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Crop Updates 2011 - Farming Systems

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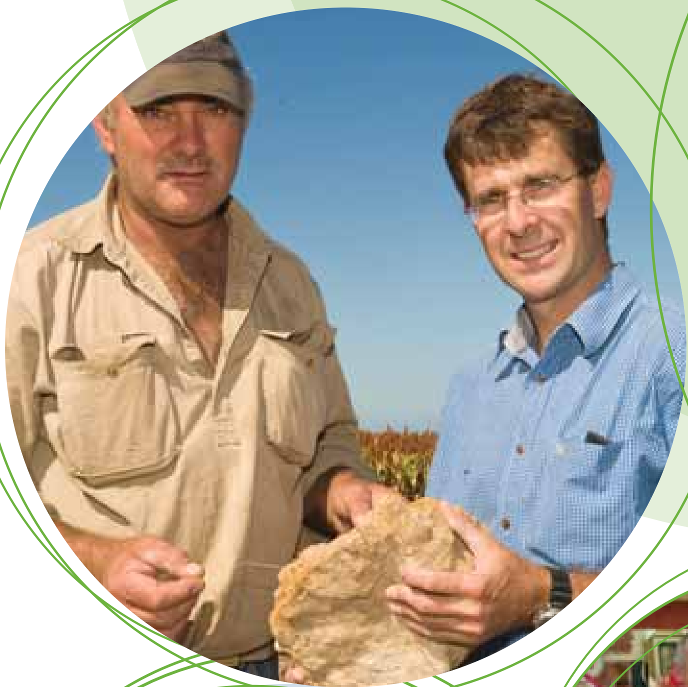
Farming Systems



CROP updates

Fallowing 50% of the farm each year — does it pay?

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Key Messages

- In this demonstration, fallowing 50% of the farm each year was not profitable where the yield benefit from the fallow was less than 0.5 t/ha.
- Wheat on winter fallow yielded significantly higher than continuous wheat and the wheat on spring fallow.
- Soil type and depth has a significant effect on water holding capacity and yield benefits from fallowing.

Aims

To investigate whole farm profitability of fallowing 50% of the farm each year compared with a continuous wheat system.

To compare the benefits of a chemical winter fallow to a chemical spring fallow.

Method

A demonstration site was set up at Mullewa Research Station, Western Australia during 2008 to simulate a grower fallowing 50% of the farm each year.

The demonstration consisted of three treatments:

1. Winter fallow followed by wheat — seeding rate of 45 kg/ha.
2. Spring fallow followed by wheat — seeding rate of 80 kg/ha.
3. Continuous wheat — seeding rate of 80 kg/ha.

There were four replications of each treatment, two of these with a fallow phase in Year 1 followed by wheat in Year 2 and two with wheat in Year 1 followed by a fallow phase in Year 2. There were two continuous wheat plots. Each plot was 10 m x 200 m long, so each phase of the rotation was represented in each year.

The winter fallow plots were sprayed out initially during July, after sufficient groundcover was established to reduce erosion risk. The spring fallow plots had their first knockdown spray during August. Subsequent germinations were sprayed out in both fallow treatments when necessary.

A soil depth survey and neutron moisture probes were used to assess and measure the demonstration site for water holding capacity and stored soil moisture levels.

The yields of each of plot were measured by taking cuts with a small plot harvester and an economic analysis was carried out to compare the profitability of treatments in two year blocks.

Results

The long-term average rainfall for the Mullewa Research Station, where the demonstration site is located, is 337 mm of which 253 mm falls during the growing season. Rainfall for the past three years has been below average, with the past two years well below average (see Table 1). Of the 13 mm of summer rain during 2009, only 1 mm fell during the early months of the year before seeding. Combined with the 8 mm that fell during the late summer months (November and December) of 2008, the site received only 9 mm of summer rain to contribute to soil moisture for the 2009 season. With growing season rainfall (GSR) also well below average, any extra soil moisture stored under the fallow treatments should be realised as a yield benefit.

Table 1. Growing season rainfall (May–October) and summer rainfall (November–April) for Mullewa Research Station for 2008–2010

	2008 (mm)	2009 (mm)	2010 (mm)	Long-term average (mm)
Growing season rainfall	129	187	136	253
Summer rainfall	165	13	97	84
Total rainfall	294	200	233	337

The capacity for storing moisture in the soil is limited by the soil depth and texture. While the demonstration site is a loam soil, the soil depth analysis indicates it is a relatively shallow site with a lot of variability across the treatments. There are some areas of the site that are as deep as 1 m while other areas are only 40 cm deep. In the shallower areas, soil water holding capacity is limited. This is shown by the monthly soil moisture readings. During May 2009, fallow plots had 36 mm more of plant available water (PAW) than wheat stubble, however two-thirds of this moisture was deep in the soil profile — between 55 cm and 95 cm.

Table 2. The rotations, yields and gross margins for the demonstration site

2008 rotation	Yield (t/ha)	Gross margin ($/ha)*	2009 rotation	Yield (t/ha)	Gross margin ($/ha)*	2010 rotation	Yield (t/ha)	Gross margin ($/ha)*
Fallow	0	-21	Wheat	2.04[a]	299	Winter fallow	0	-30
Spring Fallow	0	-33	Wheat	1.87[ab**]	251	Spring fallow	0	-18
Wheat	1.52	160	Wheat	1.7[b]	186	Wheat	0.64[b]	8.40
Wheat	1.61		Winter fallow	0	-40	Wheat	1.13[a]	127
Wheat	1.36		Spring fallow	0	-25	Wheat	0.61[b]	1.76

*Wheat price = $260/t

**Letters that are different from each other in the same column indicate they are significantly different.

Despite the winter fallow plots being sown at a lower seeding rate (45 kg/ha compared with the standard seeding rate of 80 kg/ha) there were positive yield responses during both years — 0.34 t/ha during 2009 and 0.49 t/ha during 2010. However while the spring fallow showed a yield response of 0.17 t/ha during 2009, there was no yield response to the fallow during 2010 (see Table 2).

When looking at the gross margins for 2008 and 2009 combined, all the systems are profitable, however despite the yield benefit in both the fallow systems, the continuous wheat system is more profitable by about $70/ha than the winter fallow and $130/ha than the spring fallow.

Similarly when looking at the combined gross margins for 2009 and 2010, the continuous wheat treatment is still more profitable, by $108/ha more than the winter fallow. This is despite the winter fallow treatment yielding almost 0.5 t/ha more in what was a low-yielding year. The spring fallow treatment in these years runs at a loss of $23/ha.

Discussion

According to these results, at this demonstration site, fallowing year in year out when the yield benefit is less than 0.5 t/ha will result in lower returns than continuous cropping and therefore does not pay. However, this analysis has focussed on one soil type and has not taken into account the normal variations in soil type across

a farm. Another note to be aware of is that the economics in this analysis are driven by wheat price, which varies from year to year and may influence grower decisions.

The water holding capacity of the soil at the demonstration site is limited by the shallowness of the soil. While the results show that extra soil moisture was available under the fallowed plots, if the soil was deeper, more moisture could have been stored and the yield benefit may have been greater making it more economically sustainable. This is shown by Bob French's (DAFWA) crop sequence trial (paper in these proceedings) at Wongan Hills Research Station during 2009 and 2010, where there was a yield response of 0.7 t/ha in the wheat on fallow treatment compared to wheat-on-wheat treatment.

Even though there are scientific flaws in the design of this demonstration, these flaws make it interesting anecdotally. During 2010 the winter fallow showed a significant yield response despite its lower seeding rate. At the higher seeding rate the spring fallow showed no response. This response may have been a result of the winter fallow using less moisture during the season and having more moisture available for grain fill due to its lower seeding rate.

While fallowing year in year out produces lower returns than a continuous wheat system in this demonstration, it is unclear whether fallowing one year in three or one year in four might not be more viable. This demonstration did not address this question.

In this demonstration so far, the continuous wheat has been the more profitable system. However in the long term, the continuous wheat should be less sustainable than the fallow system as disease and weed pressures increase. The demonstration will continue to run for another three years to determine how these factors affect the profitability of the system.

Key Words

Fallow, continuous wheat, profitable, sustainable

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How crop sequences affect the productivity and resilience of cropping systems in two Western Australian environments

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Key Messages

- At Katanning 2008 cropping treatments were still influencing 2010 wheat yields. 2010 wheat yields were highest after canola, fallow, field pea, lupin, oaten hay and wheat; no Jockey treatments in 2008; and after fallow, lupin and oaten hay treatments in 2009.
- 2010 wheat yields at Wongan Hills were highest after fallow, oaten hay and volunteer pasture in 2009.
- At Katanning the crop sequences with the highest gross margins over three years all included oaten hay and wheat treatments.
- Cutting wheat for hay during 2010 at Katanning was more profitable than harvesting for grain.
- 2010 annual ryegrass numbers at Wongan Hills were lowest after fallow, oaten hay, volunteer pasture and lupins in 2009.
- Simazine and atrazine were ineffective against annual ryegrass in dry conditions at Wongan Hills, but Trifluralin worked well, as did glyphosate in Roundup Ready (RR) canola.

Background and Aims

Western Australian farmers have a large range of enterprises to choose from, each with its own advantages and disadvantages. It is widely recognised that diversity in cropping systems is a good thing from the point of view of biological stability but, unfortunately, this does not always make short-term economic sense. Cropping systems in WA have become more intensive during the past 20 years — meaning there is less pasture, more cereal after cereal, less lupin, but more canola. This has been driven by both economic and agronomic considerations. Wheat, barley and canola prices have been high recently, and lupin prices relatively low. Production costs of break crops are also high relative to cereals, particularly where resistant ryegrass is present. Nevertheless, grower surveys consistently reveal the opinion that this heavy dependence on wheat and barley is unsustainable in the long run, and that more diversity is desirable.

Each cropping 'component' has its own set of advantages and disadvantages. The positive or negative contributions of each land use option depend on the state of the cropping system. For instance, legumes can provide organic nitrogen (N) to a system but this is of no particular value if nitrogen is not deficient. Canola can reduce levels of cereal root diseases, such as take-all and crown rot, but this confers no advantage when these pathogens are absent. Similarly, the differential weed control that some cropping options offer has no value in weed-free situations.

There are very many combinations of land use history, weed, disease and nutrient status and economic outlook that can arise on WA farms; and growers are likely to have a range of crop and management options available to them depending on their farm business goals. Computer models can help growers make better decisions about their cropping options by predicting the likely consequences of different decisions. The Land Use Sequence Options (LUSO) model (Lawes and Renton, 2010) is one such model. But models must be based on real-world data and tested against real-world situations before decision makers will adopt them confidently.

To help understand the processes driving the performance of WA cropping systems, and to help validate models such as LUSO, we initiated two dynamic crop sequence trials — one at Katanning during 2008, and the other at Wongan Hills during 2009. These study how crop performance depends on the previous crops in sequence, taking into account the context at each site. The ultimate objective is to answer the following questions: what factors determine the performance of different crops; how are these affected by cropping history; and how can we use this information to design ecologically and economically robust options for crop sequences.

Method

These trials are based on a design developed by Don Tanaka and colleagues at Mandan, North Dakota (Tanaka *et al.,* 2007), and consist of a range of cropping component options being grown in long plots in

one direction in the first year, and at right angles in the second year, crossing all the first-year plots. This allows the comparison of all possible two-year combinations of those components. In the third year wheat is grown across the entire site (this happened at Katanning during 2010 and will happen at Wongan Hills during 2011). These are called dynamic crop sequence trials because they are designed to help make crop sequence decisions dynamically as the cropping system unfolds in the light of the physical, biological, and economic environment at the time. The Katanning site was on a shallow duplex soil typical of the region with an average depth to clay of 42 cm, although it was as shallow as 20 cm in some places. Waterlogging is therefore a potential constraint on this site. The Wongan Hills site was on a deep earthy sand over gravelly clay below 2 m. Both sites were mildly acid at the surface.

Suitable cropping components for the local climate and soil type were chosen for Katanning and Wongan Hills (see Table 1) and laid out as described above. Each set of treatments was replicated four times. They were managed with local best-practice agronomy, except that pasture plots at Wongan Hills were slashed rather than grazed, and nitrogen fertiliser rates were not varied according to the preceding crop. Fallow plots were managed by spraying with glyphosate to prevent any plant growth (during early September and early August respectively during 2009 and 2010 at Wongan Hills), and serradella and pasture plots at Wongan Hills were topped with gramoxone and glyphosate at ryegrass soft dough stage to prevent seed set.

Table 1. Cropping 'components' in dynamic crop sequence trials at Katanning and Wongan Hills.

Katanning	Wongan Hills
Wheat	Wheat
Wheat + Jockey seed treatment	Wheat (after mouldboard ploughing during 2010)
Barley	Barley
Oats for grain	Oaten hay
Oaten hay	TT Canola
TT Canola	Clearfield juncea canola (RR canola during 2010)
Lupins	Lupins
Field pea	French serradella, brown manured
Green manure (vetch + oats)	Volunteer pasture
Fallow	Fallow

As well as monitoring crop growth and yield during these trials we monitored soil water, crop nutrient uptake, crop disease status, weed populations, soil health status and economics. This has generated an enormous body of data, only a small fraction of which is presented here. Further information is available from the authors.

Results

a) Wongan Hills

Seasonal conditions

At Wongan Hills the season broke during late May in both years, but the initial break was followed by an extended period of dry weather. May to October rainfall was 231 mm during 2009, and 132 mm during 2010, compared with the long-term average of 268 mm. Another important feature of the 2010 season was that only 12 mm rain fell after the start of September, compared with 53 mm during 2009.

Grain yields

Yields for 2009 at Wongan Hills were reasonable for the growing season rainfall (GSR), ranging from 1.15 t/ha for canola to 2.13 t/ha for wheat (see Table 2). The yield of juncea canola was very poor (0.43 t/ha) but this is a consequence of damage from herbicide drift from adjacent cereal plots. During 2010 yields were lower, but again good for the GSR. There were considerable effects of the 2009 cropping treatments (see Table 2). Overall fallow plots gave the best yields, followed by oats cut for hay and volunteer pasture. Plots

that had grown lupin or serradella during 2009 produced below-average yields, and juncea canola plots the lowest. This is contrary to normal expectation for lupin and serradella, and is due to the dry season. Plots after lupin and serradella had 20% more biomass than after wheat during early August, but this vigour led to early depletion of soil water and grain filling under stressed conditions. As a result harvest index was lower after lupins and serradella than after other crops.

Table 2. Grain yields from dynamic crop sequence trial at Wongan Hills

2009 crop	2009 yield (t/ha)	2010 wheat yield (t/ha)	2010 wheat mouldboard yield (t/ha)	2010 lupin yield (t/ha)	2010 RR canola yield (t/ha)
Wheat	2.13	1.38	1.27	0.60	0.54
Barley	1.82	1.47	1.45	0.63	0.62
Oaten hay	-	1.58	1.37	0.68	0.59
Canola	1.15	1.41	1.04	0.57	0.51
Juncea canola	0.43	1.37	0.80	0.42	0.35
Lupins	1.42	1.44	0.76	0.44	0.51
Serradella	-	1.54	0.88	0.51	0.48
Pasture	-	1.62	1.06	0.67	0.72
Fallow	-	2.10	1.79	0.76	0.92
LSD (P=0.05)	0.24	0.23	0.23	0.23	0.23

Different species responded to 2009 treatments to different extents. For instance wheat and canola yields increased after fallow by more than 50% compared with after wheat while lupin yield increased by only 25%. Wheat yield was hardly affected by juncea canola whereas yield in every other crop was reduced by 28–41%. Wheat sown on mouldboard ploughed plots overall yielded 25% less than wheat sown normally, which we attribute to poor depth control at seeding in the soft soil leading to delayed emergence and reduced establishment (95 plants/m^2 on mouldboard ploughed plots compared with 156 plants/m^2). But this reduction ranged from less than 10% after wheat or barley to between 40 and 50% after lupin or serradella.

Weeds

There were significant differences between treatments in how effectively ryegrass was controlled at Wongan Hills (see Table 3). The 2009 data show how well Trifluralin (used in wheat, barley, juncea canola and serradella) works on this site, and the efficacy of Status® used post-emergent on lupins and canola. Axial®, used post-emergent on wheat and barley, had little effect.

Table 3. Annual ryegrass densities in dynamic crop sequence trial at Wongan Hills

2009 crop	July 2009 (plants/m²)	September 2009 (after post-emergent sprays) (plants/m²)	June 2010 pasture and fallow plots (plants/m²)	July 2010 wheat (plants/m²)	July 2010 TT canola (plants/m²)
Wheat	94	81	381	10	191
Barley	90	67	235	4	93
Oaten hay	172	107	52	1	4
Canola	194	110	497	21	190
Juncea canola	79	69	391	9	148
Lupins	241	72	151	2	28
Serradella	97	-	242	6	48
Pasture	-	-	144	2	45
Fallow	-	-	54	1	5
LSD (P=0.05)	15-22	9-12	15-45	4-15	12-49

Note: LSD falls in a range due to analysis by log-linear modelling.

The ryegrass numbers germinating in the 2010 pasture and fallow plots show how the 2009 treatments affected the ryegrass seed bank, particularly the efficacy of crop topping in the lupins and cutting hay, and the greater competitiveness of barley over wheat. Spray topping pasture was not as effective as it might have been if done earlier or in conjunction with grazing. There was a big difference between these ryegrass numbers and those emerging with the crop (see Table 3), again showing the effectiveness of Trifluralin (which was not used on TT canola during 2010), and the poor effectiveness of Simazine under dry conditions. The 2010 data also showed excellent ryegrass control in Round-up Ready (RR), with Trifluralin, compared with Triazine Tolerant (TT) canola (see Table 4).

Table 4. Annual ryegrass heads in dynamic crop sequence trial at Wongan Hills during October 2010

2009 crop	RR Canola Eclipse (heads/m²)	TT Canola Cobbler (heads/m²)	LSD (P=0.05)
Wheat	5	84	13
Barley	7	55	15
Oaten hay	0	4	n.s.
Canola	15	138	24
Juncea canola	8	93	19
Lupins	0	28	10
Serradella	2	16	8
Pasture	1	32	11
Fallow	0	13	7

Water use and water use efficiency

In both years the cropping component water use exceeded May to October rainfall — by as much as 128 mm in the case of juncea canola during 2009 (see Tables 5 and 6). This indicates that crops in both years were using water stored in the soil before the growing season. For the 2009 growing season this had built up during the previous three years while the site had been in pasture; during 2010 much of it came from 40 mm that fell during late March as well as some not used by some treatments during 2009.

There were consistent differences in water use between cropping components. Fallow, barley and oats cut for hay used the least water in both years, and oilseeds the most. Water-use differences in wheat during 2010 explained a large proportion of the wheat yield variation, with the treatment using the most water (after fallow) producing the highest yield, and that using least water (after juncea canola) producing the lowest yield. There was a significant negative relationship between wheat water use during 2010 and water use by the preceding crop during 2009, indicating that low-water-using crops can leave water for the following crop to use. However, much of it is lost to evaporation over the intervening summer — wheat water use only increased by 1 mm for every 4 mm left behind during 2009. We estimate that 70–80 mm has been stored in the 2010 fallow plots. It remains to be seen how much of this will remain for the 2011 growing season.

Table 5. Seeding to harvest water use and water use efficiency for grain production in Wongan Hills dynamic crop sequence trial

2009 crop	Water use 2009 (mm)	Water use efficiency 2009 (kg/ha/mm)	Wheat water use 2010 (mm)	Wheat water use efficiency 2010 (kg/ha/mm)
Wheat	325	6.8	161	8.6
Barley	290	6.7	163	8.8
Oaten hay	301	-	164	10.3
Canola	347	3.3	156	8.9
Juncea canola	359	1.0	152	9.0
Lupins	340	4.4	166	8.6
Serradella	349	-	162	9.3
Pasture	319	-	164	10.3
Fallow	260	-	179	12.2
LSD (P=0.05)	33	1.1	14	1.7

Water use efficiency also varied among species, with lupins and oilseeds much lower than wheat or barley. Although lupin and oilseed water use efficiency was the same in both years, wheat and barley water use efficiency was higher during 2010. Preceding crop had a significant effect on wheat water use efficiency. It was highest after fallow, volunteer pasture and oats for hay, and lowest after wheat and lupins.

Table 6. Seeding to harvest water use and water use efficiency for grain production of different crop components during 2010 after wheat during 2009 in Wongan Hills dynamic crop sequence trial

	Water use 2010 (mm)	Water use efficiency 2010 (kg/ha/mm)
Wheat	166	8.6
Barley	142	8.8
Oaten hay	142	-
TT Canola	178	2.9
RR Canola	175	3.3
Lupins	161	3.7
Serradella	160	-
Pasture	167	-
Fallow	89	-
LSD (P=0.05)	21	1.8

b) Katanning

Seasonal conditions and site characterisation

The 2010 growing season was characterised by a later-than-normal break and an early dry finish. May – October rainfall was only 264 mm, compared with 401 mm during 2009. Only 6.8 mm rain fell from mid-September to end of October and there were a number of frosts around anthesis (flowering).

Grain yield of wheat during 2010

Both 2008 and 2009 treatments had significant effects on 2010 wheat yield (see Figure 1), but there were no significant interactions between 2008 and 2009 treatments. The 2008 treatments leading to highest wheat yields were canola, fallow, field pea, lupin, and oaten hay. The 2009 treatments leading to highest wheat yields were fallow, lupin and oaten hay. Not surprisingly, the second-year effect of the 2008 treatments on 2010 wheat yields were smaller than the first-year effects of the 2009 treatments. The only 2009 break crop that increased 2010 wheat yields significantly above wheat/wheat was lupins (wheat yield after lupins was 26% and 28% higher respectively than after wheat with and without Jockey).

Economic analysis

Three indicators of economic performance were considered: the three-year gross margin with price changing each year, the three-year gross margin with price changing each year if wheat was cut for hay in the third year rather than harvested for grain, and the gross margin for 2010 only if wheat was cut for hay or harvested for grain. Gross margins were calculated for each of the 400 plots in the trial. Analyses of variance were carried out on log-transformed data because of variance heterogeneity, but means are presented after back-transformation.

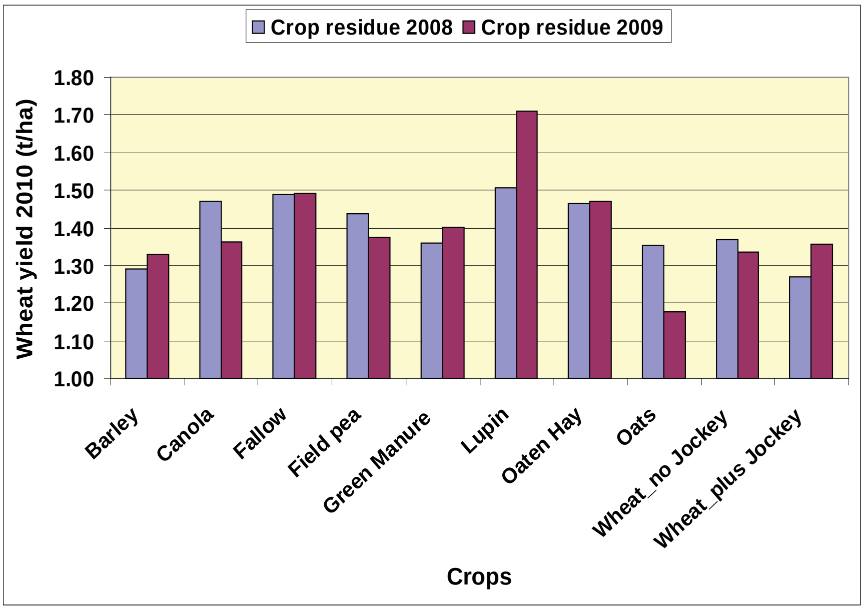

Figure 1. Wheat grain yield during 2010 as influenced by 2008 and 2009 cropping treatments at Katanning. The figure for a particular 2008 treatment is the mean (average) over all 2009 treatments following that treatment and the figure for a particular 20009 treatment is the mean over all 208 treatments preceding that treatment. LSD (P=0.05): Crop year 2008 — 0.16 and Crop year 2009 — 0.25. The LSDs used for treatment comparisons are averages from REML analysis.

The more profitable three-year crop sequences based on the three-year gross margin with wheat harvested for grain during 2010 all included oaten hay in either 2009 or 2008 (see Table 7), with the most profitable being wheat after oaten hay in both years, closely followed by wheat after wheat plus Jockey after oaten hay. This is mainly due to the combination of buoyant prices for wheat and oaten hay with yield advantages from the previous crop being less important. Despite wheat yields during 2010 being highest after lupins, low lupin prices during 2009 meant this did not necessarily lead to higher gross margins (although wheat after lupin after oaten hay had the third highest gross margin across three years). Some sequences, particularly those involving field peas and oats for grain, had negative gross margins. Field peas yielded poorly during 2008 after being frosted, wheat yielded very poorly during 2010 after oats during 2009, and the price of oats was low during 2008 and 2009.

Overall gross margin increased by $633 per hectare if wheat was cut for hay during 2010 instead of harvested for grain (see Table 8). Again the more profitable three-year crop sequences all had oaten hay in either 2008 or 2009, and the most profitable had hay cut in each of the three years. If wheat was cut for hay in the third year of the crop sequence there were no negative gross margins.

When we consider 2010 gross margins only we find cutting wheat for hay gives a much greater margin than harvesting it for grain (see Tables 9 and 10). The gross margins from cutting for hay were significantly higher ($P=0.05$) after lupins during 2009, than after fallow, field peas, canola or oaten hay (see Table 9). When wheat was harvested for grain the gross margin was also highest after lupin during 2009.

Table 7. Three years gross margin ($/ha) with commodity prices changing each year in the Katanning dynamic crop sequence trial (data back transformed from log($/ha+1000)). The significance is compared using LSD values in the log transformed data

	Crops 2009										
Crops 2008	Barley	Canola	Fallow	Field pea	Green Manure	Lupin	Oaten Hay	Oats	Wheat_no Jockey	Wheat_plus Jockey	Average
Barley	$205	$61	$172	$50	$142	$363	$668	$48	$211	$346	$227
Canola	$387	$280	$398	$321	$205	$277	$819	$239	$400	$534	$386
Fallow	$156	$94	$14	$88	$113	$171	$889	$93	$293	$427	$215
Field pea	$162	$46	$80	$118	$71	$147	$650	$279	$249	$250	$96
Green Manure	$147	$126	$6	$13	$3	$218	$383	$18	$195	$331	$139
Lupin	$338	$16	$123	$104	$206	$189	$579	$153	$494	$459	$266
Oaten Hay	$836	$547	$715	$724	$682	$919	$1,060	$723	$802	$1,011	$802
Oats	$45	$183	$40	$8	$5	$150	$458	$166	$204	$318	$116
Wheat_no Jockey	$440	$392	$370	$177	$276	$184	$724	$201	$373	$406	$354
Wheat_plus Jockey	$217	$229	$266	$175	$292	$358	$713	$120	$375	$515	$326
Average	$293	$197	$193	$154	$185	$298	$694	$93	$359	$459	$293

Table 8. Three years gross margin ($/ha) with commodity prices changing each year and wheat cut for hay in third year in the Katanning dynamic crop sequence trial (data back transformed from log($/ha+1000)). The significance is compared using LSD values in the log transformed data

	Crops 2009										
Crops 2008	Barley	Canola	Fallow	Field pea	Green Manure	Lupin	Oaten Hay	Oats	Wheat_no Jockey	Wheat_plus Jockey	Average
Barley	$1,215	$973	$ 831	$768	$819	$1,277	$1,644	$901	$1,179	$1,246	$1,085
Canola	$1,294	$905	$923	$847	$704	$865	$1,627	$870	$957	$1,247	$1,024
Fallow	$729	$562	$292	$393	$390	$633	$1,469	$361	$726	$895	$645
Field pea	$848	$475	$367	$271	$239	$562	$1,311	$249	$785	$823	$593
Green Manure	$708	$411	$187	$352	$213	$739	$1,019	$347	$596	$837	$541
Lupin	$1,224	$673	$672	$578	$645	$858	$1,389	$823	$1,304	$1,257	$942
Oaten Hay	$1,738	$1,330	$1,484	$1,197	$1,302	$1,790	$1,915	$1,484	$1,585	$1,901	$1,573
Oats	$819	$784	$425	$496	$509	$794	$1,129	$525	$ 819	$1,090	$739
Wheat_no Jockey	$1,234	$1,051	$920	$664	$823	$873	$1,512	$959	$1,153	$1,048	$1,024
Wheat_plus Jockey	$1,072	$1,009	$990	$763	$939	$1,204	$1,646	$811	$1,102	$1,424	$1,096
Average	$1,088	$817	$709	$633	$658	$959	$1,466	$733	$1,021	$1,177	$ 926

Table 9. Gross margins for year 2010 if wheat was considered cut for hay in the Katanning dynamic crop sequence trial. (LSD (P= 0.05): Crops 2008 – NS, Crops 2009 – 67; Crops 2008 x Crops 2009 – 184)

	Crops 2009										
Crops 2008	Barley	Canola	Fallow	Field pea	Green Manure	Lupin	Oaten Hay	Oats	Wheat_no Jockey	Wheat_plus Jockey	Average
Barley	$411	$590	$426	$500	$402	$708	$491	$363	$395	$449	$474
Canola	$539	$567	$641	$578	$478	$548	$460	$435	$329	$402	$498
Fallow	$354	$437	$458	$459	$501	$595	$470	$364	$337	$234	$421
Field pea	$536	$412	$646	$571	$492	$591	$508	$385	$448	$358	$495
Green Manure	$365	$382	$329	$522	$314	$670	$505	$248	$338	$331	$400
Lupin	$522	$577	$663	$579	$468	$641	$477	$420	$495	$555	$540
Oaten Hay	$464	$412	$584	$409	$451	$640	$437	$425	$387	$362	$457
Oats	$460	$585	$490	$609	$502	$652	$474	$486	$354	$475	$509
Wheat_no Jockey	$316	$484	$539	$386	$455	$509	$473	$363	$482	$334	$434
Wheat_plus Jockey	$389	$486	$624	$413	$424	$671	$486	$297	$322	$479	$459
Average	$435	$493	$540	$502	$449	$622	$478	$379	$389	$398	$469

Table 10. Gross margins for year 2010 if wheat was considered cut for hay in the Katanning dynamic crop sequence trial. (LSD (P= 0.05): Crops 2008 – 51; Crops 2009 – 83; Crops 2008 x Crops 2009 – NS)

Crops 2009											
Crops 2008	Barley	Canola	Fallow	Field pea	Green Manure	Lupin	Oaten Hay	Oats	Wheat_no Jockey	Wheat_plus Jockey	Average
Barley	$41	$74	$205	$71	$86	$234	$143	$7	$1	$139	$ 99
Canola	$101	$207	$220	$137	$128	$222	$158	$89	$171	$114	$155
Fallow	$128	$119	$184	$146	$193	$277	$243	$71	$142	$106	$161
Field pea	$182	$115	$112	$127	$154	$293	$189	$44	$154	$86	$146
Green Manure	$92	$130	$100	$106	$89	$258	$164	$28	$100	$102	$117
Lupin	$153	$105	$204	$173	$188	$232	$122	$152	$171	$184	$168
Oaten Hay	$181	$ 65	$165	$241	$104	$261	$137	$141	$143	$105	$154
Oats	$81	$164	$82	$148	$87	$226	$169	$2	$109	$106	$117
Wheat_no Jockey	$87	$162	$193	$64	$145	$121	$181	$33	$92	$110	$119
Wheat_plus Jockey	$25	$117	$163	$55	$99	$157	$83	$37	$71	$ 82	$89
Average	$107	$126	$163	$127	$127	$228	$159	$59	$115	$113	$132

Discussion

These trials demonstrate that land use can have important effects on the productivity, sustainability, and profitability of crop sequences and these effects can last at least two years. However, they depend very much on the specific conditions at a particular site. For instance at Katanning highest wheat yields were produced after lupins in the previous year, but at Wongan Hills wheat yield after lupins was no better than after wheat, and in some cases worse. This was a consequence of there being sufficient rain at Katanning to exploit the extra nitrogen provided by the lupins, but not at Wongan Hills where 2010 was one of the driest years on record. On the other hand, there was a large response to fallow at Wongan Hills and a more modest one at Katanning.

We expect the role of fallow in WA cropping systems to receive renewed attention after 2010 and, while responses at Wongan Hills are likely to be less spectacular in most seasons, it proved a very effective tool for managing annual ryegrass. Cutting oats for hay, crop-topping lupins, spray-topping pasture, and RR canola were also effective for ryegrass management. Relying on Simazine and atrazine to control ryegrass in TT canola was disappointing due to dry conditions in two years at Wongan Hills and much better results would have been obtained if they were used in conjunction with Trifluralin.

Economic analysis at Katanning showed how sensitive profitability is to commodity prices. All of the more profitable sequences had oaten hay somewhere in them and the most profitable cut hay in each of the three years of the sequence. It would be impractical to cut hay on a third or more of most farms, and such a practice would rapidly deplete soil nutrient levels, so it is clear that identification of optimal crop sequences will require more sophisticated analysis than purely on the basis of gross margins.

Wheat will be sown in both of these trials during 2011, possibly split for nitrogen rates at Katanning. Further results will be available during 2012.

Key Words

Crop sequences, break crops, integrated cropping systems, rotations

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When is continuous wheat or barley sustainable?

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Key Messages

- The priority during 2011 may be to recover lost equity through the inclusion of wheat on wheat. Consider the risk and merits for each paddock on a case-by-case basis and in relation to the whole farm.
- Consider a failed wheat crop as a 'fallow', which may include reduced weed burden, some level of stored moisture and a reduction in fertiliser inputs. The second wheat crop may be considered as a 'low-input system'.

Background

Wheat is a driver of profitability and our cropping systems evolve around using break crops or fallow and management to increase profitability. During 2011 there will be paddocks managed as part of the normal system (for example, break crop or fallow during 2010) and the plan is to put them in wheat during 2011.

In low-rainfall regions continuous wheat and utilisation of fallow and low inputs systems for flexible management have been important for successful cropping systems. However, to make up for lost cropping returns following a drought in the medium-rainfall areas, there is the opportunity to consider re-seeding wheat or barley paddocks with wheat or barley during 2011. While there are some merits there are also pitfalls.

Merits

The merits can evolve around considering a failed wheat crop as a 'fallow', which may include reduced weed burden, some level of stored moisture and a reduction in fertiliser inputs. The second wheat crop may be considered as a 'low-input system'.

Wheat crops have 'flexibility' for management — the opportunities for dry seeding with minimal upfront inputs, the choice of a range of varieties with different maturities and disease resistances to suit the seasonal break during 2011 and the opportunity to 'play the season' with fertiliser inputs as the season unfolds.

Pitfalls

Disease is the most significant pitfall for continuous wheat-on-wheat or barley-on-barley rotations particularly in the medium and high-rainfall zones.

Disease development in crops depends on the presence of disease inoculum, the susceptibility of the variety or crop sown and seasonal weather conditions. Therefore the disease risk for 2011 depends on: a) the disease levels from previous seasons (2010, 2009); b) on crop management decisions and c) what seasonal weather conditions occur.

Stubble management and rainfall are chief factors in determining risk from leaf disease in continuous cereal rotations. In contrast, previous cropping sequence will be the chief factor in determining risk from root disease (Vanstone and Loughman, 2004).

Wright *et al*., (2010) and Loughman and Vanstone (2003) have reported that crown rot, rhizoctonia bare patch and nematodes are the major soil-borne threats to a second wheat crop. Net blotch, rhizoctonia bare patch and nematodes are the main risks for barley on barley.

Management

In the wheat-on-wheat system, managing disease, weeds, variety and agronomy are keys to its success. In the low-rainfall regions, the success of continuous wheat has relied on preparation for early seeding opportunities and/or dry seeding, use of fallow, weed management tools and disease management. Flexibility in the system and capturing value from summer rain events for mineralisation of nitrogen, weed control and stored moisture are important. Minimising inputs along with cut-off dates for seeding to then change to a fallow system have minimised risk to productivity in the low-rainfall zone. Elements of these principles apply during 2011 for failed wheat crops in the medium-rainfall zone.

Disease

Leaf disease risk if seeding wheat on wheat during 2011 will be as relevant as during normal seasons. Where effective opening rains during 2010 encouraged diseases such as yellow spot in wheat and net blotch in barley, or where significant amounts of remnant infected stubble remains from the 2009 season it may not be wise to re-seed susceptible varieties during 2011. If wheat is sown after wheat and seasonal conditions favour disease, budget for foliar fungicide application. The experience from the northern agricultural region (NAR) during 2008, following the 2006 and 2007 droughts, suggests wheat-on-wheat crops had significant levels of infection from yellow spot.

As the 2011 seasonal break approaches, assess the impact of summer and autumn rainfall on disease levels and review seeding time or change the crop plan accordingly. Reassess disease risk at seeding by viewing the crop disease forecasts on the DAFWA website at: www.agric.wa.gov.au/cropdisease.

Assessing root disease risk can be difficult but there are tools available. There must be the presence of inoculum. Consider crop performance during 2010, and observations on the crop's robustness. How often have wheat crops been sown on the paddock? Have management options been adopted in previous seasons that will have reduced the build-up of inoculum over time (for example, break crops, fallow, varieties or soil disturbance during previous years). Predictive soil assays (for example, PreDicta B test) can identify the presence of some root diseases including tests to measure inoculum levels of take-all, cereal cyst nematode (CCN), rhizoctonia bare path, crown rot, root lesion nematodes (RLN) (*Pratylenchus neglectus* and *P. thornei*). Validation of this test for Western Australian conditions is underway. Predictive soil assay usefulness will be increased when interpreted with knowledge of season, paddock and crop performance during previous years.

Variety selection and agronomy

Variety sown during 2010 and their relative resistances to RLN and CCN are likely to influence the risk to production from continuous cereals. These resistances determine the plant's ability to inhibit or support nematode reproduction. Varieties with higher resistances such as Wyalkatchem – moderate resistance (MR) for RLN — sown during 2010, are less likely to have increased nematodes numbers than the varieties with lower resistances such as EGA Bonnie Rock – moderately susceptible to susceptible (MS-S).

Variety selection is likely to be less important for managing crown rot. Resistance ratings for cereals to crown rot are not available in WA. However in South Australia, ratings for Espada, Gladius, Katana, Mace, Magenta and Wyalkatchem are susceptible (S). Both wheat and barley are susceptible to crown rot, but in general, of the cereals, durum wheat is most sensitive followed by wheat and triticale, then barley then oats. Management techniques include inter-row seeding, cultivation to bury the crowns to break down infected stubble, control grass weeds, reduce moisture stress by avoiding excessive seeding rates, matching nitrogen and adequate zinc.

Incorporating weed-seed destruction

Research and grower experience has shown higher productivity with early seeding opportunities. However weeds are a significant risk when seeding continuous wheat or barley systems. Consider the weed burden at the end of 2010. Will weeds adversely affect production during 2011? Is a strategy in place to manage weeds, in particular grass weeds that are likely to emerge with the crop? Is there an opportunity to windrow burn header trails to manage weed seeds?

Case studies by Newman *et al.*, (2010) demonstrate that harvest weed-seed management is very successful at eroding the seedbank of resistant weeds in cropping situations. Incorporating techniques such as windrow burning and increased seeding rates in wheat-on-wheat systems provides an opportunity to reduce weed-seed seedbanks. This in turn provides the opportunity to benefit from early seeding opportunities during the following year, which can be critical to economic improvements.

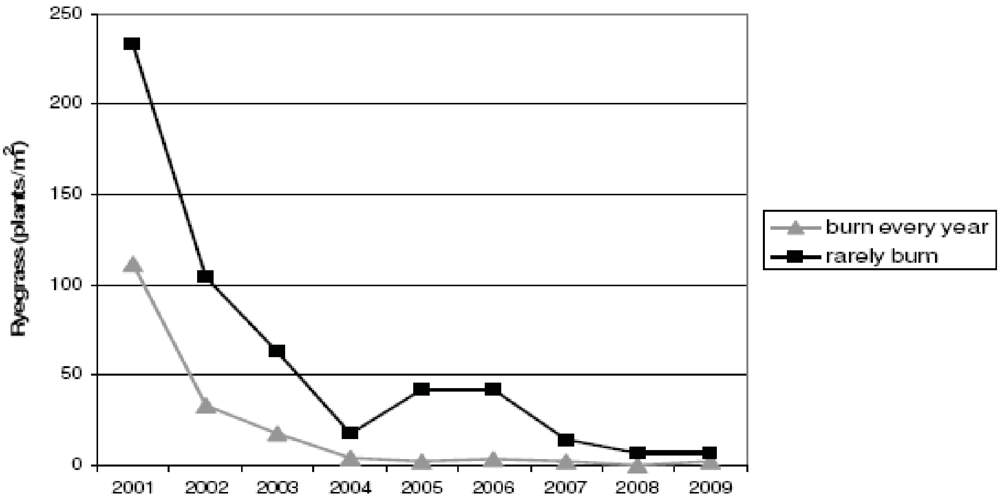

Figure 2. Ryegrass density from focus paddocks of seven growers who burn windrows or tow a chaff cart at harvest every year compared with 16 growers who rarely practice harvest weed-seed management.

Newman *et al.* (2010) reported that 'growers who don't burn windrows or tow a chaff cart have still managed to erode ryegrass seed banks'. However, this has been achieved largely through the use of trifluralin (often every year) and these growers continue to have a residual ryegrass seedbank. Growers who have burnt windrows or towed a chaff cart every year took only three growing seasons to severely erode their ryegrass seedbank and have had six seasons of very low ryegrass numbers since.

Those growers who have practiced comprehensive integrated weed management (IWM) for some years are most likely able to take advantage of early seeding opportunities with confidence compared with those who have inadequate IWM (Newman, 2011)

Low-input system: are there higher nutrient levels in the soil following a drought year?

During 2011, wheat on wheat may be considered a low-input system following drought. Scanlan and Bowden (2010) reported, in general, there is a bit more phosphorus (P) and potassium (K) left in the soil after a very low- or non-yielding crop, but the major supply of these nutrients comes from the background soil phosphorus and potassium status not these carryover effects. In the case of nitrogen (N), paddocks will carry over much of the soil mineral nitrogen because a drought year is a bit like a short-fallow year, as there is usually enough soil moisture to mineralise more nitrogen even when there is not enough to grow a crop to use the nitrogen. Last year's fertiliser nitrogen may also carry over depending on how much crop actually grew to remove it from the system.

Nitrogen carryover from poor cereal crops during 2010 will be low in comparison to the amount supplied by soil organic matter. For example, about 40 kg/ha to 60 kg/ha of nitrogen will be released by mineralisation during the growing season from a soil with an organic carbon (OC) level of 0.8%. Soil testing is the best way to find out if the mineral nitrogen levels are higher than usual.

Deep nitrogen testing may also identify the level of total nitrogen available in the soil. Experiences from the northern agricultural region (NAR) after drought show large reservoirs of nitrogen residing further down the profile than usual. This knowledge allowed growers to scale back early nitrogen applications, reducing their up-front costs and associated risk.

Phosphorus fertiliser applied during 2010 is likely to have a higher residual value for next year's crop than in 'normal' years, however, it will have little effect on the requirements of the 2011 crop. The soil test phosphorus level (for example, 10, 30 or 50 mg/kg) is more important than the residual value from last year's fertiliser. This is because soil test phosphorus and phosphorus buffering index (PBI) can be used to estimate the yield and economic response to fertiliser phosphorus. (Scanlan and Bowden, 2010).

Potassium fertiliser applied during 2010 will have a high residual value for 2011 crops. The major losses of potassium in cropping soils are in product removal and leaching. Potassium is less mobile in the soil than nitrate, so only expect potassium leaching during years when there is major leaching of nitrate (Scanlan and Bowden, 2010).

Discussion

Continuous wheat has been adopted in the low-rainfall regions. Its sustainability is relies on managing disease and weed risks, and adopting strategies that maintain profitability based on production and costs. In the medium to higher-rainfall areas, risks to productivity are increased with wheat on wheat, primarily through disease incidence. During 2011, following drought in some regions, considering the failed wheat crop as a 'fallow' may include reduced weed burden, some level of stored moisture and a reduction in fertiliser inputs. The second wheat crop may be a 'low-input system' but disease is a threat to production. Adoption of a second wheat crop in the medium-rainfall regions needs to be considered on a case-by-case basis.

Growers need to gather knowledge to better assess the risks to production of wheat on wheat (or barley on barley) and suitable management options to reduce risk.

Key Words

Wheat, rotations, disease, systems

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Identifying constraints to bridging the yield gap

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Key Messages

- Poor nutrient efficiency and management, non-wetting soils and herbicide resistance are the main constraints to crop production in the medium to high rainfall areas of WA, according to a recent series of industry workshops. Other common cropping constraints identified through the Bridging the Yield Gap workshops included soil acidity, profitable legume/break crop rotations, low soil water storage and waterlogging.
- Certain constraints were specific to localised areas, such as the issues associated with integrating livestock and cropping, staggered weed germinations, soil biology and alternative fertilisers to synthetics.
- Barriers thwarting growers from adopting solutions to the identified cropping constraints can be divided into four areas: knowledge, confidence, money (cost) and time.
- The identified cropping constraints and adoption barriers are highly diverse and working with localised groups will increase the likelihood of growers overcoming their cropping constraints to lift yields.

Aims

Investigate the barriers thwarting growers from adopting technologies to address the crop yield gap in the medium to high rainfall areas of WA.

Initiate discussions for shared investment with industry to increase crop production profitably.

Method

Through the Department of Agriculture and Food's *Bridging the Yield Gap* (BYG) project 17 workshops were held in the high- to medium-rainfall areas of Western Australia to identify the constraints to crop yields in these areas and the factors thwarting growers from adopting technologies to address these constraints.

During the workshops participants developed:

- a list of factors constraining crop yields in the medium-to-high-rainfall areas; and
- a list of technologies that could be used to overcome these constraints and the barriers thwarting some growers from adopting these.

Participants created a list of constraints to production that was then shortened to those that could be addressed by growers within the next 3–5 years. From this shortened list, participants prioritised or combined constraints to reach a 'top 10' list of constraints, which were further prioritised to develop a list of 'top three' constraints.

Participants were then asked to identify what solutions or options they had tried to address the yield constraints and the barriers they needed to overcome to adopt the solution or option.

Results

The most common crop yield constraints identified were poor nutrient efficiency and management (up to 31% of participants), non-wetting soils (up to 30%) and herbicide resistance (up to 25%) (see Table 1). Despite 2010 being very dry, up to 10% of participants identified waterlogging as another common constraint indicating that they were taking a long-term view of their cropping constraints.

Table 1. Voting percentages for top 10 constraints from each consultation workshop

(Each participant voted for their top three constraints from their group's list of 10)

	Kendenup	Cranbrook	Borden	Jerramungup	Ravensthorpe	Kojonup	Katanning	Arthur River	Wickepin	Brookton	Corrigin	Quairading	Miling	Badgingarra	Warradarge	Mingenew	Ogilvie
Number of Participants	**21**	**12**	**26**	**8**	**10**	**23**	**15**	**19**	**10**	**20**	**8**	**16**	**31**	**10**	**10**	**5**	**18**
Germination, crop establishment,												16	12	30		22	
Non-wetting, water repellence	14	21			7	3	21	15	10	27	4		19		27		27
Water holding capacity, soil water storage, understanding soil moisture	16	7				6		5			11				0	0	
WUE, optimising use of GSRF, making the most of moisture			16	14									11				
Waterlogging & trafficability	9	7			3	7		9	0	7			2				
Better inputs use, efficiency, risks with nutrients, nutrient availability, canopy mgmt, feeding to need, fertilizer toxicities, confidence, optimums	9	14	7				11	31	3	12	30		13			0	2
Alternative fertilisers to synthetics															30		
Nutrient holding capacity, leaching								5						30			
Phosphorous retention		0															
Trace elements - unavailability in local soils				9													
How pH influences nutrition decisions, precise nutrition and pH	6					12	8										
Soil chemistry (carbon, WUE, phosphorous, root exploration, biological activity)							13										
Physical soil structure, soil compaction, enhancing root penetration, shallow soil (gravel)	9									12	4	7		0	3		
Soil acidity, Al toxicity		7	5		23						15	4			7		
Sodicity					7												
Soil variation, changing soil types				9						12				0			
Soil biology, microbes, soil health		21								0							
Low OM				5													
Soil/subsoil constraints (soil depth, pH, WHC, salinity), soil characterisation				19													5
Knowledge of soil constraints – Org matter, Al toxicity, compaction, biology, structure, general understanding, ability to ID	14						15		21			22					
Herbicide resistance (mainly ryegrass, radish, also wild oat, brome grass)	8	7	13	0	7	13	15	11	10	25	11	9	11	10	20		25
Herbicide interaction with moisture						4											
Non chemical weed control (fallow), green/chemical fallow																	4
In crop weed control (various crops/stages), staggered germinations											11					28	
Diseases (specifically root diseases)			4						10	0	11		7				4
Pests, insects							2						1		7		
Rotations/Varieties, soil specific (MIG)	8		8											0		0	
Varieties - cold/wet, robustness, suitability, drought, frost, disease, waterlogging, WUE			29		7	13			0			18					
Profitable legume/break crop, diversity in continuous crop rotations, disease resistance					17	7		9	14				10			0	18
Profitable pasture legume, managing pastures												7	12				
Pasture establishment																	4
Optimum (early) seeding time - dry vs normal, nutrition, weed control		11												3		17	
Plant density (mgmt of row spacing, plant requirements, lupin establishment)															7		
Timing of crop mgmt actions				0													
Seeding equipment - placement, tynes, presswheels								2								0	
Frost management (sowing times, growth rates, nutrition, varieties), fear of frost risk	5						6		24		4						
Knowledge -availability of info on solutions, of crop resilience, of varieties				9						5							
Lack of reliability/confidence in "HRF package"						13											
Fitting cropping and livestock together, whole farm mgmt, timeliness of operations					13	22	8	5	7	0	0						
Matching inputs to yields, matching costs vs returns, risk of optimal nitrition														20	0	6	
Multi peril, risk management, attitude to risk, econ risk				9	0							4					
EPA Act (clearing single trees, vermin,)														0			
Zoning - managing paddock variation and variable soils, PA, VRT								7									12
Seasonal weather forecasting / climate forecast reliability - impact on grain quality and decisions			5	24	17							13		7			
Climate/rainfall variability			6													28	
Farm hygiene		4															
Technology limitations			6														
Availability of good labour												0					

Soil constraints were the only other constraints found to be common across the workshops. These constraints were soil acidity (up to 23% of participants), knowledge of soil constraints (up to 22%), and low soil water storage (up to 17%). This is likely due to increasing costs of production and consequently a growing interest in ways to lift production efficiencies.

Some constraints were considered to be highly important at a local level, such as integrating livestock and cropping (22% at Kojonup), staggered weed germinations (28% at Mingenew), inadequate soil biology (21% at Cranbrook) and alternative fertilisers to synthetics (30% at Warradarge).

There were no obvious regional trends in the types of cropping constraints identified through the consultation workshops. Group dynamics and preferences had much more influence on the constraints identified than the location of the workshop.

Specific constraints identified by participants were combined into related groups (Table 2). The 11 key BYG constraint areas are where the participants, with support from the BYG project, may choose to invest to build capacity to increase crop production profitably.

There were nine other areas of constraints raised by participants where the BYG project is unlikely to become directly involved. The BYG project may however be able to assist participants by linking them to organisations and agencies that are active in these particular areas.

Table 2. Key constraints as identified from consultation workshops

Key BYG constraint area	Constraints raised by participants
Plant–water relations	Non-wetting, establishment, waterlogging, water holding capacity, water use efficiency
Nutrient efficiency/management	Management decisions, optimum application rates, canopy management, nutrient availability, nutrient efficiency
Soil pH	Influence on nutrients, knowledge, cost effective application technology
Knowledge of soil constraints	Organic matter, soil biology, physical limitations, identifying soil constraints, soil variation, soil structure
Herbicide resistance	Specifically annual ryegrass, radish, wild oats, brome grass
In-crop weeds	Effectiveness of knockdowns, staggered germinations, spray-topping
Varieties – local adaptability	Breeding for local conditions — not for whole state, low confidence in varieties until 'proven'
Pests and diseases	Root diseases, insects
Fitting crops and livestock into system	Looking for synergistic techniques to enhance all farm operations, not always complementary
Profitable break crop or legume rotation	Pasture and crop legume, more choice in break crop
Frost management	Agronomic options
Other constraint areas	
Varieties — tolerances to stress	Terminal drought, frost, salinity, waterlogging, disease, cold, water use efficiency, robust
Weather and climate forecasting	Local reliability of weekly forecast, better radar coverage
Optimising growing season rainfall	Making the right decisions
New media	Podcast, mobile and internet video use, professionally produced and edited, future of extension
Finances	Different methods to evaluate and assess business finances and when to use
Research and development	Improved management of R&D, better identification of R&D needs
Frost	Multi-peril crop insurance, variety tolerances, forecasting
Staffing and employees	Finding trained staff, restricting production capacity
DAFWA (govt.) funds dilution	Shrinking agriculture budget results in less on-the-ground activities

Importantly, the consultation workshops documented the barriers that participants believed were thwarting their capacity to adopt technologies to increase crop production. Interestingly, depending on location, workshop participants sometimes identified quite different barriers to overcoming the same cropping constraint.

It is not practical in this paper to outline every adoption barrier identified by workshop participants. However, all adoption barriers can be grouped into four areas: knowledge, confidence, money (cost) and time.

A knowledge barrier was defined as not having enough information or not having undertaken enough research to ensure adoption would be successful. Attending field days, reading and seeking specific advice were identified as ways to overcome a knowledge barrier.

A confidence barrier related to the likely success and benefit of adopting a new technology in light of the information available (and its reliability) and the investment required to implement the new technology.

Many participants cited cost as the biggest barrier to adopting a change in technology with the costs associated with liming (in the current economic climate) cited as a common example of this.

Participants also cited insufficient time as a significant adoption barrier. Lack of time was especially critical where knowledge, confidence or cost were also marginal. In other words, if participants had sufficient knowledge and confidence in a technology then they would be more likely to allocate the funds and find the time to adopt it.

Discussion

The priority constraints to crop production identified by workshop participants were as varied as the regions where crops are produced in WA. To add further complexity, the barriers to adoption were even more diverse and the potential solutions available to address these adoption barriers even more varied again. This complexity highlights the need to work with the agricultural industry at a local level.

The BYG project will facilitate groups and industry to determine the constraints they want to address and will assist in the planning and implementation of activities that the groups decide to undertake. With the support of the BYG project, local growers can demonstrate solutions to others in their area, which will increase the likelihood of success of more state-wide focussed activities to bridge the yield gap.

The BYG project will work with groups involving all sectors of the agricultural industry to support and assist growers to overcome their production constraints and increase yields profitably. These areas of investment will be determined by the participating groups and may include activities, such as monitored paddocks and farms, seminars, workshops, field days or on-farm research. What activities will be undertaken will vary from group to group depending on group priorities.

Key Words

Grain, yield, production constraints

Paper reviewed by: Perry Dolling, Brenda Shackley

Land constraints limiting wheat yields in the Bridging the Yield Gap project area

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Key Messages

The yield gap for the Bridging the Yield Gap (BYG) project area averages about 1 to 1.5 t/ha.

The BYG project area is 12 million hectares of which six million hectares has three or fewer soil constraints that may be feasible to ameliorate.

The most common soil constraint in the project area is soil acidity followed by a range of land qualities that reduce the amount of soil water (moisture) available to crops.

Aims

1. Determine the gap between average wheat yields achieved on farms in the BYG project area and the realistic potential yields.
2. Estimate the area of soil-related constraints to wheat yield that may be feasible to ameliorate within the BYG project area.
3. Compare this analysis to feedback from farmers and consultants on the cause of the gap between actual and potential wheat yields.

Method

This paper reports on an analysis of wheat yield and related soil constraints commissioned for the BYG project. Potential yields for wheat within the BYG project area were estimated using the French-Schultz equation and average seasonal rainfall for six seasons: 1995-1999 and 2001. Realistic potential yields were then estimated by further reducing yields based on land constraints mapped using DAFWA's soil landscape inventory data. Subtracting average shire yields from the realistic potential yields for the same years produced an estimate of the yield gap. A detailed methodology is described in van Gool (2010). In this paper we discuss the results of the analysis for the 50 shires that make up the BYG project area (annual rainfall more than 350 mm) (Figure 1).

Results

The yield gap

Within the BYG project area there is an average 1-1.5 t/ha yield gap between the average wheat yield achieved on farms and the realistic potential that could be achieved based on rainfall and land constraints (van Gool, 2010). Figure 2 shows the distribution of the wheat yield gap across the shires of the project area. There is a general trend for a larger yield gap in the south west portion of the project area with a cluster of shires having a yield gap of between 1.5 to 3 t/ha, coinciding with higher annual rainfall. This is similar to an analysis by Anderson (2010) who found an increasing yield gap as rainfall increased within south west grain producing shires. The yield gap exists because of a complex of biophysical and farm business factors.

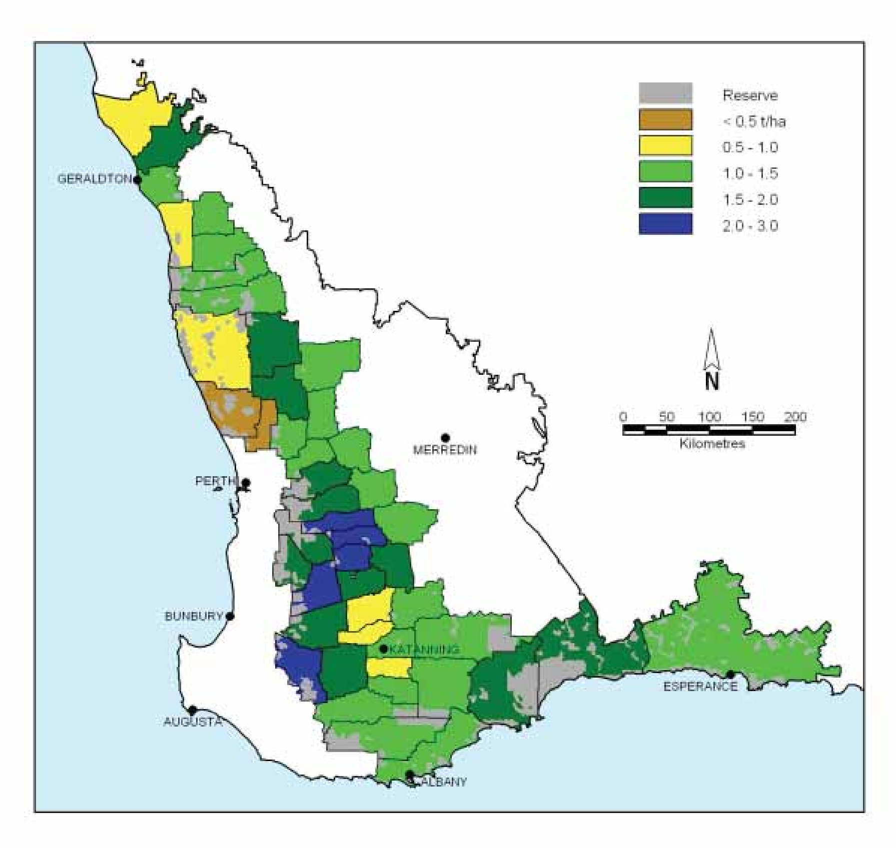

Figure 2. Gap in wheat yield (t/ha) between potential and actual 1990-1995.

Land constraints

The BYG project covers twelve million hectares, but only two million hectares is classified as highly productive for wheat (Table 1). The remaining area has one or more land or soil related limitations for wheat production. Half of the BYG project area has three or fewer constraints. Four million hectares of land have four constraints or more, or are not productive for wheat production. Land with three or fewer constraints that are feasible to remove represents a potential focus area for investment to improve productivity of grain production (note that removal of soil related constraints is only one potential focus for the BYG project).

Table 1. BYG project area soil constraints for wheat production

Area	M ha
BYG Agricultural area	12
Very high productivity wheat land	2
Constrained (3 or fewer) wheat land	6
Multiple (4 or more) constrained wheat land	3
Not productive wheat land	1

Land qualities

Soil acidity in the topsoil is the most widely occurring single constraint (Table 2). Low water storage also occurs widely but is caused by a composite of factors including subsurface compaction, subsurface acidity, waterlogging (duplex soils) and other properties limiting root penetration. Acidity has long been recognised as a constraint on crop production across the Western Australian wheatbelt and has received considerable investment in research and extension (for example, the 'Time to Lime' campaign). A telephone survey for the BYG project however, indicated that 40% of the growers were still keen to try lime application to manage soil acidity. This suggests that large areas of land are still not being adequately managed for soil acidity.

Table 2. Soil constraints for the BYG project area

Constraint	M ha
Soil acidity	3.2
Soil acidity in topsoil	2.3
Subsurface compaction	2.1
pH in subsoil	1.2
Wind erosion	1.4
Waterlogging	0.8
Salinity	0.6
Water repellence	0.6
Permeability	0.5
Water erosion	0.5
Surface soil structure decline	0.4
Soil workability	0.2
Rooting depth	0.1

The distribution of soil acidity (topsoil and or subsoil) as a constraint is show in Figure 2 as a percentage of shires in the project area with pH constraints. Figure 2 shows the pH constraint as a composite that includes either acidity or alkalinity. The majority of pH constraints in the project area are due to acidity. The only exception is in the south-east where the Esperance and Ravensthorpe shires with alkaline mallee soils contribute significant areas of pH constraint. All of the project area shires have some pH-constrained land, however there is a cluster of shires in the west of the project area that have 30 to 40% of land with pH limitations and yield gaps in excess of 1.5 t/ha as shown in Figure 2.

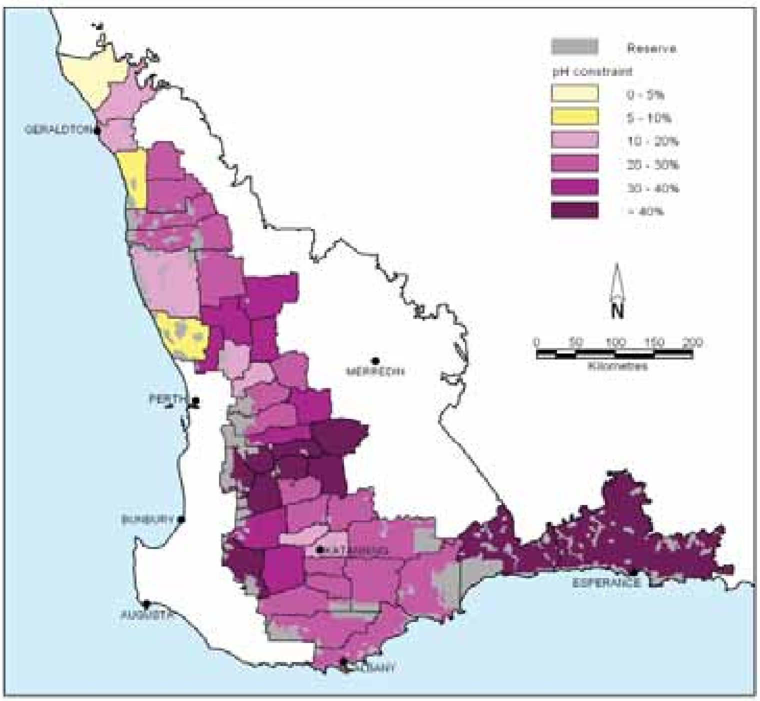

Figure 3. The proportion of land in each local government area with pH limitation in topsoil and/or subsoil.

BYG project workshops

Soil and land constraints to wheat yield within the BYG project area were discussed with about 300 farmers and consultants attending 17 BYG project workshops. The constraints most frequently identified in the workshops were: water repellence, soil water storage - particularly in relation to hostile subsoils or physical barriers to roots - soil acidity, waterlogging and physical soil problems such as compaction (McDonald, 2010). Water repellence was the only issue that farmers and consultants rated as a widespread and prominent constraint but which appeared as only a moderate constraint in our analysis. There are possibly two reasons for this difference. First, the run of dry seasons in recent years has kept water repellence prominent in growers' minds. Second, our estimates of potential yield are sensitive to the degree of constraint each land quality places on crop production.

When land assessed as high water repellence is used in the model, the result is 0.6 million hectares ha of land constrained by water repellence (Table 2). When land assessed as both high and moderate water repellence is included in the model the area increases to 2.5 million hectares of land constrained by water repellence. Table 4 shows that increasing the sensitivity of the model results in water repellence becoming the second most common constraint after topsoil acidity. However, all of the extra 1.9 million hectares has other constraints equal to or more constraining than water repellence (such as acidity of the top soil). This demonstrates that, in addressing yield constraints there will, in the majority of cases, be more than one constraint limiting wheat yields.

Table 4. Soil constraints for project area (using increased water repellence sensitivity)

Constraint	M ha
Soil acidity	3.2
Water repellence (sensitivity increased)	2.5
Soil acidity in topsoil	2.3

Conclusion

The BYG project area of 12 million hectares has an average yield gap of 1 to 1.5 t/ha. Six-million hectares of the project area have three or fewer soil-related constraints that could potentially be ameliorated to increase yield. The most common soil-related constraint is soil acidity. Generally, the soil related constraints identified by the BYG project analysis were similar to those identified by growers and consultants. The one significant difference was water repellence, which was identified as being a more prominent constraint by growers than in the BYG modelling. Increasing the sensitivity of the model to water repellence expands the area where water repellence constrains wheat yields to 2.5 million hectares.

Key Words

Yield gap, acidity, compaction, water repellence, modelling

Acknowledgments

Glenn McDonald and Keith Ohlsen for valuable data on soil constraints raised by growers and consultants in the BYG project workshops.

Paper reviewed by: Peter White

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Can livestock have a long-term role in no-till cropping systems?

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Key Messages

- Livestock are an important source of farm diversification and risk management. While net farm income tends to decline as the proportion of livestock increases, variation in net farm income also decreases, reducing volatility in revenue.
- Negative impacts of livestock on soil structure and surface cover must be balanced against consumer demands and constraints of no-till cropping (weed control issues, lack of soil cover, disease).
- Impacts of livestock, such as nutrient redistribution to livestock camps, are likely to be overestimated. Adaptation through rotational grazing or livestock removal/agistment can improve integration.

Background and Aims

Mixed farming incorporating annual cropping and ruminant livestock is practised widely across Australia's grainbelts, accounting for almost half of the country's farm enterprises (Ewing and Flugge, 2004; Hacker *et al.,* 2009; Price *et al.*, 2009). The combination of favourable crop prices relative to livestock values, improved seeding technology, more specialised crop production and initially good seasons has seen an intensification of cropping during recent decades. No-till cropping systems have many advantages including improved soil physical structure, timeliness of seeding, and improved soil water storage, especially at seeding (Flower *et al*., 2008). Further benefits from no-till cropping are seen as coming from full stubble retention and disc openers potentially combined with precision cropping and controlled traffic. There is renewed interest in livestock's value as a risk management tool due to escalating crop input costs, climate variability and improved meat prices, which raises questions regarding the 'fit' of livestock with highly-developed, no-till cropping systems.

The aim of this project was to determine whether there is a long-term role for livestock in combination with no-till cropping systems. This paper presents results from a review of livestock impacts on no-till, highlighting trade-offs, options for managing the impacts and research needs.

Method

A review of the impacts of livestock on crop production, particularly no-till systems, was carried out. The work principally comprised a scientific review, but also included focus groups and an economic analysis utilising data from case studies. This paper largely considers the findings of the review; the full report, including case studies and detailed economic analysis, is available through GRDC (Fisher *et al.,* 2010).

The scientific review, largely focussed on work from western and southern Australia, covered the impact of livestock on ground cover, soil compaction, soil water, nutrient cycling, pest management, biodiversity and crop production. Focus groups attended by 39 participants (4–12 per workshop) were carried out at five locations across the southern Australian wheatbelt (Kojonup and Northam in Western Australia, Osborne in New South Wales, Birchip in Victoria and Riverton in South Australia). The focus groups provided qualitative and semi-quantitative information from the participants regarding their experiences and perceptions of the trade-offs between livestock and cropping, especially no-till cropping. Consultants from four regions in Australia (the northern and southern wheatbelts of WA, SA, and western Victoria) provided information regarding three farming systems in their area (prices and yields for crops and livestock; farm capital, including farm land, machinery and livestock value; operating expenses, including fixed and variable costs). The consultants provided yield and price data at expected, pessimistic and optimistic levels. This information was used to calibrate a whole-farm budget for 10 of the farms. For each farm 10,000 iterations were run, using a simulation program called Crystal Ball 2000, from which mean net farm income and variance measures of net farm income for each farm were produced.

Results and Discussion

Livestock have positive and negative impacts on no-till cropping systems (see Table 1). The review described and, where possible, quantified these while exploring options to manage them.

Key trade-offs, and management options

Removal of ground cover (crop residues) and the compaction of soil due to grazing and trampling are the two major limitations to the incorporation of livestock with no-till cropping. Management options to address these may include the use of rotational grazing with strict action thresholds for minimum levels of ground cover and/or soil condition (especially wetness) combined with close monitoring of individual paddocks, or the removal of livestock to sacrificial paddocks, confinement feeding areas, other geographic locations (for example, agistment) or complete removal from the farm.

The pasture–livestock phase of mixed farms is important in increasing organic matter content of the soil and associated biological activity and in supplying nutrients, principally nitrogen. Soil organic matter increases under long phases of legume-pasture. It does not increase with pastures of shorter duration (≤ 2 years), tending to remain stable or decline (though at a slower rate than continuous cropping).

Legume-based pastures supply an average of 21–27 kg nitrogen fixed per tonne of above pasture dry matter. This contribution is increasingly important as the cost of manufactured fertiliser increases. There are negative impacts of grazing associated with the redistribution of nutrients to stock camp areas and losses due to volatilisation from urine patches. While commonly accepted and supported by research, previous assessments have come from small plots or simulated urine patches and so may be an over-estimate. The pattern of nutrient returns from livestock may be improved by grazing management, mix of pasture species and precision livestock management, but further research is needed to confirm this.

Grazing livestock provide an important option for the management of pests of cropping, particularly herbicide-resistant weeds. Managing the timing of grazing relative to the seed-set of weed species and observing withholding periods following the grazing of paddocks with a high weed burden is required to ensure seeds of weeds, or volunteer crops, are not spread in faeces. Grazing livestock in association with connected shelterbelts can form part of integrated pest management programmes, but more work is needed to confirm the benefits for complexes of pest species and to assess the impact on overall farm productivity and profitability.

Systems incorporating livestock add flexibility and may improve soil water use and profitability. Perennial pastures in farming systems may address episodic recharge, but current options are limited to the medium–high to high-rainfall areas. Similarly, options for dual-purpose crops, which are a useful and profitable means of integrating cropping and livestock, are currently restricted to high-rainfall zones. Clearly there is a need to expand options to all rainfall zones and regions if such benefits are to be realised.

In practice

Growers in the focus groups had farms that were at least 70% arable. Since the 1990s the proportion of arable land used for livestock has decreased from 40–60% to 0–30%. This proportion is expected to remain low or decrease further during the next 10 years. For most of the growers these changes are not seen to lead to complete removal of livestock. At most workshops there was at least one grower who intended to get out of livestock altogether and also at least one who intended to keep a higher proportion of livestock than the rest of the participants.

Table 1. Impacts of livestock (positive and negative) on key aspects of mixed-farming systems and options to manage them

Aspect	Positive impact	Negative impact	Management options
Ground cover	Utilisation/ management of stubble	Removal of ground cover, trampling, erosion risk	Address feed gaps and maintain ground cover (options such as perennial pastures, summer fodder crops or dual-purpose crops); ensure summer cover levels above 50% (1 t/ha DM stubbles or 750 kg/ha for dry pastures); grazing management or removal of stock to maintain ground cover
Soil compaction	Compaction shallower and over smaller area than machinery (if not control traffic)	Decreased pore space, increased bulk density, decreased infiltration, remoulding	Prioritise maintenance of pasture cover in grazing management decisions
Soil water	Decreased recharge, lowering of water tables	Drying of soil profile, decrease in crop yield (e.g. lucerne)	Integration of perennial pastures and crops — current options largely restricted to high-rainfall areas
Nutrient cycling	Supply of nitrogen, increased soil organic matter, increased biological activity	Redistribution of nutrients to stock camps	Employ more intensive grazing management (e.g. rotational grazing) to control livestock nutrient deposits; include a wider range of pasture plants in the diet or use feed supplements to modify grazing patterns
Pest management	Control of weeds, reduction of stubble and soil- borne diseases	Redistribution or burial of weed seeds, reduction in beneficial species	Uphold crop hygiene including withholding periods of up to 10 days (re-distribution of weed seeds), control seed-set with grazing (possibly in combination with burning of chaff dumps), employ good husbandry practices (e.g. shearing before seed-set); monitor timing and intensity of grazing to minimise impacts on beneficial species (especially invertebrates)
Biodiversity	Build-up of organic carbon, greater biodiversity compared with crop	Decreased species abundance and diversity	Maintain native perennial grasses in pastures (productivity, water use, biodiversity benefits); target use of phosphorus fertiliser (soil tests); reduce inputs and grazing intensity in areas inhabited by high-value native grassland; maintain connected habitats (e.g. linked shelterbelts)—encourages beneficial predatory species
Economics	Lower variability in income	Lower income compared with cropping	Reduction in variability of net farm income most evident where livestock contributes ≥ 15% farm income

The relative returns of crop and livestock have principally driven the changes in the proportion of livestock while personal preference is a major factor in the decision to maintain or remove stock altogether.

Those who had completely removed livestock focussed on the efficiency of cropping (and had a general cropping focus), the need to maintain cover, concerns over erosion and other factors (for example, labour, mulesing, emissions trading). The 100% croppers manage risk with different crops, marketing and possibly different times of planting. Cropping is recognised as high risk, but also high reward and livestock are considered to compromise sound crop management. Those with a mixed system focussed on diversity of enterprises and spreading risk. The relative profitability and viability of grazed pasture compared with crop legumes is an important factor keeping livestock in the system.

Economic analysis

The economic analysis highlighted the trade-off between income and income variability in mixed farms. Correlation analysis of the results was used to study the relationship between return on assets (ROA),

coefficient of variation of net farm income (CV of NFI) and percentage of income from livestock. The correlation between ROA and percentage of income generated from livestock was -0.75, indicating that as livestock increases in the farming system ROA declines. The correlation between the percentage of income generated by livestock and the CV of NFI was also negative (-0.70) indicating that livestock tend to reduce the variability of NFI. The decrease in the variability of NFI is most evident where livestock contributes a significant proportion of income (see Table 1).

Discussion

Livestock may be combined with no-till cropping systems. Triple-bottom-line gains can be realised through improved management of grazing practices and livestock production, attention to pasture management, a move away from a 'stock and forget' approach to sheep management and implementation of precision livestock technologies. The 'fit' of livestock in a no-till system will be determined by the productive capacity of the land and relative profitability of cropping and livestock, the management of herbicide-resistant weeds, sensitivity of soil to damage from grazing and trampling and the farmer's passion, preference and willingness to apply increased management to livestock.

Key Words

Mixed-farming, no-till cropping, livestock, interactions, economic analysis, review

Acknowledgments

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Paper reviewed by: Robert Belford

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Pros and cons of dry seeding to counter variable seasonal breaks

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Key Messages

- In many regions of the wheatbelt the timing of opening rains has become more variable and the number of days available for seeding has declined, putting pressure on the seeding operation and leading to more interest in dry seeding cereals.
- Growers differ in approach to dry seeding, from a planned approach with set percentage of the program to be dry sown, through to an aggressive approach where a large percentage of the program could be dry sown if opening rains are late.
- Growers all tend to seed wheat dry into fallowed paddocks or those following break crops (clean of weeds, higher yield potential), maintain groundcover on paddocks designated for dry seeding, use short-term weather forecasts to give confidence if seedbed moisture is marginal, commit minimal inputs up front and are prepared to be flexible with topping up, especially nitrogen, and manage frost risk with appropriate variety phenology or range of phenologies.
- Whole-farm modelling for a low-rainfall farm at Mullewa, Western Australia indicates that dry seeding up to 50% of a 3000 ha program gives yield gains for the whole farm of 0.1–0.3 t/ha in 80% of seasons.

Background and Aims

It is well established that in the absence of frost risk, early seeding invariably benefits wheat yield. While it is common practice to dry seed lupins and canola before the seasonal break, it has not been until recently that dry seeding cereals has come into prominence in the Western Australian wheatbelt. This has been driven in part by the perception that the opening rains of the season are occurring later and with more variability, and dry seeding enables growers to establish large cropping programmes in a timely manner. Wheat is the lowest risk crop to be dry sown, because it is the most resilient crop type available and most likely to return a profit when emergence is optimal. Dry seeding has been traditionally practised in the northern agricultural region (NAR), but it is gaining interest in other regions. Even in regions with more reliable early breaks, the advantages of early seeding are seen as crops being better able to withstand stresses later during the season, such as waterlogging and hot and dry conditions during grain-filling.

While dry seeding can improve the timeliness of crop emergence, there are significant risks to consider, such as crop failure, inadequate weed control, or wind erosion. It is because of these risks that growers are understandably reluctant to expose their business to large areas of dry-sown crops and associated up-front costs. An alternative to dry seeding larger areas is to increase seeding capacity by using existing machinery more efficiently, buying bigger machinery, or even a second seeding unit. The latter two options come with increased capital costs.

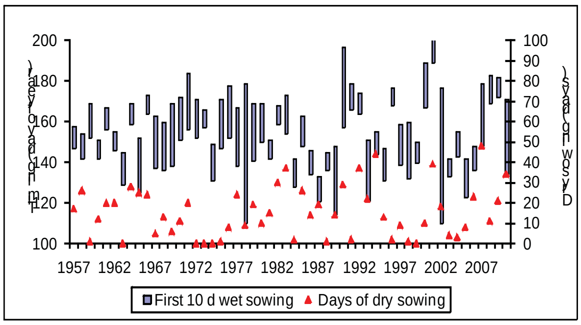
This paper will: (1) quantify trends on the timing of the break and days available for seeding at two locations in the WA wheatbelt, (2) review the range of strategies taken by growers, (3) estimate the yield benefits to dry seeding and compare this with management options to wet sow crops more quickly, and (4) review the agronomic management required in order to be able to dry sow with confidence.

Timing of the seasonal break and days available for seeding

The project team analysed, for a range of locations across the wheatbelt, the trend in the timing of opening rains to the growing season and subsequent days available for seeding until a nominated close to the seeding window, taken here as July 15. Dry seeding days accounted for days when soil moisture was too wet for dry seeding and too dry for wet seeding.

The results for two locations (see Figure 1) show that up to the mid-1970s the timing of the break and subsequent period to achieve the first 10 days of wet seeding was fairly consistent from year to year. Since then the timing of the break has been more variable and a higher occurrence of long periods (> 20 days) to achieve 10 days of wet seeding. Variability has been particularly obvious during the past 15 years. Days available for dry seeding have varied between none (during years with moist soil and/or very early breaks) to

more than 50 days in years with very late breaks, with an average of about 15–20 days until the past 15 years, when the average has increased to about 25 days, consistent with a trend for less wet seeding days.



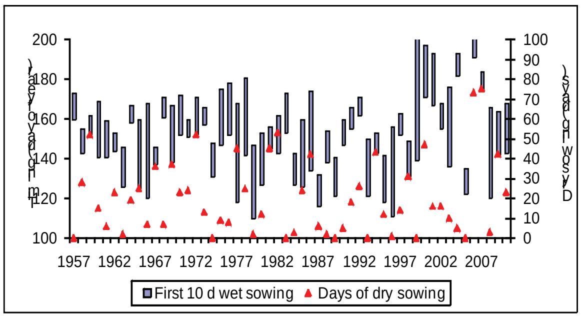


Figure 1. Historical distributions of start of wet seeding and period to achieve the first 10 days of wet seeding, plus total number of days available for dry seeding between April 15 and July 15 at Merredin (L) and Mullewa (R), Western Australia.

Dry seeding strategies and management of risk

During 2010 we interviewed three growers in the NAR that have contrasting approaches to dry seeding. One grower has a planned approach where a consistent area is sown dry (30%), so the programme can be finished on time especially when seeding canola into weedy paddocks. This grower has machinery limitations for top-dressing and spraying meaning that committing too much to dry seeding can cause post-emergence logistical issues with large areas of crop at the same phenological stage.

A second grower has a cautious approach and adopts a strategy depending on paddock weed status. He has been nervous about using trifluralin when seeding dry and this has come at a weed cost. During the past he has been worried about dry seeding too much because of wind erosion risks, and limitations on seeding capacity means during some years he has dry sown more than ideal to be guaranteed of getting the programme in. A recent purchase of a second seeding rig gives him more capacity and control over the area committed to dry seeding. With erosion the aim is to maintain groundcover on paddocks designated for dry seeding. For fallow paddocks, which will have a low weed burden and hence ideally placed for dry seeding, maintaining groundcover during the 18-month period between crops is vital. This may involve excluding grazing of crop stubbles.

A third grower likes to have his programme sown by the end of May, adopting an aggressive and confident approach. He starts as soon as possible and seeds deep into moisture if summer rain occurs.

While all growers differed in approach they all tended to seed wheat dry into fallowed paddocks or those following break crops (clean of weeds, higher yield potential). They use short -term weather forecasts to give confidence if seedbed moisture is marginal.

An often-cited risk is the financial commitment associated with a crop that may fail or emerge poorly. Table 2 indicates the scale of what is put at risk when dry seeding, by presenting partial gross margins for a typical low-rainfall scenario (the costs outlined are those remaining and truly variable from the day the seeder enters the paddock). The risk of making an operating loss is based around a complete failure through to a 0.3–0.5 t/ha crop. At $250/t (this year's approx wheat price farm gate) anything above 0.5 t/ha is likely to break even. A poor yield of 0.9 t/ha generates a useful profit of $96.40/ha. The range of outcomes shown can be used to assess how risky dry seeding wheat is based on past performance during dry years. The three growers

interviewed adopted a strategy to minimise risks associated with a failed crop or low yield potential by committing minimal inputs up front and being prepared to be flexible with topping up, especially nitrogen. One strategy with phosphorus (P) (which cannot be topped up) is to build soil phosphorus reserves to a point where a range of yield potentials can be supported from those reserves with minimal fertiliser inputs, and adopt a replacement phosphorus strategy.

During recent years in the NAR, wheat has emerged as the crop of choice to dry seed. The reason for dry seeding wheat is the yield advantage highlighted above (typically 250–400kg per 10 days) but also the fact that the 'possible' seeding window for wheat is the largest of all crop types. When a crop is dry sown it could emerge late — thus is the crop wanted at such a late date? For canola and lupins the answer is invariably no. Wheat however is the crop that in most circumstances will be accepted at a late emergence date — even if this is not the most desired outcome. Wheat is also the most resilient crop grown, which is important given that dry seeding and/or late seeding could see the crop put under environmental stresses that are not ideal.

Table 2. Partial gross margins of wheat at a range of yields and prices

Yield (t/ha)	0	0.3	0.6	0.9	1.2	1.5
Wheat price ($/t)	0.0	75.0	150.0	225.0	300.0	375.0
Income ($/ha)	0.0	75.0	150.0	225.0	300.0	375.0
Variable expenditure ($/ha)	119.6	127.3	128.0	128.6	161.3	162.0
Gross margin ($/ha)	-119.6	-52.3	22.1	96.4	138.7	213.0

In frost-prone areas, it is important to choose varieties with appropriate phenology or range of phenologies to spread risk.

In summary the key success points for low-risk dry seeding include:

1. Have a robust integrated weed management (IWM) plan in place to ensure clean paddocks for seeding into. Dry seeding regularly into weedy paddocks is a recipe for disaster.
2. Pick paddocks and crop types carefully — choose those that even in a very late break you would still choose to sow.
3. Keep input costs low to drive down breakeven yield — this is mostly about fertiliser. Remember when dry sown crops might not germinate for quite some time, driving yield potential down. To do this successfully, soil nutrition, particularly phosphorus, needs to be strong. If soil phosphorus is high then one can afford to seed with a low rate of phosphorus (i.e. 30–40 kg DAP) and the crop ends up as high yielding crop, replace the deficit the following year.
4. The later a crop is dry sown the better and lower risk — thus if there is zero forecast for rain, maybe wait and see what the forecast brings.
5. Furrow sow to maximise the value of small amounts of rain.

Estimating the benefits of dry seeding

Quantifying the yield benefits of dry seeding includes accounting for how much yield is lost due to later seeding and the (typically) lower weed burden of dry sown crops. Time of seeding trials in WA and APSIM simulations suggest 10 to 100 kg/ha loss in yield potential for each day's delay (average of about 40 kg/ha/day). Larger losses occur during years with higher yield potential. Large areas of dry sown crops allow an earlier finish to the cropping programme and hence overall higher yield potential. With weeds, a sound IWM approach will create clean paddocks suitable for dry seeding. Anecdotal evidence of growers with 100% crop and IWM (especially harvest weed seed control) have been able to deplete the weed-seed bank across most of the farm to a point where they can now dry seed the whole programme by the calendar with confidence. When thinking about how many hectares of wheat are sown during the 10 days following rain, these invariably do not get a knockdown application and if they do it is a compromised one. Thus when compared with dry-sown wheat, wet-sown crops will invariably end up worse for weeds. Dry-sown wheat will yield better and quite possibly be cleaner because the crop comes up and competes directly with the weeds.

The project team estimated the whole-farm benefits of different areas of dry seeding for 1971–2010, taking a 3000 ha wheat programme at Mullewa. For each year of the climate record the team estimated the timing of the break, days available to wet seed between April 15 and July 15, coupled this with simulated estimates of the decline in yield potential with later seeding, and calculated the whole-of-program wheat yield for various areas of dry seeding and/or faster daily seeding rate. The delay between germination of the dry-sown crop and the first wet-sown crop was also varied to allow for a period weed germination and knockdown herbicide. The estimated higher yield for dry-sown crops will be conservative because they do not account for the typically greater weediness in wet-sown crops due to greater background weed burdens and less effective post-emergence weed control.

Figure 2 shows that the response to increasing areas of dry seeding is greatest up to 1500 ha out of the 3000 ha program (0.2–0.4 t/ha). A delay in start of wet seeding of 10 days is worth about 0.2 t/ha, and more rapid seeding is worth most at lower areas of dry seeding. To illustrate the variability in benefits take one point from Figure 1, for zero versus 1000 ha dry sown, assuming 150 ha/day seeding rate and 10 days delay. Positive responses occur 90% of the time and 80% of responses lie between 0.1 and 0.3 t/ha, indicating that dry seeding generates reliable yield benefits.

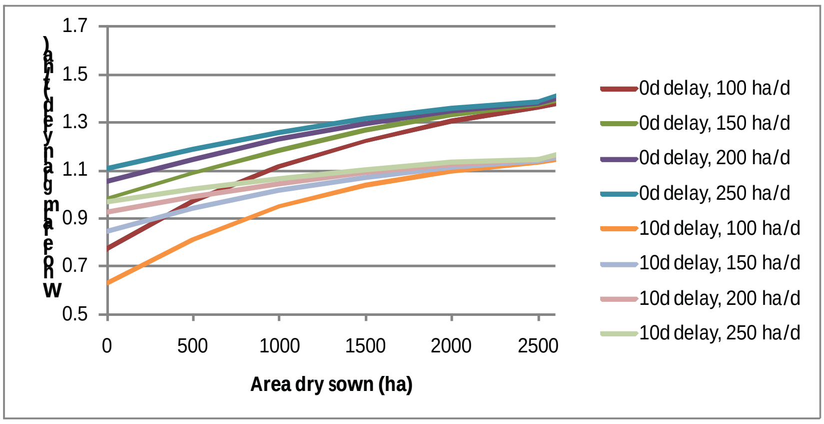


Figure 2: Response of average (1971–2010) whole-of-program wheat yield to area of dry seeding at a range of seeding rates and delays to start of wet seeding for a 3000 ha program at Mullewa, Western Australia.

Financial benefits at a whole-farm level over time

Estimates of the value of dry seeding to farm business profit were made using a year-in-year-out model based on Planfarm/Bankwest Farm Business Survey data, and allowed for varying whole-farm dry-seeding yield benefits. The model allowed for five different season types from drought to average to bumper. The key assumptions included: effective area of 5000 ha; comprising of 3000 ha wheat, 1000 ha break crops and 1000 ha fallow; wheat-on-wheat yield in an 'average' season of 1.05 t/ha; fallow advantage on average was 0.4 t/ha but varied depending on season type from 0.1–0.7 t/ha; overhead expenditure of $31/effective ha, plant value of $1,000,000 (depreciated at 12% per annum) and personal drawings $25/effective ha or $100,000 per annum. The 10-year run of seasons used for the results includes one drought, two poor, five average, one good and one bumper season.

In general the results confirmed that small increases in whole-farm wheat yield deliver significant increases in profit with time. As the assumed price of wheat goes up so does the benefit (see Table 3).

Table 3. Ten-year accumulated profit before tax at a range of value for dry seeding yield advantage and wheat price for a modelled farm

Yield advantage (t/ha)	Wheat price net on farm - ($/t)		
	200	230	260
-0.1	-2,531,575	-1,625,547	-719,519
0.0	-1,920,846	-955,379	10,087
0.1	-1,310,116	-285,211	739,694
0.2	-699,387	384,957	1,469,300
0.3	-88,657	1,055,125	2,198,907
0.4	522,073	1,725,293	2,928,513

Key Words

Climate, wheat, dry seeding, economics, modelling

Acknowledgments

Grower and agribusiness collaborators and project staff on the Department of Agriculture, Fisheries and Forestry/Grains Research and Development Corporation co-funded *Developing climate change resilient cropping and mixed cropping/grazing businesses in Australia* project.

Paper reviewed by: Roger Lawes

Defining economic optimum plant densities of open pollinated and hybrid canola in WA

Mark Seymour

Department of Agriculture and Food, WA

Key Messages

During 2010, achieving canola densities above 40 plants/m² did not reliably produce higher economic returns.

Aims

To investigate the response to plant density of Triazine Tolerant (TT), CL (Clearfield) and Roundup Ready (RR) hybrid canola compared with open-pollinated canola.

Method

During 2010 five field trials were carried out throughout the medium-high rainfall areas of Western Australia. Trials were located at Eradu, Mingenew, Cunderdin, Darkan and Gibson. The trial designs were a split plot design, with herbicide tolerance (HT) as main plots and cultivars with six plant density as sub plots. There were three replications. At each site there were 36 treatments: 3 HT — herbicide tolerant canola (TT, CL, and RR); 2 cultivar (hybrid and open-pollinated); 6 target densities (10, 20, 40, 80, 120, and 160 plants/m2). Cultivar detail: TT-ATR Cobbler, CB Mallee Hybrid; CL – 44C79 CL, 45Y82 Hybrid; RR - GT Scorpion, Hyola 502 RR. Seed size of each seed lot was measured and seed rate per plot was then adjusted using known seed size, 90% germination (as per source) and assumed field establishment was 80%. We have also included the 2009 trials reported in previous Crop Update Proceedings (2009).

Analysis

To evaluate the economic impact of treatments the assumptions in Table 1 were used. We also assumed growers purchased seed each year in accordance with rotating genetics for blackleg management. We assumed an opportunity/interest cost of 10% to plant density inputs. We did not include other costs such as machinery, labour, fertilisers, insecticides etc. as they change with location, soil type, rotation etc. By not including these costs, individuals can more readily assess the merits of using each technology. All costs were then attributed and a partial gross margin ($/ha) was then calculated for every plot in the trial. Individual trial analysis was then carried out in Genstat 13 to account for within trial spatial variation. From this analysis the spatially-adjusted partial gross margin for every plot was fitted against known plant counts per plot (see Figure 1). Curves (exponential, line plus exponential, line divided by line or quadratic divided by line) were fitted to the data and the density (ECopt) at which spending $1/ha on increasing plant density no longer returned at least $2/ha was determined for each variety x site combination (see Table 2).

Table 1. Assumptions used

	Seed size (mg)	Seed ($/kg)	Grain $/t[#]	Herbicide costs ($/ha)^	Herbicide comments
TT OP	3.04	9	550.0	46.50	2 x 1.1 kg atrazine/ha + grass herbicide
TT hybrid	4.14	24	545.0	46.50	" "
CL OP	3.04	9	550.0	66.00	600 mL Intervix/ha + grass herbicide.
CL hybrid	5.97	20	550.0	66.00	" "
RR OP	3.46	17*	536.8	28.20	Difference between Roundup and Sprayseed at seeding. 2 x 0.9 L RR/ha. No grass herbicide.
RR hybrid	5.27	23*	536.8	28.20	

*Includes $3/kg technical use agreement (TUA); #$550/t minus end point royalties (EPR) and adjusted for oil bonus/deduction (+/- 1.5% for every % above or below 42% oil — not available at time of writing); ^ as per Planfarm Herbicide Guide (2010).

Results — 2010

Canola produced similar yield and financial returns across a wide range of plant densities during 2010 (see Figure 1). On occasions when yield continued to increase at densities above 20 plants/m^2 economic returns often flattened out. On average the economic optimum density for both hybrids and OPs was 30 plants/m^2. In 65% of instances the economic optimum of hybrids was less than 30 plants/m^2. While in 62% of instances the economic optimum for OPs was less than 40 plants/m^2 (see Table 2).

In specific instances targeting more than 40 plants/m^2 of both hybrids and OPs may be economic. For example, at Gibson where average yield was above 2 t/ha, both OP and hybrid CL lines had economic optimum densities at 40 plants/m^2 or more.

Overall, RR treatments were consistently higher yielding and provided higher returns than other herbicide technologies. High yields were in some (but not all) instances attributed to improved weed control, particularly at low densities and weedy sites (Mingenew and Cunderdin — high ryegrass; Gibson — low to moderate levels of geranium, capeweed, winter grass). High returns from RR technology were attributed to high yields and reduced herbicide costs. It should be noted that in this study we did not discount RR grain. During recent weeks there has been a $20/t discount for genetically modified (GM) canola, which may bring OP RR back to the pack but in most instances hybrid RR would still have provided higher returns than other treatments.

In most instances there was no statistical difference between the economic optimum density of hybrids and OPs. However, in these experiments we found the field establishment of hybrids to be 86% (s.e. = 3) at low to medium target densities (< 80 plants/m^2) while OPs had an average field establishment of 60% (s.e. = 2). Therefore, although the target densities for hybrids and OPs may be similar in many instances care should be taken to adjust for seed size (hybrids on average are 66% bigger then OPs), germination rate and expected field establishment based on conditions (soil type, seeding gear, seeding depth, moisture) and type of seed used — hybrid or OP.

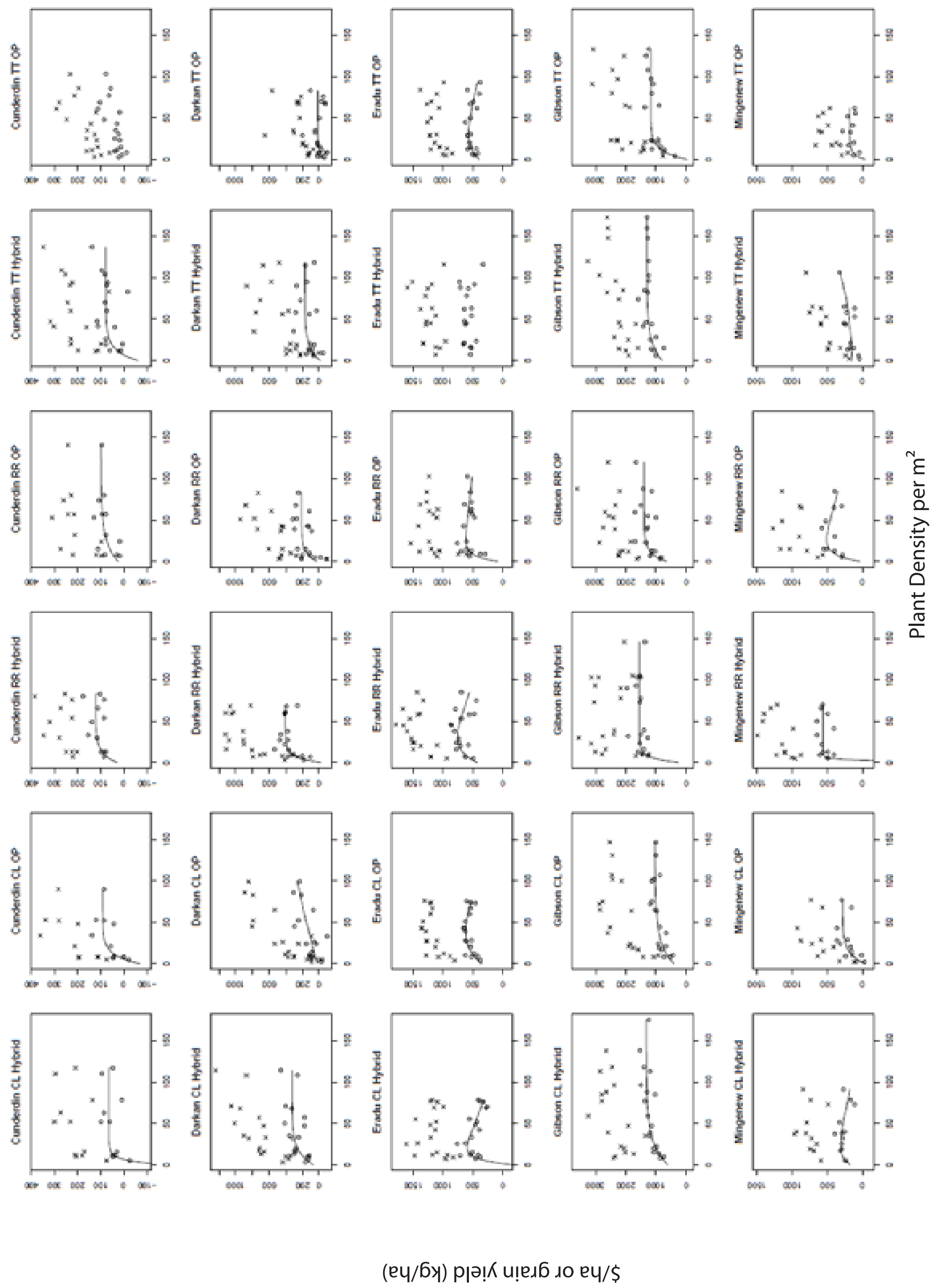


Figure 1. Trellis plot of partial gross margin (O, $/ha) and grain yield (´, kg/ha) against plant density per m^2 for each location and variety in 2010.

Table 2: Economic optimum density (ECopt, plants/m²) and standard error of the optimum density (se) for 6 canola varieties at 5 sites in 2010 and 2 sites in 2009

Site	ECopt	CL Open	CL Hybrid	TT Open	TT Hybrid	RR Open	RR Hybrid
				2010			
Cunderdin	Density	21	15	*	21	11	16
	se	6	4	*	7	26	8
Darkan	Density	64	33	13	26	21	22
	se	49	11	8	9	12	6
Eradu	Density	31	19	17	22	22	26
	se	7	5	3	8	9	9
Mingenew	Density	30	17	16	25	22	11
	se	13	8	10	8	6	4
Gibson	Density	62	68	38	54	33	24
	se	18	16	8	18	14	5
				2009			
Gibson 19 May	Density	62	22				
	se	13	11				
Gibson 9 June	Density	32	30				
	se	4	8				
Meckering 26 May	Density	45	28				
	se	7	23				
Meckering 17 June	Density	25	17				
	se	21	-				

Conclusion

In most instances in 2010, 30 plants/m² appeared to be adequate for both hybrid and OP canola. Similarly in 2009 the economic optimum densities for CL hybrid were at or below 30 plants/m², whilst CL OP had higher economic densities. In both years densities higher than 30 plants/m² for hybrids did not produce consistent increases in yield of sufficient magnitude to outweigh the extra costs incurred.

Key Words

Canola, density, hybrid, herbicide

Acknowledgments

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Project No.: GCA

Paper reviewed by: Sarah Ellis

Alternative uses for unproductive soils examined in the North Eastern Agricultural Region (NEAR)

Mike Clarke and Andrew Blake
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Key Messages

- A project carried out in the North Eastern Agricultural Area (NEAR) of Western Australia is examining the extent, current use and future potential of consistently unproductive soil types for broadacre agriculture.
- A survey of growers found an average of 8% of cleared farming land was classified as consistently unproductive.
- 75% of growers surveyed in the NEAR would be willing to permanently revegetate soils that have become consistently unproductive to crop.
- If the predicted trend towards a drier climate continues, the amount of unproductive soils is estimated to increase to 35% of the NEAR.
- The emerging carbon market may provide growers with an opportunity to permanently revegetate and generate income from these unproductive soils.

Figure1. Map showing the location of the North Eastern Agricultural Region (NEAR)

Background and Aims

The North Eastern Agricultural Region (NEAR) Strategy is a long-term plan to increase drought preparedness and resilience of farm businesses in the region. Following the 2006–2007 dry seasons there was a Ministerial request to create a 'long-term strategy for the management of issues farmers face in the event of consecutive bad years'. The Department of Agriculture and Food Western Australia (DAFWA) has worked closely with the rural communities of the NEAR and a number of projects have been developed to meet the objectives of the strategy.

One of the projects developed as part of this strategy is exploring options for changing land use on soils that are becoming increasingly unproductive. These soils have physical and chemical limitations, such as shallow depth, acid subsoil or poor water holding capacity, which are rendering them increasingly uneconomic to farm in a drying climate.

Through this project the characteristics and extent of unproductive soils in the NEAR will be defined. Current management options will be investigated and an economic analysis will take place. Suitable land use options and research gaps will also be identified. The project will provide government and the industry with policy recommendations on future management options and potential research and development opportunities.

Method

Soil analysis

An investigation was carried out to describe the characteristics and extent of unproductive soils in the NEAR. This was achieved by interrogating the DAFWA soils database, with subsequent ground truthing through discussions with growers and a soil pit survey of 10 representative sites. Samples were collected for chemical analysis and the physical characteristics described.

Grower survey

A grower survey was carried out with members of the three grower groups in the NEAR — the Northern Agri Group (NAG), North East Farming Futures (NEFF), and the Liebe Group. Information was sought on the types and status of consistently unproductive soils and how they are currently managed and could be managed in the future.

Economic analysis

Economic analysis was carried out on the management of these unproductive soils to determine profitability and break-even yields, from case studies and data collected in the survey.

Case studies

Case studies were carried out with growers trialling innovative land use practices on unproductive soils. These included overcropping perennial grasses, subdivision, new pasture species, rotary spading, precision agriculture, claying and carbon farming.

Results

Soil analysis

There are two major reasons why soils are unproductive — firstly their inherent physical and chemical properties and secondly, external influences including economics (for example, input costs and grain prices), declining rainfall and current crop rotation failures (for example, lupins). These factors combine to make areas of land unprofitable.

The DAFWA soil database analysis shows approximately 11% of soils have serious physical and chemical limitations for production in the NEAR area. Subsequent discussions with growers and evidence from field sites show many of these soils having poor water holding capacity due to the physical limitations of shallow depth and/or low clay content. Many exhibit further chemical limitations, such as acidity, and associated high levels of aluminium, salinity and poor nutrient retention. These limitations combine with economic factors to render these soils unprofitable to crop with current farm practices.

External factors are increasingly influencing areas of marginal soil. Many of these areas were previously considered productive when: rainfall patterns were reliable, terms of trade were positive and crop rotation

options were successful, are now considered risky to crop due to unfavourable changes in these factors. This may influence an additional 35% of soils in the NEAR area.

Survey results

The survey of more than 10% of all farm businesses in the NEAR has provided an insight into how growers manage these unproductive soils from Binnu to Mullewa and south to Dalwallinu. Key findings included:

- An average of 8% of cleared farming land was classified by growers as consistently unproductive.
- About 70% of growers have tried cropping these unproductive soils with 80% of those saying it was unprofitable.
- The soil types that growers classed as consistently unproductive varied throughout the region. In eastern districts growers identified salt-affected and deep acid sandplain soils whereas in the north-western districts pale deep sands and shallow sands over gravel or rock were chosen.
- 75% of growers surveyed in the NEAR would be willing to permanently revegetate soils that have become consistently unproductive to crop.

When asked what was the most important assistance that could be offered for revegetating these areas permanently, the top three responses were:

- Subsidised revegetation (59%)
- Fencing incentives (55%)
- Payment for carbon credits (52%)

Economic analysis

Growers identified these unproductive areas as unprofitable and this is supported by further economic analysis, which indicates they are consistently unprofitable when cropped. Gross margin analysis of variable costs (direct inputs) and total income indicated that in all cases, the consistently unproductive soils returned a negative gross margin. This was due to a combination of lower yields (shallow, acidic or salty soils), or high input costs (nutrition on deep sands). Hence if growers were to stop cropping these areas entirely, whole-farm profit would be increased. In some situations this is a simple process, because the offending area is adjacent to tree lines or paddock edges, but in other cases they can be discreet areas within a paddock.

From previous studies (GRDC *et al*., 2007) growers indicated variable rate technology (VRT) can assist to increase profitability on these soils. This study suggests that even with reduced inputs on consistently poor performing soils, breakeven yields were rarely achieved and negative gross margins continued to occur. However, the financial losses were lower and hence whole-farm profit is increased. VRT may help growers reduce the whole-farm loss from these areas, but it is unlikely to make them profitable in their own right. For those situations where discrete areas of unproductive soil occur within paddocks and, for efficiency reasons, growers wish to keep the paddock shape and dimensions consistent, VRT is an excellent choice to reduce variable costs and overall losses.

Case studies

Management of unproductive soils can be broken into two categories: those mitigated by the application of ameliorants or technology and those that require a change in farming system or land use.

Examples of mitigation strategies include the application of lime for acidification, clay incorporation and rotary spading for non-wetting soils and VRT. Changes in land use or farming systems include changing from annual to perennial pastures, pasture cropping and carbon tree farming.

It is too early to say whether the case studies explored in this project are profitable in their own right on these consistently unproductive soils. While some strategies such as claying, liming and rotary spading are often profitable in higher-rainfall areas, the lower yield potential in the NEAR reduces the likelihood of these practices being profitable in the short term. It is likely that other, more-productive, soils in the NEAR have the greatest ability to return a profit from such costly mitigation practices.

Gaps in knowledge

Carbon: Opportunities for the emerging carbon market were examined by undertaking some preliminary carbon analysis on native species. Tree species that are often mass planted throughout the wheatbelt, such

as oil mallees, are often not the best choice for such inhospitable soil types. Many other local native species are adapted to such environments and perform better in terms of survival and growth rates. DAFWA has been working with forestry specialists to determine just how much carbon is actually stored by native plants that thrive on these poor soils. Destructive sampling, where a quarter of a tree or shrub is pruned and weighed, was undertaken to determine carbon storage and possible financial returns from such plantings. Initial results are quite promising with a 50-year-old stand of acacia shrub land on acid wodjil soils yielding up to 108T/ha CO_2 -e. Further research is required to gain more information on the various plant species that naturally inhabit these soil types. Impediments to this land-use change occurring were identified as including high cost and uncertainty of carbon price, lack of technical advice, restriction around subdividing agricultural land and a lack of information about the carbon sequestration potential of species other than oil mallees.

Subdivision: Growers wanting to exit the industry are experiencing difficulty selling their properties. Restrictions around sub-dividing agricultural land have made dividing large lots into smaller parcels for ease of sale difficult. This can limit the ability of neighbouring farm businesses to buy land from exiting farmers due to large lot size and therefore high property values. It can also make it difficult for new industries to become established. For example, carbon-brokering firms may seek to acquire areas of consistently unproductive cropping lands for carbon planting but are forced to buy larger areas of mixed land capability (including high-value agricultural land) rather than smaller parcels of appropriate soil types. The Department of Planning (with input from DAFWA) has been reviewing the Agricultural and Rural Land Use Planning Policy and expect to release a draft for public comment early during 2011. Some Local Government Authorities (LGAs) have expressed concerns over the rise in farmland being converted to tree farms. DAFWA is supporting the LGAs by providing soil landscape information to enable better decision making and policies around the planning for such land-use change.

Discussion

About 10% of soils in the NEAR are consistently unproductive and ceasing to crop these soils is likely to lead to an increase in whole- farm profitability. Many growers would like alternative crops or pasture species for these soils because options are currently limited and 75% of growers would be willing to permanently revegetate these soils. If the climate continues to dry, then a greater percentage of soils are is likely to become unproductive and carbon plantings may provide an opportunity for businesses to generate income from these soils. Land optimisation strategies where land is managed according to its capability are worth investigating. This may require a change in ownership of some areas, but restrictions around sub-dividing agricultural land may need changing to allow this to occur.

Key Words

Unproductive soils, grower survey, carbon, subdivision

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Acknowledgments

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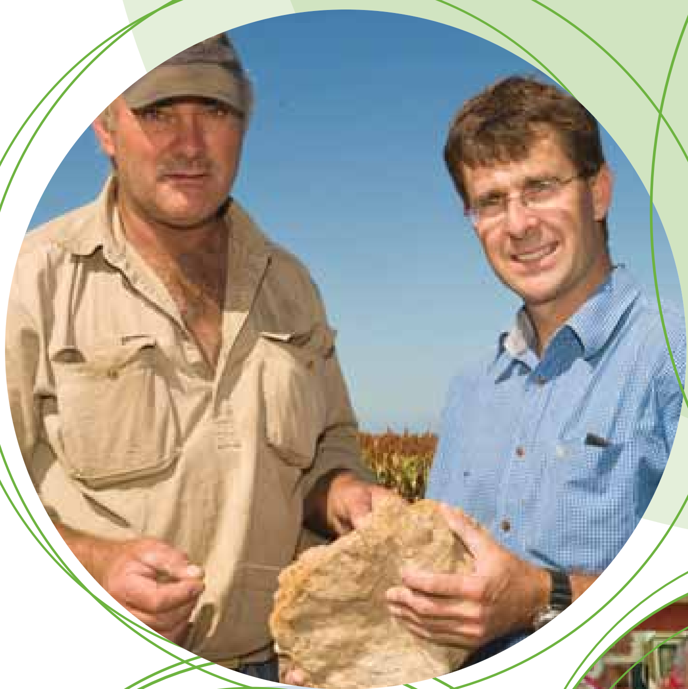
Paper reviewed by: Rob Grima and Stephen Davies

Markets



What the world wants from Australian wheat

Gordon MacAulay

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Emeritus Professor of Agricultural Economics, University of Sydney

Key Messages

- Traditional exporters, the United States, Canada, Australia and Argentina, export about 65 million metric tonnes (MMT) per year.
- Of this, Australia exports about 12 MMT/yr.
- Black Sea port countries export about 34 MMT/ year.
- Population is a long-term driver for wheat demand.
- World area planted is about 200 million hectares and yield growth is the key to meeting demand.
- The risky world market is driven by inelastic (near vertical) demand and supply relationships.
- Shares of total world exports and shares of total world wheat production over the period 1960/61 to 2009/10 have declined for both Canada and the United States while Australia's shares have remained steady. The Black Sea port countries have dramatically increased their shares.
- There are many importing countries with most importing less than 5 per cent of total exports.
- Different end-products require different wheat qualities and different qualities provide the foundation for price discrimination.

The global market — some insights

The world market has four major traditional exporters (United States, Canada, Australia and Argentina), plus the European Union and the Black Sea port countries (Figure 1). In total they export about 130 MMT/year (five-year average). Thus, there is a small number of major exporters.

World wheat production is about 600 MMT/year of which the traditional exporters, the EU and the Black Sea port countries produce 350 MMT and India and China produce about 188 MMT/year. The area planted to wheat across the world is about 200 million hectares and has been constant over a long period (Figure 2). Thus, yield growth has been essential to increased world production.

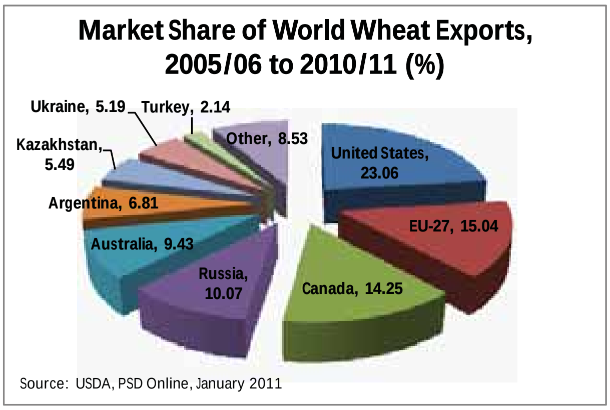


Figure 1. Shares of world wheat exports.

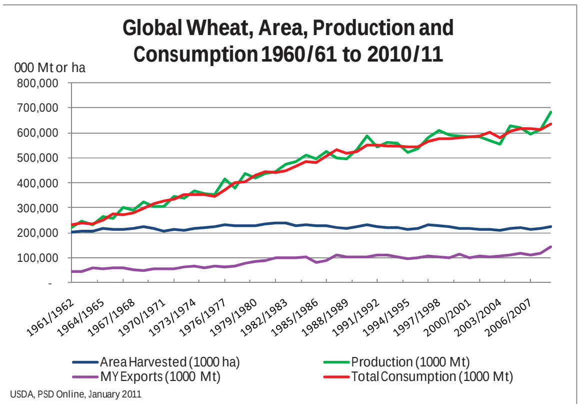


Figure 2. Global wheat production, consumption and area planted.

The Black Sea ports

Over a long period of time the shares of production and the shares of world trade of Canada and the United States have declined (Figure 3). Recently the Black Sea Port countries have dramatically increased their share as a result of reduction in the livestock sector and its use of feed grain and increases in yields. Australia has

escaped this long-term decline but has been subject to about a 10-year cyclical pattern of variation in the share of both world production and world trade. Can Australia continue to maintain its share of about 12-13 per cent of exports?

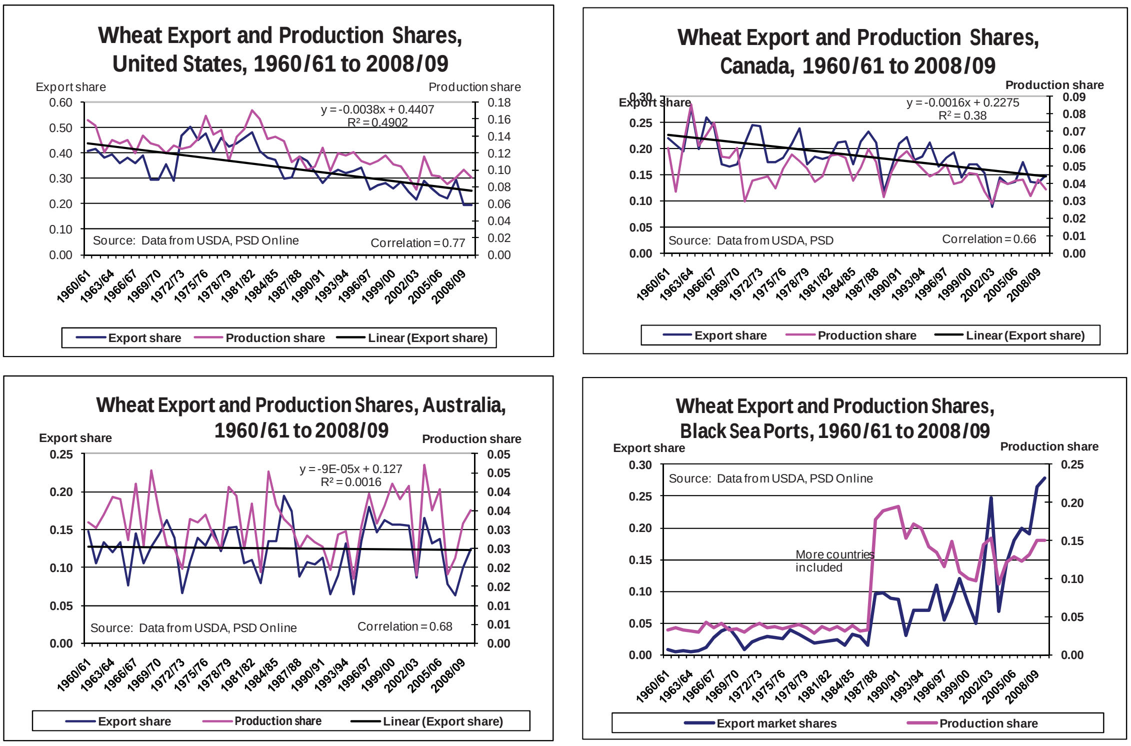


Figure 3. Selected country wheat exports and production shares.

Supply and demand

Over a very long period of time world wheat prices have frequently 'spiked'. The global 'thermometer' or measure of this phenomenon is the stocks to use ratio (Figure 4). When the ratio gets down to about 25 per cent, prices rise rapidly. However, they nearly always fall as rapidly as they rise. The simple economics of this is that the behaviour of wheat consumers and producers is such that a small change in the quantity produced or demanded gives a large change in price (Figure 5). A major reason for this is that bread and other wheat-based foods are only a small part of consumers' budgets. A second important reason is that farmers tend to base their production decisions on last year's price and can adjust the area planted easily. Put these together and you have an inelastic supply and an inelastic demand and a market that is inherently unstable with highly variable prices. Risk management strategies are thus vital for success in wheat production.

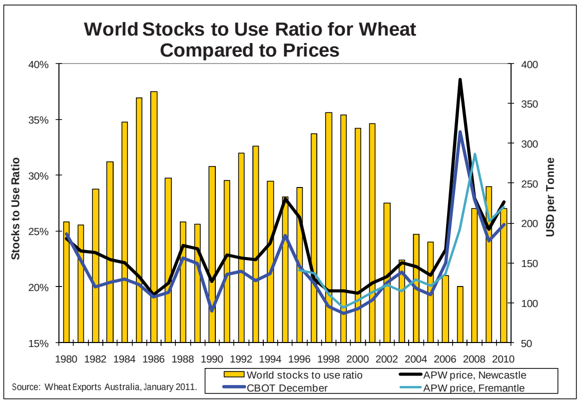


Figure 4. World stocks to use ratio and prices.

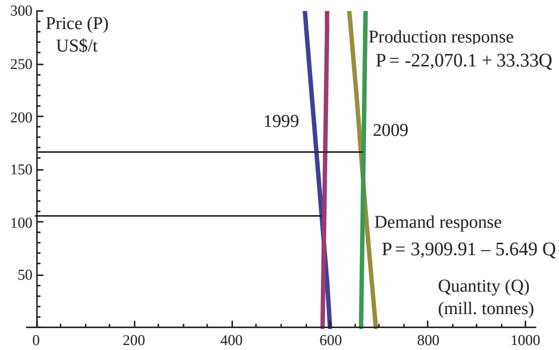


Figure 5. World wheat supply and demand relationships.

Importers

There are many importers of wheat with none importing more than about five percent of world wheat trade or 5-6 million metric tonnes. Spain, Italy, Algeria, Brazil and Japan are the largest. At times India and China have imported large quantities. A total of 118 countries have imported over 2,000 tonnes on average over the five years 2004 to 2009. Australia exports more than 2,000 tonnes to 48 different countries. To maintain market share this will require constant effort in market development. One of the promising areas for development is Saudi Arabia as it cuts back its production of water-intensive crops and has substantially increased imports of wheat since 2008/09.

Wheat consumption per person

The largest per capita consumers of wheat are in Kazakhstan and Azerbaijan (Figure 6). They consume for food and industrial uses almost a kilogram per day. The areas of potential growth in consumption and where demand growth is likely as incomes grow are countries like India, China, South Korea, Malaysia, Indonesia, Thailand and Vietnam and Philippines where the levels of consumption are relatively low and there are good prospects for income growth and the substitution of wheat for rice.

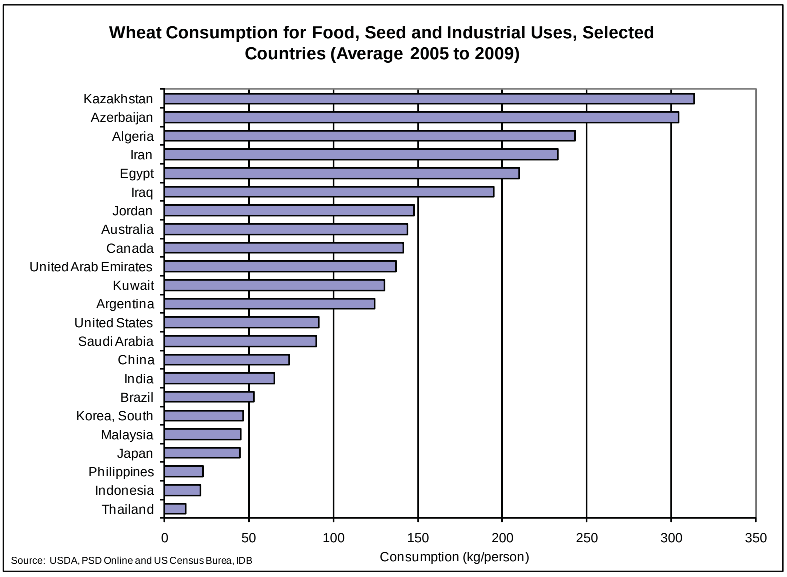


Figure 6. Wheat per capita consumption for selected countries.

Australian wheat production

Australian wheat production is highly variable varying from 10 to 25 thousand metric tonnes in one year. Weather is clearly a major cause of this variability. Relative to some other countries yields in Australia have grown slowly, particularly in recent periods while area planted has also increased slowly since 1988/89 from about 9,000 hectares to 13,000 in 2008/09. Average yields at both points in time were about 1.6 tonnes per hectare.

Australian wheat use

About 50 per cent of Australia's wheat is exported and the remainder is held or used domestically (Figure 7). Of the exports, 40 per cent is APW and 15 per cent AH grade (Figure 8). Domestic use is feed and seed at about 3 per cent and food use about 16 per cent. The remainder of 26 per cent is held in stocks at the end of the season. Feed wheat is largely used in Eastern Australia with about one third each in Queensland, New South Wales and Victoria.

The pattern of demand for Australia's wheat exports vary in some interesting ways. Australia has maintained its export share over a long period but has been subject to approximately a 10-year cycle in export share and

in the share of world production (Figure 9). This cycle has little to do with floods or droughts but is likely to be related to sheep and cattle numbers and the longer-term substitution between sheep, cattle and grain. Other major exporters do not seem to have such cycles. Another substitution is that as Australian exports to Asia increase exports to the Middle East have tended to decrease and vice versa, at least since 1996/97 (Figure 10). This has much to do with the nature of the demands in each of the regions and needs much more careful study.

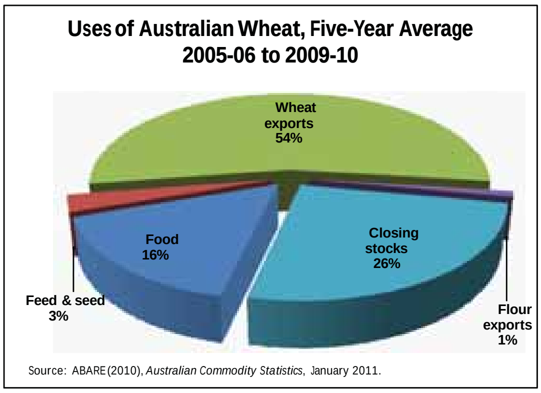


Figure 7. Uses of Australian wheat.

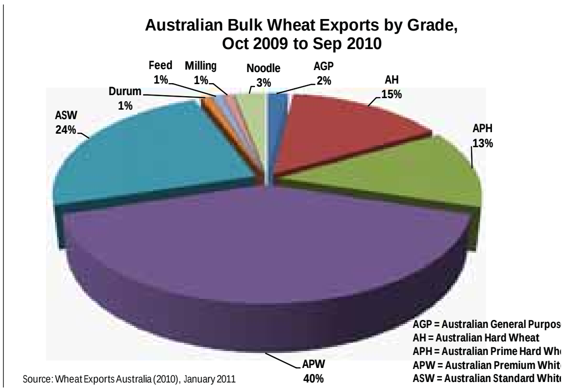


Figure 8. Australian bulk wheat exports by grade.

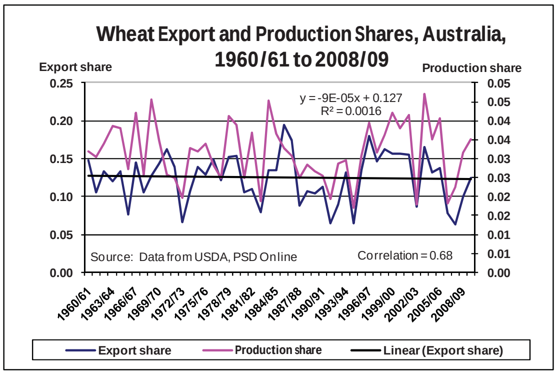


Figure 9. Australia's moving average share of exports and world production.

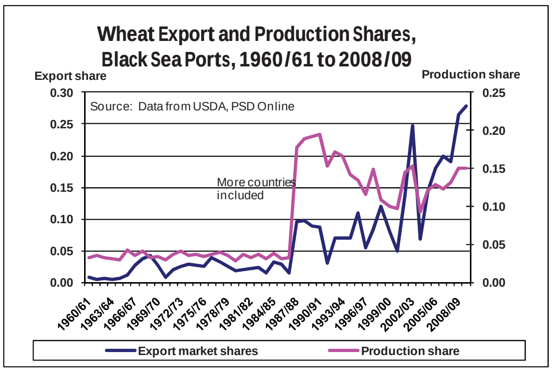


Figure 10. Share of Australia's wheat and flour exports by region.

Australia's importers

Indonesia is Australia's largest wheat importer by more than a factor of two but Italy, Sudan and Japan have the highest unit values among our export destinations (Italy imports mainly durum) (Figures 11, 12 and 13). Indonesia is intermediate in value but in total is worth about $US0.7 billion in 2009. Much of this wheat will be milled into flour for noodles and bread with only very small quantities of flour exported to other countries (about 18,000 tonnes in 2009). Meeting the needs of Indonesia is crucial to the future of the Australian wheat industry.

Vietnam is the largest destination for container exports from Australia, although Taiwan, Malaysia and Indonesia all purchased over 20,000 tonnes in October 2010 (Figure 14). Vietnam has many small mills which limits their capacity to handle large volumes of grain.

Commodity magnet

As the market for a good grows and matures it often tends toward the characteristics of a commodity (Figure 15). That is, low in relative price and high in cost to service the market (all direct and indirect costs). Computers are a good example and wheat is a commodity. Through the use of ideas such as product differentiation (segmenting customers willing to pay for additional services) and reductions in the costs of

servicing markets (better targeting of services to customers and unbundling the product and services) a commodity such as wheat can, in part, be moved away from the commodity magnet position. This all implies better measurement, quality control, packaging and better consistency of product.

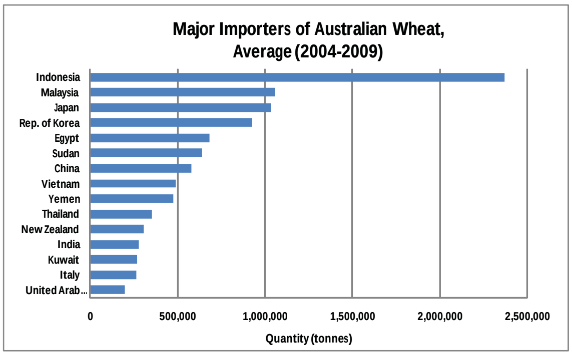


Figure 11. Major importers of Australia's wheat.

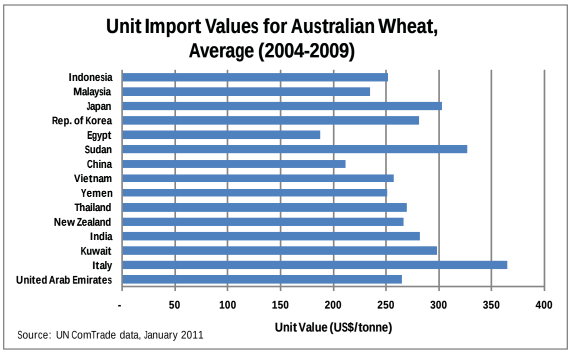


Figure 12. Unit import values for major importers of Australia's wheat.

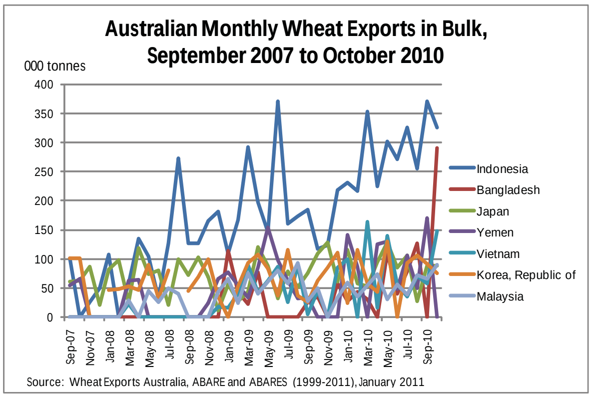


Figure 13. Australian bulk wheat exports.

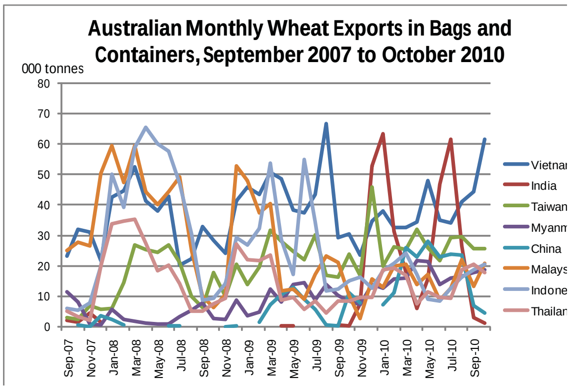
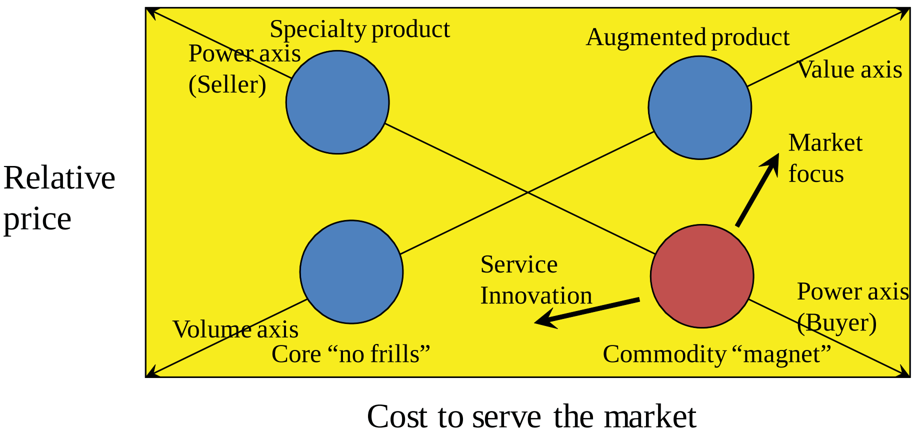


Figure 14. Australian bag and container wheat exports.



Source: Wilson, W.W. (1995), Decentralization of grain trading: Trends, implications and challenges, Australian Agricultural Economics Society, Perth, February 1995

Figure 15. The commodity 'magnet'.

Internationalisation of the Australian wheat industry

Economies of scale and scope are very strong economic forces within the grains industry. That is, the operating cost curves continue to decline over large volumes and also across different types of grain. There are many technical reasons for such economies. The implication is that it is economically efficient to have very large firms in grain markets. With deregulation of the wheat industry Australia has rapidly moved from a monopoly to an oligopoly. As in Australia, and elsewhere, there is often a very important fringe of smaller competitive firms that can take advantage of product differentiation and targeted service provision. Hansen and Simmons (1995) examine the case of the Australian wool industry and note that small competitive firms have high exit and entry rates thus providing an active trading 'fringe' that prevents under-pricing by the large firms (product differentiation and low overhead costs). At the same time, the large firms keep any inefficient small firms out of the industry. Thus these firms are vital to growers as they ensure that the powerful firms cannot use their full market power and retain all the benefits of such power.

Concluding Comments

Observation	Actions
World wheat markets are complex and risky—inelastic supply and demand	Risk management strategies, including storage management, income diversification and financial reserve policy Plan for the long term and manage the short term
Competition for market shares is intense and the new exporters will become much larger keeping pressure on prices	Innovative ways of reducing costs. Seek to sell a differentiated product, eg. through container-sized, quality-specified packages
Stocks to use ratio is the industry thermometer	Monitoring the direction of change of the world stocks to use ratio gives short-term forward looking information on prices
Wheat is a commodity and tends to the commodity magnet	Product differentiate Target market services to customer needs
Different countries have very different product consumption patterns requiring different qualities	Understand the quality requirements for the different markets you are supplying
Different end-products require different wheat qualities and different qualities provide the foundation for price discrimination and revenue improvement.	Ensure you know your quality parameters. Blend to best advantage if possible.

More Information

More information can be found at http://www.graingrowers.com.au by downloading

What the World Wants from Australian Wheat: Update 2010.

Key Words

Wheat, export, demand, supply, production, quality

Acknowledgement

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Effect of lupin flour incorporation on the physical and sensory quality of pasta

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Key Messages

Nutritional value of pasta in terms of protein and dietary fibre contents can be significantly increased by incorporating 20% lupin flour without deteriorating its physical and sensory properties.

Background and Aims

Pasta is widely consumed throughout the world and represents one of the fast-growing sectors of the food industry. However, pasta is low in nutritional value. It is generally made out of wheat semolina, which is high in starch but very low in dietary fibre and protein contents. Lupin flour, which is rich in protein (40%) and dietary fibre (28%), has a great potential to be incorporated into pasta to increase the protein and dietary fibre content.

An increased consumption of dietary fibre in daily diet has been recommended by nutritionists to improve health. Dietary fibres promote beneficial physiological effects including laxation, blood cholesterol and blood glucose attenuations. Wheat flour protein, which is poor in the essential amino acid lysine, can be complemented by the high lysine content in lupin protein.

Lupin is lower in cost compared with other similar grain legumes, such as soybean. Substitution of lupin flour would improve the nutritional quality of wheat pasta at a comparatively lower cost.

The aim of the present study was to evaluate the effect of lupin flour incorporation at varying levels on the physical properties and consumer acceptability of pasta to find maximum incorporation of lupin flour to improve the nutritional quality without deteriorating consumer acceptability.

Method

Lupin (*Lupinus angustifolius* L.) and durum semolina flours were blended in ratios of 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 (lupin flour:durum semolina; w/w). Pasta samples were extruded in the form of 2.0 mm diameter spaghetti strands using a pasta machine, dehydrated and packed in polyethylene bags.

Pasta quality in terms of cooking time and cooking loss (the amount of solid substance leached into the cooking water) was determined using standard methods. Protein (nitrogen x 5.7) content was determined according to the standard methods, whereas total dietary fibre content was calculated based on the dietary fibre contents of wheat semolina and lupin flour.

Changes in textural properties, such as firmness and stickiness, were analysed using a TA.XT2*i* texture analyser. Sensory evaluation of the samples for colour, taste, texture and overall acceptability was carried out using nine-point Hedonic scale. The results were analysed by SPSS 17 and the means were compared by using Tukey's test at $p \leq 0.05$.

Results

Incorporation of lupin flour substantially effected the cooking quality of pasta. There was a significant decrease in the cooking time with ≥ 40% lupin flour incorporation (see Table 1). Samples containing up to 30% lupin flour did not demonstrate any significant change in cooking time. Cooking loss, which is commonly-used as a predictor of overall pasta cooking performance, showed no significant differences among the samples.

Textural characteristics of cooked pasta are a prime concern with firmness and stickiness playing major roles in the acceptability by consumers. A sticky pasta is generally unacceptable. The data presented in Table 1 on the stickiness and firmness of cooked pasta reveal that the stickiness of the samples decreased at > 20% lupin flour incorporation, however, firmness of the pasta was not effected ($p \leq 0.05$) by lupin flour concentration.

Table 1. Effect of lupin flour substitution on the cooking and textural properties of pasta

Lupin flour substitution	Cooking time - (min)	Cooking losses (g/100 g)	Stickiness (g)	Firmness (g)
0% (Control)	12.5 ± 0.5[a]	6.6 ± 0.1[a]	504 ± 56[a]	319 ± 4[a]
10%	12.5 ± 0.0[a]	6.8 ± 0.2[a]	463 ± 46[a]	324 ± 10[a]
20%	12.0 ± 0.5[ab]	7.1 ± 0.4[a]	431 ± 58[ab]	314 ± 15[a]
30%	12.0 ± 0.5[ab]	7.6 ± 1.7[a]	405 ± 64[b]	321 ± 15[a]
40%	11.5 ± 0.5[b]	7.2 ± 0.5[a]	304 ± 61[bc]	326 ± 9[a]
50%	11.0 ± 0.0[b]	7.7 ± 0.6[a]	291 ± 31[c]	309 ± 7[a]

Means (averages) with different superscripts within a column are significantly different ($p \leq 0.05$).

Substitution of lupin flour up to 50% in pasta gradually increased the protein and dietary fibre contents (see Figure 1). This is because lupin flour contains substantially higher amounts of protein and dietary fibre than wheat semolina. Incorporation of lupin flour at 20% level resulted in a 50% increase in protein and 160% increase in dietary fibre contents.

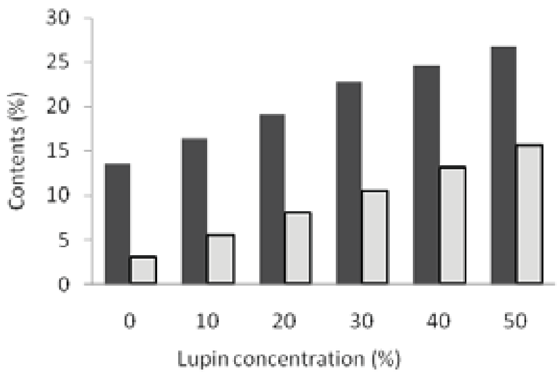

Figure 1. Protein and dietary fibre contents of uncooked dry pasta samples as affected by lupin flour concentration: protein (☐), dietary fibre (■).

The results of sensory evaluation for colour, taste, texture and overall acceptability of the cooked pasta samples are presented in Table 2. Addition of lupin flour at ≥30% significantly reduced the scores for all of the sensory attributes. However, lupin flour incorporation up to 20% had no significant effect on colour, appearance, taste, texture or overall acceptability of pasta samples.

Table 2. Effect of lupin flour substitution on the sensory properties of cooked pasta

Lupin flour substitution	Colour	Taste	Texture	Overall acceptability
0% (Control)	7.0 ± 1.8[a]	7.4 ± 1.8[a]	7.2 ± 2.0[a]	7.5 ± 1.0[a]
10%	6.7 ± 2.1[ab]	7.0 ± 1.2[a]	7.0 ± 1.1[a]	7.2 ± 1.2[a]
20%	6.5 ± 2.0[ab]	6.2 ± 1.9[ab]	6.0 ± 1.0[b]	6.7 ± 1.5[ab]
30%	5.6 ± 1.6[bc]	5.5 ± 2.0[bc]	5.3 ± 1.9[bc]	5.7 ± 1.8[bc]
40%	5.6 ± 1.5[bc]	4.7 ± 2.1[c]	4.8 ± 1.8[c]	5.0 ± 2.0[c]
50%	5.1 ± 1.9[c]	4.5 ± 1.6[c]	4.3 ± 2.1[c]	4.8 ± 1.0[c]

Means (averages) with different superscripts within a column are significantly different ($p \leq 0.05$).

Discussion

The results illustrate that lupin flour can be successfully incorporated into pasta up to 20% levels without affecting consumer acceptability. By adding lupin flour to pasta a substantial increase in protein and dietary fibre content can be achieved, improving the nutritional value. Since lupin is a low-cost protein source, its incorporation in pasta may not result in a significant increase in pasta price. The protein-rich lupin-incorporated pasta will provide an effective source of dietary protein with a balanced amino acid profile providing a solution to protein malnutrition in many developing countries. Lupin-incorporated pasta also provides dietary fibre which, along with other health benefits, is required on daily basis for better health.

Key Words

Lupin, pasta quality, physicochemical sensory evaluation

Wheat quality requirements for Saudi Arabia: baking quality and blending potential of some Australian exporting grades

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[1]Department of Agriculture and Food, WA, [2]BRI Australia

Key Messages

Bread is an important traditional food in Saudi Arabia and wheat flour is subsidised as a staple food ingredient. Saudi's baking sector has become accustomed to domestic wheat production and low cost, consistently high protein flour with very strong stable dough characteristics suitable for a range of bread types.

Comparative performance of Saudi Arabian and Australian wheat indicates both the traditional and large scale baking sectors could utilise Australian wheat with confidence in relation to milling performance, balanced dough properties and major end uses of flat bread and rapid dough baking.

Australian wheat will often be measured against versatile higher protein wheat available in the international market, achieving excellent baking properties with our varieties at our protein levels is an industry priority for ongoing competitiveness.

Aims

The aim of this study was to understand the general quality properties of current wheat and wheat flour use in Saudi Arabia and to evaluate the baking potential of Australian export grades for bread baking requirements of Saudi Arabia. Six Australian export grades including: Australian Premium White (APW) (from WA, VIC and SA), Australian Hard (AH) (from WA and NSW) and Australian Premium Hard (APH) (from NSW) have been compared to Saudi Arabian milling wheat.

Method

Detailed comparison was done using wheat samples imported under quarantine and milled under standard milling conditions for direct comparison to a range of Australian wheat quality grades from Western and Eastern Australia. A range of grain, flour, dough and baking tests were applied using national laboratory protocols. Final evaluation was undertaken with Saudi Arabian end use quality experts.

Results

Samples

Three wheat samples were imported from different regions of the Kingdom of Saudi Arabia (KSA) under quarantine for direct comparison to Australian grade samples, under standardised milling and baking conditions. Australian export grades samples were Australian Premium White (APW) (from WA, VIC and SA), Australian Hard (AH) (from WA and NSW) and Australian Prime Hard (APH) (from NSW). After comparative assessment of all nine samples, two Saudi Arabian samples were blended with APW and AH grade samples and evaluated for baking quality.

Grain properties

All samples had high test weights and low sievings. Saudi Arabian samples had very hard grain as measured by the Particle Size Index. One KSA sample was higher protein than Australian Prime Hard (APH) from NSW. The protein of other KSA samples was in the range of the Australian samples (Figure 1).

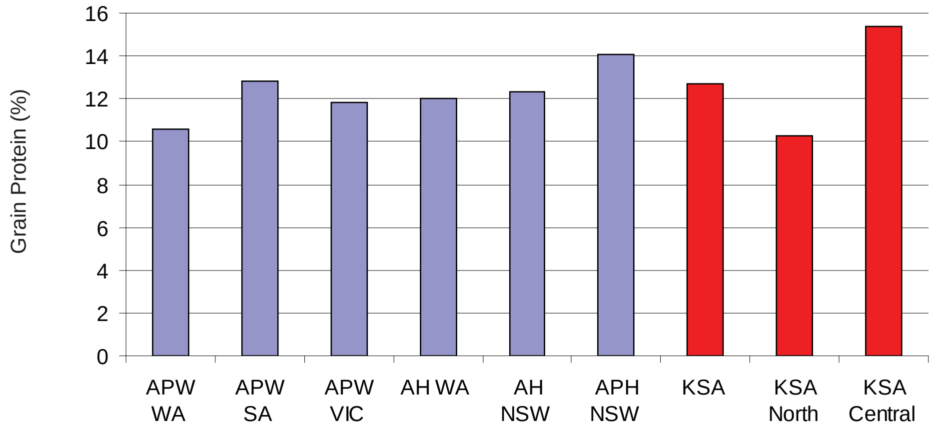

Figure 1. Grain protein content measured on 11% moisture basis of six Australian and three Saudi Arabian (KSA) samples.

Milling properties

Flour yields adjusted for bran contamination ranged from 77.3-79.3% for Australian samples and were greater than KSA samples, which ranged from 76.0-76.9%.

The highest wet gluten contents were KSA Central and APH NSW samples. The lowest wet gluten contents were APW WA and KSA North.

Dough properties

Dough development times for KSA samples were generally longer than Australian samples and two samples (KSA and KSA North) had dough development times that were longer than normal for Australian baking industries. All Australian samples exhibited development times of 4-5 minutes except the sample of APW wheat from Victoria.

Flat bread baking

Samples produced excellent flat breads with some variation in loaf colour. Flat breads made from Australian wheat performed well and compared favourably to Saudi wheat samples. Australian Premium White wheat from Western Australia did not blister, had excellent pocketing, softness and tearing characteristics and was assessed as providing the best rolling characteristics of the Australian wheats. It produced loaf colour intermediate between the KSA samples. Loaf colour can also be readily adjusted during commercial baking. The study demonstrated that Australian wheat samples, particularly APW from WA, were very suitable for flat bread production, a major traditional end use in Saudi Arabia.

Rapid dough bread baking – direct comparison of unblended flours

All Australian samples equalled or exceeded the loaf volumes produced from the Saudi wheat samples except for Australian Premium White from Western Australia. APW WA was very comparable in rapid dough baking quality to two KSA samples but did not bake as well as a third KSA sample. The range of oven spring scores observed among the Australian samples was similar to the range of scores observed among the KSA samples. Crumb colour scores of loaves made from Australian wheat samples were consistently better than for Saudi Arabian wheat samples. Variation in wet gluten content or flour protein content explained less than half of the loaf volume variation observed among the samples (R2 0.4-0.45).

Rapid dough bread baking using flours blends of APW or AH with two KSA samples

Four blending comparisons were made comprising each of two Australian samples (APW WA and AH WA flours) blended with each of two KSA samples (North and Central). Each blending comparison comprised 3:1, 1:1, 1:3 and the unblended flours. All samples were tested in duplicate.

Addition of 25%, 50% or 75% of APW WA to KSA North had similar or slightly improved loaf volume and similar or improved oven spring. With 75% APW the crumb colour was noticeably improved.

Addition of 25%, 50% or 75% of AH WA to KSA North improved loaf volume, oven spring and crumb colour.

Blending up to 50% APW WA with the KSA Central sample sustained high loaf volume and good oven spring and also improved crumb colour.

All blending ratios of AH WA with KSA Central baked well. Blending 75% AH WA with KSA Central resulted in improved loaf volume, excellent oven spring and improved crumb colour.

Conclusion

This study has demonstrated that the Saudi Arabian wheat processing industry can utilise the range of Australian hard wheat export grades with confidence in relation to milling performance, balanced dough properties, and major end uses of flat bread and rapid dough baking. APW from Western Australia was very suitable for flat bread and produced acceptable rapid dough loaves. AH from Western Australia was very suitable for flat bread and was comparable to KSA wheat for rapid dough loaves.

Blending studies demonstrated scope to blend Australian wheat samples at similar or lower protein levels than Saudi wheat samples. AH and APW wheats were very suitable for blending with KSA wheat and often sustained or improved rapid dough baking performance, in ways that sustained or improved baking performance.

Saudi Arabia currently buys around 2 Mt of wheat on the international market and this will grow to around 3 Mt in the next five years. The Australian wheat industry has a significant opportunity to access this growing market.

The Saudi market opportunity provides clear signals to the Australian wheat industry for the longer term. International markets like versatile wheats that can be used for a range of products. The Australian industry needs to continue to improve quality for flexible end uses. As our wheat will often be measured against higher protein wheat available in the international market, achieving excellent processing properties at our protein levels becomes an industry priority.

Key Words

Wheat and flour quality; flat bread baking; rapid dough baking; understanding market requirements

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