed by diagnostic laboratory analysis due to effort and cost involved. However, a high level of confidence in the reports is assumed as the majority are from trained and experienced agronomists, DAFWA staff or other industry representatives.

AIMS

To measure the occurrence and locations of pest and disease incidence in the Western Australian grainbelt for the 2006 season. To make comparisons between seasons 2005 and 2006.

METHOD

A database has been developed to tabulate information received via the PestFax service. Reports are entered into a number of categories within the database including date, disorder and location. This information is then processed into summary reports.

RESULTS

Cereal diseases

Wheat rusts

The levels of wheat stem and oat stem rust were much higher than has occurred in previous years. A total of 77 reports (Table 1) of wheat stem rust in 2006 comprised of 38 cases of infections found on volunteer cereals from April to July. These reservoirs of the disease provided a source of infection which allowed transfer onto new season's crops in the Esperance and south coast, Great Southern and east-central wheatbelt areas.

The first case of stem rust infection on a sown crop was found on the 27 July. The find was unusually early for stem rust and most likely was aided by the unseasonal sunny and warm periods experienced in May, June and early July. Throughout 2006 there were 39 cases of stem rust reported in widely dispersed crops spread from southern areas (Jerramungup and Ravensthorpe) through to northern areas (Dalwallinu and Bindi Bindi) and across the entire central area as far west as Gingin.

The reported incidence of stripe rust in 2006 (82 cases) was greater than that recorded for 2005 (57 cases). Unlike leaf and stem rust no cases of stripe rust were found reported on volunteer crops. Stripe rust was first detected from two separate crops near Cascades in the Esperance region on 19 July 2006. The number of stripe rust infections increased steadily during August and rose to a peak in September (Table 1). The disease appeared to originate from sources in the Esperance and eastern wheatbelt areas and progress north and west through the rest of the season. Stripe rust was reported over extensive areas ranging from Badgingarra and Morawa in the North through to Great Southern and south coast districts.

Wheat streak mosaic virus (WSMV)

The first known cases of Wheat streak mosaic virus (WSMV) in WA were found in self sown wheat during April 2006 (Table 1) on two properties in the Esperance region and one in the Kondinin Shire. This was followed, in mid August, by the first known case of WSMV affecting a commercial wheat crop in WA, found near Merredin. A further eight cases, of WSMV were detected within a week of the initial discovery in an area centred on Merredin and ranging from Koorda to Kellerberrin and east to Moorine Rock.

During the remainder of the season, the virus was confirmed at further locations (33 reports) across an increasingly wide area from east of Esperance to Dongara, however, it was most frequently reported from the central agricultural area.

Reduction in disease incidence

Reports of leaf spot diseases (yellow spot/septoria) in wheat for 2006 were less than half those that were recorded in 2005 (Table 1). All reports of these leaf spot diseases were from central agricultural areas apart from two cases of yellow spot from the southern agricultural area and one from the northern area. A large reduction in the number of reports of root diseases also occurred.

Table 1. Cereal disease yearly comparison and 2006 monthly reports

	Disorders	Total 2005	Total 2006	Reports by month of growing season						
				Apr.	May	June	July	Aug.	Sep.	Oct.
Wheat diseases	Rust – Wheat Stripe Rust	57	82				3	27	48	4
	Rust – Wheat Leaf Rust	9	14	1	2	4		2	3	2
	Rust – Wheat Stem Rust	5	77	16	9	9	5	2	24	12
	Wheat Streak Mosaic Virus	0	36		3			1	30	2
	Powdery Mildew	14	11					5	5	1
	Yellow Spot	15	8				1	2	5	
	Septoria nodorum/tritici	10	6					1	5	
Barley diseases	Rust – Barley Leaf Rust	18	35	9	2	5	3	1	15	
	Powdery Mildew	18	13	1	2	3	1	1	5	
	Net Blotch (spot-type and/or net-type)	18	12		1		4	2	5	
	Scald	2	2		1			1		
Oat diseases	Rust – Oat Leaf Rust (Crown)	11	4						4	
	Rust – Oat Stem Rust		12	1	3			1	6	1
Root diseases	Root Lesion Nematodes (Cereals)	23	9					3	4	2
	Rhizoctonia Bare Patch (Cereals)	13	4					1	3	
	Cereal Cyst Nematodes (CCN)	3	1					1		
	Fusarium Crown Rot (Cereals)	1	2						1	1

There were also more than 30 reports of minor cereal diseases which are not presented in this paper.

Canola diseases

Fewer reports of the incidence of canola diseases occurred in 2006 compared to 2005 (Table 2). The single report of blackleg was from the Esperance area whilst the white leaf spot and downy mildew where both from crops within the Toodyay area. The low level of reporting does not imply that disease symptoms were absent in other canola crops but more likely that levels of infection were comparatively low.

Table 2. Comparison of canola disease incidence between 2005 and 2006

	Disorders	Total 2005	Total 2006
Canola diseases	Blackleg	5	1
	Root Lesion Nematodes (Canola)	5	
	Beet Western Yellow Virus	4	
	White Leaf Spot	2	1
	Downy Mildew (Canola)	1	1

Pulse diseases

Fewer reports of the incidence of pulse diseases occurred in 2006 compared to 2005 (Table 3). The case of brown spot on lupins was from the southern agricultural area whilst the other diseases were all reported from central areas.

Table 3. Comparison of pulse crop disease incidence between 2005 and 2006

	Disorders	Total 2005	Total 2006
Pulse diseases	Anthracnose (Lupins)	5	
	Bean Yellow Mosaic Virus (Lupins)	5	1
	Brown Spot (Lupins)	3	1
	Sclerotinia White Mould (Pulses)	4	
	Rust (Pulses)	2	
	Grey Mould (Botrytis cinerea)	2	
	Ascohyta Blight (Chickpea, *A. rabiei*)	1	
Root diseases	Root Lesion Nematodes (Pulses)	10	
	Rhizoctonia (Pulses)	12	2

Invertebrate pests

Table 4. Invertebrate pest incidence in 2005/06 with the 2006 monthly breakdown

	Pest	Total	Total	Reports by month of growing season						
		2005	2006	Apr.	May	June	July	Aug.	Sep.	Oct.
Seedling establishment pests										
Mites and Lucerne flea	Redlegged Earth Mites	23	33		17	11	5			
	Lucerne Fleas	26	16		2	12	2			
	Balaustium Mites	17	16		3	7	5			1
	Clover (Bryobia) Mites	15	14		6	8				
	Blue Oat Mites	7	1				1			
Caterpillars	Cutworms	2	15		1	12		2		
	Cockchafers	4	10		5	4	1			
	Pasture Day Moths	6	1			1				
	Pasture Webworms		1					1		
	Brown Pasture Loopers	3	2				2			
	Weed Web Moths		2		2					
Beetles	Vegetable Beetles	1	13		9	3		1		
	African Black Beetles		3		2		1			
	False Wireworms	2	1				1			
	Bronzed Field Beetles		1			1				
Weevils	Vegetable Weevils	3	5		2	2		1		
	Weevils (Other)	8								
	Desiantha Weevils	1	2				2			
	Small Lucerne Weevils	1	1		1					
Other	European Earwigs	1	4			3	1			
	Slugs	4	3		1	1		1		
	Snails	0	8		1	5	2			
Grain formation pests										
Caterpillars	Native Budworms	41	36						28	8
	Diamondback Moths	19	11			1			7	3
	Armyworms		2						1	1
Aphids	Aphids (Canola)	16	32			1	3	6	22	
	Aphids (Cereal)	26	10		4	2	1	1	2	
	Aphids (Lupins)	4								
Other	Locusts	2	155	10	13	1	1	2	51	77
	Rutherglen Bugs	3	15			7	6	1	1	
	Pea Weevils	6	3					1		2

Mites and lucerne flea

Redlegged earth mites were the most frequently reported invertebrate pest attacking crop seedlings in 2006 (Table 4). The first hatchings were reported from southern areas (Esperance, Kendenup Narrikup and Cranbrook) in late April 2006. Hatching in the central areas (Muntadgin, Westonia, Wickepin, Bodallin) were delayed until early June, and in western and northern central areas (Gingin, Bakers Hill) until July.

Clover (Bryobia) and Balaustium mite damage was reported at similar levels in 2006 and 2005. Both mites had an impact on late sown and moisture stressed crops with Balaustium mite having a continued impact into the cooler month of July. The observations of lucerne flea damage were reduced from that recorded in 2005.

Vegetable beetles

Adult Vegetable Beetles (*Gonocephalum* sp.) were reported as causing substantial damage to canola seedlings in southern agricultural areas including Wellstead, Needilup, Kendenup, Gairdner, Boxwood Hills, Frankland, Cascade, Scadden, Broomehill, Kojonup and even one report from Northampton. The beetles were troublesome in crops during mid May to early August with the timing of damage linked to the seedling growth stage/time of sowing. The 13 reported cases (Table 4) of vegetable beetle damage was a dramatic increase on previous years and demonstrated their potential increased pest status which had previously been considered low.

Aphids

Canola aphids were reported at least twice as frequently as in 2005 (Table 4). Many canola crops exceeded economic spray threshold levels of more than 20% of flowering spikes containing clusters of aphids. This occurred over widespread areas mainly in the central wheatbelt but also extended from Dalwallinu to Wagin and included parts of the Esperance region. The first recordings of rising aphid levels occurred on volunteer canola at Cuballing in early June and on bolting crops in mid to late July at Bruce Rock and Esperance. In contrast, the level of cereal aphid infestations during spring was markedly reduced from 2005 levels (Table 1) with few crops reaching spray threshold levels apart from two reported cases at Narrikup and Gibson.

Locusts

The presence of Australian Plague Locusts was widespread covering 66 shires with reports to DAFWA from 2,878 properties of some hatchings of locusts. Surviving adult locusts were present in April and May and caused concern to some growers prior to sowing and during emergence of their crops. The adult locusts had previously laid large numbers of eggs which hatched in spring.

The first hatchings occurred in late August in the Moora, Walebing and Kulin areas with the peak in hatchings occurring in late September/early October. Aerial and ground spraying operations were contracted by DAFWA on 986 properties to restrict the potential of the adult locusts forming large swarms that could fly into other agricultural and urban areas.

Other pests

Cutworms and cockchafers were of concern to some growers mostly in central and northern regions this was most likely related to the poor growing conditions (drought) and the inability of seedlings to grow and compete with the level of insect feeding damage. Rutherglen bugs were reported (Table 4) at much higher levels (15) than those for 2005 (3). Summer weeds followed by dry conditions during winter in many central and northern areas favoured Rutherglen bug survival. Their damage was increased with late sowings and paddocks of moisture stressed seedlings.

Abiotic disorders

Reports of frosts, waterlogging, nutrient deficiencies and other abiotic disorders were less than 2005 (Table 5). The season was however, distinctive in having one of the driest growing season rainfalls recorded (May to October) for many localities.

Table 5. Abiotic disorder comparison between 2005 and 2006 seasons

	Disorders	2005	2006
Abiotic disorders	Frost	28	1
	Waterlogging	1	
	Nutrient deficiency/Toxicity	6	1
	Other abiotic	20	3

Although rains in January–April offered the promise of good soil moisture reserves in most areas, the expected follow-up rain did not occur. A very late break in central and northern agricultural areas either prevented or delayed seeding and the subsequent emerging crops had slow growth rates with winter temperatures. South coastal areas, and especially Esperance, had a mostly good season; however this was spoiled by low levels of September finishing rainfall. Spring rains were also inadequate for many other areas and prevented crops from finishing well and resulted in high level of screenings at harvest. The Northern agricultural area was one of the hardest hit areas where grain deliveries were about 10% of average production. The lack of winter rain, along with a 'dry finish', meant that total grain production for the state was roughly halved when compared to 2005,

DISCUSSION AND CONCLUSION

The 2006 seasonal conditions, as expected, were a dominant influence on the impact of the pests and diseases reported. Comment on the pest and disease abundance was provided in issues of PestFax throughout the growing season by Pathologists, Entomologists, and industry specialists; a consensus view of these is presented in the discussion below.

Diseases

The increase in cereal rusts in 2006 compared with 2005 resulted from the abundant summer and autumn 'green bridge' host plants which increased levels of rust inoculum. Risk area forecasts were confirmed by many reports of self sown cereals harbouring rust from early January 2006 (Condingup and Scaddan) through to May and June over extensive eastern wheatbelt areas. Seasonal preparedness meant that timely fungicide applications were made in many areas, especially Esperance, which minimised the potentially damaging impact of the rust epidemics. The Rust Report (via the PestFax service) was valuable in alerting and updating industry to the presence and rate of spread of cereal rust. The full impact of stripe rust was reduced with the drought conditions experienced in many growing areas especially the northern grainbelt.

The extent of the outbreak of Wheat streak mosaic virus (WSMV) was rapidly determined by the Department with assistance from industry. The early decision that eradication was not possible has moved the response to this disease to management by growers. The overall impact of the disease under the WA environment is as yet unknown. Although complete crop failure occurred in one crop at Merredin, virologists anticipate that this will not be a typical situation. More information on the WSMV situation is available within the 2007 Crop Update proceedings.

The reduction in the incidence of some diseases in 2006 relative to 2005 has most likely resulted from the effects of the late break and low rainfall experienced over most of the State and drought conditions in the northern agricultural area.

Invertebrates

The late break and delayed sowing times in most areas meant that crops were at younger and more vulnerable growth stages during the cooler winter period when attacked by red-legged earth mites and other mite species. A continued lack of rain compounded the problem as moisture stressed plants had more difficulty competing with the mite feeding damage. The damage from clover (bryobia) mites and balaustium mites in southern agricultural areas were also increased with the prolonged dry periods limiting plant growth. A greater awareness of the difficulty of control for some mite species in southern localities has lead to increased rates of insecticide usage and prophylactic spraying. Indiscriminate usage of insecticides encouraged by low costs could lead to selection pressure and the longer term problem of mite resistance.

Localised areas of damage caused by vegetable beetles in southern agricultural areas during May and June is of major concern especially as the adult beetles were not previously considered serious pests and the many reports of insecticide failure (few registered) to provide adequate control. The damaging effect of the beetles is likely to have been advantaged by the long dry periods of warm sunny winter weather and poor seedling growth (most cases) under dry conditions.

Summer and early autumn rainfall in 2006, providing early green feed, is most likely to have favoured some invertebrate pests such as cutworm, cockchafers, beetles and weevils. Populations of these pests which survived until crops emerged, had a larger than expected impact.

The impact of Australian plague locusts was fortunately confined to relatively small crop areas during autumn establishment and spring grain fill. Locusts present in April and May generally caused minimal damage partly due to delayed seeding and dry cool weather conditions. During spring, the crops were mostly maturing before the locusts had reached their adult feeding damage potential. Immature locusts caused little damage as they more often preferred the open pasture areas (not the shadows within a crop canopy) where they can more easily regulate their body heat under average spring temperatures.

PestFax is widely distributed to over 1600 recipients throughout the WA grainbelt, however contribution of reports back into the service are mainly from agronomists, consultants and some DAFWA staff. The level of contributions will hopefully continue to grow and expand to provide an increasing network of information.

This review provides opportunity for awareness, discussion and ongoing evaluation of changing pest and disease importance. The variation between seasons is influenced by weather patterns and other factors which evolve over time such as farming systems (crop rotations, stubble management, etc.) and changing pest complexes. Trends in these influences may be seen as longer term PestFax data sets (including back to 1996) become available. The 2005 and 2006 data has, nonetheless, provided an interesting contrast and useful information.

KEY WORDS

disease, pests, invertebrates, 2006, PestFax

ACKNOWLEDGMENTS

Supporters and contributors of reports to the PestFax service are gratefully acknowledged for their efforts and consistency in providing information that has benefited the whole of the grains industry.

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Project No.: GRDC CSE 00029 – National Pest Initiative Project (NIPI)

Paper reviewed by: Bill MacLeod

e-weed – an information resource on seasonal weed management issues

Vanessa Stewart[1] and **Julie Roche**[2]; Department of Agriculture and Food, Western Australia, [1]Merredin and [2]Northam

KEY MESSAGES

- New features to be incorporated in 2007 include a regular section on 'what weed is that?'
- e-weed is keen to receive contributions from industry that can provide information on how best to use different herbicide products.
- Will continue to provide the latest research results throughout the year.
- If you want to be added to the database to receive e-weed please e-mail your contact details to: e-weed@agric.wa.gov.au.

BACKGROUND

e-weed is an electronic newsletter providing information on weed related issues throughout the growing season. It is a somewhat irregular newsletter, providing information on issues as they arise. Since becoming available electronically the number of editions has varied from eight to 18 editions in any given year of publication. The reason for this variation has been seasonal conditions and staff availability.

e-weed is compiled and edited by Vanessa Stewart. Contributions to each edition are largely from Department of Agriculture and Food researchers working on weed related projects. Regular contributions are also received from WAHRI and the CRC for Australian Weed Management. Contributions from anyone are both encouraged and very welcome, with editorial discretion.

CIRCULATION

e-weed is now sent directly to over 1200 recipients. This includes:

~ 630 growers;

~ 180 research and development;

~ 150 agribusiness (agronomists, resellers, etc.);

~ 90 chemical company (R&D, area managers, product development, etc.);

~ 50 farm consultants;

~ 135 Eastern States based agronomists, researchers, etc.

The database and circulation/distribution of e-weed is managed by Julie Roche.

CONTENT/ISSUES COVERED

Regular features

Integrated weed management – With the increasing prevalence of herbicide resistance throughout Western Australia (and the rest of the world) there has been a need to have a strong emphasis on integrated weed management (IWM). The message of the importance of integrating weed management technology other than herbicides into weed management strategies is reinforced through the publishing of articles and data on individual weed management technologies throughout the season. A key role of e-weed is to collate data for individual tactics from as a wide a range of sources as possible. While similar articles may be run each year they should have been amended and updated to incorporate the most recent research findings or farmer experiences.

Herbicide resistance – Frequent (unfortunately) articles on new resistance confirmations, resistance surveys etc. are included in e-weed. This is not to spread the bad news further but a reminder to be vigilant and aware that herbicide resistance has developed in many different weed species and

herbicides. It is easy to focus on annual ryegrass and wild radish – our two worst resistant weeds but there is the need to ensure that strategies are in place to minimise the risk of developing resistance in other common weed species (e.g. wild oats, barley grass, brome grass, turnips, mustards, etc.).

Herbicide tolerance – Regular articles outlining the herbicide tolerance of different crop varieties designed to ensure maximum crop production through appropriate herbicide x variety choice.

Weed biology – Understanding weed biology can improve our ability to manage weeds. Feature articles on weed biology, seedbank life, fecundity, germination pattern are included in e-weed.

Seasonally specific weed management advice – Information on how seasonal conditions may impact on the biological parameters of crop production and weed competition/fecundity. Additional information on how certain climatic conditions may influence the effectiveness of different weed control strategies (especially herbicides).

Product registrations – Articles on new product releases or registrations are included to keep people up to date with what herbicide options are available. Changes to product registrations are also covered. Appropriate information on registered herbicide options can assist with QA compliance.

Legislative/policy/regulatory issues – Recently WA has seen the review of pesticide legislation, the introduction to parliament of the Biosecurity and Agricultural Management (BAM) Bill and the APVMA decision to suspend the use of 2,4-D HVE. e-weed provides updates on these events to keep the broader community informed of the implications of these decisions/policies.

Industry events – e-weed can be used as a forum to advertise events (seminars, field days, field walks, conferences, etc.) where there is a strong focus on weed related issues.

Herbicide efficacy – No point in money being spent on herbicides if the product is not applied effectively. Increasingly, we are including information on how to 'best' apply particular products under a range circumstances. In 2007 this section will focus on getting herbicides to work better through increasing understanding of the factors that influence herbicide performance, including herbicide rate, adjuvants, water volumes, application technology, etc. In addition information on how to get the best out of 'older' products will be revisited.

SEASON 2007

This year it is planned to incorporate a number of new regular features these include:

'What weed is that?' – Photos or samples of unusual weeds are frequently sent to DAFWA for identification. This proposed segment of e-weed will feature these photos, with identification and information of the weed and where the knowledge exists on information on how to control the weed.

'In review' – Every year there are hundreds of paper published in scientific journals from across the world that better help us understand weeds and weed management. Not everyone has access to these journals or the time to peruse and read the articles published in them. This segment of e-weed will provide brief reviews/summaries of key articles to help get the information out there.

'***Favourite websites'*** – Increasingly the internet is becoming a key source of information. E-weed will feature and review 'favourite' or 'frequently' used web sites featuring of weed issues.

CONCLUSIONS

- If you want to receive e-weed please send your details to e-weed@agric.wa.gov.au or return the form available in your crop updates bag.
- Contributions and suggestions on issues to cover are very welcome please feel free to send them to e-weed@agric.wa.gov.au.

Paper reviewed by: Abul Hashem

Review of Pesticide Legislation and Policies in Western Australia

Peter Rutherford, BSc (Agric.), Pesticide Legislation Review, Office of the Chief Medical Adviser, WA Department of Health

AIMS

Ensuring that the Western Australian pesticides legislation and policies are robust, workable and nationally uniform.

Ensuring the continued development of a comprehensive regulatory framework for the safe and effective use of pesticides in Western Australia.

PURPOSE AND SCOPE OF THE REVIEW

In 2004, the Western Australian Pesticides Advisory Committee (PeAC) decided to conduct a Review of pesticide legislation and policies as part of its strategic planning. The reasons for this decision were that:

- the *Health Act 1911* itself was under review, and a public discussion paper on a general framework for the proposed new public health legislation provided an opportunity to 'test' its application to a range of pesticide issues;
- there was concern that control of use of pesticides in Western Australia was falling behind that of other jurisdictions;
- the Expert Advisory Panel into herbicide exposure of ex-Agriculture Protection Board weed sprayers recommended that steps be taken to reduce the fragmentation in the control of use of pesticides in WA;
- recent spraydrift incidents had highlighted deficiencies in the legislation; and
- the last review was over 10 years ago when the (then) National Registration Authority was formed to assume responsibility for pesticide registration.

TIMETABLE FOR THE REVIEW

June 2005	Review commences with the secondment of the reviewer from the Department of Agriculture and Food to the Department of Health.
September 2005	A Review of pesticide legislation and policies in Western Australia**-Discussion Paper** was released for three months for stakeholder and public comment. It canvassed a range of issues related to the control of use of pesticides in WA.
August 2006	Draft **Policy and Recommendations Report** was released for three month consultation period.
Early 2007	Draft **Policy and Recommendations Paper** will be finalised and submitted to State Cabinet for approval to implement the Recommendations, amend relevant legislation, and commence drafting the Codes of Practice. This process also includes stakeholder and community consultation

DISCUSSION PAPER

The Discussion Paper (see references) presents the key background, structural issues and operational issues investigated by the review.

Background

Provides a brief overview of the national and Western Australian arrangements currently in place to manage pesticides.

Structural issues

Policy issues that explore different options that the government could use to administer pesticides controls.

Operational issues

Impact directly on the use of pesticides, and the safety of the applicator, the bystander and the environment.

EXECUTIVE SUMMARY FROM THE POLICY AND RECOMMENDATIONS REPORT

The Policy and Recommendations Report (see references) presents legislative and policy platforms to regulate and support the safe use of pesticides in Western Australia. It has been developed from the issues canvassed in the 2005 Public Discussion Paper and the broad range of submissions received.

The Report makes ten Recommendations. The recommendations are underpinned by adopting the National Operating Principles of the National Registration Scheme as the objectives for a system of control of use of pesticides in Western Australia.

Recommendations 1 and 2

Recommendations one and two seek to establish a new legislative structure for the control of use of pesticides in WA, in which a comprehensive Code of Practice setting out the essential requirements in the handling of pesticides is called up, either in total or in part, by the legislation of the relevant State agencies.

A regulatory amendment to make the causing or risking of an adverse effect illegal will provide the legislative power for the general provisions of the Code of Practice.

This legislative model allows the agencies to continue to regulate their own area of interest and expertise, while the policy and technical information which supports the legislation will be available in the consolidated Code.

Recommendation 3

The third Recommendation is that the Code be developed and maintained by a central coordinating committee. The committee will replace the Pesticides Advisory Committee, and be more representative of the regulatory agencies and community stakeholders. This committee will also be responsible for the monitoring of pesticide use in WA and the coordination between agencies.

Recommendations 4 and 5

Recommendations four and five require the development of specific new regulations, in addition to those that call up the comprehensive Code of Practice. These are:

- Regulations specifying the circumstances in which off-label use will be permitted; and
- Licensing of the commercial Pest Control industry to continue under Health legislation but complemented by a specific consumer protection Code of Practice.

The remaining five Recommendations relate to operational issues covered in the Discussion Paper and which will be included in the comprehensive Code of Practice. These issues include:

- Mandatory training for commercial pesticide users.
- Spray drift prevention and management measures.
- Incident reporting.
- Waste disposal.

REFERENCES AND LINKS

Discussion Paper and the **Policy and Recommendations Report** are available as viewable/downloadable *pdf* files on Department of Health website.

www.health.wa.gov.au, click on Publications&Reports *(By Subject)* click on Poisons.

KEY WORDS

pesticides, control of use

ACKNOWLEDGMENTS

Paper reviewed by: Doug Abrecht

Future wheat yields in the West Australian wheatbelt

Imma Farré and **Ian Foster**, Department of Agriculture and Food, Western Australia;
Stephen Charles, CSIRO Land and Water

KEY MESSAGES

Climate change will likely result in higher temperatures and lower rainfall in the West Australian wheatbelt.

Future rainfall is likely to increase over summer and decrease during the growing season, especially over the autumn period.

Crop simulations with simulated climate data show future yields lower than current yields in most locations and soil types. Yield reductions will be greater on clay soils than on sandy or duplex soils. Future yields may increase in some high rainfall locations due to reduction in the level of waterlogging.

AIMS

Climate change projections for the mid 21st century for southern WA indicate an increase in temperatures, a decrease in rainfall and higher CO_2 concentrations. These changes could have adverse impacts on some agricultural systems, but they may also offer new opportunities (i.e. in areas where the risk of waterlogging may be reduced). The aim of this paper is to quantify the impact of climate change on the wheat production in the wheatbelt of WA. Downscaled climate data from a CSIRO Global Climate Model (GCM) was used as input into the APSIM-Wheat simulation model, in order to evaluate the wheat yields under future climate in a range of representative locations and soil types of the West Australian wheatbelt.

METHOD

The Cubic Conformic model (CCAM), which is a higher-resolution nested model of the CSIRO GCM MK3, was downscaled to provide daily climate data for current (1976-2005) and future (2035-2064) periods for different locations in the West Australian wheatbelt. Differences in future and current simulated rainfall was assessed in terms of monthly rainfall.

The APSIM-Wheat model was run with current and future climate data to simulate grain yield. The wheat model was run with two sets of climate data for 30 year periods: 1) current simulated climate for the period 1976-2005 with current level of CO_2 (350 ppm); and 2) future simulated climate for the period 2035-2064 with expected CO_2 level in the mid 21st century (440 ppm).

The APSIM-Wheat model simulates crop development (phenology), growth, yield, water uptake and nitrogen accumulation in response to temperature, radiation, day length, soil water and nitrogen supply. The model uses a daily time-step and is driven by daily weather inputs. It calculates the water-limited potential yield of the site, that is, the yield not limited by weeds, pests, and diseases, but limited only by temperature, solar radiation, water, and nitrogen supply at that site.

Simulations were run for eight representative locations and three soil types of the WA wheatbelt. The locations were chosen to represent the range of rainfall zones (high, medium and low) and agricultural regions (north, central and south) present in the wheatbelt of WA (Table 1). Three typical soil types of the area, a sandy soil, a duplex soil and a clay soil, with 59, 86 and 116 mm plant-available water, respectively, were chosen. Waterlogging effects on crop growth and yield were accounted for on the duplex soil. Simulations were performed for periods of 30 years assuming the soil was dry at 1 January each year. Sowing time was controlled by a sowing rule. Every year sowing occurred in the first sowing opportunity between 25 April and 31 July. A long season cultivar was sown if sowing occurred before 20 May, a medium season cultivar was sown between 21 May and 9 June, and a short season cultivar was sown after that date. Current management in the area was selected for the simulations.

Table 1. Selected locations, latitude, longitude, rainfall zone, agricultural region, average annual rainfall for the period 1976-2005 and 2035-2064

Location	Latitude	Longitude	Rainfall zone	Agricultural region	Annual rainfall 1976-2005	Annual rainfall 2035-2064
Merredin	31.48ºS	118.28ºE	Low	Central	353	329
Badgingarra	30.34ºS	115.54ºE	High	North	576	524
Dalwallinu	30.20ºS	116.43ºE	Low-Medium	North	386	355
Corrigin	32.33ºS	117.87ºE	Medium	Central	389	368
Wandering	32.68ºS	116.67ºE	High	Central	597	534
Lake Grace	33.10ºS	118.46ºE	Medium	South	367	336
Wagin	33.31ºS	117.34ºE	Medium-High	South	462	413
Esperance	33.83ºS	121.89ºE	High	South	664	622

RESULTS

The climate model used in this study simulated annual rainfall reductions of 5 to 11% across the eight locations studied for the period 2035-2064 compared to the period 1976-2005 (Table 1). Total annual rainfall reductions tended to be higher in the high rainfall locations than in the low or medium rainfall locations. In terms of rainfall distribution, the model simulated a small increase in summer rainfall (0 to 20% increase in rainfall in January to March period) (Figure 1). April to October rainfall is simulated to decrease in the future for all locations. The greatest rainfall reductions are simulated to occur in the period April to June (0 to 30% reduction) (Figure 1). Some of this decrease appears to come from a seasonal bias within the CCAM simulation of WA climate, and some of it comes from atmospheric response to higher CO_2 concentrations.

Given that the amounts of summer rainfall are usually small and highly variable, the increase in summer rainfall may have only a small contribution to higher stored soil water at sowing. The decrease in autumn rainfall will result in late sowing opportunities and therefore reduced expected yields. The decrease in April to October rainfall will result in increased crop water deficit, especially where water is already a limiting factor. The decrease in growing season rainfall will be positive in locations and soil types where excess water is currently causing waterlogging problems.

The impact of future climate expressed as percentage yield difference showed yield decline in most locations (Figure 2). However, there was a less than 5% increase in yields in Corrigin on the sandy and duplex soil and a 6% yield increase in Esperance on the duplex soil. Future yields increased on all three soil types in Wandering. Yield decline was in the range 10-13% on the clay soil in six locations. On the sandy and duplex soils yield decline ranged from 2 to 8%. The crop model simulated the effects of waterlogging on crop growth and yield on the duplex soil. In Corrigin, Esperance and Wandering yields increased in the future on the duplex soil, as a consequence of the reduction of the detrimental impact of waterlogging in the future. Among soil types, yield reductions were greater on the clay soil than on the sandy or duplex soils.

The yield decrease was due to lower rainfall and higher temperatures, which caused shorter growth duration and more water deficit in most locations. The lower rainfall in autumn caused delayed sowing, which caused a reduction in growth duration and increased chance of a more severe water deficit during grain filling. In most locations, the positive effect of increased CO_2 levels was more than offset by the negative effect of lower rainfall, delayed sowing and increased temperatures.

The yield increase in some high and medium rainfall locations was due to the positive effect of increased CO_2 levels and reduction of waterlogging effects.

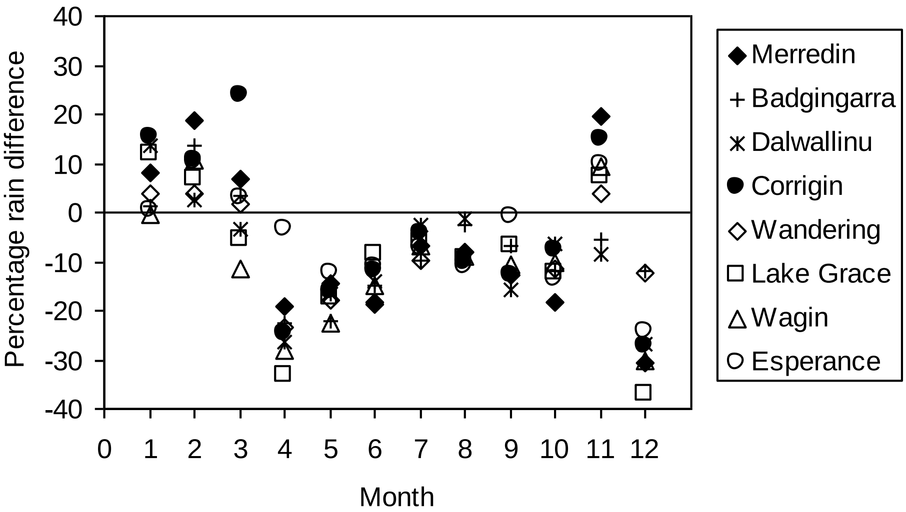

Figure 1. Percentage difference between future (2035-2064) and current (1976-2004) monthly rainfall for eight locations in the West Australian wheatbelt. Rainfall obtained from downscaled CCAM model.

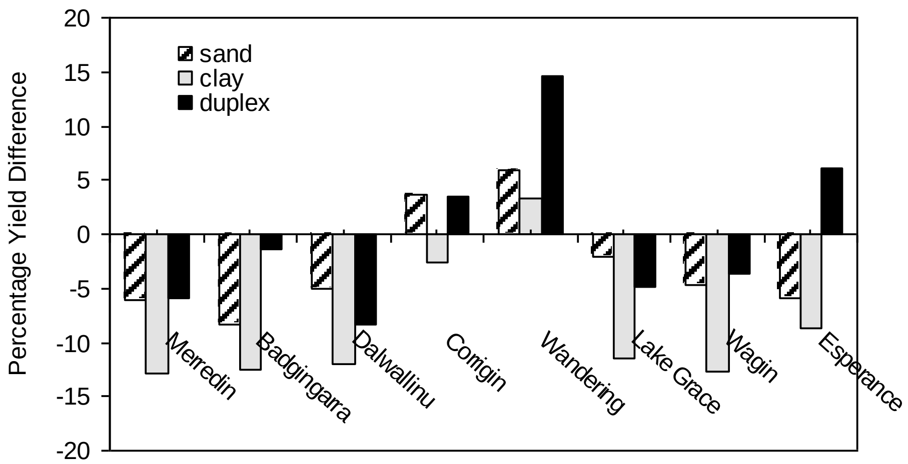

Figure 2. Impact of future climate on yield expressed as percentage yield difference between future and current simulated yields for eight locations and three soil types. Simulated climate obtained from the CSIRO CCAM model. Simulated yields with APSIM-Wheat model.

CONCLUSION

Prospect for future yields shows a consistent decline in the low rainfall zones and a yield increase in some high rainfall locations and waterlogging prone soils. Heavier soil types (i.e. clay soil) are more vulnerable to climate change than light textured sandy soils.

Adaptation will be needed to overcome some of the projected adverse impacts of climate change. Adjusting farm management (i.e. fertiliser management, cultivar choice) may counteract some the negative impacts of climate change.

Improvements to climate models are expected to add confidence to regional climate change projections.

KEY WORDS

climate model, APSIM-Wheat model, rainfall

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Organic matter in WA arable soils: What's active and what's not

Frances Hoyle, Department of Agriculture and Food, Western Australia and **Daniel Murphy**, UWA

KEY MESSAGES

- Soil organic matter is not all the same – it is composed of labile pools through to very stable pools. Total carbon is the sum of all these pools.
- The labile (particulate organic matter) carbon pool provides an energy source for biological activity, and is important in both nutrient cycling and soil structure.
- Labile carbon is sensitive to changes in management practices (changes within < 5 years).
- It is often difficult to measure changes in the total soil organic matter pool, whilst labile pools of carbon change relatively rapidly.

Our research focus has been to separate total soil organic matter into fractions that have chemical, physical or biological importance to soil maintenance.

DISCUSSION PAPER

Grain production is driven by availability of water – essential for plant growth – and nitrogen – the primary nutrient limiting crop production throughout the world. But the 'gearbox' for these 'drivers' is the matrix of soil micro-organisms on which all plants depend. Providing good physical and chemical conditions in the soil and labile (active) carbon as a food source is the starting point for increasing the mass – and often the diversity – of soil micro-organisms.

Sustainable management of soil, in particular soil organic matter (SOM), is essential for the continued viability of the WA agricultural sector. SOM plays a key role in C, N, S and P cycling and also acts to improve soil structure. Agricultural practices and plant inputs influence both the quantity and quality of SOM, which directly impacts on soil productivity, soil resilience and soil sustainability. A fundamental understanding of these active components of SOM is required to assist with the development of better farming systems.

The soil is composed of approximately 90-98% minerals and only 2-10% organic matter. Of the SOM present in soil, approximately 15% of this is 'living' (made up of roots, fauna and micro-organisms). Micro-organisms are the predominant component of this 'living' pool of organic matter and as they turnover rapidly (Table 1) are considered essential for organic matter decomposition and nutrient cycling, degradation of chemicals and soil stabilisation.

Table 1. Turnover times for fractions of organic matter and soil aggregate sizes (from Carter, 2001)

Type of organic matter	Estimated turnover time (years)
Organic matter in fractions	
Litter, crop residue	0.5-2
Microbial biomass	0.1-0.4
Macroorganic matter	1-8
Light fraction	1-15
Organic matter in aggregates	
Non-aggregated	1-7
Macroaggregates	1-23
Microaggregates	3-80
Organomineral particles	5-1000

In Western Australia (WA), although significant amounts of SOM are present in agricultural soils, some of the carbon is relatively inert (Figure 1) and is associated with highly weathered soils and historical burning. The labile pool of carbon is primarily influenced by 'new' organic matter (originating from plants and/or animals) contributed annually and has a significant role in nutrient turnover and supply. The contribution of this labile component to the total soil organic matter pool influences the biological fertility status of the soil – with a higher proportion associated with a more 'fertile' soil. In Figure 1, a range of soils have a measurable total soil organic matter pool of 10 t/ha (equivalent to 1.0% organic carbon at a bulk density of 1.0). However, the soil with 50% of its total soil organic matter present as a labile pool, suggests a more biologically active soil with greater potential for nutrient turnover than the soil with just 5% labile carbon (Figure 1).

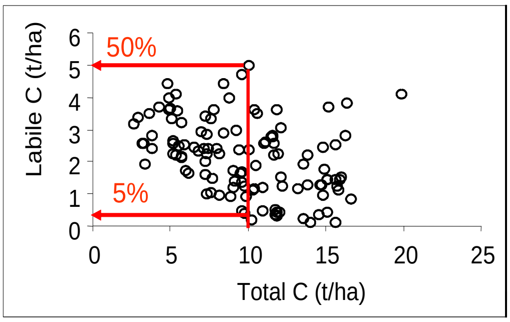

Figure 1. The quantity of labile carbon (t/ha) as a proportion of the total soil organic matter content (t/ha) in a range of arable soils from WA.

The extent to which mineral N and active components of SOM are release into the soil system depends on the rate at which above and below-ground plant residues decompose, their content of soluble materials and the interaction with decomposer communities and environmental conditions. The chemical composition and quality of organic residues have a major influence on the rates of decomposition from plant residues when added to soil (Cadisch and Giller, 1997). However, as the extent of organic matter decomposition increases, the C:N ratio decreases, and the material becomes both nutrient rich but also more resistant to further breakdown. Although factors related to the quality, quantity and placement of organic matter affects its rate of decomposition, in total, between 40 and 60% of organic carbon in crop residues and animal by-products added to soil is respired as CO_2 by micro-organisms and lost from the soil.

The capacity of micro-organisms to release plant-available N is influenced by the quality of organic matter inputs, with net release of nitrogen occurring where the C:N ratio of the labile SOM pool is below 22:1 (Figure 2). This data also illustrates that inputs of more recalcitrant residues (e.g. wheat stubble) can increase the ratio of carbon to nitrogen, resulting in net immobilisation of nitrogen from the soil, making it unavailable for plant uptake. Thus strategic fertiliser inputs are required to optimise N supply.

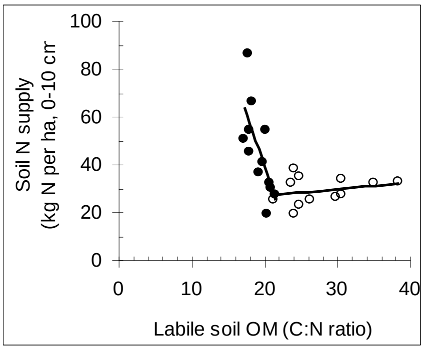

Figure 2. The relationship between the quality of labile carbon (C:N ratio) and soil nitrogen supply (kg N/ha) in a range of arable soils from WA.

CONCLUSIONS

- Information on the amount and quality of the labile carbon pool allows landholders to determine the likely impact of changing management practices on soil quality within a much shorter time frame than measuring total carbon in soil.

KEY WORDS

soil organic matter, labile carbon, micro-organisms

ACKNOWLEDGEMENTS

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Project No.: UWA395

Soil quality indicators in Western Australian farming systems

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INTRODUCTION

Agricultural management practices ultimately seek to optimise plant and animal productivity within the overriding constraints of both climate, and the capacity of the soil (physical, chemical and biological attributes) to support plant growth (Abbott and Murphy, 2003). Whilst optimal physical and chemical conditions of the soil for plant growth are often well defined, we have a much poorer understanding of the control that biological factors, particularly non-pathogenic associations, have on plant growth. The objective of this paper is to examine the relative contribution of soil biological attributes to crop production in Western Australian farming systems. Once these key attributes have been identified, management practices can be selected that take into account the potential for enhanced soil biological fertility and improved yield.

The grain production zone (wheatbelt) in Western Australia (WA) covers an area of more than seven million hectares (ha). Grain production is primarily restricted to areas where average annual rainfall is between 325 and 750 mm, the majority of which falls during the growing season (late autumn-late spring) in the south-west of Australia. Major soils in this region (Chromosols, Sodosols, Kandosols) are highly weathered with low surface clay and soil organic matter (OM) contents. The summer weather pattern is typified by hot dry conditions with infrequent storm events, largely restricting production to an annual winter cropping phase. Low winter rainfall and dry summers therefore constitute the primary constraint (environmental) to OM production and accumulation. A lack of new plant residues and root exudates to soil (as a carbon food source), as well as problems associated with desiccation over summer as surface soil temperature peaks above 40ºC, present significant challenges to the build-up of biological components in soil compared to temperate environments. However, this does not mean that soil biology is not important. Indeed, the Western Australian farming system is reliant on a cyclic pattern of biological activity which ‘explodes into action’ with rainfall and then slows at the onset of soil drying.

The relatively low growing season rainfall (GSRF) and the inherently low capacity of major soil types in WA to retain water and plant nutrients are realised in poorer crop growth. Low potential yields have thus resulted in relatively low input systems, and these systems are therefore more reliant on biologically fixed nitrogen (N) and OM decomposition to supply plant available nutrients and support crop production. In southern Australia for example, Angus (2001) calculated that on average 80% of crop uptake was supplied via biological processes, therefore the amount of N cycling through a Western Australian soil during the growing season can be more than enough to satisfy crop N demand (43-122 kg N ha^{-1}; Murphy *et al.* 1998), even where no fertiliser is applied. The exceptions to this are: (i) soils with a high leaching potential – which can result in the loss of both water and mobile nutrients below the rooting zone; and (ii) soils where microbial immobilisation of N out-competes plants for N availability (e.g. decomposing plant residues with high C:N ratio). Strategically timed or split fertiliser applications (generally. 20-80 kg N ha^{-1}) are therefore used to overcome the difficulties of matching biological nutrient supply with plant demand. Developing management strategies to improve asynchrony (i.e. microbial nutrient supply occurring when plant demand is low) and synlocation (i.e. plant available nutrients being located in the soil matrix where there are no plant roots) is often difficult but essential for future sustainable production (Murphy *et al.* 2004).

Identifying soil constraints to crop production

The average wheat grain yield (1960-1990) in WA (data from 62 shires) was 1.9 t ha^{-1}, with less than 5% of shires assessed in 1990 having reached 50% of their rainfall limited yield potential (Hoyle and Anderson, 1993). In our current research we have used the WA-Wheat model (Department of Agriculture and Food, WA), which has been developed as a front-end system for the APSIM model, to target districts that consistently under perform. To do this WA-Wheat was used to initialise (seeding date, varietal maturity, fertiliser application, actual rainfall, soil type) model simulations (1960-2001) on a shire basis for comparison against actual historical yields. Where potential yield is not achieved our approach has been to assume that this is the result of inappropriate management practices and/or soil physical, chemical or biological constraints to crop production (Figure 1).

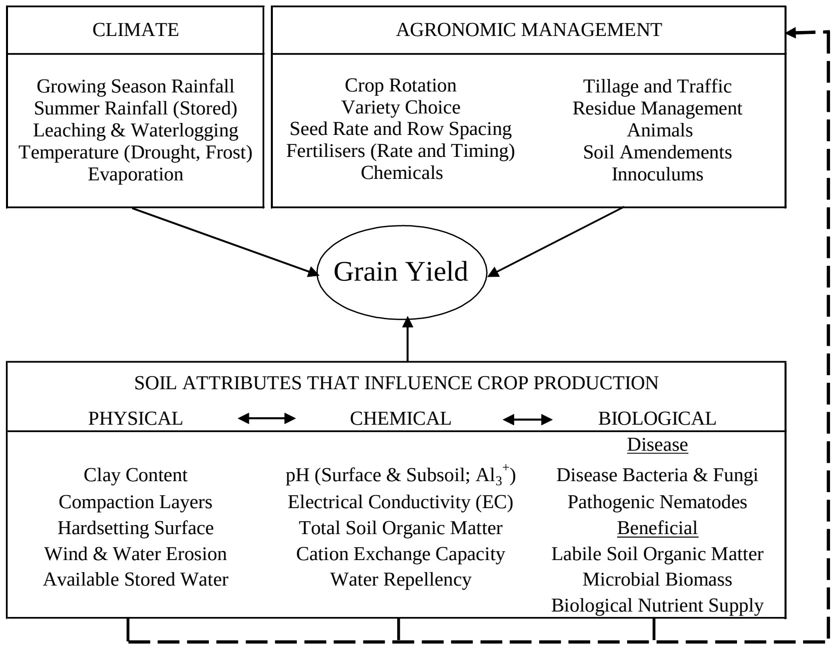

Figure 1. Climatic and agronomic factors along with key soil physical, chemical and biological constraints to yield production in Western Australian farming systems – A conceptual model.

Once soil constraints are identified their economic importance can be assessed (i.e. cost and practicality of removing the constraint versus potential yield benefit) prior to implementing changes in agronomic practice. This approach focuses on discrete soil attributes that: (i) have a known direct impact on crop production; and (ii) can be measured and interpreted in the context of management solutions. This approach provides an economic evaluation of 'cause' and 'effect', enabling prioritisation of high return solutions to overcome major agronomic and soil limitations instead of placing effort in further detailed site characterisation which is not feasible over a large scale.

ACKNOWLEDGEMENTS

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KEY WORDS

soil biology, soil quality

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Project No.: UWA395

Paper reviewed by: Matthew Braimbridge, Tamara Flavel

Impact of stubble on input efficiencies

Geoff Anderson, formerly employed by Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Retention of wheat stubble reduces soil nitrogen availability in the short term.
- The impact appears to occur in the first month after cultivation.
- NCAL (CSIRO, Land and Water, Nitrogen Calculator) is a useful tool for studying the process.

AIMS

Wheat stubble retention is an important soil conservation practice in the wheatbelt of Western Australia. Currently, one of the issues, impacting on the adoption of stubble retention practices by farmers, is the potential adverse impacts this practice has on nitrogen fertiliser, trifluralin herbicide and fungicide requirements. Recent developments in tramline farming with the use of accurate GPS (2 cm) have now made it possible to establish accurate tramlines. These techniques have the potential to improve stubble management and increase nitrogen (N) fertiliser, trifluralin herbicide and fungicide efficiencies. Inorganic nitrogen, nitrate and ammonium, is the form of soil nitrogen taken up plants. Soil nitrogen immobilisation, or the conversion of inorganic nitrogen to organic nitrogen, occurs when wheat stubble is incorporated into the soil. The measurements collected were used to examine the ability of NCAL to predict the extent of immobilisation of soil inorganic nitrogen by retained wheat stubble.

METHOD

Stubble treatments

Stubble treatments were established at harvest in 2004 and included the treatments:

(1) windrow system (cut low and stubble wind rowed and wind row burnt);
(2) burning system (cut high and burnt);
(3) retention system 1 (cut high and retained); and
(4) retention system 2 (cut low, spread out and retained).

Management treatments

An omission type experiment was conducted in 2005. These treatments evaluated nitrogen fertiliser, trifluralin herbicide and fungicide responses for the different stubble management treatments. This was achieved by comparing the biomass or grain yield of the treatment where all inputs where applied to the treatment when one input is removed. Nitrogen in the form of Flexi-N was applied at a rate of 50 kg N/ha. There were two nitrogen treatments. The main treatment was banding of N below the seed during the seeding operation. The second treatment was surface application of nitrogen using Flexi-N applied using a boom spray immediately before seeding at site 1. While at site 2, top dress nitrogen was applied in the form of urea a week before seeding. The trifluralin treatment 1.5 L/ha were also applied using the boom spray. At site 1 this was done with the nitrogen application. While at site 2 the treatments were applied separately.

The management treatments are:

(1)	Control:	- nitrogen,	- trifluralin	– fungicides	(-N-T-F);
(2)	Banded N:	+ nitrogen banded,	+ trifluralin,	+ fungicides	($+N_B$+T+F);
(3)	Topdress N:	+ nitrogen topdress,	+ trifluralin,	+ fungicides	($+N_T$+T+F);
(4)	Minus N:	- nitrogen	+ trifluralin,	+ fungicides	(-N+T+F);
(5)	Minus trifluralin:	+ banded nitrogen,	- trifluralin,	+ fungicides	($+N_B$+T+F); and
(6)	Minus fungicide:	+ banded nitrogen,	+ trifluralin,	- fungicides	($+N_B$+T+F).

Site details

The experiment was undertaken at two sites with different soil types. A yellow loamy earth, located near Bruce Rock on the Lewis family farm (site 1) and a calcareous loamy earth located near Mukinbudin on Mr John Shadbolt's farm (site 2).

At site 1, wheat stubble was derived from both 2003 and 2004 crops due to the 2004 wheat crop being sown within the inter rows of the 2003 wheat crop. The 2005 wheat crop was sown using a row spacing of 42 cm and wide points. After seeding most of the stubble was retained on the soil surface within the inter row.

At site 2, wheat stubble was only derived from the 2004 crop. The wheat crop was sown across the previous seeding row using a row spacing of 30 cm and knife-points. This resulted in stubble incorporation into the soil during seeding.

The season broke on 1 May 2005. This resulted in significant weed (ryegrass and radish) germination prior to seeding that was controlled by the application of roundup (glyphosate) and spray seed (paraquat and diquat). The sowing dates of the experiments were 28 May at site 1 and 1 June at site 2. Post seeding radish control was achieved by application broad leaf selective herbicides. These seasonal conditions and herbicide applications resulted in site 1 having high but variable levels of rye grass density. While site 2, had very few rye grass plants even before the application of knock down herbicides. Basal fertiliser application included 8 kg P/ha, 17 kg K/ha, 10 kg S/ha, 0.11 kg Zn/ha, 0.19 kg Cu/ha and 0.011 kg Mo/ha were top dressed at both sites 2 weeks before seeding.

Soil nitrogen supply

The soil capacity to supply inorganic nitrogen was determined by measuring the soil profile inorganic nitrogen content, to a depth of 0.9 m, at the break of the growing season and the amount of net mineralisation over the growing season (Anderson *et al*. 1998a,b). This study was done only using soil samples collected from management treatment 1 (nil inputs) and stubble treatment 1 (windrowed stubble) with soil samples collected off the windrow.

At each site three replicate, 50 mm soil cores to 900 mm depth were divided into 100 mm increments. Replicate samples from each soil layer at a site were combined and ammonium and nitrate N content were measured using the procedures outlined in Anderson *et al*. (1998b). Net soil nitrogen immobilisation and mineralisation was measured using the soil incubation technique described by Anderson *et al*. 1998a. Three replicate soil cores were collected from one replication of the windrow stubble treatment. These cores were then transferred and incubated in the ground near the weather station on the Merredin research station. Three sampling periods were used with the starting date of 21 June and finishing date of 5 October during 2005 (Table 3).

RESULTS

Seasonal conditions

The annual rainfall in 2005 was 320 mm at site 1 and 257 mm at site 2. The growing season was characterised by higher than average rainfall during May (60 mm), average rainfall during June (78 mm), August (50 mm) and September (29 mm) and below average in July (13 mm). Stubble characteristics and wheat stubble levels (t/ha) were measure in April 2005 (Table 1). It is hypothesised input efficiencies will be influenced by the amount and particle size of the stubble. As a result the stubble was divided into three groups, long, medium and short.

- The long stubble group had straw lengths of 10-20 cm for the cut low treatment and 20-30 cm for the cut high treatment and contained material that did not pass through a 4 mm sieve.
- The medium stubble groups had straw lengths 2-10 cm and contained material that did not pass through a 2 mm size sieve.
- The short stubble group had straw lengths of less than 2 cm contained material that did not pass through a 1 mm size sieve.

Wheat stubble levels were up to 6.6 t/ha at site 1 and 4.7 t/ha at site 2 (Table 1). The higher amount of stubble at site 1 was due to retention of stubble over two years. Wind rowing of stubble reduced levels by 36%-47%. Burning of stubble reduced levels by 81% at site 1. Cutting stubble low reduced the long fraction by 26% and increase medium and short fraction amounts at site 2.

Table 1. Measured wheat stubble levels (t/ha) for the long, medium and short stubble groups at the three sites

Treatment	Wheat stubble group			
	Long	Medium	Short	Total
Site 1				
Wind rowed	3.3	0.6	0.3	4.2
Burnt	0.5	0.5	0.3	1.3
Retained cut low	4.2	1.8	0.6	6.6
Site 2				
Wind rowed	1.3	0.6	0.4	2.3
Retained cut high	3.0	0.8	0.5	4.3
Retained cut low	2.4	1.4	0.9	4.7

The C:N ratio was greatest for the long stubble group (143-162) and least for the short stubble group (54-73) (Table 2). Wheat stubble contained up to 13 kg N/ha at site 1 and 11 kg N/ha at site 2. The carbon content of the stubble was 1946 kg C/ha at site 1 and 983 kg C/ha at site 2.

Table 2. C:N ratios of wheat stubble levels and nitrogen and carbon content (kg/ha) for the long, medium and short stubble groups at the two sites

Site	Measurement	Wheat stubble group			Total/
		Long	Medium	Short	Average
Site 1	C:N ratio	162	121	73	119
	kg N/ha	9.6	2.3	1.6	13.5
	kg C/ha	1551	277	119	1946
Site 2	C:N ratio	146	56	54	85
	kg N/ha	4.2	4.4	2.4	11.0
	kg C/ha	606	250	127	983

Soil nitrogen supply

Total inorganic nitrogen was calculated to be 77 kg N/ha at site 1 and 131 kg N/ha at site 2 assuming a bulk density of 1.2. Net immobilisation of 5 kg N/ha was measured at site 1 in the first period (21/06/05 to 28/07/05) after cultivation (Table 3). At site 2 greater incorporation of stubble at seeding would have contributed the higher level of net immobilisation of 12 kg N/ha. In subsequent sampling periods there was net nitrogen mineralisation. Rates of net mineralisation were lower (4-11 kg N/ha) over the August sampling period compared to the September sample period (23-28 kg N/ha). Total net mineralisation was measured to be 33 kg N/ha at site 1 and 15 kg N/ha at site 2 (Table 3). Net nitrogen mineralisation is related to soil carbon (Anderson unpublished data). Therefore, higher rate observed at site 1 is due to the soil having a higher soil carbon levels (1.2%) compare to site 2 (0.8%) and lower amounts of net immobilisation. It is important to note these measurements are a net result of mineralisation and immobilisation. The actual turn over of nitrogen by the processes of immobilisation mineralisation at the sites will be greater than the net measurements indicated.

Table 3. Net mineralisation (kg N/ha) measured for the windrow stubble treatment at the two sites during 2005

Period	Site 1	Site 2
21/06/2005 – 28/07/2005	-5.5	-12.0
29/07/2005 – 1/09/2005	10.6	4.2
5/09/2005 – 5/10/2005	27.7	23.2
Total	**32.8**	**15.4**

The impact of wheat stubble retention on soil nitrogen availability is determined by the following factors (Baldock 2005):

- Amount of stubble (kg/ha).
- Proportion of wheat stubble removed by harvest procedure or grazing.
- C:N ratio of the stubble; and
- Proportion of stubble C that is mineralised which depends on the above.

The proportion of stubble carbon that is mineralised refers to the stubble carbon that is given off as carbon dioxide due to micro-organism decomposition. When stubble is incorporated into the soil, experiments have measured 50% to 70% of wheat stubble carbon as being respired by the micro-organisms during the growing season. When carbon in the form of wheat stubble is retained, immobilisation of soil inorganic nitrogen occurs. This is because soil organic matter has a C:N ratio of 10-15 while wheat stubble has a ratio of 70-170. For the C:N ratio of the soil to be maintained, the conversion of soil inorganic nitrogen to organic nitrogen by the process of immobilisation is required.

A major feature of the current harvest and cultivation systems is wheat stubble can either be retained on the soil surface or incorporated into the soil (Photograph 1). When the stubble is retained on the soil surface it has poor contact with the soil and is considered to be inactive or removed from the decomposition process. Preventing the contact of the stubble with the soil will reduce the amount of carbon respired, especially in the short term, resulting in reduced inorganic nitrogen immobilisation.

Table 4. Calculated (NCAL) impact of incorporation of various stubble fractions on predicted amounts of nitrogen immobilised (kg N/ha)

Sites	Stubble management	Stubble retained (t/ha)	Predicted N immobilised (kg/ha) when stubble fractions are incorporated in the soil		
			S	S + M	S +M + L
Site 1	Windrowed	4.2	2	6	28
	Burnt	1.3	2	5	9
	Retained cut low	6.6	4	16	45
Site 2	Windrowed	2.3	2	4	9
	Retained cut high	4.3	2	5	17
	Retained cut low	4.7	4	9	19

S is short fraction, M is medium and L is long stubble fractions.

The predicted impact, using NCAL equations, of incorporating the various stubble size fractions into the soil is presented in Table 4. This equation makes a calculation on the amount of growing season net immobilisation. The amounts of nitrogen immobilised are calculated to be small, less than 4 kg N/ha, when only the short stubble fractions is considered to be incorporated into the soil. When the short and medium stubble fractions are incorporated into the soil nitrogen immobilised increased up to 16 kg N/ha. Finally, when all stubble fractions are incorporated into the amount soil inorganic nitrogen immobilised can be up to 45 kg N/ha.

Immobilisation was observed to be greater for the first sample period following stubble incorporation at site 2 compared to site 1 (Table 3). This occurred even thought site 1 had more retained stubble than site 2. The amount of immobilisation measured in the first period (Table 3) corresponds to the predicted immobilisation for the incorporation of the short and medium stubble fractions at site 1 and all the stubble fractions at site 2 (Table 4). These findings indicate three important points:

- First, careful management of wheat stubble is required when non-legume crops are grown in the presence of wheat stubble due to the large potential for incorporated stubble to immobilise soil nitrogen.
- Second, because the current cropping system has the ability to retain stubble on the soil surface it would appear appropriate to include an additional term in NCAL to account for the amount of stubble sitting on the soil surface
- Third, stubble management at harvest can have an impact on stubble characteristics (Table 1 and 2) that in turn influence rate of nitrogen immobilisation.

The soil's inorganic nitrogen supply to the growing wheat plant is calculated by adding initial soil profile content to net mineralisation. This amount was calculated to equal 110 kg N/ha at site 1 and 146 kg N/ha at site 2. These levels are similar to those, 120-165 kg N/ha, observed by Anderson *et al*. (1998b). However, the environment conditions in terms of rainfall and soil characteristics are different between the two studies. In the study by Anderson *et al*. (1998) the rainfall is high but variable, 294-703 mm, and the soil had a low water holding capacity 54 mm/m. In this situation 15-60 kg N/ha or 23-76% of soil's inorganic nitrogen supply was leached below the plant roots and 33-69 kg N/ha and only 33-64% of the soil's inorganic nitrogen supply was taken up by wheat. In contrast, in the current study the annual rainfall was 294 mm and the soils have higher water holding capacity between 50-150 mm/m. In this situation it is unlikely the soil's inorganic nitrogen supply would be leached below the rooting zone.

Crop production

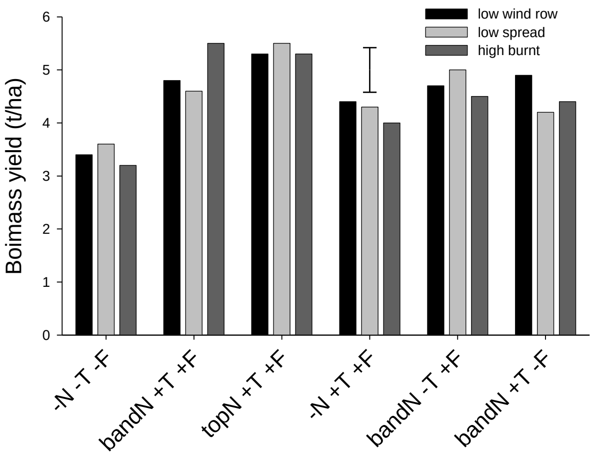

Figure 1. Wheat biomass yield (t/ha) measured for various treatments at site 1 in November 2005.

At site 1, grain yield was affected by a number of frost events thus biomass yields measured in November are presented in Figure 1. Biomass yield were significantly affected by management treatments but not by stubble treatments. Highest biomass yield was obtained for the top dress nitrogen plus trifluralin plus fungicide treatment. Top dress nitrogen was 7% more effective than banded nitrogen for biomass production (comparison between treatments 2 and 3). When nitrogen was banded ryegrass control with trifluralin gave a 5% (comparison between treatment 2 and 5). The response to seed-applied jockey fungicide was 10%, comparison between treatment 2 and 5. The combine response to the three inputs or comparison between treatment 2 and 1 was 37%.

At site 1, rye grass density ranged from 0-1.5 t/ha for the minus trifluralin plots across the site. This uneven distribution of rye grass resulted in a relatively small response to application of trifluralin. There was an inversed relationship between ryegrass biomass (x) and wheat biomass (y), $y = -1.12x + 3.95$, $r^2 = 0.69$. Thus when 1 t grass rye biomass /ha was presence wheat biomass was reduced by 28% of maximum biomass production 3.95 t/ha compared to 2.83 t/ha.

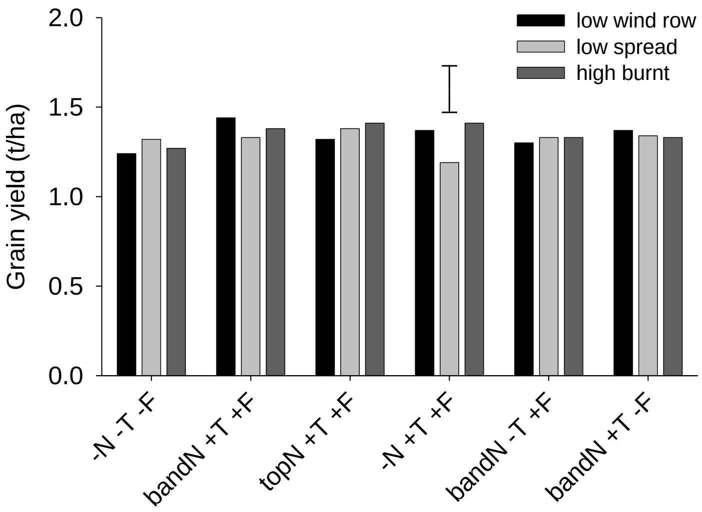

Figure 2. Wheat grain yield (t/ha) measured for the stubble and management treatments at site 2 in November 2005.

At site 2 stubble or management treatments had no effect on grain yield (Figure 2). Wheat grain yield was observed to range between 1.2-1.4 t/ha. Incorporation of 1.3 t wheat stubble /ha resulted in 12 kg N/ha immobilisation. However, the reduction in yield was small due to relatively high levels of inorganic nitrogen (146 kg N/ha) and the relatively low wheat grain yield. No response to trifluralin application is consistent with the observation that the site contained only a few ryegrass plants. Also the disease pressure would also have been low due to the relative low rainfall growing season rainfall of 257 mm.

Anderson *et al*. (1998a) showed a wheat crop with a biomass yield of 3.6 t/ha contained 36 kg N/ha and gave a grain yield of 1.6 t /ha which contained 29 kg N /ha in the wheat grain. At site 1, the biomass yield was 4.2 t/ha for the –N + T + F treatment, average across stubble treatments. This biomass is estimated to contain 42 kg N/ha or the wheat plant had taken up 38% of the soil's inorganic nitrogen supply. The nitrogen cycle is complex and detailed experimental measurements are required to accurately define the cycle for specific conditions in terms of both climate and soil types Anderson *et al*. (1998a,b). Estimates of removal of the soil's inorganic nitrogen supply are considered to be low, assuming that there was no leaching lost of nitrogen. Recent research has been conducted in both the high (Anderson *et al*. 1998a, b) and medium rainfall zones (Fillery and Poulter 2006). The lesson learnt and the techniques developed from these studies mean it would be relatively easy to develop a project with the aim of quantifying the components of the nitrogen cycle in the low rainfall cropping zone of Western Australia.

CONCLUSION

The stubble treatments had no effect on biomass yield and grain yield at either site. In contrast, management treatments (nitrogen, trifluralin and jockey) increased yield when biomass production was greater than 3.0 t/ha. Also responses to trifluralin and jockey occurred when rye grass and disease were present.

Current harvesting and cultivation systems, which retain wheat stubble on the soil surface within the inter rows can reduce the effect of stubble on nitrogen immobilisation. However, there is a potential for this retained wheat stubble to have a large impact on soil nitrogen availability when wheat stubble levels of greater than 1.5 t/ha are cultivated into the soil (Table 3).

KEY WORDS

wheat stubble, input efficiencies, nitrogen, trifluralin and jockey

ACKNOWLEDGMENTS

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Project No.: DAFWA Farming System Project

Paper reviewed by: Bill Bowden

Mixed farming vs All crop – true profit, not just gross margins

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KEY MESSAGES

Gross Margins aren't good enough to make decisions on the most profitable farming system for a farm business. Operating profits per hectare and the return on productive assets are more relevant measures and take into account the full costs of each enterprise. Increasing input costs and herbicide resistance are reducing the profitability of high crop percentage systems. Farmers need to check their own operating profit figures, as good grain legume yields alone are not a good indication on their own that the rotation in use is the most profitable available. Many farmers in the low rainfall zone may well be more profitable by moving to a lower crop percentage.

AIMS

The aim of this study was to compare the profitability and key features of farm businesses using a 'Mixed Farming' system (i.e. crop and pasture phases) versus businesses using a 'Full Crop' system (i.e. no pasture). We are aware that a number of indicators suggest that farms in the wheatbelt of Western Australia need to move to a lower crop percentage to remain profitable. Research conducted by the Birchip Cropping Group, modeling done by the Department of Agriculture and Food and modeling done by ourselves, indicates that rotations which involve a pasture phase appear to be as profitable as intensive crop rotations, with a lower risk, particularly on farms with a mix of soil types rather than a straight sandplain block.

METHOD

The study looked at the past and current profitability of a selection of clients from the Low, Medium, and High Rainfall zones. These clients were separated into 'Mixed Farming' (40-60% Crop) and 'Full Crop' (90-100% Crop). The farms were compared across rainfall zones and we have looked at the variability across seasons. The future profitability was assessed by increasing costs in key areas such as fertiliser, fuel, and machinery costs, and examining the effect of changes in commodity prices.

The analysis uses real data rather than the output from farming system models. The analysis examines the profitability, investment levels, cost structures and productivity of these farms and highlights the differences between the two systems.

The impacts of poor seasons were examined with two years out the last five seasons being well below average. This provided a better understanding of the risk profile of the different farming systems. The analysis yields a better understanding of the likely impacts of the changing external environment on these farm businesses and what farming system may be better placed to handle these changes, and how these systems may need to change.

BACKGROUND INFORMATION

Setting the scene

There have been a number of significant influences on the average cropping percentage of our clients over the last 20 years.

Reserve Price Scheme

In the late 1980s high wool prices, supported by the Reserve Price Scheme, artificially inflated the profitability of the pasture phase in the Wheatbelt and a common rotation on medium soil types was two years pasture followed by one wheat crop then back to pasture. On some of the heavier soil types many growers were starting to utilise medics and this would traditionally be a one year medic pasture followed by wheat and then returned to a medic pasture. A number of clients had been using a

lupin/wheat rotation on their sandier soils, with good results. There was some fallowing still being employed in the Eastern Wheatbelt, however this was becoming less common. Cultivation prior to seeding was still quite common, and a few more conventional clients would also 'work back'.

In February 1991 the Reserve Price Scheme for Wool was suspended due to the build up of a stockpile following a slow down in demand and the reserve price being set too high. The slump in wool prices that followed the suspension of the Reserve Price Scheme saw a shift to a higher crop percentage in much of the wheatbelt. With the low wool price, lupins were pushed onto less suitable soil types. Often the first crop of lupins would produce a reasonable result due to very little disease pressure however, once these paddocks were taken to a second lupin phase the yields started to decline rapidly. The risk with lupins on these less favorable soil types was found to be much higher than on the sandplain and there was some years when yields were as low as 0.2 to 0.4 t/ha.

Other grain legumes

In the early 1990s many of our clients with medium to heavy soil types where trying to set up rotations which used alternative grain legumes; field peas, faba beans, albus lupins, chickpeas and lentils. However it was soon obvious that these rotations only worked well on the best of the heavy soil types which had high pH and high clay content, and a wetter than average season. Lack of reliability and problems with management of diseases, reduced the area of these crops although field peas has started to make a comeback with the more erect cultivar of Kaspa. I do see some potential for chickpeas into the future with the better disease tolerance to Ascochyta Blight as new cultivars emerge from the breeding programs.

Herbicide resistance

Through the early 1990s many growers were starting to see the first signs of herbicide resistance. This was having a significant impact on the intensive rotation of wheat and lupins and we also started to see some decline in lupin yields in this rotation due to disease pressure. The first move was to extend the rotation and have two cereals followed by a lupin phase. This helped to reduce the disease impact and increased the profitability of the rotation, which allowed the rotation to remain profitable until the late 1990s.

In the late 1990s the impact of herbicide resistant ryegrass was being felt particularly on long term wheat/lupin rotations. The profitability of the lupin phase was being reduced by the in-crop competition from the large numbers of ryegrass that could not be controlled by grass selective herbicides. The rotation overall was still profitable due to the good wheat and barley prices and the control of the ryegrass seed set with a technique called 'crop topping'. FARMANCO was responsible for taking a client's observation and turning it into a valuable tool for reducing ryegrass seed set in lupins and other grain legumes. This technique is considered standard practice now, but it does reduce the profitability of the grain legume phase, through additional costs, and some yield penalties.

Ryegrass also started to impact on wheat and barley crops with loss of efficacy from 'Fop' selectives and sulfonylureas on many ryegrass populations. FARMANCO pioneered the use of high rates of trifluralin as a PSPE (post sowing pre-emergent) treatment then moved to IBS (incorporated by sowing) with the emergence of better minimum tillage equipment. The ability to use high rates of trifluralin was the single biggest reason for our clients adopting minimum tillage seeding equipment through the late 1990s.

TT Canola

Triazine Tolerant Canola was first thought to be a major weapon in the battle against herbicide resistant ryegrass but unfortunately has not proven to be a good management tool in seasons with a patchy start. Poor seasons have produced large losses and poor ryegrass control for many clients in the low rainfall zone. Canola does have a place if we get a nice wet start to the season and good follow up rains. Then the high rates of atrazine used in TT Canola can produce good ryegrass control. Unfortunately we have not received many of those sorts of seasons, particularly in the last five years. What TT Canola has done though, is provide an excellent component of a common rotation in the medium to high rainfall areas; pasture for two years followed by canola then wheat. The great thing about this rotation is the removal of the need to manipulate pastures in the year before the crop. This phase has the double benefit of maintaining a higher stocking rate and reducing the costs in the second year of pasture.

There are a few high rainfall farmers who are using a Canola, Canola, Canola rotation to boost their profit levels. The potential failure of this rotation and the repercussions for the whole industry is a major concern but these growers are making good profits at this time.

The graph below shows that many of these effects have been felt Australia wide, with wheat and coarse grain areas increasing, however pulses and oilseeds have been decreasing over the last five years. The total crop area has increased indicating an increase in crop percentage.

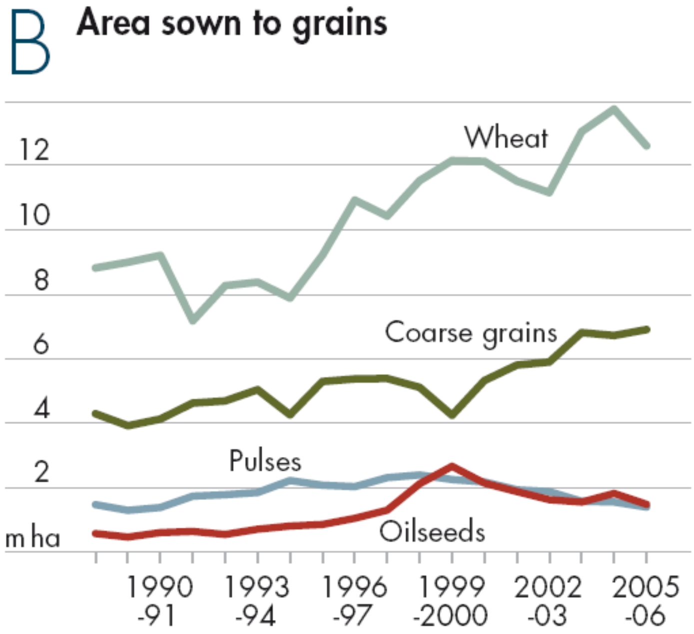

Figure 1. Crop areas in Australia.

Source: ABARE (2006).

With this background we now find the West Australian wheatbelt with a broad range of farming systems, from the extremes of complete cropping all the way back to complete livestock. The farming systems need to change when the components of that system changes. These changes can come from the external environment, such as climate and prices, and can also be affected by the attitude and abilities of the people managing the system. The questions from our clients are “what is more profitable?” and “what is less risky in variable seasons?”. We hope to provide some insight into those questions through the following analysis.

Operating profit not gross margins

When looking at the profitability of different enterprises over the long term it is critical that you use Operating Profit rather than Gross Margins. Gross Margins are useful for making decisions over a short time frame when the machinery and infrastructure are already in place. Over the long term however it is possible for an enterprise with a high gross margin to have a lower operating profit because of the extensive machinery or infrastructure required for that enterprise. The fixed operating costs that are taken off after the Gross Margin level are: i) business overheads; ii) an allowance for replacement of machinery and infrastructure; and iii) a management allowance. This provides you with what we have called operating profit and is also commonly referred to as EBIT (earnings before interest and tax).

The biggest difference between cropping and livestock ‘fixed operating costs’ is the machinery replacement cost or depreciation. To put this into perspective, one large broad acre ‘machinery unit’ or ‘tractor unit’ which comprises, a large 4WD tractor and air seeder, a 30 metre boom spray, and a large capacity header can be used to crop an area of around 2,000 to 3,000 hectares in the central wheatbelt. If a client has a farm of 6,000 hectares, he will need two tractor units for an ‘All Crop’ farming system, or one tractor unit for a 50% Crop or ‘Mixed’ farming system. The capital tied up in a ‘tractor unit’ can vary from $500,000 to $1,000,000 depending on the age of the equipment. The machinery required to run 8,000 ewes on the other 3000 hectares is around $50,000 to $75,000.

There is a difference in the infrastructure required for livestock and cropping, but machinery sheds, fertiliser storage, and grain storage matches the replacement of shearing sheds, fences and water supply required for stock. The repairs and maintenance is higher for livestock infrastructure and in our analysis these costs are included in the livestock variable costs, which is included in the calculation of a gross margin.

Many young farmers talk of the management ease of cropping relative to livestock. This doesn't relate to a difference in the cost of management, but is a lifestyle choice that an owner can make. If this choice is made it should be recognised that it may come at a cost to the business.

What about the cost of stocking 3,000 hectares? The sheep required to stock 3,000 hectares would be $250,000 to $500,000 depending on market prices. The good thing about a ewe is that once they are worn out, they can reproduce a replacement for themselves then you can sell them. The costs of replacing stock are therefore calculated prior to the gross margin level. It would be nice if the header would spit out a replacement in its last year of operation!

The table below shows the profitability of the components of common rotations in the central wheatbelt and also shows how we arrive at an Operating Profit and a Return on Productive Assets which is a key profitability measure in the study.

Table 1. Rotation profit for an average client in the Central Wheatbelt

	Wheat	**Lupins**	**Sheep**	**WWL**	**WP**
Crop %	100%	100%	0%	100%	50%
Land value (inc. infrastructure)	$1,000	$1,000	$1,000	$1,000	$1,000
Machinery	$400	$400	$110	$400	$255
Sheep ($40/DSE = $60/ewe)			$200		$100
Productive assets	$1,400	$1,400	$1,300	$1,400	$1,355
Yield t/ha stocking rate DSE/ha	2.2	1.2	5.0		
Price $/t income/DSE	190	200	42		
Income $/ha	418	240	210	359	314
Variable costs $/ha	218	190	110	209	164
Gross margin $/ha	200	50	100	150	150
Overheads $/ha	25	25	25	25	25
Machinery $/ha	50	50	10	50	30
Infrastructure $/ha	6	6	6	6	6
Management $/ha	30	30	30	30	30
Total operating fixed costs	111	111	71	111	96
Total operating costs	319	301	181	320	263
Operating profit (EBIT)	89	(61)	29	39	59
Return on productive assets (no capital growth)	***6.4%***	***-4.4%***	***2.2%***	***2.8%***	***4.4%***
Funding cost @ 8.5% (Op. costs for 6 mths, machinery and livestock fully funded)	48	47	34	48	41
Net profit – before tax (EBT)	41	(108)	(5)	(9)	18
Return on land value (no capital growth)	***4.1%***	***-10.8%***	***-0.5%***	***-0.9%***	***1.8%***

The first thing to note about the above analysis is the low levels of profit on a dollars per hectare basis, and how this translates into very poor returns on current land values. With some farmers paying this price and considerably more for land at the moment, suggests they either believe the profitability of agriculture is going to suddenly improve, or they are happy to make a low return on their investment.

The lupin operating profit needs to increase by $72/ha, which would be an extra 0.4 t/ha, to beat the wheat/pasture rotation. Therefore, the breakeven yield for a lupin crop to match a 5.0 DSE/ha pasture is 1.6 t/ha not the 1.2 t/ha that a gross margin analysis would suggest.

By intensively measuring the profitability of enterprises, (right down to a paddock basis for some clients), we are able to show many clients that the legume component of their intensive crop systems is making a significant loss, which couldn't be made up through the remainder of the rotation. What we discovered through this analysis was that although livestock enterprises based on clover pastures weren't producing an operating profit, a small loss for pasture was significantly less than the loss being sustained through the grain legume phase. Our analysis also showed there was a huge range of profitability of livestock enterprises and that often good livestock managers were not the best crop managers or didn't have suitable soil types for grain legumes. Often the most profitable move was for our clients to reduce the grain legume content of their rotations and to increase their pasture percentage.

Farm system models

Modeling using the Midas model developed and regularly updated by the Department of Agriculture and Food (Kingwell and Pannell 1987; Kingwell 2002; O'Connell *et al.* 2006) shows that for an average set of commodity prices and average production for an average mixed soil type farm that the optimum area of crop is between 50 and 80% and that the theoretical optimum is around 65% for the Central Wheatbelt.

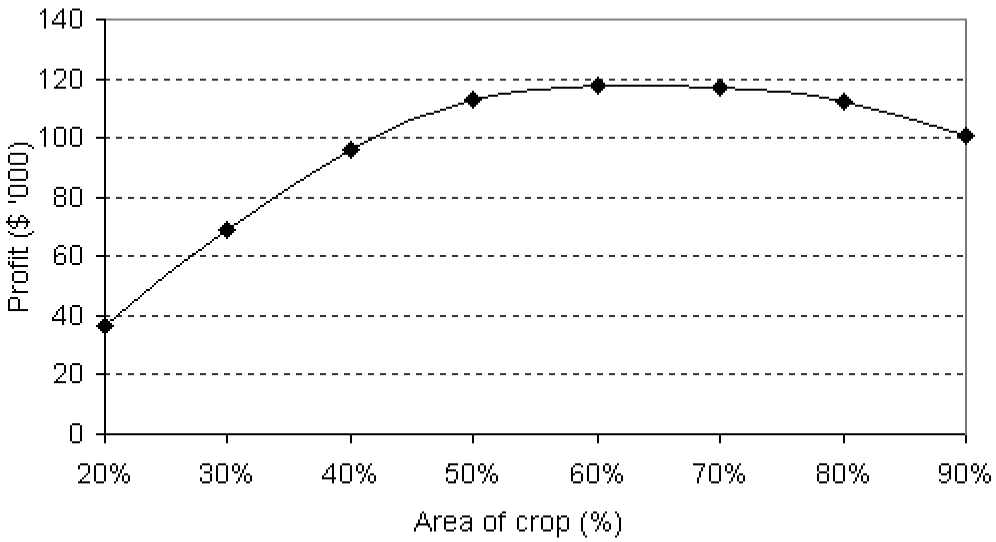

Figure 2. Standard MIDAS output for the Central Wheatbelt Model.

The Great Southern model normally shows that increasing your area of crop results in a drop in profits.

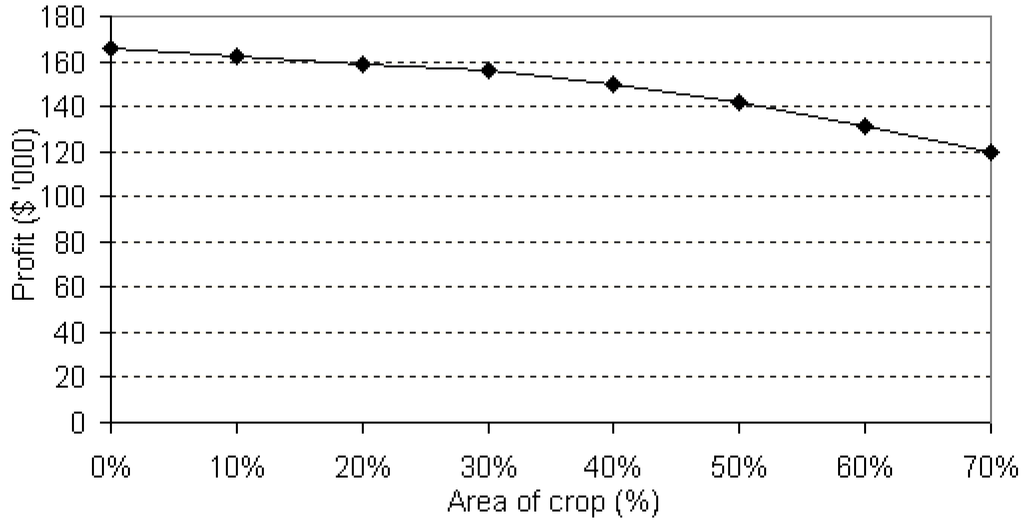

Figure 3. Standard MIDAS output for the Great Southern Model.

When the Great Southern model used a range of commodity prices which have been experienced in the past then we can see that the reality for even the Great Southern is that the optimum crop percentage will change with the change in commodity prices and the relativity between those commodity prices. Obviously with low wool prices and high grain prices together with good yields, we would expect the optimum area of crop to increase.

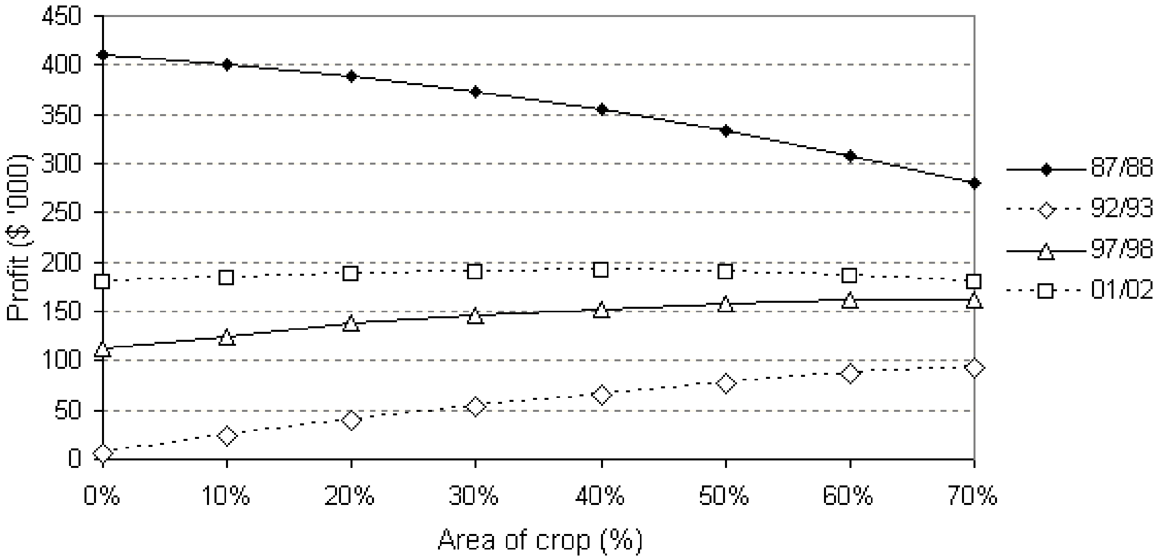

Figure 4. MIDAS output for the Great Southern Model using historical prices.

ABARE data in Figure 4 below uses Farm Cash Income, which we have shown will favour the higher crop percentage farming systems. However the graph still shows that while lower crop percentage systems have been well behind the high crop systems through the 1990s, the gap has closed in the last five years.

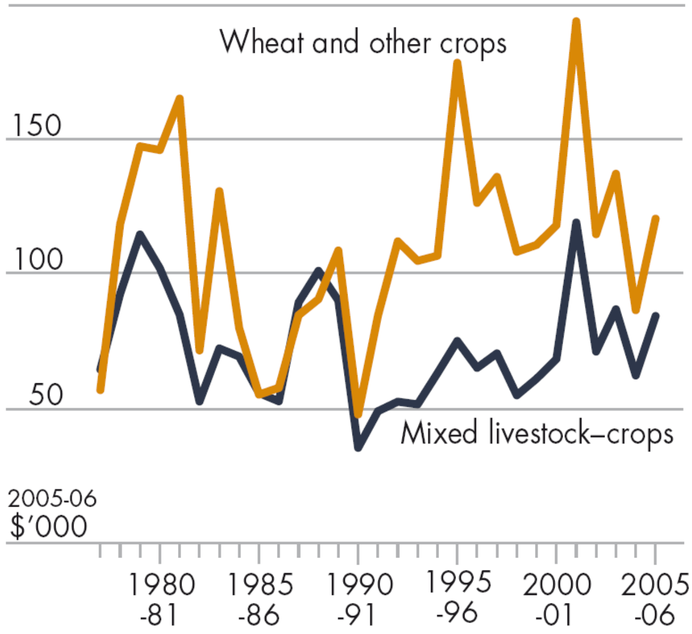

Figure 5. Farm Cash Income – Grains Industry.

Source: ABARE (2006).

The Birchip Cropping Group set up a long term trial in 1999 to look at different farming systems. The systems are described below. It is worth noting that the most profitable system was the 'Hungry Sheep' which aims at 70% crop and used pastures or sown oat crops when necessary to maintain

high stocking rates, and only used pulses when the season suited. The poorest performer was the 100% crop and a philosophy of no sheep. Being a slave to an idealistic grain legume based rotation cost this system a lot of money through the poor performance of the grain legumes in poor seasons.

Table 2. Results from the Birchip Cropping Group Farming Systems Trial – 2000 to 2005 seasons

System	Fuel burner	Hungry sheep	Reduced Till	Zero Till
	Cereals, Fallow, Pasture and limited pulses	Cereals, Pulses and Pasture	Cereals, Oilseeds, Pulses, some pasture	Cereals, Pulses, Oilseeds, No Livestock
	60% Crop	70% Crop	80% Crop	100% Crop
Income	212	366	225	184
Variable costs	127	269	142	148
6-yr av. GM	**85**	**98**	**82**	**37**
Fixed machinery cost	**44**	**37**	**37**	**35**
Profit before mgmt, overheads, infrastructure, interest and tax	**41**	**61**	**45**	**2**

Source: BCG (Birchip Cropping Group) (2006).

RESULTS

Operating profit

Examining actual operating profits of 290 of our clients shows there is no strong relationship between cropping percentage and the five year average arable enterprise operating profit in dollars per hectare. This diagram clearly shows that for any level of cropping percentage there is a large range of profit levels. The factors which contribute to this range, such as soil types and management can be greater than the effect of crop percentage.

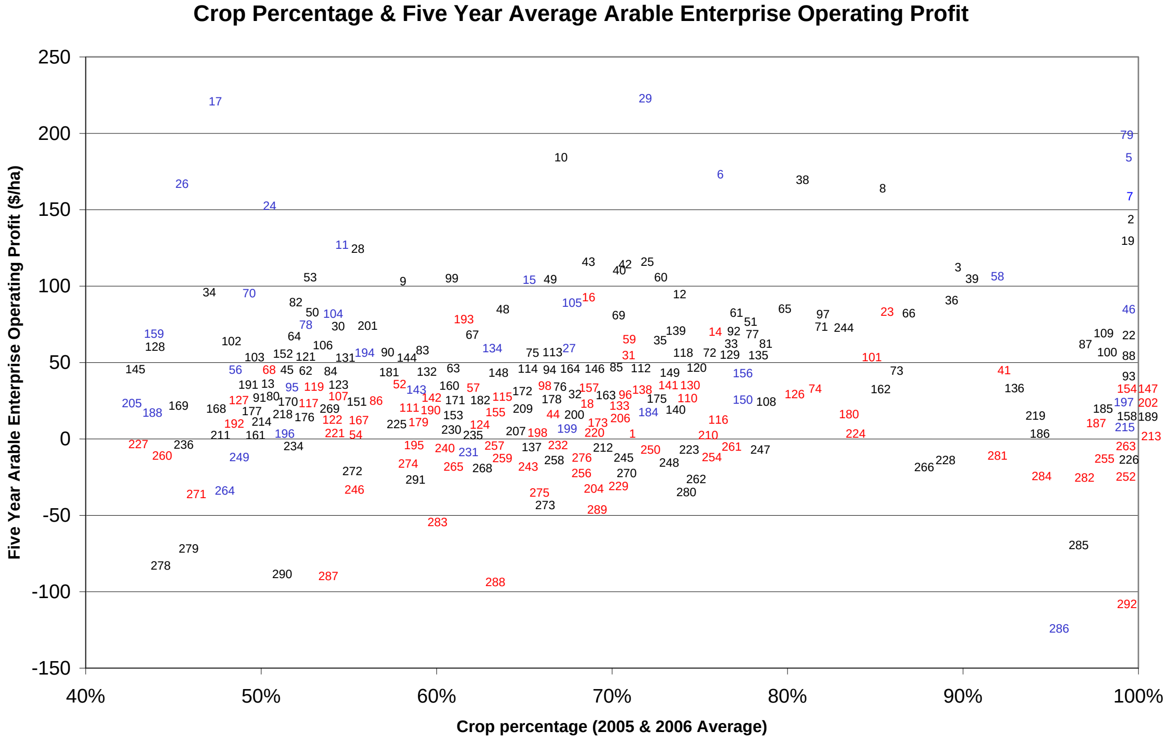

Figure 6. Individual data points for the FARMANCO Profit Series.

The average FARMANCO client can be compared against all Australian broadacre farm businesses. The ABARE figures for the grain industry shows that even the ABARE 'grain specialist' at 48% crop has a significantly lower crop percentage than the average FARMANCO client at 65%. The FARMANCO average client's equity percentage is well below the average of the grain industry and slightly below the grain specialist. While it does appear that our clients have a considerably higher total debt level at $799,000 compared to the grain industry of $321,000, when we compare it on a dollars per hectare operated basis, then our average client's $117/ha is slightly below the ABARE grain specialist at $145/ha. This analysis highlights the issue of looking at total debt rather than net debt. What we have noticed within our client base is that there is a considerable amount of liquid assets which includes grain equities, FMD's (Farm Management Deposits), and credit funds, which offsets the significant debt.

Looking at the components of farm income it is interesting to note that although the ABARE grain specialist has a significantly lower crop percentage, that over 76% of farm income is generated from cropping compared to our client average of 71%. FARMANCO clients are slightly more wheat focused with 48% of income coming from wheat compared to the ABARE grain specialist at 44% and the only other significant difference is that the combined area of pulses and oilseeds for our clients at 10% is double the ABARE grain specialist of 5%.

Our clients have a higher crop percentage, but also a higher percentage of income from livestock at 20% compared to the ABARE grain specialist at 15% and the ABARE industry average at 27%. The ABARE 'grain specialists' are based on Australian averages and the drought conditions in the Eastern States has had a big impact in recent years.

Table 3. ABARE vs FARMANCO clients

Parameters	ABARE grain industry	ABARE grain specialist	FARMANCO client
Area operated	1950	2036	3226
Crop percentage	36%	48%	65%
Equity	88%	84%	82%
Debt	$321,101	$457,452	$799,382
Liquid assets	$183,659	$162,590	$422,368
Net debt	$137,442	$294,862	$377,014
Net debt $/ha	70	145	117
Components of farm income			
All crops	63%	76%	71%
Wheat	36%	44%	48%
Barley	10%	12%	12%
Other crops	2%	3%	2%
Pulses	1%	2%	5%
Oilseeds	5%	3%	5%
Sheep sales	11%	7%	10%
Wool	8%	4%	7%
Cattle	8%	4%	3%
Other enterprises	19%	21%	8%

It is worth noting that the ABARE description of their farming systems is different from our descriptions. Their grain specialists with an average crop percentage of 48% being closer to our mixed farming enterprise and their mixed enterprise with a cropping percentage of only 25%, being in line with our 'livestock dominant' system. The table below shows how the ABARE groups line up with our definitions.

Table 4. How the ABARE definitions line with the study definitions

ABARE farming system	Crop %	FARMANCO farming systems	Crop %
Grain specialists	48%	All crop	90%+
		Combination	71%-89%
		Mixed	40%-70%
Mixed enterprise	25%	Livestock dominant	< %40
Grains industry average	36%	Client average	65%

An overview of the FARMANCO data set is listed in Table 5. The FARMANCO client base is biased towards the medium rainfall zone and away from the high rainfall zone with 54% in the medium rainfall zone and only 17% in the high rainfall zone.

This study looks at data from the 'All Crop' and 'Mixed' Farm Systems. We have removed the 'Combination' category from this analysis as we are focusing on the differences in businesses with different crop percentages. We have also removed the livestock dominant group as we want to look at pastures within a crop rotation rather than permanent pastures. It is important to note that only 10% of our client base runs an 'All Crop' system, and in the high rainfall zone it is only 4% which is only two clients.

Table 5. The FARMANCO data set

Farming system	Crop %	Low	Medium	High	All rainfall zones
All crop	90%+	9 (10%)	19 (12%)	2 (4%)	30 (10%)
Combination	71%-89%	41 (48%)	54 (35%)	20 (41%)	**115 (39%)**
Mixed	40%-70%	34 (40%)	67 (43%)	15 (31%)	116 (40%)
Livestock dominant	< %40	2 (2%)	17 (11%)	12 (24%)	**31 (11%)**
Total		**86 (29%)**	**157 (54%)**	**49 (17%)**	**292 (100%)**

Rate of return on productive assets

The rate of return on productive assets over the last five years in the Australian grains industry has been a rollercoaster of good returns in 2001, poor returns in 2002, good returns in 2003 and then relatively poor returns in 2004 and 2005 and it looks like 2006 will be another poor return on the current forecast (see Table 6).

The Western Australian ABARE data has less variation than the national data however the same pattern exists. It is worth noting that the Western Australian average over the last five years is significantly more than the Australian average. The 2006 year may well be the worst result in recent history, both nationally and in WA.

Comparing the ABARE 'Grain Specialist' versus the ABARE 'Non Grain Specialist' it can be seen that there is a greater amount of variation for the 'Grain Specialist' but the average return of 2.9% is above the 'Non Grain Specialist' at 1.9%.

For FARMANCO clients the average is 3.6%, only just above the ABARE WA average of 3.4%. However the magnitude of the variation from year to year is significantly more with the good years of 2001 and 2003 providing returns of 12% and the 2002 year -4%.

Comparing the 'All Crop' and the 'Mixed' farm systems shows that both farming systems had a particularly good year in 2001. In 2002 the 'All Crop' clients suffered a significantly larger loss than the 'Mixed' clients. In 2003 the 'All Crop' group performed extremely well with a return of 17% versus the 'Mixed' clients at 11%. The 'All Crop' average was only 0.1% above the 'Mixed' group, and we believe that in 2006 both groups will suffer significant losses and that the 'All Crop' magnitude of the loss will be slightly higher than the 'Mixed' which could well mean the 6 year average would be equal or favour the 'Mixed' clients.

The conclusion from this data is that the average profitability of the 'All Crop' clients is very similar to the average of the 'Mixed' clients but the variation between years is significantly more for the 'All Crop' clients. The lower variation will translate to lower risk for the business particularly when the business is stretched financially from a land purchase, or some other major funding requirement.

Table 6. Rate return on productive assets by years

Year	ABARE Australia	ABARE WA	ABARE grain sp.	ABARE non sp.	FARMANCO all clients	FARMANCO study group	
						All crop	Mixed
No.					292	30	116
2001	7.5%	5.0%	7.5%	4.4%	12%	15%	13%
2002	-0.3%	2.0%	-1.5%	0.1%	-4%	-10%	-2%
2003	3.2%	5.7%	5.5%	2.4%	12%	17%	11%
2004	1.1%	2.1%	1.1%	1.7%	0%	0%	0%
2005	1.4%	2.0%	2.0%	1.0%	1%	0%	0%
5 yr av.	**2.6%**	**3.4%**	**2.9%**	**1.9%**	**3.6%**	**4.5%**	**4.4%**
**Coeff. of Variation	117%	55%	123%	85%	175%	258%	160%
*2006 F	-1.0	-0.1%					

* ABARE Forecast.

** Coefficient of variation is the ratio of the standard deviation of the rate of return divided by the mean rate of return, expressed as a percentage.

Source: ABARE (2006).

In Table 7 we look at the whole client base by rainfall zone and it can be seen that the low rainfall zone has had a particularly tough run with a five year average return of only 2.1%. The medium rainfall has achieved a return of 3.9% and the high rainfall has an average return of 4.9%. These results are not surprising given that the last five years have been below average rainfall years for the wheatbelt which tends to favour high rainfall areas where water logging is a problem in average to wet years.

The coefficient of variation in wheat yields in WA is typically less than 30%. Contrast that with the variability in farm returns of over 100%. The variation in yield will be magnified by the fact that the operating profit is typically less than 10% of the income. A 6% increase in income for a wheat pasture rotation can double the operating profit of that rotation. Biological risk (e.g. yield variability) is not the only determinant of variability in farm returns. The combination of variation in yield, price and production costs lead farm businesses to be characterised by pronounced variability in returns. Few businesses display the volatility in returns that broadacre dryland farming does.

The business return including capital growth shows that while farms have been making below average profits the large increases in land values have underpinned the growth in equity. With equities growing, banks have been willing to lend more money for businesses to fund their trading losses. A significant downturn in land prices would make it more difficult for businesses who have sustained a run of poor returns, to secure the funding needed to continue trading.

Table 7. Return on productive assets

Year	All clients	Low	Medium	High
No.	292	86	157	49
2001	12%	10%	13%	22%
2002	-4%	-12%	-2%	8%
2003	12%	16%	11%	6%
2004	0%	-2%	1%	1%
2005	1%	1%	1%	2%
Coeff. of variation	175%	417%	140%	108%
5 yr average	**3.6%**	**2.1%**	**3.9%**	**4.9%**
4 yr average	2.3%	0.8%	1.8%	4.3%
Business return incl. cap growth	9.90%	8.71%	10.41%	10.40%
Crop %	**65%**	**70%**	**66%**	**58%**

If we look at the break up of those rainfall zones within our study group, it can be seen that in the low rainfall zone the five year average for the ‘All Crop’ group has been 0.9% and the ‘Mixed’ farm group 3.8%. This shows that in the last five years the mixed farming enterprise has been able to perform well in the good years of 2001 and 2003 and match the ‘All Crop’ group returns however in the dry years, the losses sustained by the ‘Mixed’ group is a great deal less than the ‘All Crop’ group. It is worth noting that the average crop percentage is highest in the low rainfall zone which is showing the poorest returns for high crop percentage farming systems.

In the medium rainfall zone the 19 farms in the ‘All Crop’ group had a 5 year average return of 6.2% and this compares to a mixed farming system return of 4.3%. Once again the variation between years is far greater for the ‘All Crop’ group however the very good years of 2001 and 2003 more than made up for the poor years.

In the high rainfall zone there are only two farms that fall into the ‘All Crop’ group and both these farms have performed very well over the last five years and have returned a 10.9% return. Both these farms are located in the Esperance area and had a particularly good year in 2001. It is worth noting that removing that one year from the average and looking at the four year average that the ‘Mixed’ farms produce half a per cent better return than the ‘All Crop’ farms. It is also worth noting the very large business returns for these two farms is a result of the rapid increases in land values over the last five years. The lower land values in 2001 have also been a factor in the very high returns on productive assets in 2001.

Table 8. Return on productive assets by rainfall zones

	Low rainfall zone		Medium rainfall zone		High rainfall zone	
Year	**All crop**	**Mixed**	**All crop**	**Mixed**	**All crop**	**Mixed**
No.	9	34	19	67	2	15
2001	7.1%	11.8%	17.1%	12.7%	38.5%	16.6%
2002	-18.0%	-10.0%	-6.5%	-0.7%	-5.1%	8.7%
2003	20.0%	17.1%	15.9%	9.4%	18.4%	6.7%
2004	-4.6%	-0.6%	1.9%	0.1%	0.0%	0.9%
2005	-0.2%	0.7%	2.7%	0.2%	2.9%	1.9%
5 yr average	0.9%	3.8%	6.2%	4.3%	10.9%	6.9%
4 yr average	-0.7%	1.8%	3.5%	2.3%	4.1%	4.6%
Business return incl. cap growth	7.1%	8.4%	13.9%	11.5%	23.3%	16.1%
Crop %	97%	62%	95%	58%	100%	52%

Productivity measures

The physical ability of the rainfall zones to produce an economical yield for lupins and field peas could be a major factor in why the low rainfall figures suggest that a mixed farm enterprise would be more profitable. It could be seen that an average lupin yield of 0.74 t/ha for lupins and 0.81 t/ha for field pea would result in a negative gross margin and after adding fixed costs would result in a considerable operating loss. The high rainfall zone however has been able to achieve reasonably high yields of 1.64 t/ha for lupins and 1.39 t/ha for field peas but this will need to compete with a more productive sheep enterprise with the average of 6.2 DSE/ha and 20.26 kilograms of clean wool per winter-grazed hectare. With the average wool prices over the five year period in the study, the high rainfall clients with suitable soil types may make more money out of an all crop enterprise, which appears to be only two clients in this group.

Table 9. Five year average production statistics for FARMANCO clients

Production measure	All clients	Low	Medium	High
No.	292	86	157	49
Effective area farmed	3,291	3,735	3,146	2,967
Wheat yield (t/ha)	2.03	1.52	2.12	2.69
Lupin yield (t/ha)	1.09	0.74	1.12	1.64
Field pea yield (t/ha)	1.00	0.81	1.02	1.39
Sheep DSE/ha	3.80	2.08	4.05	6.20
Clean kg of wool/WGha	11.78	6.44	12.70	20.26
GM ($/ha)	75	34	85	118
Profit	6	-1	8	9

If we look further at some of the production measures within the study group it is apparent that in the medium and high rainfall zones the ‘All Crop’ farms are achieving a better result with higher yields than the ‘Mixed’ farms. This is related to soil types, with the two growers in the ‘All Crop’ high rainfall zone having good cropping soil types which produced above average wheat and pulse yields

Within the medium rainfall zone the lupin yield is a critical success factor for the ‘All Crop’ system with an average yield of 1.23 t/ha compared to 1.02 t/ha on the ‘Mixed’ farms, however they also have a higher wheat yield which has a bigger impact on the profitability than higher lupin yields. The higher wheat yield may be a result of the rotation with lupins but I would suggest that they may also have soil types which have a higher yield potential and would be less likely to have shallow soils or soils prone to waterlogging.

Results for the low rainfall show that wheat yields are higher in the mixed farming system at 1.60 t/ha compared to 1.46 t/ha and this could well be due to the ‘All Crop’ farms with their low lupin and field pea yields having to force more cereals into the rotation which has dropped the average yield. The ‘Mixed’ farms in the low rainfall are not dependent on the sheep enterprise making a profit as it can be seen that the average profit of the sheep enterprise of this group is -$10/ha which is below the client group average of -$1/ha. However in the medium and high rainfall zones the profitability of the sheep enterprise in the ‘Mixed’ system is well above the client group average for those zones.

Table 10. Five year average production statistics study group

Production measure	All zones		Low		Medium		High	
	All crop	Mixed	All crop	Mixed	All crop	Mixed	All crop	Mixed
No.	30	116	9	34	19	67	2	15
Effective area farmed (ha)	2893	2948	2313	3532	2993	2669	3738	2869
Wheat yield (t/ha)	2.09	2.01	1.46	1.60	2.30	2.06	2.84	2.72
Canola yield (t/ha)	0.84	0.99	0.64	0.66	0.83	0.93	1.31	1.52
Lupin yield (t/ha)	1.18	0.97	0.69	0.66	1.23	1.02	2.26	1.55
Field pea yield (t/ha)	1.04	0.84	0.81	0.75	1.05	0.85	1.44	1.08
Sheep DSE/ha		3.98		2.16		4.36		6.64
Clean kg of wool/WGha		11.08		6.50		12.11		20.15
GM ($/ha)		83		44		90		147
Profit ($/ha)		12		-10		17		43

Key business indicators

Table 11. Key indicators of the FARMANCO client base by rainfall zone

Indicator	All clients	Low	Medium	High
No.	292	86	157	49
Arable enterprise income ($/ha)	$285	$191	$289	$437
Operating costs ($/ha)	$246	$184	$247	$350
Operating profit ($/ha)	$39	$7	$42	$87
Machinery value ($/ha)	$288	$232	$297	$361
Machinery value to income (no.)	1.01	1.08	1.02	0.88

Table 12. Five year average key business indicators by rainfall zones for the study group

Indicator	All clients	Low rainfall zone		Medium rainfall zone		High rainfall zone		All rainfall zones	
		All crop	Mixed	All crop	Mixed	All crop	Mixed	All crop	Mixed
No.	292	9	34	19	67	2	15	30	116
In dollars per hectare farmed									
Arable enterprise income	$288	$227	$199	$352	$290	$489	$405	$322	$275
Total op. costs	$246	$224	$172	$275	$249	$355	$318	$265	$235
Operating profit	$42	($3)	$17	$77	$41	$134	$87	$57	$40
Machinery value	$288	$286	$214	$358	$280	$500	$344	$346	$248
Total variable cost	155	140	106	170	154	251	172	170	139
Variable cost % of farm income	55%	59%	56%	52%	55%	52%	50%	54%	55%
Wages	10	5	6	13	9	28	13	12	9
Fertiliser	45	46	30	55	40	65	47	54	37
Pesticides	31	38	21	40	28	66	24	42	25
Fuel and oil	16	16	12	17	15	20	14	17	14
R&M machinery	15	18	13	18	16	25	12	19	14
R&M infrastructure	2	2	1	3	2	2	4	2	2
Total fixed costs	101	84	75	128	101	241	117	127	94
Fixed cost %	36%	35%	40%	39%	36%	50%	34%	40%	37%
Machinery capital	37	26	26	52	29	104	44	50	30
Infrastructure capital	8	3	8	10	11	10	7	10	10
In dollars per cropped hectare									
Crop variable costs	186	151	151	177	199	255	259	178	187
Fertiliser crop	60	47	49	57	62	66	85	55	60
Pesticides crop	42	40	34	42	46	68	52	44	42

If we look at the key business indicators for the study group it is apparent that the 'All Crop' farms do have a higher cost structure with total operating costs per hectare of $265 compared to $235 for the 'Mixed' farms. The variable costs as % farm income however, is very similar and this indicates that the extra costs in the 'All Crop' farms are matched by additional income.

The operating profit in dollars per hectare is higher for the 'All Crop' group at $57/ha versus the 'Mixed' group at $40/ha but has been influenced by the extremely good 2001 results for the medium and high rainfall zones.

Although in steady-state terms the farm based on more cropping may on average generate greater profit, the transition costs of shifting toward much greater crop dominance need to be considered in formulating sound advice to a farmer. For some businesses the transition costs (e.g. up-grading cropping gear and related infrastructure) may negate the steady-state financial advantage of shifting to greater crop dominance.

In terms of individual costs on a per effective hectare basis total variable costs are consistently higher for the all crop system with the average being $170/ha for the ‘All Crop’ group and $139/ha for the ‘Mixed’ farms. The costs of fertiliser are consistently higher and this is not surprising given that crop fertilisers are significantly more expensive than pasture fertiliser, the same can be said for pesticides, fuel, oil, repairs and maintenance. The ‘All Crop’ farms will have a higher cost structure and this is normally matched by a higher income, however it does mean that in very poor years you will sustain a larger cash loss. If these costs increase and your income doesn’t change significantly then the advantage that the ‘All Crop’ system enjoys at the moment may disappear.

If we look at the crop variable costs within each of the farm systems then it is of some surprise to me that the cropping fertiliser cost for the ‘Mixed’ group is above the ‘All Crop’ group although the pesticide cost is slightly less, the reverse is true for the medium rainfall. The ‘Mixed’ farms may have higher pesticide costs in the medium rainfall due to the need to manipulate pastures which in general is not as necessary in the high rainfall due to higher stocking rates, and is less common in the low rainfall due to the lack of legumes in the pastures. I don’t have a ready explanation for the higher fertiliser costs for mixed farming systems but it is higher across all rainfall zones.

Individual case study farms

Using average data helps remove the effect of individual managers however it also tends to reduce the very real differences between businesses. We compared two farms with similar rainfall, and soil types in the medium rainfall group. Farm A is in the ‘All Crop’ group and farm B is a ‘Mixed’ farming enterprise with 66% crop. These two farms are within 10 km of each other and their average rainfall over the last 10 years is very similar. The ‘All Crop’ farm is to the West of the ‘Mixed’ farm.

The area of the ‘All Crop’ farm is less than the ‘Mixed’ farm however, they both have a reasonable scale of operation. Both managers are considered to be technically very good managers. Farm A has been in an ‘All Crop’ system for some time and was one of the first farms in the district to find herbicide resistant ryegrass in their wheat/lupin rotation.

The ‘All Crop’ farm has been dealing with significant amounts of herbicide resistance for nearly 15 years and we believe that the profitability of the farm is being seriously impacted by herbicide resistant populations of ryegrass and radish. Over the last five years the ‘All Crop’ farm has produced a return on production assets of 2.6% while the ‘Mixed’ farm has produced a return of 5.0%.

Looking at the crop yields you would think that the ‘All Crop’ farm would be just as profitable as the ‘Mixed’ farm. It generates more income per hectare however with higher variable costs the ‘All Crop’ farm is behind on a gross margins comparison. The big ticket items of fertiliser and pesticides are very similar, so it is the repairs and maintenance of machinery where the ‘All Crop’ farm is over-spending. Some of this cost is coming from a tendency to make things in the workshop, so some of this cost could be transferred to the machinery capital cost. If we compare the combined cost of machinery capital and R&M then the ‘All Crop’ farm cost is $29/ha more than the ‘Mixed’ farm.

The difference in enterprise profits between the two farms shows how the yields don’t tell the whole story, with quality of the grain and increased costs contributing to put the ‘All Crop’ farm profit well behind the ‘Mixed’ farm. The mixed farm runs a good sheep enterprise and the difference between the lupin profit of minus $79/ha and the sheep profit of plus $26/ha is a staggering $105/ha.

Table 13. An 'All Crop' farm versus a 'Mixed' farm

Indicator	Farm A: 'All crop'	Farm B: 'Mixed'
Average rain (10 yrs)	272	270
Area farmed (Arable)	1748	2390
Area cropped	1748	1589
Crop %	100%	66%
Productive assets $/ha	2,177	2,096
Infrastructure value	206	129
Crop machinery $/ha	423	324
Livestock machinery $/ha		14
General plant $/ha	63	31
Livestock $/ha		60
5 yr yields Wheat	2.56	2.64
Barley	2.62	2.59
Canola	0.89	1.05
Lupins	1.56	1.15
Field peas	0.81	1.20
Arable enterprise income $/ha	421	384
Variable cost ($/effective ha)	250	179
Variable cost %	59%	47%
Wages	10	16
Fertiliser	65	54
Pesticides	54	45
Fuel and oil	18	10
R&M machinery	44	12
R&M infrastructure	7	3
Gross margin	171	205
Fixed costs ($/effective ha)	115	100
Fixed cost %	34%	26%
Overheads	45	27
Drawings	30	30
Machinery capital	35	38
Infrastructure capital	4	4
Total op. costs $/ha	365	279
Operating profit $/ha	56	105
Return on productive assets	2.6%	5.0%
Crop variable costs ($/crop ha)	262	216
Fertiliser crop	73	74
Pesticides crop	62	63
Farm income/labour unit	$565,000	$305,000
Hectares/labour unit	1,165	812
Machinery capital and R&M $/ha	79	50
Enterprise profit $/ha		
Wheat	112	230
Barley	89	123
Canola	38	39
Lupins	(63)	(79)
Field peas	(127)	43
Sheep		26

FUTURE

Using the FARMANCO crop rotation model, we have used current average production levels and expected prices and costs for 2007. The projections are that the pasture/wheat rotations will perform as well or better than the normal full crop rotations which have been employed in the past. These rotations are heavily dependant on the price of wheat. Increases in the wheat price will favour those rotations which have a high wheat component.

Table 14. Commodity prices used in the FARMANCO rotation model

Commodity	Price used
Wheat (FOB)	$235/t (High price $250/t)
Barley (FOB)	$235/t (High price $260/t)
Canola (FOB)	$410/t (High price $440/t)
Lupin (FOB)	$230/t (High price $250/t)
Wool (Clean – Gross)	$9.50/kg
Ewes (Gross)	$30/hd
Merino lamb (Gross)	$50/hd
Xbred lamb (Gross)	$65/hd

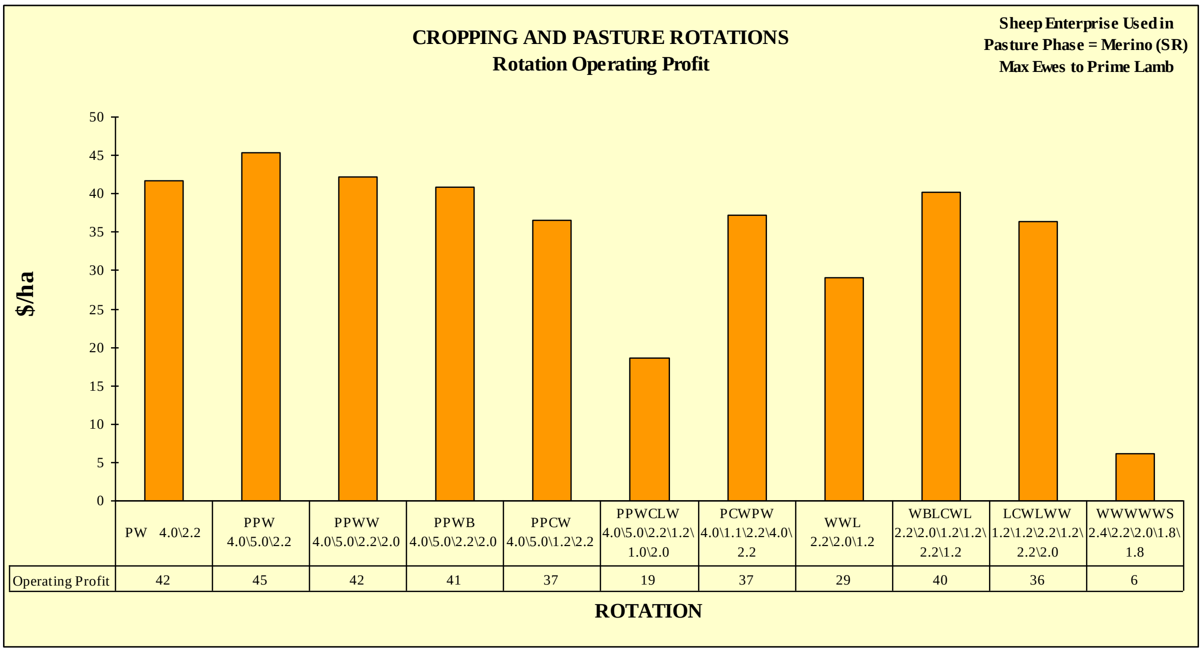

Figure 7. Calculated rotation operating profit assuming average production levels and expected prices for 2007.

Source: FARMANCO Crop Rotation model.

Note: The graph shows the rotation as PPCW which is pasture, pasture, canola, wheat and the numbers following the letters correspond to the stocking rate and the yield, 4 DSE/ha in the first year of pasture 5 DSE in the second year 1.2 t/ha of Canola followed by 2.2 t/ha of wheat.

If we use high grain prices in the model, we can get the rotations that include canola to become more profitable then the pasture rotations. The model assumes that you wont be sowing canola or lupins unless you expect them to yield 1.2 t/ha or more.

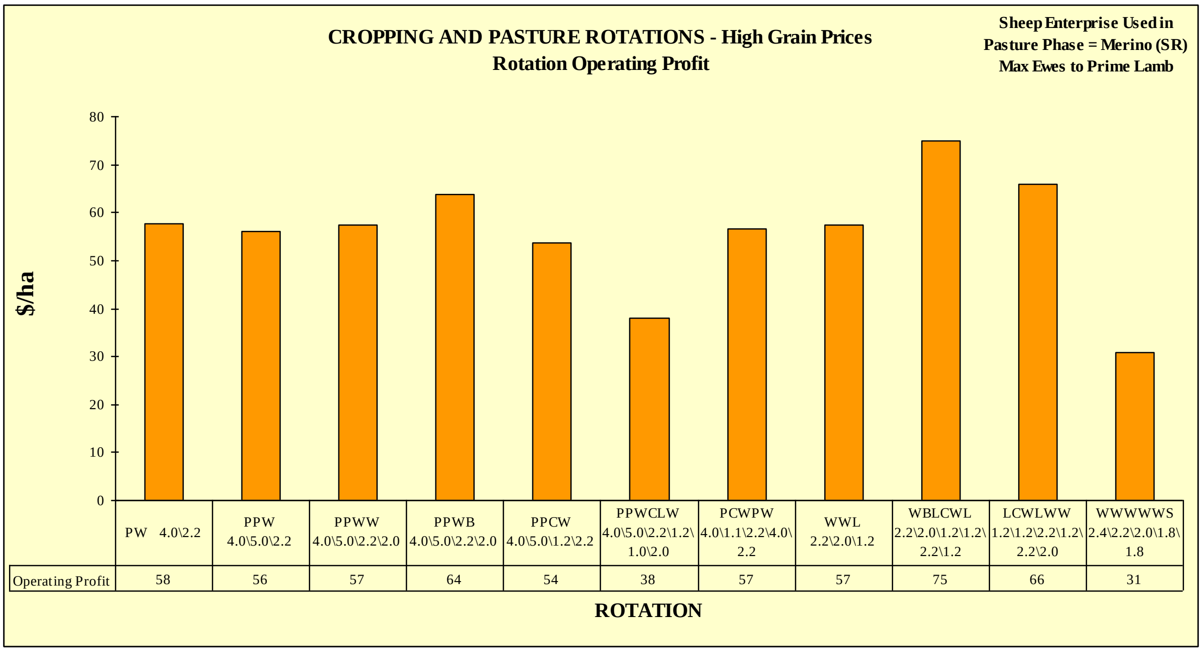

Figure 8. Calculated rotation operating profit assuming average production levels and high grain prices.

Source: FARMANCO Crop Rotation model.

If we assume that prices for energy and steel increase and force the prices of fertiliser, fuel and oil, and the costs of machinery ownership up by 10%, the graph below shows that the pasture based rotations would be favoured. We could go back to the good old days of PPW (pasture/pasture/wheat) rotations.

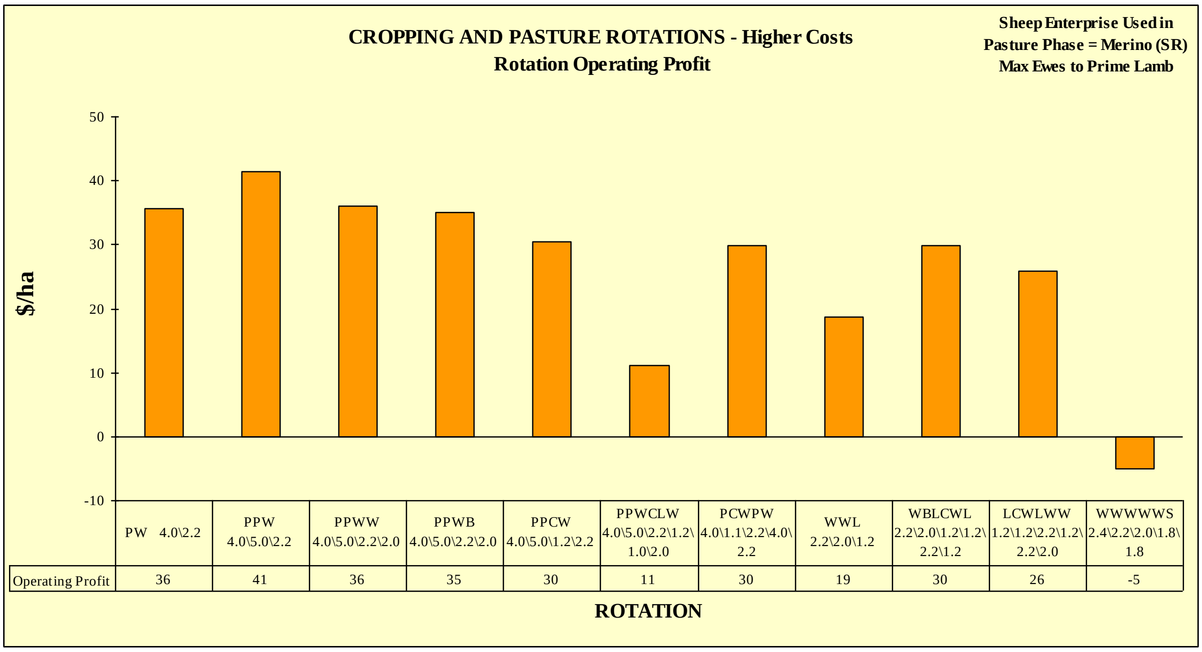

Figure 9. Calculated rotation operating profit assuming average production levels and high grain prices, and an increase in fertiliser, fuel and oil, and machinery costs of 10%.

Source: FARMANCO Crop Rotation model.

The rotation variable cost chart highlights the large differences in the variable costs between rotations. With pasture rotations being around two thirds of the cost of the cropping rotations but still producing a similar operating profit, it makes the pasture rotations a much lower risk to your business.

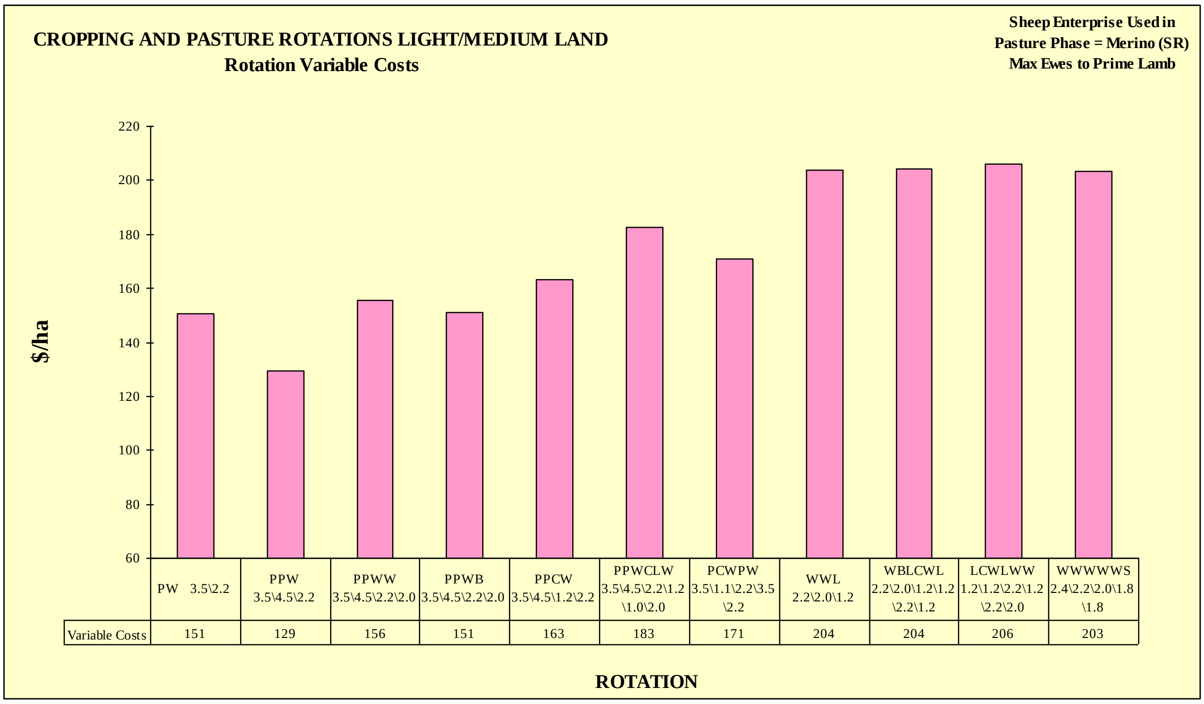

Figure 10. Calculated rotation variable costs.

Source: FARMANCO Crop Rotation model.

Climate change is a popular topic in scientific communities. The table below shows some of the work that Ross Kingwell and Michele John have done on the likely effects on farms in the eastern wheatbelt using the predicted changes to the climate in this region by the CSIRO modelling (John *et al.* 2005). The bad news is that farm profit is expected to halve. The interesting point in terms of this study into cropping percentage is that the optimum pasture area is likely to increase for both the Alluvial farm and the Sandplain farm. The other interesting point is the modelled optimum crop percentage is less than 50% for all scenarios.

Table 15. Optimal farm plans for the alluvial plains and sandplain farms with and without climate change

Activity	Unit	Alluvial farm		Sandplain farm	
		No climate change	With climate change	No climate change	With climate change
Farm profit	$'000	89.9	42.0	93.1	46.7
Profit per ha	$/ha	24.0	11.2	24.8	12.5
Pasture area	ha	1893	1957	1726	1870
Crop area	ha	1646	1582	1788	1644
Cropping percentage	%	44	42	48	44
Lupin area	ha	45	116	121	179
Expected lupins fed	tonnes	161	159	150	153
Sheep numbers	dse	6862	6371	6577	6219
Winter stocking rate	dse/ha	3.7	3.0	3.8	3.1
Agistment	dse	0	648	97	594
Sheep sold	hd	2505	2327	2248	2266

Source: Kingwell (2003).

CONCLUSION

Looking at average performance can mask what is happening within an industry and ignores what is happening in individual businesses. By investigating the spectrum of businesses it is possible to gain insights about the performance of different farming systems. Using gross margins alone as the investigation tool to determine the best farming system will generate potentially misleading information, and some farmers may be encouraged to implement a system which actually could lose money.

The optimum crop percentage for your business will be a result of establishing the optimum crop rotation on a paddock by paddock basis. The optimum crop rotation for a paddock will be determined by the sum of all parts of that rotation. Poor performing grain legumes can reduce the overall profitability of a rotation well below that of a 50% pasture rotation. High crop percentage systems are more costly and are a higher risk system. High crop percentage farms in the low rainfall zone have consistently produced lower returns than farms with a cropping percentage between 40 and 70%.

A paddock-based analysis also needs to allow for the logistics of operating the entire farm. For example, two paddocks with identical management histories and soil types may generate very different rotation GMs depending on when crops are sown as part of the cropping program. Not every paddock can be sown at the 'optimal' time. Where crops have different sowing windows or different responses to 'late-sowing' then the relative GMs will differ across paddocks depending on when operations can take place.

There are a number of growers that have a short growing season in the northern wheatbelt who are now looking at incorporating livestock into their enterprise, however it is not the traditional livestock enterprise where you have your own breeders, you breed sheep or cattle and then sell them. What they are doing is buying livestock, utilising the feed that is available, and then selling livestock further down the supply chain. What this allows them to do is avoid the problem of holding large numbers of stock through the summer period but still turn pasture into dollars.

KEY WORDS

farm management, farming systems, crop percentage, profitability, crop rotations

ACKNOWLEDGMENTS

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Paper reviewed by: Ross Kingwell and Doug Abrecht

Evaluation of Local Farmer Group Network – group leaders' surveys 2005 and 2006

Paul Carmody, Local Farmer Group Network, Network Coordinator, UWA

KEY MESSAGES

- In one year there was a 16% increase in awareness of research opportunities by group leaders.
- A phone survey is an effective way to establish some formal feedback on project but not the best way.
- A third of Group Leaders had found LFGN helped them develop their leadership and networking skills.
- The expression of interest method is not the best delivery mechanism to the small groups.

THE LOCAL FARMER GROUP NETWORK

Background

The Local Farmer Group Network (LFGN) is a support network for local farmer groups which began in 2004. The project is funded by the Grain Research Development Commission, The Department of Food and Agriculture (DAFWA) and hosted by the Faculty of Natural and Agricultural Sciences, University of Western Australia (FNAS). The project is managed by a committee made up of grower group representatives, UWA, DAFWA and a representative from an agribusiness company. There are over 40 local farmer groups throughout the Western Australian grainbelt including the large groups which are a part of the Grower Group Alliance (GGA). The LFGN and GGA are both based at UWA and work in partnership to support WA grower groups.

The primary objective of the project is to increase the adoption of new technology through a network of support for local farmer groups.

LFGN began without any groups connected in its network. By the end of 2006 there were over 25 local groups who had become members of the Network. These local farmer groups have a wide range of activities and interests but most are focused on raising the productivity and profitability of their group members. The groups are predominantly focused on grain production in addition to those which have either a community or catchment management focus.

AIMS

Local farmer group leaders survey were conducted in December 2005 and 2006 to help evaluate the project and to establish some future directions and strategies for the project.

METHOD

Twenty five local farmer group leaders were interviewed by phone by a project staff (2005) or contracted student (2006). The local group leaders were informed prior to the interview that a survey would be conducted and that the purpose was to help evaluate the project and provide some future directions.

Six questions were repeated each year out of a total of 13 questions to measure the project's progress. The full survey with the repeat questions can be found at the website www.lfgn.org.au/forms.

The phone survey usually took 30-40 minutes to complete and sheets were completed at the end of each interview. The local group leaders had two options; to conduct to survey on the spot or arrange another time that was mutually suitable to both the group leader and the interviewer. Twenty-one group leaders were contacted in 2005 with 19 interviewed and 27 group leaders in 2006 were contacted with 25 being interviewed. The network had also grown by 6 groups within that one year.

RESULTS

Key findings 2005

The role of the LFGN was clearly defined and established with the group leaders in December 2005. Their general viewpoint was that the LFGN is there to assist in organising and coordinating the groups, thereby enabling them to access information on:

- other groups' activities;
- availability of establishing partnerships with other groups;
- availability of speakers and workshops;
- research project outcomes;
- accessing GRDC resources;
- accessing professionals who could address common local farming issues.

The responses indicated that the LFGN is perceived as primarily having a support/facilitation role, as well as a communication role. Linking groups to funding projects, other groups (especially those with a common interest) and GRDC resources was deemed an important role.

The main expectation of the LFGN was to continue to foster communications between groups, thereby reducing duplication in trials and workshops. Information on other groups and their activities was also valued as a means for individual groups to assess their progress – in turn motivating their members. Improved access to resources such as training workshops and other group trials was given a high priority by 37% of respondents. Twenty-one per cent had no expectations for mixed reasons including: "information provided was too broad" and "don't know much about LFGN, only new to it".

The level of awareness created by the project was evident with 84% of respondents agreeing with the statement that the LFGN "has made you more aware of opportunities available to groups". The LFGN electronic newsletter 'Newswire' – which began in August 2005, provides groups with a summary and links to current opportunities and activities of other groups. The question of timing and format was made and 73% of respondents requested it be on a monthly basis and in an email format. One group leader wanted it by post.

A question on "How LFGN has helped you to become more aware of what other groups in WA are doing?" Ninety-five per cent of the group leaders agreed that this was the case, citing such reasons as "introduced us to other groups, especially within our own region", "video was useful" and the "website has been a useful".

When asked of their awareness of research opportunities, 63% responded "yes" providing the following reasons: "Information about Bob Gilkes workshop was useful", "Now aware of availability of funding", "Aware of useful research people who potentially can provide workshops".

The Expression of Interest (EOI) was first established in 2005 as a technique for distributing opportunities to groups equitably. Sixty-one per cent agreed that it was a good way but it had limitations. These were cited as: "The group is not adequately set-up to receive EOI's", "EOI's lacked detailed information", "Too many other sources and already there is plenty of material to digest" and "More planning time is required than often allowed by an EOI".

Key findings 2006

A key finding from the 2006 survey was that local farmer group leaders felt the LFGN was helping them to build a sense of place in agribusiness networks. A level of trust has formed and group leaders would like to see LFGN continue its level of service. The local group leaders "really appreciate" it and get a lot of benefit out of networking with other grower groups and researchers.

Suggestions from the chairpersons to improve their groups' success included information on; extension skills, more coordination to link the groups together, keeping the group's informed of what other groups are doing, supplying them with a list of researchers and reducing their work load by filtering information coming through and to avoid overloading them with information.

A number of groups, namely some of the more informal small production groups said that LFGN had done all it could for their group – "Now it is up to the group to move into action and take up the opportunities offered to them".

A third of the group leaders had found the network helped them develop their leadership skills and networking skills to some degree.

Table 1. Results of LFGN Group Leaders surveys from 2005 (19 respondents) and 2006 (25 respondents) on whether or not the Network had increased their awareness in opportunities, other groups and research

Awareness questions	2005 % Yes	2006 % Yes	% Change
i) Awareness of opportunities available to your group.	94	96	2*
ii) Awareness of what other groups in WA are doing.	84	87	3*
iii) Awareness of research opportunities for your group.	**63**	**79**	16**

* Not significant.
** Significant.

The results in Table 1 summaries the responses to yes / no questions on the group leaders awareness being created by the network. Strong awareness of opportunities for groups and what other groups was clear but awareness of the research opportunities was weaker but had improved significantly within one year.

When asked about activities for the year, the most impressive LFGN event/activity they have participated in was the Group Leaders Study Tour to Victoria which included a visit to the Birchip Cropping Group's Expo day. Tour members stated that the contacts made on the tour were highly relevant and still in use. Many other events/activities were mention including; Soil biology workshops, plant available water workshops, group breakfast meetings, access to funding from GRDC, assistance in applying for tender, assistance with administration when organising a field day and being made aware of research opportunities.

The interviews in 2006 also established the importance of the Newswire as a vehicle for delivery of information to the groups. Seventy-six per cent of those surveyed found the Newswire to be a useful resource for their group and felt its length and scope was adequate. For a few the Newswire did not contain anything relevant to their group with some groups' receiving more than one newsletter which covered similar material. Suggestions were made for further information on animal husbandry – not just on crops and pasture. It was also suggested that Newswire should include information on issues that are being currently faced by rural communities, such as fire safety.

DISCUSSION

The result of the two surveys are encouraging for the LFGN as it has clarified areas of improvement for the project team. The second survey was conducted by an independent person and this has help clarify the strengths and weaknesses of the project. The results of the second survey reinforced how difficult it is to make real change within a network of groups in one year. There was no measurable increase in the group leaders' awareness of opportunities or of other groups, but a significant change in their awareness of research opportunities was measured in one year.

In 2005 overall there were 12 workshops coordinated through LFGN which were delivered to 32 groups and attended by over 530 farmers. Sixteen groups received the subsoils constraints workshop and attended by over 280 growers. The plant available water workshops were delivered to four local groups and attended by over 120 growers and agronomists. The dry season in 2006 saw a marked drop off involvement in Network opportunities and workshops that were presented to groups. Six regional breakfast meeting were held and these were important in link groups at a regional level. Only one plant available water workshop was taken up by the Local Farmer Groups and a limited number of the other workshops were taken up.

Areas for improvement

Areas for improvement as a result of the surveys were:

- Groups want more information on stock rather than just crops and pastures.
- EOI process for small groups needs an alternative approach.
- Group leaders' need formal exchange on group results and activities at the Annual Forum.
- More information on current issues being faced by groups, e.g. fire safety, flood response.
- Profiles on researchers and their projects more accessible to local grower groups.

Key learnings from the survey

The primary learnings on conducting the survey within the project were:

- Evaluation surveys are best conducted by someone external to the project.
- Phone survey worked well and provided a quick turn around for the results.
- The interviews provided the group leaders with time to reflect upon the project and their roles.
- Avoid being too ambitious with the outcomes and keep questions simple.

CONCLUSION

The survey identified Group Leaders through the project was beginning to "gel well" and felt that a level of trust had formed between network members. The group leaders would like to see the LFGN continue its current activities and continue to support their groups. A real challenge for a phone survey is to capture the true essence of what the group leaders and their groups have obtained by being a part of the network. It is a cost effective technique but would be better supported by some focused discussion with group leaders and their committees. Unfortunately the large number of groups together and the limited life of the project has not allowed for a more detail evaluation at time of printing.

The critical finding was that in a short space of time the network project had a marked impact on the skills of groups' leaders. Over a third of them agreed that the activities created by the project had improved their leadership and networking abilities. The significant increased in the awareness by group leaders of researchers and research opportunities in one year were also encouraging for a network project. The systems and processes are only just beginning to be developed and understood by the local farmer groups as was evident by their comments on the EOI's. This process will need further refinement to suit the smaller groups within the network. A clear message from group leaders was the need for a network which they can call upon as required to help them move forward with what they want to achieve as a local farmer group.

Group leader members of the Local Farmer Group Network in 2006

Local farmer group	First	Surname	Town
Beaumont Better Farming	John	Hyatt	ESPERANCE
Bodallin Catchment Group	John	Butcher	BODALLIN
Brookton LCDC	Micheal	Eva	BROOKTON
Casuarina Walkaway Farm Improvement Group	David	Forrester	GERALDTON
Duli Farm Improvement Group	Mike	Kalajzic	CADOUX
Freebairn Farm Progress Group	Keith	Wilson	KULIN
Gibson Lupin Group	Nils	Blumann	GIBSON
Grass Patch Sustainable Farm Group	Ron	Longbottom	GRASS PATCH
Greenhills Production Group	Leon	Ryan	YORK
Jerdacuttup TopCrop and Pasture Group	John	Smeeton	ESPERANCE
Kellerberrin Demonstration Group	Scott	Dixon	KELLERBERRIN
Neridup Soil Conservation Group	Mick	Fels	ESPERANCE
Newdegate Crop Improvement Group	Steve	Thompson	NEWDEGATE
Ninghan Farm Focus Group	Luke	Sprigg	MUCKINBUDIN
North Mallee Farm Improvement Group	Terry	Guest	SALMON GUMS
North Stirling - Pallinup Natural Resource	Graeme	Jones	ONGERUP
Northern Agri Group	Gordon	Wilson	NORTHAMPTON
Nyabing Farm Improvement Group	Ben	Hobley	NYABING
Munglinup Local Farmer Group	Gavin	Gibson	ESPERANCE
RAIN Group	Jenny	Chambers	RAVENSTHORPE
Wandering Productivity Group	Melvin	Schorer	WEST PINGELLY
West River Catchment Group	Luke	Caelli	RAVENSTHORPE
West Wagin TopCrop Group	Kelly	Patterson	WAGIN
William Productivity Group	Geoff	Higham	WILLIAMS
Woolocutty Local Farmer Group	Peter	Pascoe	NAREMBEEN
Yuna Farm Improvement Group	John	Warr	YUNA

More details about each of these groups are available from the LFGN website:

www.lfgn.org.au

KEY WORDS

grower groups, grower surveys, networks, integrated farming systems research, local groups, TopCrop

ACKNOWLEDGMENTS

Lara Swift, MURESK, Lisa Mayer, Local Farmer Group Grower, Group Leaders of LFGN.

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Paper reviewed by: Tracey Gianatti, Grower Group Alliance

Seeding rate and nitrogen application and timing effects in wheat

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KEY MESSAGES

The optimum seeding rate for wheat in the medium and low rainfall central wheatbelt ranges between 60 to 80 kg/ha targeting a density that ranges 120 to 150/m^2 on average depending on the seasonal conditions. Rates greater than this would be to tackle specific management issues, i.e. weed competition.

Growers should consider deep soil sampling (1.5 to 2 m) for N analysis in mid-late April to assist in the decision making of the amount or if any further N is required by the crop and the timing of that application, dependent on the seasonal conditions that prevail at the time.

AIMS

To determine whether seeding rate and / or nitrogen input and timing of its application influences tillering in wheat and therefore yield and quality in wheat.

BACKGROUND

This farmscale experiment follows on from a similar one conducted the year earlier in 2005 that looked at the effects of seeding rate, nitrogen application timing and rates. This 2005 experiment was complicated by a frost occurring at the site and confounded by having non equivalent amounts of N applied at different timings post seeding. Nevertheless it raised a few questions that warranted further investigation. It was found that seeding rate played a greater role in determining tiller numbers and ultimately head number rather than the amount and/or the timing of an N application. Soil testing found that this site had background levels of nitrate N of totalling 89 kg/ha to a depth of 2.0 m.

METHOD

In 2006 a 'Level 4' farmscale experiment (Russell, 2001) was conducted by the Kellerberrin group to investigate the effects that seeding rate of wheat and the time of applying additional N had on grain yield and quality. Three seeding rates were tested – 40, 80 and 120 kg/ha. Nitrogen was applied in the form of urea at about 50 kg/ha to give 23 kg/ha N at either seeding, then 6 weeks after seeding (20 July) or at booting stage of the crop (28 August) to coincide with forecast rainfall. For ease of operation a split plot design was implemented using the N application as the main blocks and seeding rate as randomised sub treatments within. The treatments were replicated three times.

The paddock had been in lupins in 2004 and wheat in 2005. The experiment was sown on the 26 May to wheat cv Calingiri. Each plot was an airseeder width of 12 m and ran for 150 m in length. A compound fertiliser was used at seeding on all treatments to give about 10 kg/ha of N. The urea was applied as topdressing over the plots using the airseeder to give a consistent and defined spread.

Measurements taken at the site included detailed soil sampling by CSIRO in April. Plant counts were conducted on the 21 July (Z14.5/22), tissue testing (18 August) for diagnostic and descriptive purposes and head counts prior to harvest. Crop yield was determined by harvesting the centres of the plot with a conventional harvester of front width 10 m and the grain weighed in a weigh trailer. Samples of grain from each plot were taken to CBH for analysis and grading as is the convention for grower deliveries.

RESULTS

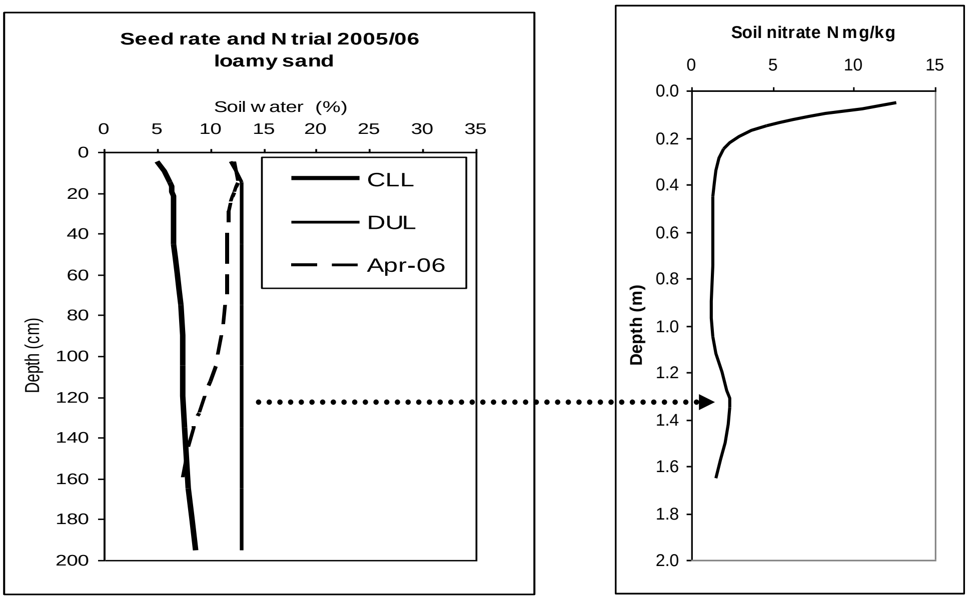
Soil testing by CSIRO revealed the site to be a loamy sand to 90 cm over light clay with clay at 140 cm soil. Soil moisture levels in April 2006 were found to be quite high (Figure 1) due to the well above average summer rains that occurred in the eastern wheatbelt (Table 1). This provided a buffer to the exceptionally low growing season rainfall that was recorded for 2006.

Table 1. Rainfall at Kellerberrin for the 2006 year (BoM, 2006)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	*GS
Ave	10	15	22	22	43	57	53	41	26	19	12	13	**333**	**239**
2006	100	41.2	17.2	23.9	10.3	10.8	19.6	28.2	33.9	2.8	17.6	12.0	**317.3**	**105.6**

*GS = growing season rainfall (May-Oct.).

Soil pH was below 4.5 at 20 to 30 cm depth but rose to a pH of about 6 at 40 cm and below. High levels of nitrate N were measured in the topsoil – 20 kg/kg in the 0-10 cm, 8 kg/kg in the 10-20 cm. Nitrate N levels increased at a depth of 1.2 m. In total there was measured 66 kg/ha of nitrate N to a depth of 1.7 m.



CLL = crop lower limit, DUL = Drained upper limit.

Figure 1. Soil moisture and nitrate N profiles of the site on 26 April 2006.

Tissue testing results of treatment samples taken in August indicated only a marginal response to N was likely to be the case at a target yield of 2.5 t/ha. N levels of the booting samples taken prior to application of the urea showed slightly below marginal levels of N. In crop measurements taken through the season (Table 2) show highly significant (p = 0.05) impacts of the seeding rate effect on plant number at establishment and the resulting number of heads prior to harvest. This would be expected and was also observed in the 2005 experiment. It is clear that many plants died and did not produce grain as the number of heads counted at the end of the season is considerably less than the original plant density. Given the nature of the 2006 season this is probably not unexpected yet seeding rate still had a highly significant (p = 0.5) impact on this outcome.

Table 2. Crop measurements taken through the 2006 growing season

Seeding rate (kg/ha)	Time of application	Plant number (plants/m²)	Head number (heads/m²)
40	Seeding	83	152
	6 was	78	118
	Booting	79	118
80	Seeding	135	330
	6 was	126	287
	Booting	132	313
120	Seeding	182	374
	6 was	172	400
	Booting	169	382
lsd (5%)	Timing	22	44
	Seeding rate	19	35

Seeding rate also had a significant influence on overall crop yield ($p = 0.05$) but no influence on grain protein content (Table 3). There was no clear influence of either seeding rate or the time of the N application as having an effect on the weight of grains or the extent of small grain. In all cases screenings were kept to a level unlikely to have had any economic impact being less than 5%. These trends were also seen in the related 2005 experiment.

Table 3. Yield and grain quality responses to seeding rate and time of application of urea in wheat

Seeding rate (kg/ha)	Time of N application	Yield (kg/ha)	Protein (%)	Grain weight (kg/hL)	Level of screenings (%)
40	Seeding	1,927	10.7	79.3	2.6
	6 was	1,974	10.1	80.1	2.5
	Booting	1,974	10.2	80.4	2.7
80	Seeding	1,967	10.2	80.5	2.1
	6 was	2,030	10.1	80.1	2.6
	Booting	1,972	10.6	79.6	3.0
120	Seeding	1,843	10.2	79.8	2.3
	6 was	1,919	10.0	79.7	2.6
	Booting	1,712	10.6	79.6	2.5
lsd (5%)	Timing	419	0.5	1.73	0.7
	Seeding rate	139	0.5	1.93	0.4

CONCLUSION

From both experiments conducted, seeding rate was found to have a greater influence on the yield of wheat than the timing of a N application in environments of good general N status. Neither did it have any influence on grain quality. The yield data suggests that seeding rate is of greater consequence to production where nutrition is adequate and it does not really impact on grain quality.

The head count data prior to harvest shows that the crop will self adjust to the season. The number of heads at the higher seeding rates is lower in proportion to plant number compared to the 40 kg/ha seeding rate. It would seem that a seeding rate of between 60 to 80 kg/ha is the optimum in this environment to target about 120 to 150 plants/m² **on average** over a probable range of 100 to 200 plants/m² depending on the season, which gives the crop enough plasticity to adjust to good and bad conditions.

The number of heads was not seemingly influenced by when the N had been applied but by the earlier crop density influenced by seeding rate. This was also seen in the 2005 experiment where seeding rate was found to have the greatest impact on tiller number and head density. 2005 was a good season rainfall wise the opposite to 2006.

It would be expected that the timing of the application of N had no influence on plant number as this would be related strongly to seeding rate. The effect of the timing of the N application is more likely on tillering and on the number of heads produced which seen in these experiments to run a little contrary to the expected theory. The 2006 seasonal conditions helped to account for this. However, the deep soil test results show that there was more than an adequate amount of N at depth for the crop and given the season this was enough.

Where there is then no likely leaching of N going to take place below the root zone the efficiency of this N utilisation is likely to be high. This means that a grower can afford to leave until much later in the season any application of N – if required – and play the season, as these decisions of N timing and rate are dependent on seasonal rainfall. In 2005 crop roots were measured on a similar soil (slightly deeper sand) to have penetrated to below 2 m. Even though 2006 was dry and with a difficult start soil moisture was adequate down the profile to at least 1.4 m where residual N was detected (Figure 1). It is thought that in this scenario the crop's roots may have accessed this water and N to explain what was seen and why there was no time of N application effect.

Further consideration

A suggested outcome from this work is that to assist in the understanding of the amount of N in the soil that is likely to be available for the crop it is necessary to take deeper soil measurements than is the convention, i.e. to 1.5 to 2 m depending on soil type / likely rooting depth. The timing of this sampling is important. It needs to be around the 2nd or 3rd week of April and in context to the previous crop history, i.e. wheat after legume, wheat after 2nd cereal or wheat in a continuous cereal phase. Also two major soil types need to be considered, i.e. sandplain and a medium/heavier soil to build an understanding of the position of the N in the soil profile at the beginning of the season.

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KEY WORDS

wheat, seeding rate, nitrogen application, timing, on farm research

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Paper reviewed by: Darshan Sharma

Foliar fungicide application and disease control in barley

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KEY MESSAGES

Applying foliar fungicides to Stirling barley for the control of leaf diseases, even if it is being grown after a previous barley crop, does not seem to be an economically sound practice. Visual assessment of crop disease levels should be conducted as part of standard management practice to ascertain if foliar fungicides are required. Decisions to spray should be made on the level of infection present, the disease pressure, seasonal prognosis and the likely yields to be achieved.

AIMS

To determine the effectiveness that applying a foliar fungicide has on leaf disease development in barley and to establish the optimum timing and rate for use of the fungicide.

BACKGROUND

In 2005 an experiment was conducted by the Kellerberrin Farm Demonstration Group to investigate the objective mentioned above in Stirling barley. The site was however, affected by frost events that occurred that year. Nevertheless some interesting questions arose from this, and also from an earlier experiment done in 2004, that implied there was still much to learn about determining the optimum rate and timing of fungicide (a.i. propiconazole) applications for the control of leaf disease in barley.

The finding from the 2005 experiment was that the main effect on leaf disease gleaned from visual observations, appeared to be as a result of a second foliar application and at a higher rate (250 mL/ha). This unfortunately was not translated to yield performance or grain quality at harvest. The frost causing some over riding interference of the results.

METHOD

Two ‘Level 4’ farmscale experiments (Russell, 2001) were undertaken in 2006 to investigate the effects and interactions of applying fungicide (a.i. propiconazole 250 g/L) at three different rates and two application times during the crop’s seasonal development. The barley crop was established as a conventional paddock following after a cereal crop. Presowing fungicide treatments were applied to the seed in line with normal grower practice. Nitrogen was applied at seeding to ensure no deficiencies were to occur, with the rate determined from crop history and management practice. The barley variety Stirling was used as it fits in the current cropping system of consecutive cereal crops, and has market preference as a malting variety and for the ‘Shochu’ market.

Fungicide treatments were applied by boomspray across the direction of seeding. The plots were very wide at 33 m and 150 m long. Three rates of fungicide (0, 125 and 250 mL/ha) were applied at the 4 to 6 leaf stage of the crop (Z24). Fungicide was then applied a second time at the same three rates just prior to flag leaf emergence (Z36).

Diagnosis of leaf disease within the nil fungicide plots were made about eight weeks after seeding and used as a reference guide to the nature and level of infection. Visual ratings of disease were made prior to the application of the first spray regime. Visual ratings of disease in all treatments were made before the second spray application and then before milky dough stage of the crop. Disease ratings were made on the F-2, F-1 and flag leaves at this final time.

Crop yield was determined by harvesting the centres of the plots with a conventional harvester with the grain weighed in a weigh trailer. Samples of grain from each plot were taken to CBH for analysis and grading as is the convention for grower deliveries in the state.

RESULTS

The season at Kellerberrin was very dry with a difficult start following on from a very wet summer and autumn (Table 1).

Table 1. Rainfall at Kellerberrin for the 2006 year (Post Office and BoM, 2006)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	*GS
Ave	10	15	22	22	43	57	53	41	26	19	12	13	**333**	**239**
2006	100	41.2	17.2	23.9	10.3	10.8	19.6	28.2	33.9	2.8	17.6	12.0	**317.3**	**105.6**

*GS = growing season rainfall (May-Oct.).

The dry nature of the winter months was not conducive to leaf disease occurring and the diagnostic tests and visual observations attested to this (Table 2).

Table 2. Disease observations and fungicide application dates at the two sites

Site	Visual sampling/observation dates			Fungicide application dates	
	1	2	Detailed measurements	First	Second
1	10 August Very low levels spot type net blotch	20 August Low levels of spot type net blotch	1 September	18 August	2 September
2	na	28 August Low levels of spot type net blotch	1 September	10 August	11 September

Leaf disease measurements of observed leaf area affected were extremely low in 2006 (Table 3). At site 1 there was no significant effect of any of the fungicide treatments on the F-2 and F-1 leaves. Disease scores of the flag leaf showed a significant affect ($p < 0.10$, 10% level of confidence) from the first application of fungicide, at both the 125 and 250 mL/ha rates which were applied a fortnight before. Site 2 had disease ratings only slightly greater than site 1 but there were no significant affects of fungicide application in reducing the level of foliar disease in the crop.

Table 3. Leaf disease visual ratings (% of leaf area) taken at the two sites on 1 September 2006

Site	First\ Second	F-2 leaf			F-1 leaf			Flag leaf		
		0	**125**	**250**	**0**	**125**	**250**	**0**	**125**	**250**
1	**0**	5.6	3.0	3.5	3.2	1.4	2.4	1.3	0.6	1.2
	125	3.4	2.6	2.9	1.6	1.2	1.9	0.9	0.4	0.6
	250	2.7	6.0	2.1	1.4	2.3	1.7	0.3	1.0	0.6
	lsd (5%)	4.2			2.5			0.8		
		0	**125**	**250**	**0**	**125**	**250**	**0**	**125**	**250**
2	**0**	6.1	10.6	8.3	3.2	3.9	3.8	0.2	0.6	0.9
	125	7.4	10.4	9.8	3.5	3.5	3.5	1.0	0.9	0.6
	250	6.0	8.5	6.8	3.1	3.1	3.4	0.5	0.4	0.5
	lsd (5%)	5.1			1.4			0.8		

Harvest measurements from both sites do not show any convincing trends. The yield data (Table 4) shows no significant differences ($p = 0.05$) between the treatments. Likewise for the grain quality measurements there were no significant differences ($p = 0.05$) to be seen at each site.

Table 4. Grain yield and quality measurements of the barley at the two sites

Site		Yield (kg/ha)			Protein (%)			Grain weight (kg/hL)			Level of screenings (%)			Grade
		0	**125**	**250**	**0**	**125**	**250**	**0**	**125**	**250**	**0**	**125**	**250**	
1	**0**	2735	2550	2365	11.4	11.8	12.3	67.8	66.8	66.6	9.9	7.2	9.6	All malt
	125	2395	2595	2390	11.9	11.8	12.1	66.6	66.5	66.8	8.7	8.6	9.2	
	250	2445	2500	2460	12.0	12.2	12.2	68.6	67.8	66.3	8.6	8.1	8.2	
	lsd (5%)	263			0.7			1.4			2.5			
2		**0**	**125**	**250**	**0**	**125**	**250**	**0**	**125**	**250**	**0**	**125**	**250**	All malt
	0	1975	1860	1895	10.9	10.9	11.1	66.2	67.8	66.5	13.0	12.6	12.9	
	125	1915	1855	2035	10.9	10.8	11.0	67.0	66.0	67.0	12.7	14.7	11.7	
	250	1940	1945	2045	11.0	10.7	10.8	66.2	66.5	67.0	14.4	13.7	13.3	
	lsd (5%)	639			0.8			2.0			5.7			

CONCLUSION

The findings of these two experiments and that of the year earlier indicate that applying a foliar fungicide to barley, even when grown as consecutive barley crops is of no real advantage to the crop and so no economic benefit. It should be noted that this work has been done on Stirling barley in the low rainfall central wheatbelt. Other varieties may respond differently, however, Stirling was used as it is still useful for meeting market demands and making money for growers.

An outcome of this work is the suggestion that a disease management plan for barley paddocks should be adopted by growers for their farm to make the tactical decisions required in the season for disease control. Growers should intensively monitor only a select number of barley paddocks on their property only. The selection should be based on different crop histories but with similar yield potentials and highest likelihood of disease occurrence. Within these select paddocks, two to three sites should be repeatedly and regularly monitored throughout the season. Decisions to then apply a foliar spray can then be made according to these observations of disease development taking into account the current weather conditions seasonal forecast and prevailing levels of disease in the district. This is then applied across the whole of farm program.

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KEY WORDS

barley, leaf disease, fungicide application, timing, on farm research

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Brown manuring effects on a following wheat crop in the central wheatbelt

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KEY MESSAGES

Brown manuring a crop should only be seen as a tactical and opportunistic response to something like a poor season or weed control problem. It does not seem to be justified to **intentionally** establish a paddock with a brown manure crop even with low inputs in order to 'renovate' at the end of the season. It would be better to leave it out to regenerating weedy pasture to brown manure.

AIMS

To determine whether deliberately brown manuring a sown crop species has any advantage for a following wheat crop, over brown manuring regenerating pasture.

METHOD

2005

A farmscale Level 4 experiment (Russell, 2001) was established in 2005 of large scale blocks of manure treatments at two sites in the Kellerberrin district. The blocks were set out to go across existing paddock workings. Details of the sites are given in Table 1 below.

Table 1. Description of the set up at each site

<table>
<tr><th>Year</th><th>Site 1</th><th>Site 2</th></tr>
<tr><td>2005</td><td>Site unsprayed before treatments
Manure: Volunteer pasture (non legume, capeweed, radish and vol cereal)
Peas @ 60 kg/ha
Peas + Canola @ 60 + 3 kg/ha
Canola @ 3 kg/ha
Compound fertiliser 10N, 6P
Blocks: 12
Dimensions: 48 m x 150 m
Replicates: 3
Time of brown manuring: Mid August
Left ungrazed until seeding 2006. Residue managed for seeding.</td><td>Site sprayed out before treatments
Manure: Volunteer pasture (non legume, ryegrass)
Peas @ 60 kg/ha
Lupins @ 90 kg/ha
No fertiliser
Blocks 9
Dimensions: 36 m x 150 m
Replicates: 3
Time of brown manuring: September
Grazed over summer.</td></tr>
<tr><td>2006</td><td>Crop: Wheat cv. Calingiri
Sown: 26 May
Basal: 80 kg Agstar ~ 11 kg N
Subplots: 3 rates of N — Total
Treatments: 0 kg N/ha — 11
25 kg N/ha — 36
50 kg N/ha — 61
Application: Flexi N – liquid cart, drilled below the seed.
Plot dimensions: 16 m x 150 m</td><td>Crop: Wheat cv. Wyalkatchem
Sown: 29 June
Basal: 60 kg Agflow ~ 8 kg N
Subplots: 3 rates of N — Total
Treatments: 0 kg N — 8
16 kg N — 24
41 kg N — 49
Application: Flexi N – through boom spray sections at seeding.
Dimensions: 12 m x 150 m</td></tr>
</table>

Manure crops were established at relatively low seeding rates to reflect likely low input management practices. Minimal fertiliser was used. Post-emergent herbicides were not used and the blocks were sprayed out at the first signs of ryegrass head emergence using (a.i. glyphosate 540 g/L) at 1.2 L/ha and Ester 60% at 200 mL/ha followed by Gramoxone (a.i. paraquat 250 g/L) at 1 L/ha four weeks later. The option was left open to respray if weeds re-emerged afterwards.

Soil sampling for nutrients and determining plant available water capacity (PAWC) was undertaken by CSIRO prior to seeding. Plant density counts were taken at four weeks after seeding along with visual assessments of weed densities.

2006

Soil sampling was again conducted by CSIRO prior to seeding in April. This was used to determine the N treatment rates of the subplots. The blocks were sown to wheat with a basal compound fertiliser at three regimes of N. The subplots were set out in a randomised order. Standard paddock management practices were conducted across the plots trough the season. The rates of N were set based on an understanding of the soil type and seasonal target yields at seeding to give a response.

A visual observation of crop vigour was made at the 6 leaf stage. Tiller counts were conducted at site 2. Tissue testing was also done at this time on at least 1 replicate of treatments. Grain yield was measured from harvesting the centre of the subplots with a conventional harvester and determined with use of a weigh trailer. Grain quality and grade was determined from grain samples of each plot sent to the CBH as is normal farming practice.

GENSTAT v7 was used to conduct ANOVA and regression analyses of the data measurements.

RESULTS

2005

It should be noted that in January and into February and early April of 2006 these site recorded exceptionally heavy summer and early autumn rainfall (Table 1). 2005 was an above average season while 2006 was an extremely dry growing season.

Table 2. Rainfall at Kellerberrin for the average, 2005 and 2006 years (Post Office and BoM, 2006)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	*GS
Ave	10	15	22	22	43	57	53	41	26	19	12	13	**333**	**239**
2005	0	1	29.9	18.2	70.5	50.8	11.1	61.2	33.2	16.4	8.6	1.2	**302.1**	**243.2**
2006	100	41.2	17.2	23.9	10.3	10.8	19.6	28.2	33.9	2.8	17.6	12.0	**317.3**	**105.6**

*GS = growing season rainfall (May-Oct.).

Good growing conditions in 2005 allowed for plant establishment of the manure treatments to achieve those of crop levels despite the lower than normal seeding rates used. Pasture growth was also quite vigorous. The biomass of the volunteer pasture treatments at site 1 was observed to be much greater than that seen at site 2. At site 2 the crop species were observed to have a greater biomass.

Table 3. Plant densities of treatments in 2005 at six weeks after seeding

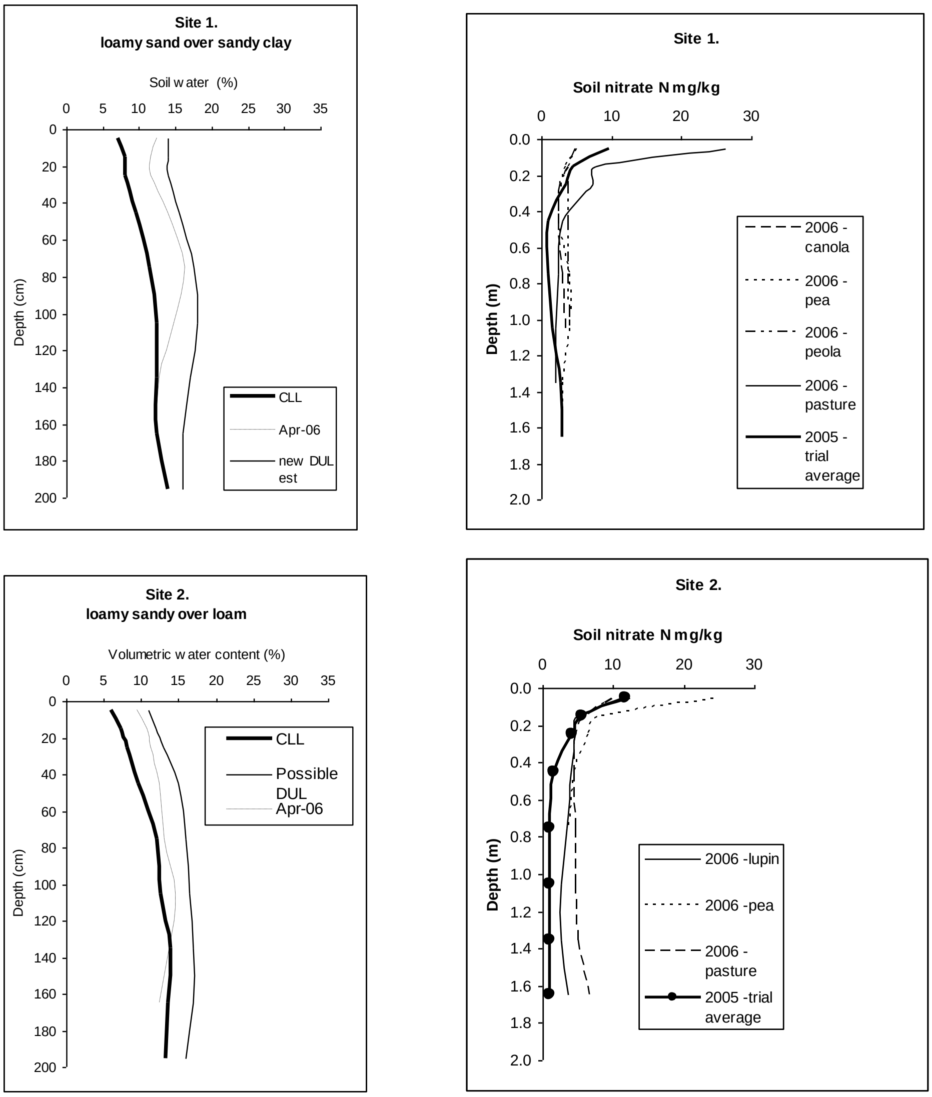
Site 1			Site 2		
Crop	**Plant density plants/m²**	**Weed density**	**Crop**	**Plant density plants/m²**	**Weed density**
Grassy pasture*	44%*	na	**Grassy pasture***	64%*	na
Peas	37	56	**Peas**	46	232
Peas + canola	97	53	**Lupins**	48	311
Canola	73	38	* Estimate of surface cover at 6 was. 'Pasture plant' numbers were in there 100s. esp. site 2.		

2006

Deep soil profile testing for nutrients and soil moisture show that the manure treatments in 2006 at both sites had very high levels of nitrate N (Table 4) above that of the previous year and that the soil profiles were very wet by late April (Figure 1) after the very heavy summer and autumn rains. N levels at depth in the soil prior to seeding in 2006 had increased on those measured for the sites in 2005.

Table 4. Soil nitrate N levels at depth (kg/ha) at each site in 2005 and 2006 prior to seeding

Site 1		Site 2	
Crop	**Nitrate N to 1.2 m**	**Crop**	**Nitrate N to 0.9 m**
2005 site average	44	**2005 site average**	52
2006			
Grassy pasture*	100	**Grassy pasture***	72
Peas	63	**Peas**	70
Peas + canola	78	**Lupins**	66
Canola	56		



CLL – crop lower limit, DUL – dry upper limit.

Figure 1. Soil moisture and N profiles to 2m of each site as at late April 2006.

Yield effects were seen at site 1 for both the manured residue type and the rate of N treatments (Table 5). This was also true for all of the grain quality attributes. The nature of the type of manured residue was not as prominent as for the rate of N applied. Wheat yields were significantly ($p = 0.05$)

greater on the grassy pasture residues and at the highest rate of N applied while protein levels were the inverse of this. Grain weight was acceptable but screenings were on the slightly higher end of having an economic impact being 5% or more on the pea and canola residues with applied N.

Of the tiller counts were conducted at site 2, neither manure residue had any significant effect ($p = 0.05$) on the level of tillering. The general trend seen was that there were more tillers produced in the crops grown on the lupin and pea residue blocks than the grassy pasture blocks. Also at this site these manure treatments yielded more than the grassy pasture treatment but not to any significant degree ($p = 0.05$) (Table 5).

Table 5. Grain yield and quality measurements of the wheat at the two sites

Site		**Yield (kg/ha)**			**Protein (%)**			**Grain weight (kg/hL)**			**Level of screenings (%)**			**Grade**
	N	**11**	**36**	**61**	**11**	**36**	**61**	**11**	**36**	**61**	**11**	**36**	**61**	
1	**GP**	1790	1837	1957	11.6	13.1	13.3	80.0	79.0	79.0	2.2	2.9	2.7	Mostly ASW
	Peas	1430	1487	1507	12.2	14.2	14.9	78.8	76.9	76.6	3.8	5.0	5.0	
	Can	1450	1583	1510	11.3	12.9	14.1	78.9	78.0	77.3	3.3	4.4	5.1	
	P+C	1617	1663	1697	12.0	13.6	14.3	79.4	78.1	77.7	2.9	4.0	3.8	
	lsd (5%)	197 68	Crop N rates		0.9 0.9	Crop N rate		1.2 1.2	Crop N rates		1.1 1.0	Crop N rate		
2	N	**8**	**24**	**49**	**8**	**24**	**49**	**8**	**24**	**49**	**8**	**24**	**49**	Mostly APW2
	GP	2397	2559	2554	10.5	10.8	11.1	79.1	79.0	79.2	5.2	5.3	4.6	
	Peas	2581	2821	2871	10.3	10.7	11.0	80.6	79.7	78.9	3.1	3.9	4.9	
	Lup	2935	2909	3005	9.9	10.3	10.4	80.3	80.1	79.9	3.2	2.3	3.0	
	lsd (5%)	696 290	Crop N rates		0.9 0.6	Crop N rate		1.8 1.4	Crop N rates		2.2 1.6	Crop N rate		

CONCLUSION

These two experiments show that the reason for brown manuring a paddock needs to be well considered. Three main reasons for brown manuring are: i) controlling weed seed set; ii) increasing organic matter levels; and iii) to increase N levels.

These experiments suggest that it is better to allow a paddock requiring manuring to regenerate as a volunteer pasture than to deliberately sow a brown manuring crop. A regenerating volunteer pasture has been seen to assist with meeting two of the factors mentioned above. It may be useful to consider an autumn tickle of the pasture to encourage early weed growth in the manuring year as a tool to enhance weed germinations and control which was not used here.

Site 1 certainly supports the above with the pasture treatments out yielding manure crop treatments by 200-380 kg/ha a value of $40 to $80/ha at long term average grain prices of $200-210/t. Site 2 has it going the other way which needs to be put against the carrying capacity of the pasture and the seeding costs of the manuring crop. This makes for a possibly either way argument for a manure crop or allow for regenerating pasture.

This work needs to be held in context with the season. Deep soil analysis (Table 4 and Figure 1) show high levels of soil moisture at the beginning of the season along with high levels of N to depth. The summer rains of 2006 are likely to rule out any residual moisture impacts from the different manure treatments on the following wheat crop.

N responses were seen at both sites and while significant at site 1, the economic benefits needs to be considered for applying additional N. At site 1 it was not a paying response to apply 25 kg/ha of N while at site 2 it was almost break even at the highest rate of N, 41 kg/ha, giving an additional 172 kg/ha (average).

An observation from this work opens other areas of investigation. The pasture at site 1 was seen to be greater in biomass than that on site 2. Is having more biomass grown in the manuring year going to give a better result for the following crop? As long as the residues can be managed well enough to seed the following year's crop.

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KEY WORDS

wheat, renovation cropping, brown manuring, nitrogen application, on farm research

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Management of annual pastures in mixed farming systems – transition from a dry season

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KEY MESSAGES

A low level of annual legume seed production in 2006 has implications for future pasture management. Assessing seed banks can help make decisions about the level of intervention for topping-up seed banks or resowing. The choice of pasture species and cultivar is a function of the type of farming system, soil type and climate. A range of decision aids are available to help set the strategy for pasture management.

BACKGROUND

The false break of season and below average rainfall in many regions of the wheatbelt during 2006 had a major impact on pastures with reduced feed availability and low seed production. Subterranean clover pastures were perhaps the most severely affected, with biserrula and yellow serradella being noticeably more resilient. This paper aims to focus on some general pasture management issues surrounding the transition from a dry season. The main issues for farmers are how to maintain adequate levels of ground cover over summer/autumn, how to top up seed banks and how to give pastures the best chance at the break of the season.

KEY DECISION POINTS

Summer grazing

Grazing sheep on paddocks with low amounts of feed will encourage more surface seed to be eaten by sheep and reduce the quantity of seed available for germination at the break of season. Seed reserves will decline to drastically low levels before animal condition begins to deteriorate. Medic and yellow serradella pods are the easiest for grown sheep to eat but they will also dig for sub. clover burr, especially when ground cover gets below about 70-80 per cent. Small seeded species like biserrula, balansa clover and gland clover are less vulnerable as a high proportion of ingested seed (40-50%) will pass through the animal in the faeces.

Sandy soils are at greatest risk of wind erosion. Once ground cover gets to about 50% (about 500 kg/ha dry matter), sheep should be moved to a feedlot or hand fed on stubble or grassy paddocks that still have sufficient ground cover.

Assessing pasture seed banks

Seed reserves hold the key to the availability of early sheep feed as well as pasture composition. The more legume seed that is ready to germinate with the first rains, the higher the pasture productivity and the greater the benefits to animal and crop production.

A low level of legume seed production in 2006 has implications for future pasture management, particularly if paddocks were cropped in 2005, the most recent year when spring conditions were conducive to good pasture seed production. Low seed pools (< 100 kg/ha) will be reflected in poor regeneration for 2007. In this situation pastures will need intervention such as re-seeding or topping up of seed reserves to boost production.

Seed reserves are difficult to assess because of the difficulty in measuring the amount of seed buried in the soil from cropping. Seed size and the number of seeds per pod also vary considerably. However, guidelines for a simple estimate of the seed reserve are provided below for some self-regenerating pastures, based on counting the number of pods or burrs at the soil surface (Devenish 2001):

1. Make a quadrat from the rim of a 2 L ice-cream container 16 cm x 16 cm (0.025 m^2). Count the pods or burrs in 5-10 quadrats for a paddock and then average (may have to dig and sieve sub. clover over flywire). February/March is the best time for this.

2. Collect about 15 pods or burrs and check the average number of seeds per pod by gently pulling them apart. Hold them over a sheet of paper or tray because the seeds will fly out.
3. Compare the number of pods, and seeds per pod, with Table 1 below to give an estimation of what your paddock seed levels are like. (If the seed number per pod differ from the table then you will need to make a percentage adjustment.)

Table 1. Estimating sub. clover, medic, yellow serradella and biserrula seed reserves by counting the pods (new or surface seed only – an allowance needs to be made for any buried seed)

Species	Average number of seeds/pod	Ideal numbers pods/quadrat (400 kg/ha seed)	Reasonable number of pods/quadrat (200 kg/ha seed)	Critical low numbers of pods/quadrat (< 100 kg/ha seed)
Sub. clover (e.g. Dalkeith)	3	70	35	**17**
Burr medic (e.g. Santiago)	4	100	50	**25**
Barrel medic (e.g. Caliph)	6	50	25	**12**
Yellow serradella (e.g. Santorini)	6	60	30	**15**
Biserrula (e.g. Casbah)	16	60	30	**15**

These indicative numbers are more appropriate for fresh pods of these species. It is less useful for aged pods where seeds have been lost and neglects free seed in the soil. The assessment is not directly applicable for mature Cadiz French serradella which will break into individual pod segments with single seeds. These segments should be counted separately and the total divided by 5-6 to convert the result to a pod number basis.

Seed banks of 200 kg/ha will survive a crop phase. Paddocks with seed banks of 100 kg/ha need to be carefully managed to ensure new seed production takes place. Re-seeding is likely to be required if seed banks are less than 50 kg/ha. **Note:** Soft seeded species (e.g. Cadiz serradella) can regenerate adequately from seed banks as low as 50 kg/ha if there are no losses from summer rains. Biserrula and yellow serradella performed well in the spring of 2006 so these paddocks are likely to be better buffered against declining seed banks.

Only a proportion of the seed bank will become germinable each year depending on the species and the amount of hardseed breakdown. For some species (e.g. sub. clover) the proportion of the seed pool available for germination can be assessed using the ring technique described by Carter *et al.* (1989) where germination is induced by adding water (about 5 L) to open ended cylinders (about 300 mm diam.) driven into the ground. This should be done in mid-autumn to assess the likelihood of future pasture emergence, although it is less useful for species with delayed seed softening (e.g. annual medic, yellow serradella). About 3-5 cylinders in each paddock, wet up as described, can give an indication of legume content (pasture paddocks the priority).

Re-sowing is the best and most reliable method to renovate pastures and increase legume seed reserves, but can be expensive. Some alternative options to top-up seed banks are provided below but have a much greater risk of failure.

Choice of species

The array of annual pasture legumes species has expanded greatly over the last 10 years (Table 2). The choice of pasture species and cultivar is a function of the type of farming system (e.g. self regenerating pastures in a crop rotation, tactical short-term phase pastures), soil type (e.g. texture, pH) and climate (e.g. rainfall, frost incidence). Guidelines for species choice can be found in the GRDC Ute Guide – Pasture Legumes for Temperate Farming Systems and the 2007 Farm Budget Guide – Pasture Legume Recommendations. Targeting pasture improvement on sandplain soils less suited to cropping is a sensible place to start (Revell *et al.* 2007).

Low cost pasture establishment

Sowing a pasture legume (e.g. biserrula, hardseeded French serradella) at 1 or 2 kg/ha (seed) with 20 to 30 kg/ha of cereal can provide early feed and soil protection along with the opportunity to build up pasture legume seed numbers. Varieties like Cadiz French serradella that can be produced and stored cheaply on farm can also be used tactically to top-up the density of pastures. Cadiz should be

sown at rates around 15-20 kg/ha pod. In the event that low legume plant densities (10-50 plants/m^2) already exist, it can be more economic to manage these with insecticides, herbicides and grazing management, rather than take on the expense of a full reseeding program.

Dry seeding

Sowing into moist soil after germinating rains and appropriate weed control is the preferred strategy for pasture establishment. However, opportunities for dry sowing have expanded in recent years with the availability of granular inoculants that allow rhizobia to survive in dry soil until the germinating rains. Dry sowing is more effective with modern air seeders fitted with knife edge points. Simply lift the machine up so that the points only dig about 5 cm deep, drop the seed in the groove, then follow behind with press wheels leaving the seed 1 cm deep and ready to germinate with early rains. Be careful using rotary harrows because they can leave the seed buried too deep. If you are not sure of getting the right depth then add some lupins (they are easier to find in the soil) for the first few laps of the paddock.

It is important that at least 50% ground cover be left after the seeding operation to minimise the risk of wind erosion. This might limit the dry-seeding technique in drought affected areas.

Topdressing seed when applying fertiliser in autumn is a cheap method but tends to be hit-and-miss because the seed is left lying on the surface and can be eaten by ants or more easily subjected to losses from false breaks.

Inoculation is less critical for sub. clover or medic seed on paddocks with a recent history of that pasture or for serradella on paddocks that have recently grown serradella pasture or lupins (serradella can pick up background lupin rhizobia but they are slightly less effective). New species being sown for the first time need to be sown with the correct inoculant. To minimise the risk of nodulation failure with conventional peat inoculation, increase inoculation rates and seed as close to the break as possible.

Insect control

When legume pasture density is low, it is important that insects are controlled. Red legged earth mite (RLEM) and lucerne flea are the main concern. Paddocks correctly treated with the Timerite® spray last spring should not be troubled by RLEM. Control measures should be considered on all other paddocks to ensure the best conditions for the growth of the pasture (clover in particular). There is normally a stock withholding period after application to consider.

Deferred grazing

At the break of season deferred grazing can improve seedling establishment and pasture density. The benefit is often greater in seasons with a late break where the capacity to establish a critical leaf area is reduced. It is this leaf area that determines future pasture growth. Deferring grazing until food-on-offer (FOO) is about 600-800 kg/ha can be advantageous in this situation. Sub. clover has the capacity to grow at its maximum rate above a leaf area index (LAI) of 4, which corresponds to FOO > 1300 kg DM/ha. It has been estimated that a LAI of 1-3 will result in herbage yields that are 20-70% of the production when LAI is between 3 and 6.

For pastures to recover following hard grazing, they clearly need an opportunity to rapidly develop some leaf area. This may mean deferment of grazing for one to two weeks. With good rains and warm conditions for late winter and early spring, pastures should respond quite quickly provided plant density has been maintained.

USEFUL DECISION SUPPORT TOOLS

GRDC Ute Guide – Pasture Legumes for Temperate Farming Systems (GroundCover Direct).

2007 Farm Budget Guide (Farm Weekly) – Pasture Legume Recommendations.

Woolpro Placemate Series (DAFWA).

Kondinin Group Pasture Pic Booklet.

CSIRO and DAFWA Pasture Growth Rate website (www.pasturesfromspace.csiro.au).

DAFWA Pasture Farmnotes and website (www.agric.wa.gov.au).

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Table 2. Annual legume species selection guide (adapted from the GRDC Ute Guide)

FARMING SYSTEM	Infertile acidic sands	Acidic sands to sandy loams	Neutral to alkaline sand to sandy clay loams	Neutral to alkaline loam to clays	Winter waterlogged soils
1. Phase farming (pasture re-sown at the beginning of each pasture phase)					
1-3 yrs pasture followed by several years of crop	French serradella	Sub. clover French serradella Gland clover Rose clover	Strand medic Balansa clover Persian clover Gland clover Rose clover	Strand medic Balansa clover Persian clover Gland clover Lucerne	Persian clover Balansa clover Gland clover Sub. clover ssp. *yanninicum*
2. Ley (regenerating) pasture					
More than 1:2 crop to pasture	Yellow serradella French serradella*	Sub. clover French serradella* Gland clover Rose clover Yellow serradella Biserrula	Strand medic Barrel medic Hybrid disc medic Burr medic Biserrula Rose clover	Strand medic Barrel medic Burr medic Snail medic	Sub. clover ssp. *yanninicum* Balansa clover Persian clover Gland clover
1:1 crop to pasture or 2:1 crop to pasture	Yellow serradella French serradella*	Yellow serradella French serradella* Biserrula	Strand medic Barrel medic Hybrid disc medic Burr medic Biserrula	Strand medic Barrel medic Hybrid disc medic Burr medic Snail medic	
3. Fodder					
Hay or silage	French serradella	French serradella Arrowleaf clover Crimson clover	Balansa clover Persian clover Crimson clover Snail medic Vetch	Balansa clover Persian clover Vetch	Sub. clover ssp. *Yanninicum* Balansa clover Persian clover
4. Permanent pasture					
Annual	Yellow serradella French serradella	Sub. clover French serradella Rose clover Gland clover	Strand medic Balansa clover Persian clover Rose clover Gland clover Barrel medic Hybrid disc medic Biserrula	Strand medic Balansa clover Persian clover Gland clover Barrel medic Hybrid disc medic	Sub. clover ssp. *yanninicum* Balansa clover Persian clover Gland clover

* Hardseeded varieties only.

KEY WORDS

pasture, legume, seed banks, regeneration, sowing, establishment

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The value of new annual pastures in mixed farm businesses of the wheatbelt

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KEY MESSAGES

Serradella and biserrula can substantially improve farm profit in mixed farming systems of the wheatbelt, either through the ability to improve stocking rate, reduce supplementary feed or increase the area of cereal at the expense of pulses and oilseeds. Higher pasture growth rates and feed quality can improve profitability between $13-71/ha, depending on soil type. Targeting pasture improvement on sandplain soils is a useful starting point.

AIMS

Serradella and biserrula are examples of a suite of pasture legumes that have been developed to address particular technical and economic limitations in traditional species such as subterranean clover and annual medics. Some of these characteristics include enhanced productivity on acid, infertile soils, persistence through intensive crop rotations, extended growing season from deeper root systems and better pest and disease tolerance. Serradella is suited to the acid, infertile sandy soils of the WA wheatbelt, while biserrula is suited to more duplex and loam soils of neutral to mildly acidic reaction. The aim of this paper is to discuss the economic benefits of these new species to farmers in the medium and low rainfall wheatbelt of Western Australia.

METHOD

The complexity of mixed farming system and the interactions between enterprises demand a whole farm approach to economic analysis. The Central Wheatbelt version of MIDAS (Model of a Dryland Agricultural System) provides such an approach and was used to assess the increase in profit resulting from improvements in growth rate and pasture quality resulting from the adoption of serradella and biserrula on a typical farm in the Central Wheatbelt of WA (the point of reference in the model is Cunderdin).

The MIDAS model describes a typical farm and the resource endowments of a typical farm business (Kingwell and Pannel 1987). The yields and costs reflect the ability of a manager that is better than average (around the 3rd decile of farmers in the region). Cropping history (or rotation) is represented by up to 60 different activities for each of eight land management units (LMU) described in the model (Table 1). The season is divided into 10 periods of varying length depending on the growth rate of pasture. There are five periods of growth, expanded to 6 to incorporate the new species (Table 2).

Table 1. Description and area of LMU's in the typical farm described by the Central Wheatbelt Model

LMU	Area (ha)	Short description
1	140	Deep pale sand.
2	210	Deep yellow sand.
3	350	Yellow gradational loamy sand.
4	210	Sandy loam over clay.
5	200	Rocky red brown loamy sand/sandy loam, Brownish grey granitic loamy sand.
6	200	Red brown sandy loam over clay; Red clay valley floor; Grey clay valley floor.
7	300	Deep sandy surfaced valley; Shallow sandy surface valley soil.
8	390	Loamy sand over clay.
Total	2000	

An annual pasture is a mixed sward of grasses, herbs and legumes. The quality and quantity of feed is the average of the sward for each period. Each period varies in length according to growth rate and pasture quality (digestibility). Pasture is assumed to germinate in Period 1. Germination is dependent on soil class and crop/pasture sequence. Growth rate in subsequent periods is a function of feed on offer (kg of dry matter per ha), and is approximated by linear segments. Pasture quality and quantity decline rapidly after senescence (Periods 6–10). Conservation constraints prevent over-grazing of pastures and crop residues.

Merino and merino-cross livestock options are described in MIDAS. The flock is self-replacing and the model can select between three livestock enterprises or a combination of them. These are a wool enterprise, a merino prime lamb enterprise and a cross-bred prime lamb enterprise.

The analysis was based on the introduction of yellow serradella onto the acidic sandy soils (LMU 1, 2 and 3) and biserrula onto the duplex and loam soils (LMU 4, 5, 7 and 8). Productive legume pastures were assumed to exist on LMU 3 and 5 (subterranean clover) and LMU 6 (annual medic). Estimates of pasture growth of the new legumes were made based on trial data and researcher experience.

The first part of the analysis was based on changes in pasture growth rate for individual LMU's and combined LMU's. The second part examined the impact of changes in pasture quality and wool price. The growth rates assumed prior to the introduction of yellow serradella and biserrula and the estimated increases in growth rate after adoption are shown in Tables 2 and 3, respectively.

Table 2. Maximum growth rates of pasture for each period without yellow serradella and biserrula

Period	Days	Pasture growth rate (kg/ha/day)							
		LMU1	LMU2	LMU3	LMU4	LMU5	LMU6	LMU7	LMU8
1	14	6	11	18	11	17	14	16	16
2	21	7	10	14	10	14	13	13	13
3	35	7	10	14	10	14	11	10	13
4	56	29	41	48	34	48	43	41	43
5	28	28	48	56	39	50	45	56	50
6	21	0	0	0	0	0	0	0	0

Table 3. Relative growth rates of pasture resulting from the introduction of serradella (LMU 1-3) and biserrula (LMU 4-8)

Period	% Increase in pasture growth rate (kg/ha/day)							
	LMU1	LMU2	LMU3	LMU4	LMU5	LMU6	LMU7	LMU8
1	100%	25%	0%	33%	0%	0%	11%	11%
2	40%	29%	0%	43%	0%	0%	11%	11%
3	40%	29%	0%	43%	0%	0%	14%	11%
4	33%	6%	0%	43%	0%	0%	6%	11%
5	60%	18%	30%	86%	44%	0%	30%	44%
6	-50%	-25%	***	-25%	0%	NA	-25%	-25%

*** Estimated P6 growth rate is 28 kg/ha/day. % changes in P6 are relative to LMU 3.

The costs of establishing the improved pasture was assumed to be $90/ha. This includes seed machinery costs, herbicides and fertiliser costs. The annual maintenance costs, made up of herbicide and fertilisers, was assumed to be $28/ha annually. This gives an annual amortised cost of around $35/ha. The standard wool price was 720¢/kg WMI and the standard wheat price was $200/t Net Pool Return (forecasts for a medium term outlook).

RESULTS

Whole farm profit was increased substantially as a result of the introduction of more productive pasture species on all but one LMU. Introducing biserrula onto LMU6 resulted in no change in profit, as production was not increased. Table 4 shows that the largest increase in whole farm profit occurs in

LMU 8 (fine textured loam) and pasture was the most profitable activity on this soil in the absence of a production increase. However, the largest per hectare increase in profit occurred on LMU 1.

Table 4. Increase in farm profit, pasture area and stocking rate resulting from the introduction of yellow serradella and biserrula on individual LMU's and a combination of LMU's

LMU for production change	Farm profit ($)	Change in farm profit ($)	Area of improved variety(s)	Total area of pasture	Change in profit ($/ha)	Stocking rate (dse/ha)
No change	115,194	-	-	814	-	6.2
1	125,116	9,922	140	776	71	6.7
2	118,650	3,456	210	908	16	5.8
3	118,686	3,492	263	796	13	6.3
4	119,556	4,362	158	985	28	5.9
5	117,748	2,554	150	789	17	6.3
6	115,194	0	0	814	0	6.2
7	121,957	6,763	225	1,007	30	5.8
8	129,360	14,166	293	940	48	6.3
1, 2 and 3	130,651	15,457	560	815	28	6.6
All	145,254	30,060	1,060	1,060	28	6.1

An important feature of the results in Table 4 is that the increase in profit resulting from the introduction of more productive pasture varieties on individual soils is not additive. This is evident by comparing the sum of the changes in profit for LMUs 1, 2 and 3 and the increase in profit estimated by the model when production is increased on all of these LMUs.

Another feature of the results is that there is apparently no consistent relationship between the increase in stocking rate and production increases. The largest production increases occur on LMU 1 and LMU 4 (Table 3). However the stocking rates on the farm are relatively high where production is increased in LMU 1 and relatively low where pasture growth is increased on LMU 4 (Table 4).

The dominant rotations prior to adoption of the new varieties were continuous annual pasture and continuous cropping. The introduction of yellow serradella and biserrula improves the profitability of pasture crop rotations relative to continuous rotations. Intensive pasture crop rotations are part of the optimal land use sequences for most soils (Table 5). Improvements in pasture production invariably lead to a substitution of pulse and oilseed crops with pasture.

Table 5. Optimal rotations and next best rotations selected by the model following the introduction of yellow serradella and biserrula on individual land management units (P – annual pasture, W - wheat, B – barley, O – oats, L – lupin, F – field peas, N – canola, A – faba bean, K - chickpea)

LMU	Best	Within $10-20/ha
1	PPPP	PPPW, PPPO
2	PPPP, PPPW, PPW	PWPW
3	PPPW, PPPP, PPW	PWPW, WNWL
4	PPPW, PWPW, PPW, PPPP	PPWW, WWF, WNWF
5	PPPW, PPPP, PPW	PWPW
6	WWF, WNBK,WNBF, WBK, PPPW, PPW	
7	PPPW, PWPW, PPW,	WWBA
8	PPPW, PPPP, PPW	PWPW

The modelled increase in farm profit resulting from improved pasture production increases with wool price. The optimal area of pasture also increased with rising wool prices. However stocking rate was fairly constant over the range of prices. To maintain the stocking rate as pasture area increased more supplementary grain was needed. This was in contrast to the results for the baseline (no new pastures). Whilst more supplementary grain was needed for livestock the stocking rate declined with higher wool prices.

Improvement in the digestibility of pasture (a conservative flat 2% increase in all periods) led to substantial increases in the profitability of pasture and hence livestock production. Improvements in winter digestible dry matter increased farm profit by 25% (around $2,000) more than the same increase over the dry months of the years assuming no increase in pasture growth rate. Where pasture growth was improved on the lighter soils the increase in profit was increased by a further 30% (around $5,000). However, given the substantial loss of dry matter and energy over summer (even with deferment) it is apparent that increasing pasture growth contributes less to reducing the autumn feed gap, compared to improving the quality of summer feed.

CONCLUSION

This study has shown that serradella and biserrula can substantially improve farm profit on all of the LMUs for which the analysis was undertaken. Their role in improving production and quality in the Central Wheatbelt substantially improves whole farm productivity either through the ability to improve stocking rate, reduce supplementary feed or increase the area of cereal at the expense of pulses and oilseeds.

The field performance of yellow serradella and biserrula in the difficult growing season of 2006 supports this economic analysis. Biserrula was one of the few annual legume pastures to provide early feed despite the late break of season. Although legume plant densities were often low, plants germinated on the summer rain and individual plants became quite large, surviving through to the break of season. In late spring both serradella and biserrula remained greener for several weeks longer than grass or sub. clover pastures, filling an important feed gap between the senescence of unimproved pastures and the availability of lupin and cereal stubbles. This allows young animals to be maintained in a stable or rising plane of nutrition.

The increase in profit per hectare resulting from higher pasture growth rates on individual soils is between $13-71/ha. The average increase in profit is $28/ha if the growth rate is increased simultaneously on all soils (except LMU 6). It may be reasonable to assume that the pastures are sown on soils where the per hectare benefit is highest. In practice the increase in demands on management and labour suggest that not all soils will be sown to these new species. The benefit of these species to industry will depend critically on which soils they are sown. Targeting improved pastures on the poor sandplain country is a sensible starting point. The decision to adopt may also be driven more by sustainability problems such as the occurrence of herbicide resistant crop weeds (a constraint not considered in this particular analysis).

It should be noted that photosensitisation of sheep grazing biserrula dominant pasture in spring continues to be a concern but can be well managed by deferring the grazing of these pastures until after senescence. The feed quality of biserrula as a dry feed appears to be particularly high and there is growing evidence that animal production can respond in this situation.

KEY WORDS

pasture, legume, rotation, modelling, midas, wheatbelt

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The influence of winter SOI and Indian Ocean SST on WA winter rainfall

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KEY MESSAGES

This study shows that the concurrent Southern Oscillation Index (SOI) significantly influences winter rainfall in high rainfall WA wheatbelt locations, with rainfall significantly lower in El Niño winters. The relationship between winter rainfall and the SOI combined with Indian Ocean Sea Surface Temperatures (SST) patterns around Indonesia and in the central Indian Ocean varies.

AIM

The SOI has a strong correlation with Queensland and New South Wales annual rainfall, but has a much lower correlation with Western Australian annual rainfall (Whetton, 1997). The relationship between the SOI and WA rainfall is complicated by the correlation of SSTs between Indonesia and the central Indian Ocean (England *et al*. 2006). This paper looks at the influence of June to August (winter) SOI and July SST on winter rainfall of eighteen WA wheatbelt locations.

METHODS

The SOI is calculated from monthly or seasonal atmospheric pressure differences between Tahiti and Darwin. The average value of the SOI in winter for years 1907 to 2006 was grouped into four categories: i) La Niña (SOI greater than 10); ii) SOI between 10 and 0 (Neutral); iii) SOI between 0 and – 10 (Neutral); and iv) El Niño (SOI below – 10). The corresponding winter rainfall in each SOI category was averaged for nine WA locations with annual rainfall of about 300 mm (low rainfall locations), and nine WA locations with annual rainfall of about 450 mm (high rainfall locations).

SST in July of each year was grouped into four categories: i) warm near Indonesia and cool west of WA (an enhanced gradient of SST); ii) cool near Indonesia and warm west of WA (weak SST gradient); iii) uniformly warm; or iv) uniformly cool. The corresponding winter SOI and rainfall in each SST category was compared to the long-term average rainfall on the basis of the SST category. This allowed for the influence of both SOI and SST on winter rainfall to be studied.

The relationship between winter rainfall and the SOI, SST, and a combination of the SOI and SST was tested using the Kruskal-Wallis test at a 95% confidence interval.

RESULTS AND DISCUSSION

SOI influence

The SOI has a varying influence on WA winter rainfall, with no influence on half of the locations studied. In the high rainfall locations (except Nabawa) and in Koorda, rainfall in El Niño winters was significantly lower ($p < 0.04$) than rainfall in the other SOI categories (Table 1).

SST influence

Indian Ocean SST considered alone, did not have a significant influence on winter rainfall for any of the locations studied ($p > 0.2$).

SOI and SST combined influence

The SOI and SST combined significantly influenced winter rainfall in seven of the eighteen locations studied. The influence of the SOI combined with SST varied, depending on the SST pattern and rainfall location.

Low rainfall locations

There is no statistical evidence to suggest that the state of the Indian Ocean influences low rainfall locations, as winter rainfall in all SOI categories within the four SST categories is similar. In two exceptions, Koorda and Bencubbin, El Niño winter rainfall is drier than La Niña winter rainfall when SST in Indonesia are cool and warm west of WA (Table 2B), and when SSTs are uniformly warm (Table 3 'WARM').

Table 1. June to August average rainfall (standard deviation in brackets) of low and high rainfall WA wheatbelt locations, and average June to August rainfall under the different SOI categories. Within a location, letters show significantly different ($p < 0.05$) rainfall

Location	All years average	La Niña	SOI < 10 to 0	SOI 0 to - 10	El Niño
Number of years	100	11	37	36	16
Low rainfall locations					
Pindar	141 (50)	162 (59)	145 (51)	137 (45)	126 (52)
Wubin	156 (56)	180 (58)	161 (50)	154 (60)	134 (54)
Kalannie	144 (51)	163 (53)	141 (46)	148 (54)	125 (50)
Koorda	131 (42)	149 (48) b	132 (36) b	138 (51) b	108 (42) a
Ejanding	144 (43)	160 (43)	142 (42)	151 (45)	124 (37)
Bencubbin	134 (44)	151 (56)	139 (41)	135 (48)	114 (45)
Nungarin	132 (43)	150 (51)	134 (41)	134 (40)	114 (41)
Southern Cross	114 (41)	121 (39)	115 (42)	118 (40)	97 (41)
Holt Rock	124 (42)	136 (33)	128 (46)	129 (43)	106 (41)
High rainfall locations					
Nabawa	257 (79)	284 (79)	267 (79)	250 (75)	229 (81)
Moora	238 (67)	277 (69) b	244 (65) b	236 (67) b	202 (56) a
Calingiri	229 (64)	249 (60) b	239 (64) b	231 (67) b	186 (46) a
York	235 (69)	260 (61) b	243 (70) b	235 (70) b	196 (56) a
Brookton	236 (65)	262 (59) b	245 (68) b	237 (68) b	197 (38) a
Pingelly	228 (66)	252 (57) b	237 (67) b	231 (67) b	188 (49) a
Wagin	202 (56)	221 (57) b	206 (61) b	211 (53) b	162 (34) a
Woodanilling	215 (57)	231 (63) b	220 (61) b	222 (51) b	175 (47) a
Tambellup	188 (46)	213 (42) b	192 (49) b	192 (39) b	153 (38) a

Table 2. June to August rainfall (standard deviation in brackets) for low rainfall WA locations A. when SST near Indonesia was warm and SST west of WA is cool, or B. when SST near Indonesia cool and SST west of WA is warm, under the different SOI categories. Within a location, letters show significantly different ($p < 0.05$) rainfall

Table A	Table A average	La Niña	SOI < 10 to 0	SOI 0 to - 10	El Niño
Number of years	26	4	9	11	2
Pindar	152 (61)	151 (88)	154 (85)	132 (56)	185 (78)
Wubin	156 (57)	160 (84)	154 (83)	131 (55)	194 (59)
Kalannie	147 (51)	146 (76)	149 (76)	128 (50)	187 (51)
Koorda	136 (46)	122 (64)	138 (70)	119 (45)	165 (66)
Ejanding	146 (46)	137 (70)	139 (67)	143 (58)	154 (31)
Bencubbin	137 (49)	115 (62)	144 (75)	119 (44)	171 (67)
Nungarin	140 (50)	148 (87)	132 (69)	120 (46)	184 (45)
Southern Cross	119 (47)	101 (61)	118 (66)	113 (50)	129 (56)
Holt Rock	133 (47)	132 (72)	114 (67)	127 (47)	157 (62)
Table B	**Table B average**	**La Niña**	**SOI < 10 to 0**	**SOI 0 to - 10**	**El Niño**
Number of years	28	2	10	10	6
Pindar	138 (57)	202 (125)	151 (69)	133 (48)	103 (35)
Wubin	158 (59)	237 (140)	163 (66)	166 (59)	111 (25)
Kalannie	140 (50)	210 (130)	136 (57)	153 (48)	100 (16)
Koorda	133 (56)	194 (115) b	120 (46) a	158 (68) ab	91 (21) a
Ejanding	135 (43)	175 (129)	126 (57)	154 (36)	105 (26)
Bencubbin	133 (52)	183 (112) b	132 (58) b	149 (58) b	91 (15) a
Nungarin	127 (42)	171 (116)	125 (55)	139 (33)	96 (20)
Southern Cross	106 (42)	136 (87)	114 (59)	112 (32)	72 (24)
Holt Rock	123 (49)	137 (88)	120 (62)	141 (53)	91 (33)

Table 3. June to August rainfall (standard deviation in brackets) for low rainfall WA locations when Indian Ocean was warm (WARM) or cool (COOL) under the different SOI categories. Within a location, letters show significantly different ($p < 0.05$) rainfall

WARM	SST warm average	La Niña	SOI < 10 to 0	SOI 0 to - 10	El Niño
Number of years	23	3	10	5	5
Pindar	140 (43)	155 (9)	145 (53)	136 (35)	124 (45)
Wubin	169 (63)	190 (20)	175 (60)	180 (98)	133 (40)
Kalannie	153 (62)	173 (26)	145 (58)	178 (96)	133 (49)
Koorda	138 (48)	177 (15) b	136 (42) ab	146 (65) ab	109 (47) a
Ejanding	158 (57)	199 (24)	154 (53)	173 (82)	128 (46)
Bencubbin	149 (54)	194 (41) b	146 (46) ab	152 (73) ab	126 (51) a
Nungarin	141(49)	165 (14)	144 (47)	145 (71)	116 (39)
Southern Cross	128 (45)	147 (24)	123 (39)	132 (71)	121 (45)
Holt Rock	134 (50)	145 (37)	143 (57)	130 (56)	112 (44)
COOL	**SST cool average**	**La Niña**	**SOI < 10 to 0**	**SOI 0 to - 10**	**El Niño**
Number of years	23	2	8	10	3
Pindar	129 (52)	155 (24)	113 (23)	147 (54)	137 (71)
Wubin	138 (58)	148 (38)	132 (32)	155 (55)	141 (100)
Kalannie	135 (47)	132 (57)	121 (32)	151 (49)	121 (80)
Koorda	125 (34)	118 (20)	122 (31)	135 (40)	104 (37)
Ejanding	142 (34)	132 (8)	139 (37)	147 (36)	138 (38)
Bencubbin	124 (32)	124 (37)	123 (20)	131 (37)	102 (43)
Nungarin	124 (36)	113 (1)	119 (34)	137 (39)	99 (40)
Southern Cross	106 (30)	109 (21)	92 (26)	122 (30)	86 (30)
Holt Rock	115 (30)	129 (20)	116 (16)	118 (41)	91 (14)

High rainfall locations

Generally the state of the Indian Ocean together with the SOI had no influence on winter rainfall. Of those locations with statistical significance, SST pattern of Indonesia warm and cool west of WA had conflicting influence. In Tambellup, La Niña winters are significantly wetter, but in two locations El Niño winters are wetter than La Niña winters. However this exception has only occurred twice, 1941 and 1965 (Table 4A). In a reverse SST pattern (Indonesia cool and warm west of WA), in five locations La Niña winters are significantly wetter and El Niño years significantly drier (Table 4B).

Table 4. June to August rainfall (standard deviation in brackets) for high rainfall WA locations when SST near Indonesia was warm and cool off WA (Table A), or SST near Indonesia cool and warm off WA (Table B), under the different SOI categories. Within a location, letters show significantly different ($p < 0.05$) average

Table A	Table A average	La Niña	SOI < 10 to 0	SOI 0 to - 10	El Niño
Number of years	26	4	9	11	2
Nabawa	271 (93)	252 (121)	273 (148)	247 (97)	298 (54)
Moora	231 (69)	237 (116)	209 (106)	220 (82)	253 (62)
Calingiri	223 (68)	206 (102) a	207 (109) a	210 (76) a	262 (2) b
York	240 (87)	228 (110)	212 (123)	233 (102)	280 (73)
Brookton	242 (77)	228 (110)	219 (118)	235 (94)	252 (21)
Pingelly	234 (79)	214 (103) a	219 (121) ab	222 (90) ab	266 (38) b
Wagin	208 (75)	184 (92)	199 (111)	208 (87)	194 (16)
Woodanilling	215 (72)	198 (95)	209 (115)	207 (79)	194 (51)
Tambellup	193 (57)	209 (101) b	179 (96) a	179 (60) a	170 (14) a

Table 4 continued …

Table B	Table B average	La Niña	SOI < 10 to 0	SOI 0 to - 10	El Niño
Number of years	28	2	10	10	6
Nabawa	260 (89)	397 (217)	268 (113)	253 (77)	211 (68)
Moora	234 (72)	327 (207)	243 (93)	245 (69)	173 (27)
Calingiri	218 (59)	317 (173) c	215 (83) b	237 (44) b	160 (21) a
York	231 (67)	341 (179)	243 (88)	235 (65)	164 (25)
Brookton	236 (68)	343 (177)	240 (92)	243 (67)	180 (21)
Pingelly	230 (65)	340 (155) c	237 (82) b	242 (67) b	161 (15) a
Wagin	191 (53)	281 (147) c	192 (77) b	201 (41) b	144 (19) a
Woodanilling	206 (56)	325 (152) c	204 (75) b	214 (45) b	158 (17) a
Tambellup	181 (42)	255 (156) c	186 (62) b	187 (42) b	140 (19) a

Uniformly warm SST patterns had significant influence on winter rainfall in five of the nine high rainfall locations. With El Niño winters significantly drier than La Niña winters in three locations and drier than rainfall in the other SOI categories in two locations (Tables 5 'WARM'). Uniformly cool SST patterns generally had no influence on winter rainfall, with rainfall in all SOI categories being similar (Table 5 'COOL').

Table 5. June to August rainfall (standard deviation in brackets) for high rainfall WA locations when Indian Ocean was warm (WARM) or cool (COOL) under the different SOI categories. Within a location, letters show significantly different ($p < 0.05$) average rainfall

WARM	SST warm average	La Niña	SOI < 10 to 0	SOI 0 to - 10	El Niño
Number of years	23	3	10	5	5
Nabawa	253 (75)	278 (11)	270 (82)	243 (106)	217 (37)
Moora	254 (76)	304 (54)	265 (85)	242 (85)	211 (45)
Calingiri	249 (84)	284 (26) b	267 (81) b	257 (125) ab	187 (33) a
York	245 (76)	261 (56)	270 (84)	227 (95)	206 (37)
Brookton	248 (73)	273 (28)	270 (87)	228 (85)	206 (21)
Pingelly	242 (71)	266 (17) b	269 (83) b	216 (79) ab	201 (32) a
Wagin	215 (62)	261 (29) c	229 (70) ab	205 (68) b	171 (14) a
Woodanilling	229 (63)	248 (29) b	247 (71) b	232 (71) b	177 (25) a
Tambellup	191 (57)	220 (34) b	202 (70) b	200 (47) b	145 (18) a
COOL	**SST cool average**	**La Niña**	**SOI < 10 to 0**	**SOI 0 to - 10**	**El Niño**
Number of years	23	2	8	10	3
Nabawa	243 (72)	250 (20)	225 (34)	255 (75)	245 (159)
Moora	238 (67)	264 (23)	234 (58)	243 (77)	216 (92)
Calingiri	229 (57)	216 (9)	237 (49)	235 (71)	198 (46)
York	228 (52)	245 (41)	215 (47)	241 (61)	211 (46)
Brookton	225 (56)	234 (4)	214 (47)	237 (72)	208 (31)
Pingelly	211 (56)	219 (22) b	186 (27) a	236 (71) b	188 (52) ab
Wagin	198 (44)	175 (13) a	176 (20) a	227 (45) b	176 (59) a
Woodanilling	213 (51)	176 (23) a	189 (27) a	241 (43) b	204 (100) ab
Tambellup	189 (40)	170 (5)	169 (25)	207 (39)	195 (70)

Table 6. Summary table showing the driest (↓) and wettest rainfall (↑) under each SOI and SST category where there is significance ($p < 0.05$) for low and high rainfall locations. Numbers in brackets indicate the number of locations this occurred. − indicates no significance

SST pattern	Location	SOI value				SST alone	
		La Niña	SOI < 10 to 0	SOI 0 to - 10	El Niño	Low	High
Indonesia warm WA cool	Low rainfall	−	−	−	↓ (1)	−	−
	High rainfall	↑ (1)	−	−	↓ (1) ↑ (2)		
Indonesia cool WA warm	Low rainfall	−	−	−	↓ (1)	−	−
	High rainfall	↑ (5)	−	−	↓ (5)		
Uniformly warm	Low rainfall	−	−	−	−	−	−
	High rainfall	↑ (1)	−	−	↓ (2)		
Uniformly cool	Low rainfall	−	−	−	−	−	−
	High rainfall	−	−	↑ (1)	−		
SOI alone	Low rainfall	−	−	−	↓ (1)		
	High rainfall	−	−	−	↓ (8)		

Findings from Table 6 suggest that SST patterns do play a role in high rainfall locations winter rainfall. Of the eight high rainfall locations which had significantly drier El Niño winters when the influence of the SOI was considered alone, only a maximum of five locations had significantly drier El Niño winters under one SST pattern.

CONCLUSIONS

It is well reported that El Niño winters are generally dry for Australia and while this is true for the eastern states (Whetton, 1997) the impact of El Niño on WA varies. This study found that the winter value of the SOI had no influence on half of the locations studied, but El Niño winters in high rainfall locations is significantly lower than rainfall in the other SOI categories.

This study found that the relationship of SST patterns combined with SOI is variable for WA winter rainfall, and SST patterns have the potential to change how we receive forecasts based on the SOI. Other studies (England *et al*. 2006) have shown that when warm Indonesia water compared with cool water west of WA (as in 2005) moisture inflow from the tropics is increased bringing rain bearing north-west cloud bands. In the reversed SST pattern, cool Indonesia water and warm water west of WA (as in 2006), moisture inflow does not occur and north-west cloud bands do not form. This study on winter rainfall, generally did not find a connection with SOI combined with SST on rainfall, as north-west cloud bands are active in autumn and early winter. A study on autumn rainfall should see a stronger association with SST patterns.

KEY WORDS

Southern Oscillation, sea surface temperatures, winter rainfall

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Market outlook – Grains

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The Department of Agriculture and Food, WA (DAFWA) is estimating a total Western Australian winter crop of 7.18 million tonnes as of 1 October 2006 for 2006/07. In 2005/06, the State's winter crop was 14.95 million tonnes, 7.8 million tonnes larger. The 2006/07 winter crop will be the smallest since 2002/03 when there was 6.81 million tonnes and the second smallest for the past 15 years.

Table 1. WA Crop production, 2002/03-2006/07 (million tonnes)

	2006/07 (01/10/06) est.	2005/06 (03/10/05) est.	2004/05	2003/04	2002/03	5-year average
Wheat	4.617	10.186	7.705	10.437	4.047	7.398
Barley	1.585	2.668	2.080	2.941	1.349	2.125
Canola	0.323	0.567	0.490	0.606	0.299	0.457
Lupins	0.227	0.878	0.688	0.969	0.587	0.670
Total	7.181	14.950	11.702	15.820	6.810	11.293

Source: Department of Agriculture and Food, 2006.

Estimated prices for all grains are up compared to last year and are approximately 15 per cent higher than the five year average (Table 2). In 2007/08 all pool returns are expected to return to more average levels, given a return of normal seasonal conditions in Western Australia. Prices are expected to be lower however the declines are not forecast to fall dramatically due to the current tight world grain stocks in wheat and coarse grains, plus the increase in world demand for canola into the biodiesel market.

Indicative pool prices for 2006/07 are higher than their five year averages and the highest since the drought-affected 2002/03 pools.

Table 2. WA grain prices quoted as Estimated Pool Returns 2002/03-2004/05 and estimates for 2005/06 and for 2006/07, and forecasts for 2007/08 FOB (A$ per tonne)

Grain type	2003/04	2004/05	2005/06	5 year average	2006/07 (estimate)	2007/08 (forecast)
Wheat (APW)	233	199	191	225	**245**	**215**
Barley – malting*	199.48	220	195[2]	240	**280**	**215**
Barley – feed	179.48	170	162[2]	198	**240**	**170**
Lupins	218.38	190	188	226	**265**	**220**
Canola	423.29	345	338	417	**470**	**420**

Average prices of commodities from 2002/03 to 2006/07 using pool estimates.

2 GPPL pool prices for barley are based on the number 1 pool.

* Malting barley prices are based on the Stirling variety.

Source: Department of Agriculture and Food, WA.

The Australian dollar/US dollar exchange rate remains a major factor influencing prices in Western Australia, as nearly all grain is sold in $US. Currently the $US/$AU exchange rate remains in a 0.7400 to 0.7700 trading range.

GLOBAL WHEAT OUTLOOK

The 2006/07 global outlook for wheat prices remains bullish with global production declining again this season after a smaller world crop in 2005/06. The United States Department of Agriculture (USDA) projects a decrease in production and ending stocks and a corresponding decline in total use (see Table 3).

Table 3. World Wheat Supply and Demand, 2001/02-2006/07 (million tonnes)

	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Source USDA				Oct. 2006	Oct. 2006	Oct. 2006
Beginning stocks	206.5	202.5	166.1	132.68	151.45	147.23
Production	581.1	567.7	554.2	628.84	618.85	585.14
Total supply	787.6	770.2	720.3	761.52	770.3	732.37
World trade	110.7	109.9	104.5	111.19	115.31	108.96
Total use	585.2	604.0	588.6	610.07	623.07	613.07
Ending Stocks	**202.50**	**166.10**	**131.70**	**151.45**	**147.23**	**119.30**
Stocks/Use	34.6%	27.5%	22.4%	24.83%	23.63%	19.46%

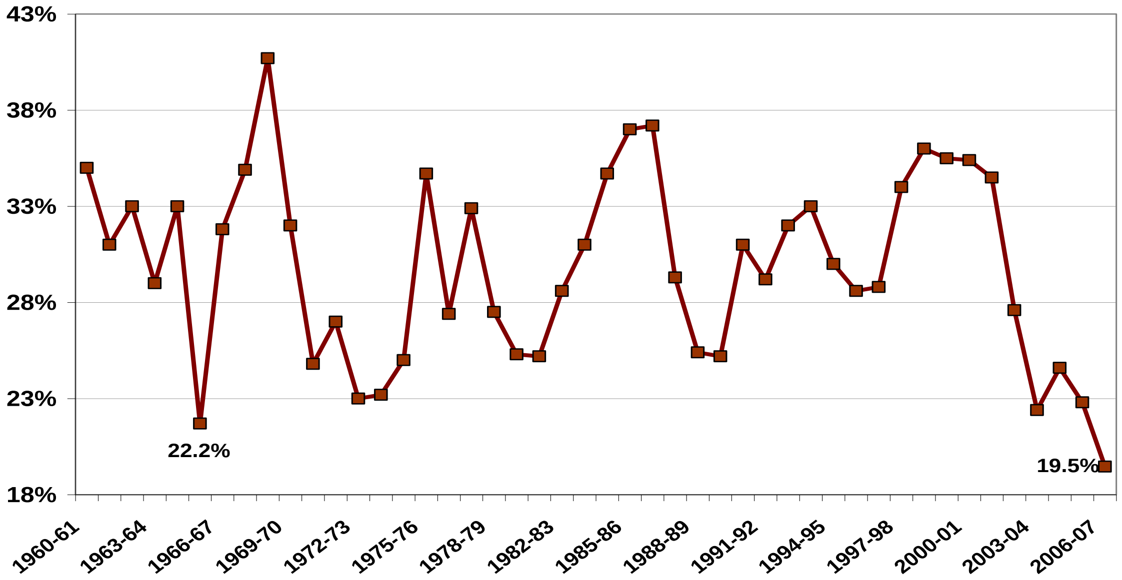
Source: USDA, 2006.

Global wheat production is expected to fall 33.7 million tonnes (five per cent) to 585.14 million tonnes in 2006/07. This production estimate is 43.7 million tonnes (seven per cent) lower than the record production year of 2004/05. The continued decline in world production is a result of the smallest global wheat crop area planted in 40 years, the considerably smaller Australian crop due to drought, as well as smaller crops in the United States (US), European Union 25 (EU-25), Brazil, Russia and the Ukraine. This has partially been offset by a larger crop in China.

With the smaller world crop, global consumption is slightly lower in 2006/07 than the previous year, down 10 million tonnes to 613 million tonnes compared to 623 million tonnes in 2005/06. Consumption is expected to fall slightly in the EU-25, Brazil, China, increase in North Africa and India and remain constant in other major importing countries.

With the large fall in world production, global wheat ending stocks in 2006/07 are forecast to decline 7.1 million tonnes (19 per cent) to 119.3 million tonnes. This is down significantly from 147.2 million tonnes in 2005/06 and the lowest global ending stocks in 25 years.

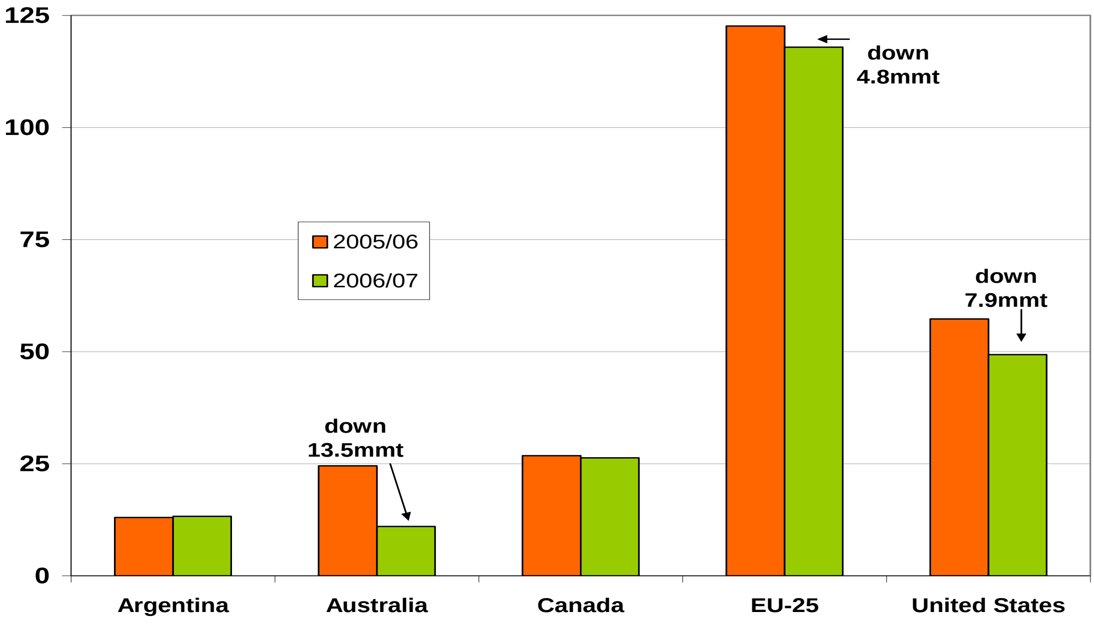
As a result of the steep decline in global ending stocks, the forecast stocks-to-use ratio for 2006/07 has fallen sharply to 19.46 per cent. This stocks-to-use ratio is the lowest for the past 45 years and is down from 23.63 per cent in 2005/06. This is illustrated in Figure 1 overleaf.



Source: USDA, 2006.

Figure 1. World wheat ending stocks versus use ratio, 1960/61-2006/07 (%).

The dramatic fall in the global stocks-to-use ratio is largely due to smaller crops in the US, Australia and the countries collectively known as the FSU, whilst global consumption has not fallen proportionately. The US, Canada, Australia, EU-25 and Argentina are the major five exporters of wheat globally, and this season will export around 75 per cent of world trade. The production in these five countries has fallen 11 per cent this season with the US crop estimated to be 7.9 million tonnes lower, the EU-25 to be 4.8 million tonnes lower and Australia 13.5 million tonnes lower.



Source: USDA, 2006.

Figure 2. Production – Five major wheat exporters 2005/06 versus 2006/07 (million tonnes).

Over the past five years, the Former Soviet Union (FSU) has emerged as large exporters of wheat when crop production has allowed them to do so. The abundance of these non-traditional wheat exports had contributed to the erosion of world wheat prices at times to levels below the cost of production in the traditional wheat exporting nations in the past two years. This year production in the FSU is projected to fall 12.3 million tonnes (13 per cent) and is a major contributing factor to smaller world production and therefore the extremely tight stocks-to-use ratio. The Ukraine Government has this month introduced Government controls and quotas restricting further exports of wheat from that country to insure adequate internal supplies in 2006/07.

World trade is projected at 108.96 million tonnes in 2006/07 compared to 115.31 million tonnes in 2005/06. Projected global imports are up 0.63 million tonnes in 2006/07 compared to 2005/06 with higher imports into India, Brazil and the US. This will partly be offset by lower imports into the EU-25, North Africa, Pakistan and China.

For the 2007/08 season, winter wheat planting is well underway in the northern hemisphere, and world wheat areas are expected to be significantly larger than in 2006/07 if normal seasonal conditions prevail, and in line with 2005/06 area of 215 million hectares (up from 206 million hectares in 2006/07). Increased plantings are likely in the EU-25 including France, Germany, Hungary, Poland and the United Kingdom (UK). Increased plantings are also expected in Russia, with recent warm and dry weather ensuring good conditions for winter wheat planting and establishment. In the Ukraine, the winter wheat area is expected to increase by about 9 per cent to 5.8 million hectares in 2007/08, with conditions proving favourable.

In the US, winter sowing is well advanced with 86 per cent completed at the time of writing (October 2006), close to the 5-year average. In parts of the Great Plains and the Pacific Northwest dryness is hindering favourable planting. In Canada, poor weather conditions in Ontario are likely to reduce the winter wheat area by up to 20 per cent. However most of the Canadian wheat crop is spring planted.

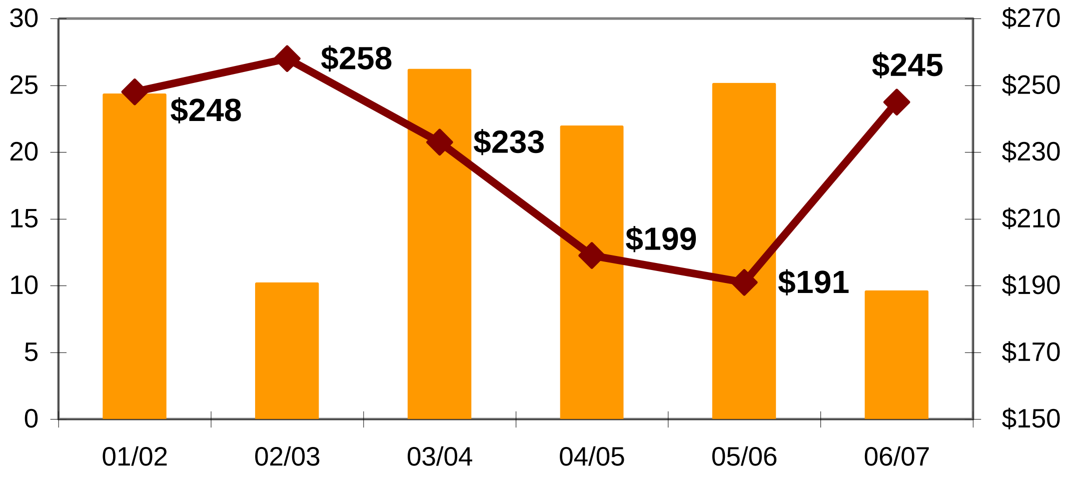
In China, the wheat area is expected to be in line with 2006/07, however it is expected farmers will increase the share of higher quality wheat varieties. Most wheat growing regions except parts of northern China have sufficient soil moisture for adequate crop development. Competition from other crops including canola and pulses are limiting the expansion of wheat areas in China.

Prices

World wheat export prices have rallied to 10-year highs in October 2006. This has been due mainly to the widespread drought conditions in Australian wheat growing areas. As a result the AWB Estimated Pool Return (EPR) for APW is A$245 per tonne (Free On Board, GST exclusive), AH is A$250 per tonne and ASWN is A$252 per tonne for 2006/07, at the time of writing (October 2006). EPR for feed wheat is A$205 per tonne, and durum is A$258 per tonne. The current cash prices for APW in Western Australia are in line with the AWB National Pool EPR.

The pool EPR values are likely to be unchanged to slightly increased for 2006/07. Current international prices are well above average levels, however there is limited upside potential given the likelihood that the Northern Hemisphere will increase production for the harvest next summer (i.e. June 2007) and these supplies will become available from June 2007 onwards. The key to Western Australian prices will be the outcome of the current National Pool given extremely tight domestic supplies on the east coast, the AWB forward hedging program in place and the movement of international wheat prices over the next six months.

In 2007/08, the APW pool is expected to fall A$25-A$40 per tonne from current EPR for APW of A$245 per tonne in 2005/06. This fall is due to the expectations that global wheat production will increase next year due to the positive price signals and crop prospects together with the increased area planted. Support for 2007/08 prices will come from the extremely tight global supplies of both wheat and coarse grains. If another major production hiccup occurs in 2007/08, prices will be volatile and remain at high levels. If Australian production returns to average levels, this will allow for adequate domestic supplies and ensure Australia is a key exporter once again.



Source: ABARE and AWBI

Figure 3. Australian Wheat Production (mmt) and the AWB National Pool return (A$), 2001/02 - 2006/07.

The movement of the AWB National Pool versus Australian wheat production in million tonnes for the past five seasons is illustrated in Figure 3 above. In the last drought year of 2002/03, the AWB National Pool returned A$258 per tonne for APW. In the following crop year of 2003/04, the AWB National Pool returned A$233 per tonne. If production returns to above average levels in Australia next year, it is probable there will be a decrease in the pool return in 2007/08.

WORLD COARSE GRAINS OUTLOOK

Corn accounts for around 71 per cent of the total global coarse grain market, followed by barley with 14 per cent, sorghum at six per cent, oats two per cent and rye at one per cent.

The US corn crop is estimated at 277 million tonnes in 2006/07 compared to 282.26 million tonnes in 2005/06 and 299.91 million tonnes in the record year of 2004/05. The 2006/07 corn crop is two per cent smaller that the 2005/06 crop which was the second highest US corn crop on record. The decline in US corn production this marketing year is attributable to a smaller harvested area (notably in Illinois, Nebraska and Ohio), and lower yields due to hot and dry weather.

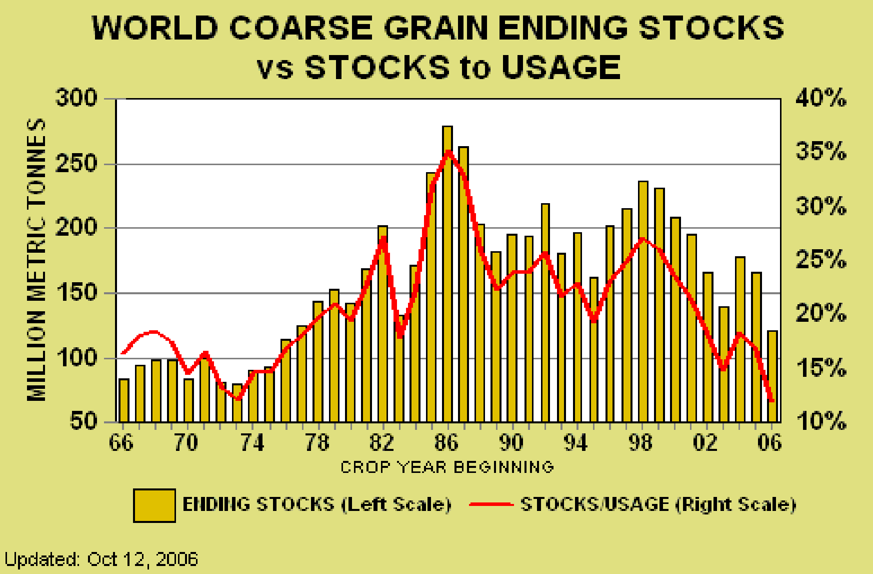
World coarse grain production has continued to fall at a greater degree than the fall in US corn production. The USDA expects total world coarse production to be 964.76 million tonnes in 2006/07, down five per cent or 9.64 million tonnes from 2005/06. This decline is due to a decline in corn, sorghum and rye production this marketing year in comparison to 2005/06. World corn production is expected to be 689 million tonnes compared to 693 million tonnes in 2005/06 and 712.31 million tonnes in the record year of 2004/05. The fall is also due to lower barley production in Australia and Canada. This has been offset in part by higher corn production in China and Mexico and higher European barley production. Chinese corn production is expected to reach record levels at 141 million tonnes in 2006/07 due to a record area and near record yields. In Europe, the barley harvest is excellent with yields coming in at above expectations.

World coarse grain consumption is expected to reach record levels in 2006/07. The USDA estimated global consumption at 1010.61 million tonnes, up 24.35 million tonnes from 2005/06. Consumption for feed is forecast to increase to 478 million tonnes from 474 million tonnes in 2005/06, due to tighter world feed wheat availabilities and prospects for improved poultry demand.

It is expected the industrial use of corn will grow sharply due to rising ethanol production. In the US, recent analyst estimates for industrial use at 84.6 million tonnes, including 54.6 million tonnes for the manufacture of ethanol. The latest data from the Renewable Fuels Association in the US showed ethanol production reached a record 412 million gallons in July 2006. Ethanol production continues to increase in the US with 44 refineries currently under construction, and 105 refineries in operation. In Asia, total corn consumption is forecast to rise 5 per cent, due to Chinese consumption rising sharply, mainly due to strong demand in the industrial sector, improved prospects for poultry demand, higher pork production and tighter world feed wheat availabilities.

World coarse grain ending stocks are estimated to fall by a massive 45.86 million tonnes (28 per cent) to 121 million tonnes in 2006/07 compared to 166 million tonnes in 2005/06. This fall in global ending stocks is due to the increase in global consumption of coarse grains and at the same time a decline in global production. World usage is projected at 1011 million tonnes, which exceeds production of 965 million tonnes by 46 million tonnes.

Given the increase in global consumption of coarse grains and the decline in production, the world stocks-to-use ratio has declined to 12 per cent compared to 16.9 per cent in 2005/06 and 18.3 per cent in 2004/05. The world coarse grains stocks-to-use ratio is the lowest since 1973 and both ending stocks and the stocks-to-use ratio have been declining since 1998. Ending stocks are now at the lowest levels in thirty years. This is illustrated in Figure 4.



Source: USDA, 2006.

Figure 4. World coarse grain ending stocks vs stocks to usage, 1965/66-2006/07.

WORLD BARLEY OUTLOOK

In 2006/07, world barley production is expected to be 139.8 million tonnes, slightly higher than 2005/06 production of 139.6 million tonnes and 14.5 million tonnes lower than production in the 2004/05 year. Australian barley production is estimated at 4 million tonnes by the International Grains Council (October 2006) a fall of 5.9 million tonnes from the 2005/06 crop year. This large fall in production has been offset by larger crops in Europe, the FSU and Africa.

The EU-25 is currently expected to produce 54.4 million tonnes of barley. Overall yields are up, however hot temperatures in early summer, followed by excessive rains in August/September, lowered yields in northern Europe, while in Spain production recovered from the previous year's drought. In France, malting barley quality is reported to be better than last year, with about 20 per cent of winter barley and 65 per cent of spring barley considered suitable for malting. In the UK, the proportion of malting barley is reported to be smaller than last year due to pre-harvest sprouting in parts of England and Scotland. In the FSU, increased area and higher yields have pushed barley production up this year.

In North America, the Canadian crop has been affected by rainy weather which has delayed the harvest in Alberta, the major barley producing province, and the US crop is also lower than last year, due to a smaller sown area and reduced yields.

World barley consumption is expected to be 148.1 million tonnes in 2006/07, 5.2 million tonnes higher than 2005/06 production. Analysts estimate demand for feed barley will reach a 10-year high at 102 million tonnes, up 1 million tonnes from 2005/06, due to tightening stocks of other feed grains. Forecast feed barley use in the EU, accounting for nearly one-third of world consumption, is expected to be higher in 2006/07, mainly due to the higher overall consumption of feed grains and a rebound in use in Spain following the drought-affected crop there in 2005/06.

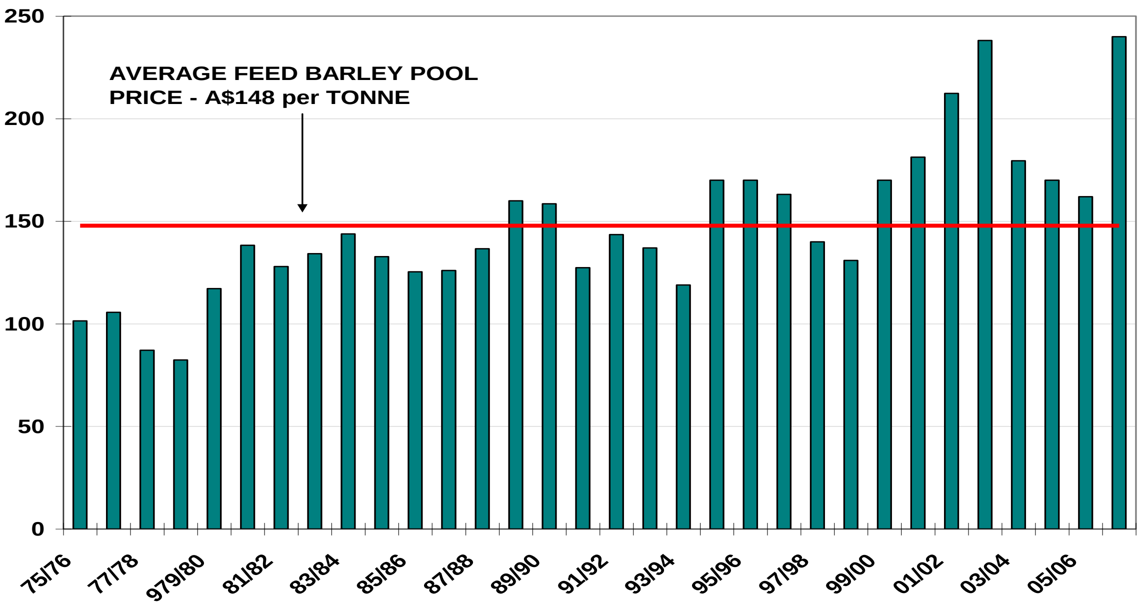
Following the trend from 2005/06, world barley consumption will continue to exceed production, by 8.3 million tonnes in 2006/07. With consumption exceeding production for two years in a row, world barley ending stocks are expected to drop to 19.6 million tonnes in 2006/07, which is an 11-year low and down 30 per cent from 2005/06 ending stocks pegged at 27.9 million tonnes. The single largest change is in the EU-25, where analysts expect ending stocks to fall to 4.8 million tonnes in 2006/07, down from 7.6 million tonnes in 2005/06, due to higher estimates of domestic use and exports. Interestingly, Saudi Arabia is expected to reduce its stocks by 1 million tonnes to 1.5 million tonnes in 2006/07 due to the tightening global situation.

Global trade is forecast to decrease by 2.3 million tonnes in 2006/07 to 15.5 million tonnes, compared with 17.8 million tonnes in 2005/06. The drought affected Australian crop has contributed to the decline in international exports in 2006/07.

Prices

Grain Pool Pty Ltd (GPPL) indicative pool prices for feed and malting barley are posting strong quotes in response to the small forecast crop, continued dry conditions both in Western Australia and the East Coast and global outlook. Since mid-April of this year when the GPPL barley pools were first quoted for 2006/07, the feed barley estimate for the number 1 pool has increased by A$105 per tonne to A$240 per tonne FOB, and the malting barley number 1 pool price has risen by A$120 per tonne to $280 per tonne FOB (based on Stirling which is the traditional variety quoted in historical pools). Figure 5 illustrates the GPPL feed barley pool price in 2006/07 is the highest since 1975/76.

GPPL introduced a new premium pool system in 2005/06 for barley. In 2006/07 the malting barley Premium Pool is A$285-$290 per tonne (based on the Stirling variety), A$15.00 per tonne higher than the number one pool. The feed barley Premium Pool is A$250-$260 per tonne which is also A$15.00 per tonne above the number one pool.



Source: Department of Agriculture and Food, 2006.

Figure 5. Grain Pool Feed Barley Pool Price 1975/76-2006/07 (A$/t).

In 2007/08, the GPPL price for feed barley is likely to be lower than in 2006/07, providing there is a return to average seasonal conditions, and is forecast at A$170 per tonne. This is due to expectations that consumption will remain at similar levels and production will increase, leading to an improvement in global ending stocks as well as stocks of wheat. Given global feed grain supplies are tight, this will buffer the pullback in prices to an extent. Corn prices are also expected to be supportive to feed barley prices in 2007/08 with stronger corn prices are forecast in comparison to last year.

The GPPL malting barley pool price is also expected to be lower than 2006/07 due to a return to normal production conditions.

WORLD OILSEEDS AND PULSES OUTLOOK

There are seven major oilseeds produced globally. Soybean production dominates with in 2006/07 a 58 per cent share of the world oilseed production, followed by canola (11.9 per cent), cottonseed (11.1 per cent), peanuts (8.1 per cent), sunflowers (7.5 per cent), palm kernel (2.7 per cent) and copra (1.3 per cent). The percentage share of production of each oilseed is largely unchanged from 2005/06.

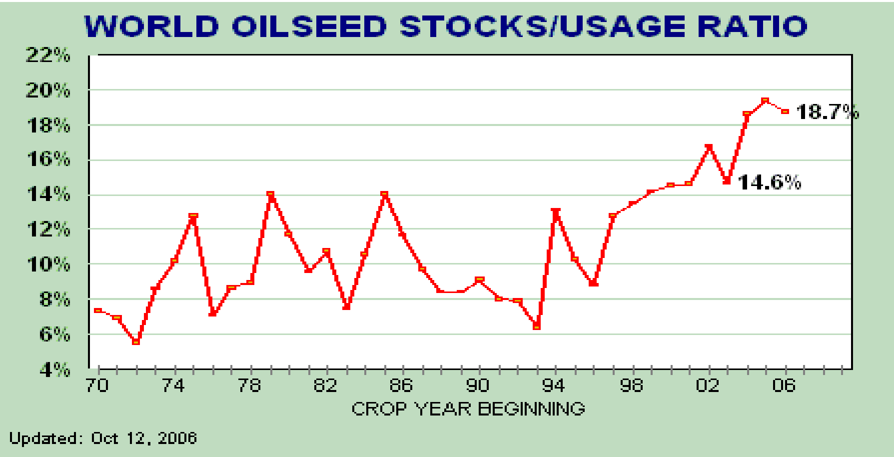
Global oilseed production for 2006/07 is projected at 390.39 million tonnes, up 2.08 million tonnes from 2005/06 and 9.1 million metric tonnes from 2004/05. Global oilseed production has risen over the past five years. This is largely due to the increased production in the major producing countries outside the US, with 2006/07 oilseed production outside the US raised by 7.4 million tonnes from 2005/06. The increase in production is due to higher soybean, cottonseed and palm production which has more than offset reduced canola, sunflower and peanut production.

Table 4. Global oilseed supply and demand, 2002/03-2006/07 (million tonnes)

	2002/03	2003/04	2004/05	2005/06 Oct.	2006/07 Oct.
Production	330.26	335.16	381.29	388.31	390.39
Exports	70.11	67.07	74.68	76.86	82.67
Imports	71.53	64.73	73.11	75.86	81.08
Crush	268.83	278.38	302.08	317.23	325.94
Ending stocks	47.48	43.86	56.19	61.46	61.07
Stocks-to-use	17.7%	15.8%	18.6%	19.4%	18.7%

Source: USDA Report, October 2006.

Ending stocks are expected to fall slightly in 2005/06 by 0.39 million tonnes to 61.07 million tonnes, due to the increased crush, up 8.71 million tonnes or 2.7 per cent. The world stock to use ratio of total oilseeds remains at high levels, despite the slight decrease from 2005/06 (Figure 6).



Source: USDA, 2006

Figure 6. World oilseed stocks to usage ratio, 1970/71-2005/06 (million tonnes).

World soybean production is expected to be at records levels in 2006/07, and slightly higher than last year. This is due to larger crops in the US and South America. In 2006/07, the US is expected to harvest a record crop at 86.78 million tonnes due to higher yields and an increased harvested area.

South American soybean production will continue to impact the global oilseed balance sheet. The USDA is projecting Argentina to grow 41.3 million tonnes and Brazil to grow 56 million tonnes of soybeans, up from the previous year. In Argentina soybeans may benefit from the El Niño weather phase present, with a higher probability of above-normal rainfall from November to February (summer

2006/07). Other international analysts project a smaller soybean crop in Brazil (52.5 million tonnes compared to 55 million tonnes last year) due to drought, a prospective sizable decline in plantings and a reduction of inputs (fertilisers and pesticides).

Global oil prices have traded at record levels this past year however crude oil prices have fallen in the past two months. The outlook for the global biofuel industry remains very positive, aided in part by generous government support and the obligatory admixture to petroleum diesel. In 2006/07 it is estimated the combined world consumption of oils and fats as biofuel (i.e. for the production of biofuel and electricity) is around 13 million tonnes, up from around 9 million tonnes (i.e. up 44 per cent) in 2005/06. Furthermore it is estimated that world biofuel production capacities will reach 20 million tonnes by the end of 2007, compared to 6.3 million tonnes at the end of 2005. From 2007 onward increased biofuel production in Malaysia, Indonesia, Argentina, Brazil and the USA will raise domestic consumption. This will limit exports of palm oil and soya oil, resulting in a decline in ending stocks of oilseeds and vegetable oils.

Canola

In 2006/07, world canola production is forecast to decrease by 2.05 million tonnes (4.4 per cent) to 47.02 million tonnes compared to the record crop of 49.07 million tonnes in 2005/06. This is the first decline in world production in four years and is largely attributed to smaller crops in Canada, China and Australia.

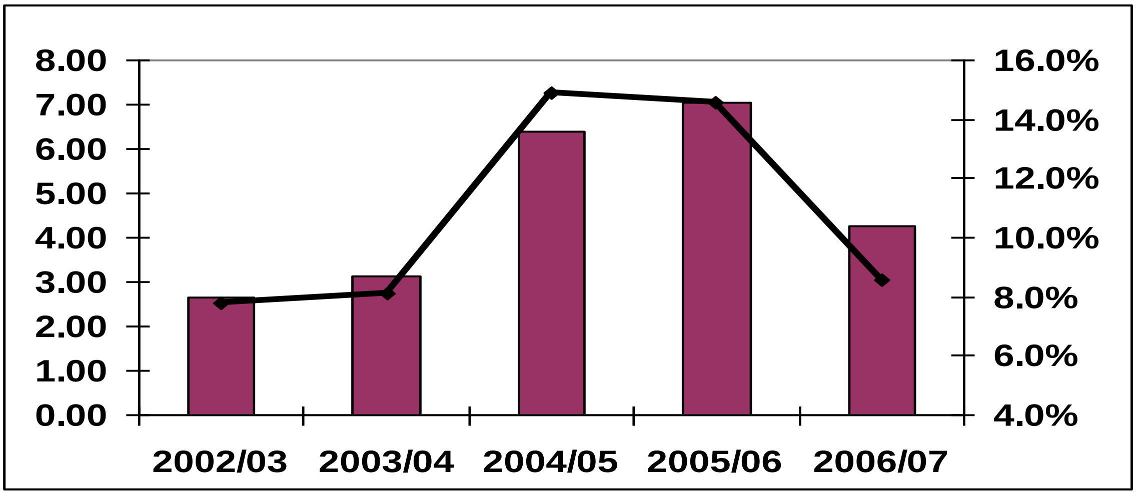
Australian canola production has been devastated by the extenuating drought across most of the growing areas on the east coast and in Western Australia. Latest forecasts from ABARE indicate Australia will produce on 440,000 tonnes of canola compared to 1.44 million tonnes in 2005/06. The Chinese crop is also smaller this year, with estimates at 13.05 million tonnes, down 0.85 million tonnes from 2005/06. Canada is forecast to produce 8.65 million tonnes of canola in 2006/07, down just over 1 million tonnes (10.5 per cent) from the record crop of 9.66 million tonnes produced in 2005/06.

World demand for canola is expected to increase in 2006/07 and will lead to an increase in crushing, despite lower production. Analysts expect the global canola crush to be 46.66 million tonnes in 2006/07, up 2.06 million tonnes (4.4 per cent) from the previous year. It is expected most of the growth in crushing will occur in the EU-25, where rapeseed crush capacity has increased sharply, as a result of new crush plants and the recent technical transformation of some key soybean crushing plants into multi-seed plants. Increased demand is also expected from the US, China and the United Arab Emirates.

In Canada there is expected to be record demand for canola in the 2006/07 season, with analysts predicting that total usage likely to exceed production substantially. This will more than halve Canadian canola stocks to 0.9 million tonnes (down from 2.02 million tonnes in 2005/06). This reduction in stocks is reflected in a fall in the stocks-to-use ratio from 21 per cent last year to 9.1 per cent in 2006/07. The increased demand for Canadian canola is due to increased domestic crushing demand combined with strong foreign demand - (due in part to the drought stricken Australian crop.

Prices

Canola prices have recovered from below average levels on offer in 2005 and earlier this year. The average price of canola is expected to remain at above average levels in 2006/07 through to 2007/08 due to the strong global demand for crushing and the decline in both production and ending stocks. Figure 7 illustrates the down turn in both global ending stocks and the stocks-to use ratio. Stocks are also expected to decline in sunflowers in 2006/07.



Source: Department of Agriculture and Food, WA, 2006.

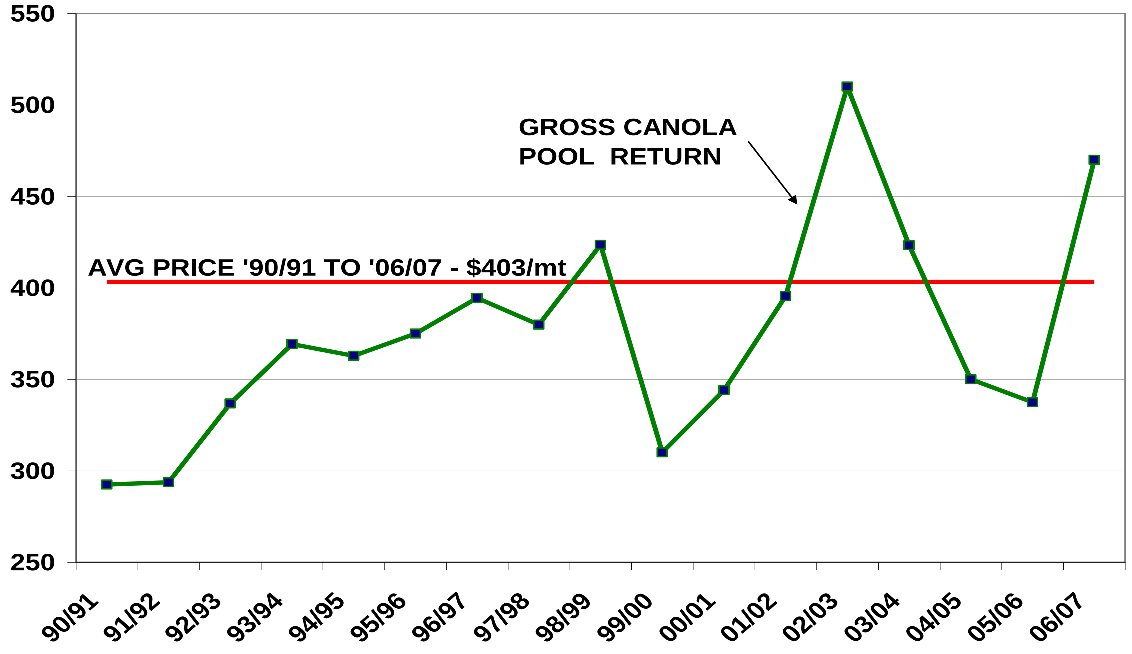
Figure 7. Global canola ending stocks and stocks-to-use ratio – 2002/03 to 2006/07.

A significant price increase for canola has been witnessed in the second half of 2006 at the Winnipeg Commodity Exchange (WCE). In August 2006, nearby canola futures were trading around CAD$290 per tonne. Nearby canola futures have now recovered and are currently trading at CA$330 per tonne (November 2006).

The soybean market has also been experiencing similar price increases recently, trading from below US$5.50 per bushel in September 2006 to be currently above US$6.50 per bushel. The medium to longer-term demand fundamentals for soybeans suggest soybean prices may contract from current levels, despite the outlook for production being less than ideal in most countries outside the US and Argentina, notably in Brazil and China.

In Europe, canola has widened its price premium to sunflower and soybeans. Canola crush margins have declined pronouncedly in the EU-25, but the strong demand and high prices of canola oil are keeping them above breakeven and quite reasonable. Analysts expect ending stocks to fall to 0.48 million tonnes in 2006/07 down from 1.26 million tonnes in 2005/06, while crushing will increase from 14.69 million tonnes to over 16 million tonnes. This will provide continued underlying support to higher canola prices in that region.

With the worsening seasonal conditions and lack of rainfall in canola regions in Australia, canola cash prices have been trending upwards since May 2006. Over the past month, canola prices have increased around $75 per tonne to $475 per tonne delivered port in late October 2006. The Australia dollar / Canadian dollar is around 0.8600, which is also a positive for Australian prices. The GPPL canola pool price for 2006/07 has risen by over A$100 per tonne since the beginning of May to A$470 per tonne FOB (estimate as at late October) which is now at similar levels to the 2002/03 canola pool, in the last year of drought related lower production. In contrast the 2005/06 Grain Pool canola pool was A$337.50 per tonne. Figure 8 depicts the Grain Pool gross pool return for canola from the first year canola pooling was offered to Western Australian farmers and illustrates the current pool return is well above average levels (17 per cent).



Source: Department of Agriculture and Food, WA, 2006.

Figure 8. GPPL canola pool gross return, 1990/91-2006/07 (A$/mt).

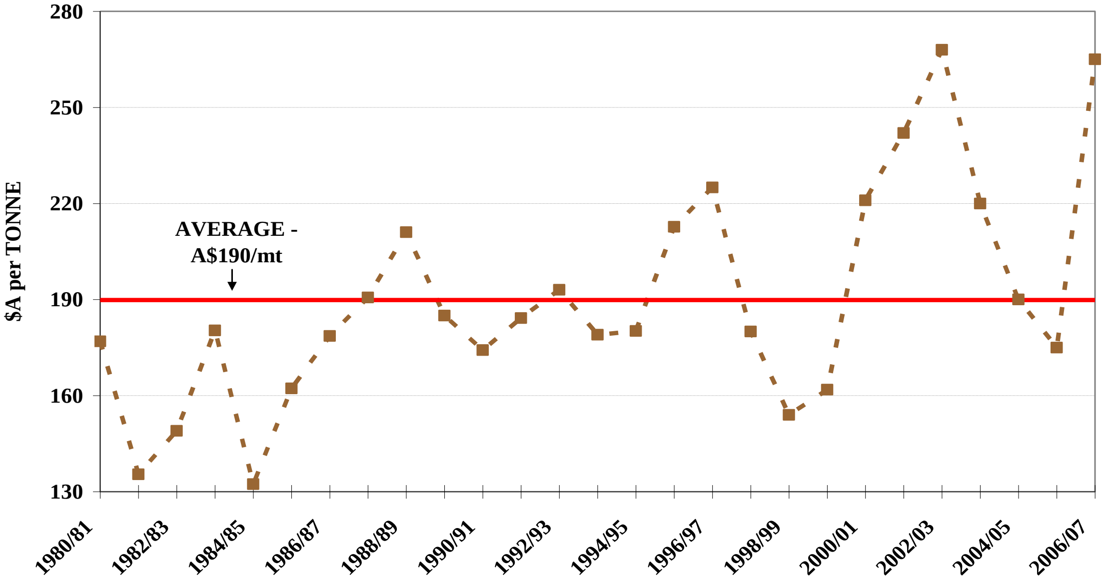
In both Canada and Australia, the outlook for canola prices in 2007/08 is for levels to remain at average to above average levels. Currently, forward cash prices for canola in Western Australia are around A$440 per tonne. In Canada, prices will benefit from the anticipated record demand in the 2006/07 season, resulting from the higher requirements of the domestic crushing industry as well as from strong foreign demand for Canadian canola.

Growers need to recall the big advantage the pool over cash bids is the unlimited oil bonification payments, whereas cash contracts have a limit of 44.5 per cent oil. However the other consideration for pooling versus cash contracts is cash flow.

Lupins

Western Australian lupin production for 2006/07 is forecast to be dramatically reduced at approximately 0.23 million tonnes. This represents a 74 per cent decrease in production from 2005/06 due to poor seasonal conditions. The Estimated Pool Return for 2006/07 lupins is A$265 per tonne FOB compared to $A1175 per tonne FOB for the 2005/06 pool price. Cash bids are currently at $280 per tonne delivered Kwinana. It is expected very little lupins will be delivered to the pool in 2006/07 due to seasonal conditions and the probability of farmers retaining or selling production for stock feed.

In normal production years, soybean meal is a major factor influencing lupin prices. If production returns to normal levels in 2007/08 in Western Australia, soybean meal will again by a major influence. Soybean meal currently a 61 per cent market share of the oilmeals (there are 12 oilmeals traded globally including sunflower and canola). Two of the negative factors expected to influence soymeal prices this coming year should be highlighted. Firstly the US is expected to produce a record soybean crop in 2006/07 insuring good supplies of soymeal from that origin. Secondly, Argentina is also expected to increase soymeal production with a larger soybean crop forecast. Major positive fundamentals that are expected to provide support for the global oilmeal market include increased consumption in the EU-25 due to the higher global grain prices and tightening global grain supplies, at a time when those countries are experiencing improved profitability of livestock. Analysts also expect increased demand from Asia due to both a decline in Asian oilseed production and increased oilmeal consumption. It is expected that China, Indonesia, South Korea, Thailand and Vietnam will all increase consumption of oilmeals.



Note: 1994/95 was a year of vey low grain production in the eastern States which supported WA lupin prices. 2002/03 was the last year of very low lupin production and hence exports.

Source: Grain Pool Pty Ltd, 2006.

Figure 9. Western Australian lupin price 1980-2006 (A$ per tonne).