Crop production potential and constraints in the high rainfall zone of southwestern Australia: Yield and yield components

Heping Zhang, Neil C. Turner and Michael L. Poole

CSIRO Plant Industry, Private Bag 5, Wembley, WA 6913. Email heping.zhang@csiro.au

Abstract

An experiment was carried out from 2001-2003 at Kojonup in the high rainfall zone (HRZ) of southwestern Australia to examine crop yield potentials and constraints to achieving these potentials. Subsurface waterlogging early in the growing season reduced ear number which was identified as a major constraint to crop production. Ear numbers were found to be the major contributor to yield differences and therefore it is important to maintain higher ear numbers for high yields in the HRZ**.**

Media summary

Transient subsurface waterlogging is a major constraint to crop production in the HRZ. Ear number is the main factor contributing to differences in grain yield of wheat and at least 500 ears/m^2 are required to achieve yields greater than 5 t/ha**.**

Keywords

Wheat, canola, barley, subsurface waterlogging, high rainfall zone

Introduction

Crop production in the high rainfall (annual rainfall 450−750 mm) zone (HRZ) of southwestern Australia is increasing as farmers respond to the prolonged poor wool prices during the 1990s. Higher rainfall and the longer growing season in the HRZ compared to the traditional wheatbelt result in a much higher yield potential for major crops, with potential yields ranging from 5-6 t/ha for wheat and 3-4 t/ha for canola. However, current crop yields are only about 50% of the potential for both wheat and canola. As expansion of annual cropping into the HRZ in southern Australia continues, there is a need to understand crop growth, water use and the influence of expansion of cropping on the water balance. The main aims of this study were, firstly, to examine the grain yield of cereals and canola in the HRZ of southwestern Australia, to determine if the potential yield of crops can be achieved, and if not, to identify the constraints limiting yield; and secondly, to identify the crop characteristics required for high yield and appropriate yield targets in the HRZ.

Methods

An experiment was conducted 30 km southwest (33^{o}55$^{'}$S, 116^{o}54$^{'}$E) of Kojonup in Western Australia. The site has a mean annual rainfall of 540 mm and the soil is a red sandy duplex soil with approximately 40 cm of gritty loamy sand (<10% clay) overlying a red clay (>40% clay). Prior to the commencement of the experiment, the site had been in annual, predominately subterranean clover pasture for 8 years.

A three-year crop rotation of cereals after canola and canola after cereals was used in the experiment from 2001 to 2003. A randomized completed block design was used with four replicates. Spring wheat (*Triticum aestivum* L. cv Wyalkatchem), barley (*Hordeum vulgare* L. cv Gairdner), canola (*Brassica napus* L. cv Pinnacle), and the long-season wheat (*Triticum aestivum* L. cv Tennant) were sown on 25 May 2001, 9 May 2002, and 14 May 2003 using a cone seeder at a rate of 5 kg/ha for canola, 65 kg/ha for wheat and barley in 2001 and 2002 and specified rates (65, 90, 120 kg/ha) in 2003. All crops were supplied with 100 kg N/ha and 27 kg P/ha each year and with 50 kg K/ha in 2001.

Rainfall was measured using a tipping-bucket raingauge connected to a datalogger at the site. The height of the perched water table was recorded using a Dataflow single channel down-hole datalogger installed in dip wells.

At maturity, 4 quadrat samples (total 2.16 m^2) were cut at the soil surface, dried in a forced-draught oven at 70^{o}C and weighed. Sixty wheat heads were randomly chosen from each sample to count the number of grains per ear and the kernel weight. In the cereals, the number of ears per unit area was counted using four samples of two adjacent 1-m rows in the field before harvesting and in canola the number of pods per plant was counted using 10 randomly-chosen plants in the field.

Results

Growing-season rainfall (sowing to harvest) was 377 mm in 2001, 424 mm in 2002 and 449 mm in 2003, compared with an average of 419 mm. No perched water table was observed in 2001 due to low rainfall. In 2002, well-above-average rainfall in April and close-to-average rainfall thereafter caused a perched water table above 30 cm for a period of 10 days in mid July when cereals were at tillering and canola was at the rosette stage (Figure 1). A perched water table was also observed for a short period when rainfall exceeded 100 mm in August 2003 when the cereals were at stem elongation.

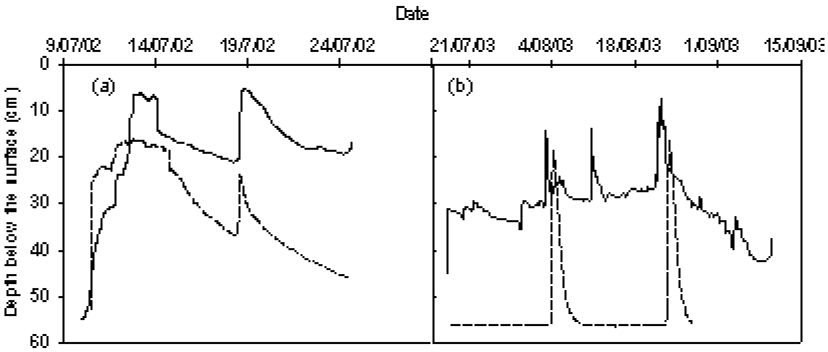

Figure 1. The perched subsurface water table observed at lower (solid line) and upper (dashed line) part of the site in (a) 2002 and (b) 2003.

The yield of spring wheat in 2001 and 2003 approached the potential yields estimated using the French and Schultz (1984) equation after taking into account drainage beyond the root zone (Figure 2). The yield of wheat in 2002 was significantly lower than those in 2001 and 2003 and 20% lower than the estimated potential. Canola yielded close to the potential in 2001 and 2002, but significantly lower than the potential in 2003 due to an infection of blackleg (*Leptosphaeria maculans* L.) disease.

Spring wheat reached anthesis first, followed by barley. The long season wheat flowered more than 30 days later than the spring wheat and exposed the plants to water stress during grain filling. Barley had the highest grain yield in both 2001 and 2003. The yield of barley was about 10 to 12% higher than the yield of spring wheat (Figure 3). The higher yield of barley was achieved through a higher HI not a higher biomass. The long-season wheat yielded least in 2001 due to delayed anthesis, lower ears/m^2 and fewer grains/ear.

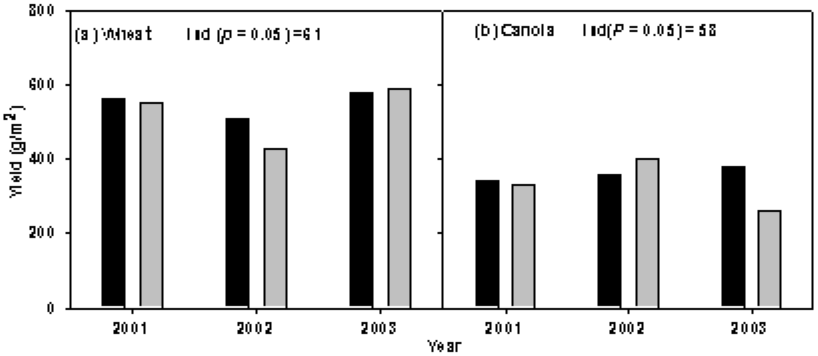

Figure 2. Potential (dark bar) and actual (grey bar) yields of (a) wheat and (b) canola at Kojonup from 2001 to 2003.

Increasing the seeding rate had little effect on the yield of wheat in 2003 when subsurface waterlogging occurred after stem elongation. Subsurface waterlogging after stem elongation had no effect on ear numbers (Table 1). The ear number/m^2 increased but grains/ear decreased with increasing seeding rate. The contribution of the increased ear numbers to the yield compensated for the loss from the reduced grains/ear.

Using the data from this study and the data collected at another location near Kojonup by Condon and Giunta (2003), Figure 4 shows that the number of ears was the main factor contributing to differences in grain yield, followed by grains/ear. The number of ears explained about 73% of yield variation and grains/ear about 29%. There was no clear relationship between yields and grain weight because grain weight was partly compensated by fewer grains/ear.

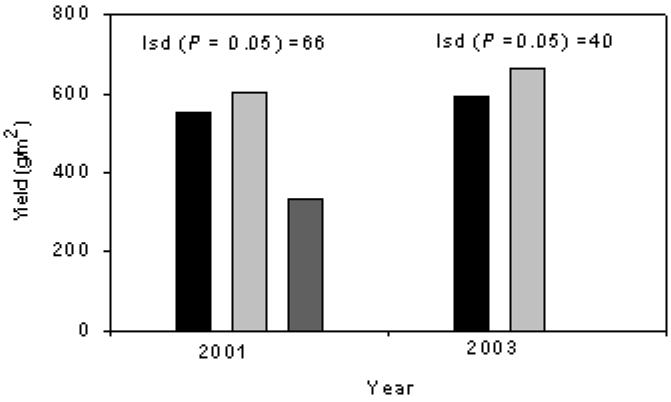

Figure 3. Yield of spring wheat (black bar), barley (light grey bar) and long-season wheat (dark grey bar) at Kojonup in 2001 and 2003

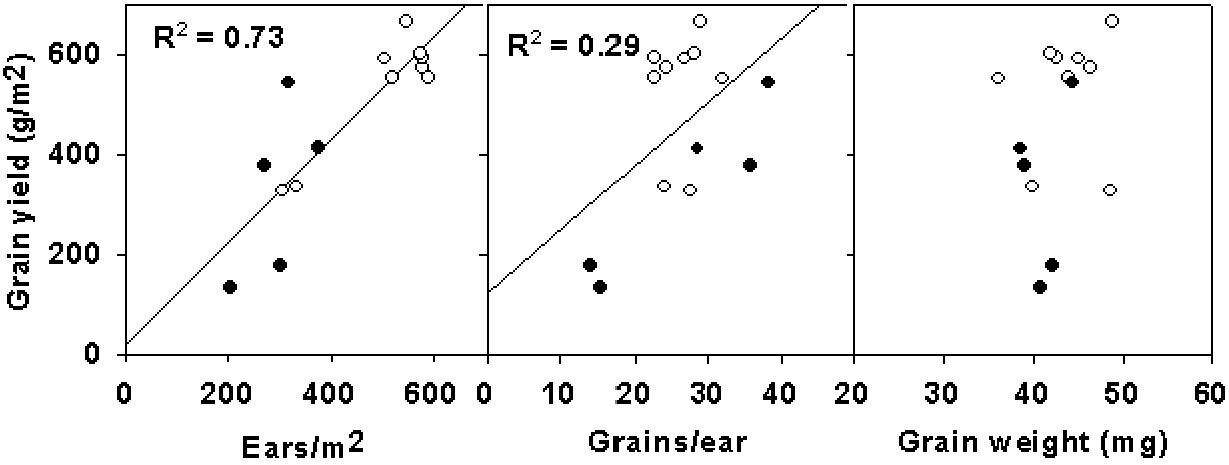

Figure 4. Components of yield expressed in relation to yields of wheat and barley based on the data from this study (•) and other data by Condon and Giunta (2003) (˜) in the HRZ.

Discussion

This study examined the yield potential of wheat, barley and canola in the HRZ of southwestern Australia and aimed to identify the constraints limiting yields. Comparison of the yield of wheat in 2002 with 2001 and 2003 suggests that the transient perched water table or subsurface waterlogging early in the growing season was a major constraint in the HRZ through reducing ears/m^2 (Zhang *et al.* 2004). However, the timing of waterlogging on the yield of wheat was complicated. Subsurface waterlogging after stem elongation did not affect ears/m^2 and therefore had no effect on yield. This study demonstrated that ear numbers accounted for two thirds of yield differences in cereals (Figure 4), indicating that ear number is the major contributor to yield in the HRZ. The data in Figure 4 suggest that at least 500 ears/m^2 are required to reach a yield of 5 t/ha in wheat**.**

Table 1. Effect of seeding rate on total biomass, machine-harvested grain yield, harvest index (HI) and yield components of the spring wheat Wyalkatchem in 2003.

Seeding rate	Plant/m^2	Yield (g/m^2)	Biomass (g/m^2)	HI	Ears/m^2	Grains/ear	Grain weight (mg)
65	132	591	1650	0.36	504	26.6	45.1
90	174	586	1600	0.37	578	24.2	46.4
120	194	566	1530	0.36	593	22.5	44.0
l.s.d. (*P* = 0.05)	-	n.s.	n.s.	n.s.	45	3.1	n.s.

The grain yield of barley was 10% higher than that of wheat in 2001 and 2003 and this was due to higher HI (15-18%) not higher biomass. Although it flowered about 5−7 days later than wheat, barley matured about 7 days earlier than wheat. This indicates that barley has a higher rate of assimilation or is much more efficient in its transfer of assimilates to grains than wheat. The HI (0.34−0.38) of wheat was low compared with the HI values (0.5−0.53) achieved in temperate environments such as the United Kingdom (Foulkes *et al.* 2002), but was comparable to those (0.34−0.38) from the conventional wheatbelt of WA (Siddique *et al.* 1989). Considering the higher rainfall and longer growing season in the HRZ these HI values were low. This indicates that considerable gains in yields could be made if HI was improved in the HRZ. Flowering date, stem-soluble carbohydrate reserves, post-anthesis green area duration and water uptake after anthesis can affect HI. Future work is needed to examine how these factors affect HI of wheat and can provide useful information for breeding suitable cultivars for the HRZ.

References

Condon AG, Giunta F (2003) Yield response of restricted-tillering wheat to transient waterlogging on duplex soils. *Australian Journal of Agricultural Research* **54**, 957 - 967.

Foulkes MJ, Scott RK, Sylvester-Bradley R (2002) The ability of wheat cultivars to withstand drought in UK conditions: formation of grain yield. *Journal of Agricultural Science, Cambridge* **138**, 153-169.

French RJ, Schultz JE (1984) Water use efficiency of wheat in a Mediterranean-type environment. I. The relation between yield, water use and climate. *Australian Journal of Agricultural Research* **35**, 743-764.

Siddique KHM, Belford RK, Perry MW, Tennant D (1989) Growth, development and light interception of old and modern wheat cultivars in a Mediterranean-type environment. *Australian Journal of Agricultural Research* **40**, 473-487.

Zhang H, Turner NC, Poole ML (2004) Yield of wheat and canola in the high rainfall zone of south-western Australia in years with and without a transient perched water table. *Australian Journal of Agricultural Research* **55**, 461-470.