Crop characteristics for high yield of wheat in the high rainfall zone of Western Australia

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Abstract

This study examined the accumulation of dry matter, dry matter partitioning, yield and yield components of six cultivars and breeding lines at Kojonup in the high rainfall zone (HRZ) of Western Australia (WA) and aimed to identify crop characteristics for high yield. Dry matter accumulation followed potential accumulation from sowing to up to 4 weeks after flowering for the early sown crops and from sowing to flowering for wheat sown at the normal time, and then fell below the potential afterwards. Grain yield was positively related to the number of grains per unit area.. Higher yield can come either from increasing ears/m2 or from more grains/ear. While the current management practices achieve wheat crops with 500 ears/m^2, it is suggested that breeding and further management to achieve a greater number of grains/ear is a possible way to lift yields further in the HRZ of WA.

Introduction

The wheat cultivars grown in the HRZ of WA are bred for the low and medium rainfall areas of the wheatbelt. When grown in the HRZ, where longer-season growing conditions and more water is available, they may have limitations to achieving high yields. The aims of this paper are 1) to evaluate the performance of wheat cultivars with a range of phenologies and yield potentials; and ii) to identify the crop characteristics for achieving high yields in the HRZ of WA.

Materials and methods

An experiment was conducted in 2005 on a farm 30 km southwest of Kojonup in WA. Four cultivars (Wyalkatchem, Calingiri, Chara, Wylah) and two breeding lines (HRZ2185, HRZ216) were selected to give a range of phenologies ear size and yield potential. The crop was sown at 2 times (30 April and 31 May 2005). The experiment was replicated 4 times with a randomised block design. Crop phenology was recorded based on the Zadoks scale. Light interception by crop canopy was measured using a ceptometer. Plant samples were collected at 2- to 4-week intervals using a quadrat of 0.54 m^2 from each plot over the growing season and the number of plants and tillers counted. Ten plants were randomly subsampled and separated into leaf lamina, stems plus leaf sheath, and spikes. All separated samples and the rest of the bulk sample were dried to constant weight in a forced-draught oven at 70^oC and weighed separately. At maturity, all plants in 3 quadrats (1.62 m^2) were harvested from each plot for determining the number of ears and grain yield. Ten plants from the harvested samples were randomly selected and separated into leaf, stem plus leaf sheath, and ears, then dried in a forced-draught oven as above, weighed and hand-threshed to determine grains/ear and kernel weight. The net change of dry matter of stems and leaf sheath between anthesis and maturity (ΔDM_{a-m}) was calculated to provide a measure of the apparent dry matter remobilisation from stem to grain.

Results and discussion

When sown on 30 April, Wyalkatchem, HRZ2185 and HRZ216 flowered on the 8, 15, and 17 September, respectively, while Calingiri and Chara flowered 15 days later than Wyalkatchem. Due to its vernalisation requirement, Wylah flowered 30 days later than Wyalkatchem. The frost experienced in 2005 during flowering significantly reduced the yield of the short season cultivars Wyalkatchem. This indicates that the medium to short season cultivars were not able to utilize the longer season created by an early break because they were subject to a high frost risk at flowering. When sown on 30 May, Wyalkatchem, HRZ2185 and HRZ216 flowered within 2-3 days around 17 October when the frost risk was much lower. Calingiri and Chara flowered on 20 October, while Wylah flowered on 27 October.

When sown on 30 April, dry matter accumulation of Calingiri followed the estimated potential dry matter accumulation, estimated from measured light interception and a radiation use efficiency of 2.4 g/MJ/day, up to 4 weeks after flowering and departed from below the estimated potential thereafter (Fig. 1). Similarly, HRZ216 sown on 30 May accumulated dry matter at the potential rate until flowering and then fell below the potential (Fig. 1).

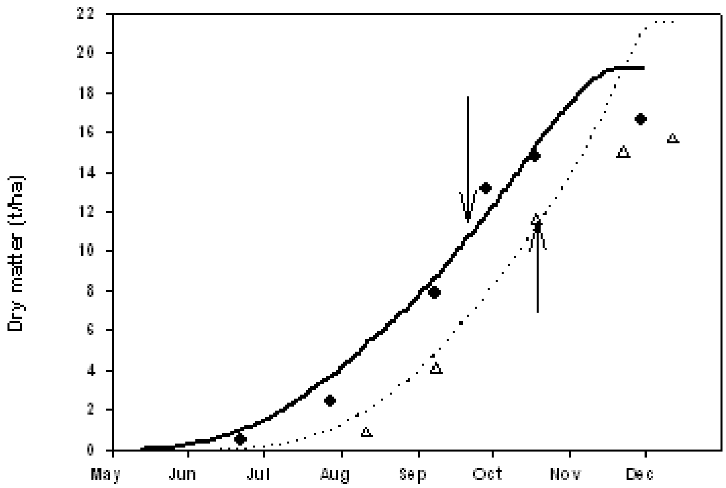

Figure 1. Actual and potential dry matter accumulation for Calingiri (˜, solid line) sown at 30 April 2005 and HRZ216 (∆, dotted line) sown at 30 May 2005. The potential dry matter accumulation was estimated from the measured light interception by canopy and radiation use efficiency of 2.4 g/MJ/day. Arrows indicate the date of flowering.

At maturity, no significant differences in total dry matter accumulation were observed among the 6 wheat cultivars except Chara (Table 1). For the first time of sowing, there was no decrease in dry matter of stems and leaf sheaths between anthesis and maturity except in Wylah (Table 1). For the second time of sowing, the apparent dry matter remobilisation from the stems and leaf sheaths was equivalent to 2.10 t/ha for HRZ216, negligible for Calingiri, and 1.3-1.5 t/ha for the other 4 cultivars. This suggests that post-anthesis photosynthesis could account for the final grain yield of the early sown crops and no remobilisation was required. The increase in $\Delta DM_{a\text{-}m}$ indicates that the sink capacity of the wheat was limited, probably because of an inherent low number of grains/ear or a reduced number of grains/ear arising from frost damage. We suggest that there appears to be potential to increase the remobilisation of stored carbohydrates to the grain by increasing sink size.

Table 1 Dry matter (DM) at maturity, net change in DM of stems plus leaf sheaths between anthesis and maturity ($\Delta DM_{a\text{-}m}$), yield and yield components of six wheat cultivars at two sowing dates.

Cultivar	DM (t/ha)	$\Delta DM_{a\text{-}m}$ (t/ha)	Yield (t/ha)	Ear/m^2	Grains/ ear	Kernel weight (mg)	HI
Sowing date: 30 April 2005							
HRZ2185	16.8	+2.37	4.7	295	36.7	43.5	0.28

HRZ216	15.6	+1.75	5.0	374	35.7	39.5	0.34
Calingiri	16.6	+0.08	5.6	352	44.6	39.5	0.32
Chara	19.3	+1.69	4.8	426	37.4	30.1	0.29
Wyalkatchem	15.1	+2.56	3.0	446	20.7	40.3	0.19
Wylah	16.2	-1.42	3.9	487	26.1	34.8	0.27
lsd (5%)	0.25		0.65	55	6.5	4.8	0.04
Sowing date: 31 May 2005							
HRZ2185	17.2	-1.48	5.7	390	43.2	39.4	0.34
HRZ216	15.6	-2.10	5.7	473	35.8	36.6	0.35
Calingiri	15.3	-0.04	4.8	420	26.3	41.1	0.28
Chara	15.1	-1.44	5.1	524	24.8	34.9	0.28
Wyalkatchem	15.5	-1.49	3.8	531	19.7	41.3	0.24
Wylah	14.5	-1.32	3.4	527	20.7	35.0	0.24
lsd (5%)	n.s.		0.76	38	8.7	5.1	0.07

When sown early, Calingiri produced significantly higher yield than Wyalkatchem, HRZ2185 and HRZ216, whereas at the second sowing date, HRZ2185 and HRZ216 yielded significantly more than the other 4 cultivars. When sown early, the long-season wheat Wylah flowered at the same time as the Wyalkatchem and HRZ216 that had been sown a month later, but it yielded significantly lower than HRZ216, and when sown early it produced the lowest yield. Not surprisingly, the grain yield at maturity was significantly correlated to the number of grains/m^2 (Figure 2).

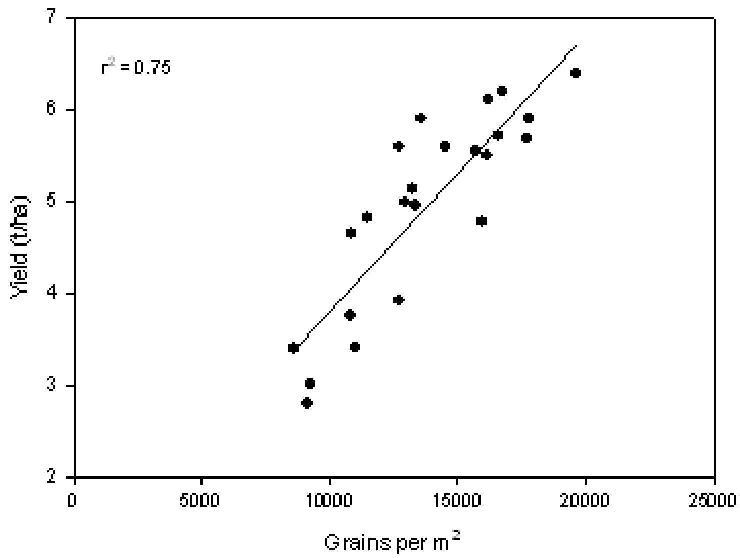

Figure 2. Relationship between grain yield and the number of grains per m^2 from the 2005 experiment in Kojonup.

With the current management practices, growers can achieve 450-500 ears/m^2 and 10 t/ha dry matter at anthesis, both of which are the targets for a 5-6 t/ha yield in the HRZ of WA (Zhang *et al.* 2006). These are also similar to the dry matter accumulation at anthesis and the number of ear/m^2 achieved in the cool environments of the UK (Foulkes *et al.* 2002) and New Zealand (Stephen *et al.* 2005). However, all the cultivars in this study had much fewer grains/unit area compared to those in the UK and New Zealand. It is suggested that the number of grains/ear possibly is a major limitation to sink capacity, A conclusion also drawn from the lack of decrease in stem and leaf sheath dry matter between anthesis and maturity in the early-sown wheat.

Conclusion

The initial results from this experiment suggest that the cultivars that have an intermediate flowering time can not take advantage of long season in the HRZ of WA, especially when the break of the season is early. We hypothesize that a lacking of dry matter remobilisation from stems and leaf sheaths in the early sown crops indicates a limited sink capacity in the cultivars used in the experiment, particularly those affected by frost. By comparing yield and yield components achieved in the HRZ of WA with the UK and New Zealand, it is suggested that selection and management to achieve more grains/ear be a possible way to lift yields further in the HRZ of southern Australia.

Acknowledgement

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