High rainfall zone grains: yield gaps, production trends and opportunities for improvement

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Abstract
There is growing recognition of the potential to increase crop production in the higher rainfall zones (HRZ) of southern Australia. We combined a survey of agricultural consultants, and an analysis of crop yields in order to (1) investigate recent trends in crop production, (2) quantify the gap between potential and actual crop yields, and (3) consider the factors thought to limit on-farm yields. The survey of agricultural consultants revealed that in the last 10 years there is a trend towards more cropping, an increased use of canola, adoption of dual purpose crops, and advances in the adaptation of cultivars to the HRZ. In Victoria, NSW and South Australia the long-term water-limited potential yield, estimated by modelling, consultants and experimental measurements, for HRZ wheat and canola was 5-6 and 2-3 t/ha for a decile 5 season. The equivalent values for WA were 4-5 and 2-3 t/ha, where yields were less responsive to good seasons than in the other states. There was a large gap between APSIM simulated potential yield and farmer-realised yields, however the top performing farmers were achieving close to the water-limited potential yield. In all regions, there appears to be scope for large gains in yield and productivity benefits by encouraging the below-average cropping farmers to adopt the practices and behaviours of the above-average farmers, such as being prepared to pay for inputs, more timely sowing, weed and disease control, and N-topdressing.

Key Words
High rainfall zone, crop, technology, wheat, canola

Introduction
In the last decade, there has been a growing recognition of the potential to increase crop production in the higher rainfall zones (HRZ) of southern Australia. The comprehensive review of Zhang et al. (2006) highlighted the potential to increase grain production in the HRZ, and discussed the biophysical constraints to crop production that would need to be addressed to underpin expansion. They also emphasised the issue of perceived poor adaptation of the then currently-grown crop cultivars to HRZ. Since this 2006 review, there has been a trend towards more cropping in the HRZ, an increased use of canola in rotations compared to the medium and low rainfall zones, and adoption of dual purpose (grazing and grain production) use of cereals and canola. In the last 10 years a substantial program of research, development and extension specifically focussed on the HRZ has been conducted, funded by the Grains Research and Development Corporation, state and federal government agencies, and universities. This program has examined agronomic and cultivar adaptation issues, soil and climatic constraints and more recently environmental concerns such as nutrient and pesticide runoff, acidification, and biodiversity threats to agricultural expansion. In order to inform directions for further research in the HRZ, there is a need to assess the impact of this recently completed research and reassess crop production trends and practices in the HRZ, against a background of changing trends in climate, improved cultivars and new management systems, and contemporary perceptions regarding the constraints to crop production in the HRZ.

Therefore in order to examine the current status of HRZ cropping systems and identify opportunities for further research, development and/or extension programs, we combined a survey of agricultural consultants and an analysis of crop yields in order to (1) investigate recent trends in crop production, (2) quantify the gap between potential and actual crop yields, and (3) consider the factors thought to limit on-farm yields.

Methods

We collected data on current on-farm crop yields, constraints to increasing yield, and the scope for increasing production on-farm. Fifteen farm consultants from New South Wales (NSW), Victoria, South Australia (SA) and Western Australia (WA) were interviewed about trends in grain production in the last 10 years, perceived constraints to production, and future needs for RD&E. They also nominated typical grain yields produced in different seasons by farmers varying in their level of management skill. The consultant's views of on-farm yields was compared with potential yields observed in high-yielding experimental conditions from 2009-2013 and previously published estimates generated from simulations using the APSIM model (Bell et al. 2014, Lilley et al. 2014).

Results and Discussion

Potential yield

According to consultant estimates, the above-average farmers in Australia's HRZ are achieving yields between 4.5 and 6 t/ha for winter cultivars of wheat in a decile 5 season in NSW, Victoria and SA (Figure 1). These yields are consistent with long-term simulations for winter cultivars (Bell et al. 2014), who simulated lower yields for spring cultivars (approx. 0.5 t/ha less) due to their shorter season length and hence lower yield potential. Moreover, experimental plot yields (Table 1) confirm that over the long-term between 5 and 6 t/ha is a reasonable yield expectation for wheat crops that are being managed close to their water-limited potential. In high-yielding seasons (timely sowing, growing season rainfall >350 mm) observed experimental yields suggest that yields of nearly 10 t/ha are possible using cultivars of winter wheat, as also observed in simulation studies (Bell et al. 2014, Lilley et al. 2014) where a 25% yield advantage was associated with winter wheat cultivars over shorter season spring types. At the other end of the distribution for yield expectations, experimental yields (Table 1) and consultant estimates for above-average farmers (Figure 1) suggest that wheat yields of 3 t/ha could be expected from well managed crops in a decile 2 season (equivalent to about 200 mm growing season rainfall). These results suggest that leading farmers in the HRZ are growing crops close to the water-limited potential. Results of the consultant survey indicated that consultants primarily attributed these higher yields to the farmers' (1) preparedness to pay for inputs, (2) timeliness of operations, and (3) focus on effective weed, pest and disease control. The results also raise the question whether a lack of adapted germplasm remains one of the principal constraints to exploiting the potential yield in the high rainfall zone.

Table 1 Summary of grain yields of wheat and canola measured under experimental conditions by the authors in the high rainfall zone of four states. GSR = growing season (April-November) rainfall.

State	N	Yield (t/ha)		Sowing date		GSR (mm)	
		Mean	Range	Mean	Range	Mean	Range
				Wheat			
NSW	18	6.1	0.1 - 8.7	12th April	11 Mar - 24 May	398	239 - 883
VIC	46	4.8	2.4 - 7.3	24th May	5 May - 6 July	434	216 - 584
SA	14	6.3	2.3 - 9.3	2nd June	16 May - 25 June	514	276 - 659
WA	8	4.8	3.4 - 5.9	20th May	9 May - 30 May	400	292 - 526
				Canola			
NSW	25	3.5	0.3 - 5.7	13th April	11 Mar - 24 May	360	162 - 572
VIC	18	2.0	0.7 - 3.0	25th May	2 May - 3 July	457	216 - 622
SA	13	2.8	2.1 - 3.8	2nd June	14 May - 9 Jul	415	254 - 544
WA	8	3.0	2.5 – 4.0	18th May	9 May - 25 May	433	250 - 504

There is similar consistency for canola yields achieved by above-average farmers in the HRZ across consultant estimates (Figure 1) and experimental yields (Table 1) with ca. 2.5 t/ha to be expected in a decile 5 year, declining to 1 t/ha in a decile 2 and up to 3.5 t/ha in a decile 8. However simulated estimates (Lilley et al. 2014) of long-term potential yield were 3.5-4 t/ha, noticeably higher than consultant estimates for a decile 5 year. It is therefore possible that even above-average farmers are not yet achieving the water-limited yield potential in above-average seasonal conditions, perhaps due to disease, inadequate nitrogen application or waterlogging. In our dataset of experimental yields we recorded numerous examples of canola yields of >4 t/ha in NSW, as did Christy et al. (2013).

The notable exception to the national trend described above was the lower estimates of water-limited yield potential for WA. Whereas in Victoria, NSW and South Australia the long-term yield potential for wheat and canola was 5-6 and 2-3 t/ha, the equivalent values for WA nominated by consultants were 3 and 1.5 t/ha. These estimates were some way below those recorded in experimental plots (5 t/ha for wheat and 3 t/ha for canola, Table 1) and simulations (4.5 t/ha for spring wheat and 3.5 t/ha for spring canola, Lilley et al. 2014), and it is possible that the consultant estimates were biased in some way, perhaps by drier recent seasons, whereas the long-term simulations and experimental yields spanned a longer climate record.

Yield gap

The results of the consultant survey and comparisons with experimental yields indicate the existence of a sizable yield gap between above average farmers and below-average farmers. In high rainfall seasons, the scope for improvement was 1-3 t/ha for wheat and 0.5-1.5 t/ha for canola, the difference between the below and above-average farmers. The yield gap was smaller in poor seasons (i.e. decile 2) when seasonal factors are the limiting factor to production rather than agronomic management.

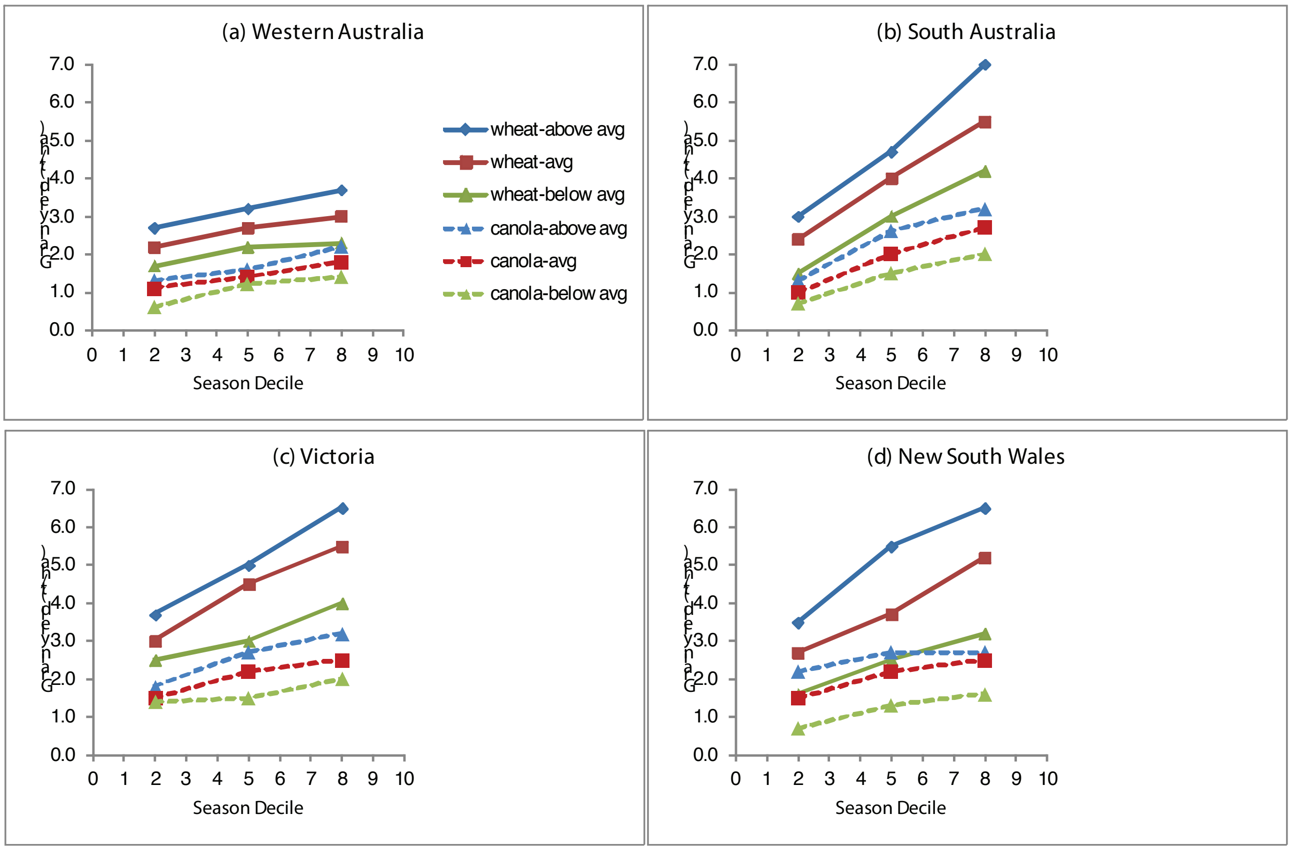

Figure 1: Consultant estimates of grain yields produced of wheat and canola for below-average, average and above-average performing farmers as a function of season decile. Data are averages collected from consultants in (a) Western Australia (n=4), (b) South Australia (n=3), (c) Victoria (n=4), (d) New South Wales (n=4)

Consultants had consistent views on the reasons for poor performance by the bottom one-third of grain producers in the HRZ. A key theme across consultants in all four states was that poor timeliness of key operations was a major factor in the poor performance of below-average farmers. Improved timeliness of these key operations (nominated as sowing, weed and disease control, and N-topdressing) could reduce some of the yield gap we have quantified here. The consultants also highlighted that above average farmers tend to be more are organised and efficient, achieve more effective weed control, are more willing to invest financially on inputs, and keep or have access to well maintained machinery for sowing and harvesting. In all regions, consultants saw the scope for large gains in yield and productivity by encouraging the below-average cropping farmers to adopt these practices and behaviours of the better farmers. Reasons for the differences in behaviour must take account of the whole-farm socio-managerial context. For example, lack of timeliness from a crop production perspective may be a consequence of compromises that have to be made on a mixed farm around pasture and livestock management. A greater understanding of this may help identify ways to maximise farm production and profitability, and not that of grain alone. The issue of greater timeliness is particularly pertinent when considering the opportunities for early sowing shown in Bell et al. (2014) and Lilley et al. (2014). They showed that in at least 50-60% of years there exists an opportunity to sow between mid-April and mid-May, and in at least 30-40% of years there is an opportunity between 1 March and 15 April. In moving the average date of sowing earlier, potentially with longer-season cultivars, will require higher levels of inputs to exploit the greater water-limited potential (Kirkegaard and Hunt 2010).

A smaller number of consultants were also of the opinion that recent advent of widespread grain production in the high rainfall zone means that the skill and knowledge base within the HRZ is smaller than that found in more established grain production regions. There was also a view that a lack of up-to-date infrastructure and services is constraining the industry's ability to adopt new technology. The high rainfall zone is characterised by smaller farms, often with smaller paddocks and in undulating terrain, and may be a factor in constraining the adoption of some technologies such as controlled traffic and variable rate technology that require larger-scale areas to make them profitable. However there have been no definitive studies to identify the role that infrastructure and farm configuration/size play in improving production and productivity on grain producing farms.

Conclusions

The results of this review and analysis suggest a number of opportunities for R, D and E in the high rainfall zone to lift crop yields. Firstly, given the sizable gap between the performance of above- and below-average farmers, there is a case for development and extension to identify causes of lower yield by poor-performing farmers, the socio-managerial context for poor timeliness by HRZ crop producers, and on-farm demonstrations to show the benefits of improved agronomy. Secondly, the promising yields from winter types of wheat and canola suggests that research is warranted to better understand the yield potential possible with new combinations of genotype, and environment and the management inputs required to express yield potential, particularly nitrogen. Thirdly, crop yields in the HRZ of WA do not respond as well as those in other states to water supply in wet seasons, hence research and development is required to identify the reasons for these differences. Finally, the HRZ is clearly still a landscape in transition. Future decisions about R, D and E will be better informed if trends in farm-level production, management practices and attitudes are monitored as the transition toward increased grain cropping continues in the HRZ.

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