Early maturity improves grain yield and water use efficiency of wheat in low rainfall regions of Western Australia

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Summary. Wheat cultivars appropriate for late sowings in low rainfall short season environments are currently unavailable to farmers in the eastern and north-eastern wheatbelt of Western Australia. In 1991 and 1992. field experiments were conducted in low rainfall regions of the Western Australian wheatbelt to study phenology, water use and grain yield components of some early maturing genotypes. Early maturing genotypes had faster developmental rates and reached anthesis up to 12 days quicker than some of the standard cultivars without any reduction in biological yield, harvest index and grain yield. The pattern of water use also changed for these genotypes with more water used in the post-anthesis period. which resulted in greater water use efficiency.

Introduction

Analysis of historical rainfall records shows that the break of the season occurs after I June in about 25% of years in the low rainfall (< 325 mm) eastern and north-eastern wheatbelt of Western Australia (I). Wheat seeding may be even later because earliest planting opportunities in each year are often used to plant grain legumes. Yields in these seasons are likely to be low as the high yielding package of early sowing, longer season cultivar and greater fertiliser input, that has been successful where the season breaks early (2), does not apply.

At present. cultivars flowering earlier than those currently grown commercially are not available to farmers in the low rainfall parts of the Western Australian wheatbelt. Demonstration that very early maturing genotypes can out-perform current cultivars would open new opportunities for breeding programs to select high stable yielding cultivars for these environments. The experiments reported here are part of a project to investigate whether improved water use efficiency and greater and more stable wheat yields can be achieved with wheat genotypes that reach anthesis earlier than currently available cultivars in low rainfall, short season environments.

Materials and methods

Field experiments were conducted at Merredin in 1991. and Merredin, Morawa and Mullewa in 1992 in the eastern and north-eastern wheatbelt of Western Australia. Sowing dates and growing season rainfall for each experiment are presented in Table I. At Merredin in 1991 two standard cultivars and five early maturing genotypes were sown in a randomised block design with three replicates. In 1992. the experiments at Mcrredin, Morawa and Mullewa included five standard cultivars and six early maturing genotypes sown in a randomised block design with five replicates. Plot size was 2.16 m (12 rows), wide by 40 m except Morawa. which was 1.42 m (8 rows) wide by 20 m.

The early maturing genotypes used in this study included F, derived lines grown in the F_5 generation in 1991 and F_6 in 1992 from the WADA wheat breeding program (W87-022-511, W87-072-523. W87-1 14549 and W87-410-509). TFQ-I 13 is an introduced line from eastern Australia which is very early and the other lines (113-2 and BD9-I B) were obtained from Dr R. Richards, CSIRO, Canberra. Kulin. Gamenya, Halberd, Spear and Wilgoyne were selected as standard cultivars.

Table I. Site. year, sowing date and growing season rainfall for field experiments at Merredin. Morawa and Mullewa

Site	Year	Sowing date	Rainfall[a] (mm)
Merredin	1991	7 June	148
Merredin	1992	15 June	257
Morawa	1992	19 June	222
Mullewa	1992	23 June	192

[a] Rainfall from sowing to October 30th.

Anthesis dates for each genotype were determined in days after sowing (DAS) and thermal time or degree days (3). Grain yields were determined from I m^2 quadrat samples harvested at ground level at maturity. Soil water measurements at Merredin in 1991 were monitored at fortnightly intervals from sowing until maturity using a neutron moisture meter.

Results and discussion

In this study. the time from sowing to anthesis varied from 71 to 123 DAS across sites and years and some genotypes (TFQ-1I3 and W87-022-51 I) reached anthesis up to 11 and 12 days earlier than Kulin (Table 2). One of the potential problems with rapid development is that it may reduce the amount of biomass produced at anthesis, and hence, potential yield (4). Although we observed lower anthesis biomass in some of the earlier genotypes by maturity, biological yields were comparable to standard cultivars (results not presented here).

Table 2. Time to anthesis in days after sowing and mean thermal time (?C.day) for wheat genotypes at Merredin (ME), Morawa (MO) and Mullewa (MU) in 1991 and 1992

Genotype	Days after sowing				Mean thermal time
	1991	1992			
	ME	ME	MO	MU	
TFQ-113	88	-	-	-	1051
W87-022-511	91	99	76	71	1070
W87-114-549	93	103	80	75	1114
W87-072-523	94	104	83	76	1132
W87-410-509	97	105	87	79	1170
IB-2	-	108	87	79	1182
BD9-1B	-	109	87	81	1197
Wilgoyne	-	109	87	81	1197
Kulin	99	111	88	83	1219
Gamenya	106	116	97	90	1274
Halberd	-	121	102	98	1385
Spear	-	123	102	104	1426

The mean grain yield was greatest at Merredin in 1992 (Table 3). There was a trend, although this was generally not significant (P=0.05), for the earlier maturing genotypes to yield more and have a higher harvest index than the standard cultivars at all sites in 1991 and 1992. Poorer yield trends were evident at the Mullewa site due to herbicide damage. Herbicide applied when early maturing genotypes had extended flag leaves resulted in leaf bleaching and, consequently, may have reduced photosynthesis. Harvest index was fairly consistent for each genotype across sites, except Merredin in 1992. Despite having the highest yield at this site, the mean harvest index was only 0.28 compared to 0.37 (Merredin

1991), 0.36 (Morawa) and 0.38 (Mullewa). This was probably due to the large amount of biomass produced in the pre-anthesis period as a result of higher than average rainfall.

At Merredin in 1991. total water use was greater for Gamenya than the other genotypes (Table 4). Water use was greater with later maturing genotypes due to greater water e \ traction. except for Kulin (5). The ratio of pre- to post-anthesis water use was generally lower for genotypes reaching anthesis quicker. Grain yields and water use efficiency for grain production were highest in the range of genotypes flowering between 91 and 99 DAS. lowest for Gamenya and intermediate for TFQ 113 (88 DAS). Despite some of the genotypes reaching anthesis from five to twelve days before Kulin there were no yield penalties and water use efficiencies remained high.

Table 3. Grain yield (g/m^2) and harvest index for genotypes grown at Merredin (ME). Morawa (MO) and Mullewa (MU) in 1991 and 1992

Genotype	Grain yield				Harvest index			
	1991	1992			1991	1992		
	ME	ME	MO	MU	ME	ME	MO	MU
TFQ-113	193	-	-	-	0.35	-	-	-
W87-022-511	228	238	205	190	0.39	0.29	0.35	0.38
W87-114-549	236	226	222	180	0.39	0.26	0.38	0.39
W87-072-523	221	258	193	152	0.37	0.29	0.37	0.37
W87-410-509	242	227	242	204	0.40	0.29	0.41	0.42
IB-2	-	276	242	189	-	0.34	0.38	0.39
BD9-1B	-	237	227	130	-	0.34	0.42	0.42
Wilgoyne	-	246	225	187	-	0.27	0.35	0.37
Kulin	230	266	208	184	0.36	0.31	0.38	0.40
Gamenya	179	187	206	204	0.32	0.25	0.33	0.36
Halberd	-	188	202	207	-	0.22	0.31	0.35
Spear	-	183	204	181	-	0.20	0.32	0.34
Mean	218	230	215	183	0.37	0.28	0.35	0.38
l.s.d.(P = 0.05)	30.4	47.5	25.9	27.9	0.03	0.04	0.03	0.01

Table 4. Pre-anthcsis water use (E_{ta}), post-anthesis water use (E_{ta}), total water use (E_1). ratio of pre to post-anthcsis water use (E_{ta}/E_{tpa}) and water use efficiency for grain yield (WUE_{2r}) for genotypes at Merredin in 1991

Genotype	E_{ta} (mm)	E_{tpa} (mm)	E_T (mm)	E_{ta}/E_{tpa}	WUE_{gr} (kg/ha/mm)
TFQ-113	98	46	144	2.1	13.4
W87-022-511	113	31	143	3.7	15.9
W87-114-549	102	41	143	2.5	16.5
W87-072-523	110	45	155	2.4	14.2
W87-410-509	125	30	155	4.2	15.6
Kulin	114	30	144	3.8	15.9
Gamenya	137	27	164	5.1	10.9
Mean	114	36	150	3.4	14.6
l.s.d.(P=0.05)	16.8	12.0	17.2	-	-

Greater yields in early maturing genotypes are likely to be expressed more in years where rainfall diminishes rapidly in the post-anthesis period. Although in 1992 the rainfall received in October was low, all sites received more than double the average during August and September. This increased the amount of stored water available and the amount of assimilate reserves as a consequence of greater biomass production and may have reduced the penalty in yield expected for the later maturing genotypes. In 1991, Merredin received 12% less rainfall than the seasonal average with low rainfall in August and a dry finish. The amount and distribution of rainfall in this season is more consistent with the type expected to illustrate yield advantages of early maturing genotypes with late sowing.

The results from these initial experiments illustrate a potential for wheat with early maturity in low rainfall, short season environments. However, they are from a limited number of sites and years and the genotypes used were selected on maturity alone. Further research is currently underway to identify appropriate agronomic practices for these and other genotypes to establish their value for commercial crop production.

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