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Screening durum wheat for heat tolerance

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Abstract. In the Australian wheat belt, periods of moderate to extreme high temperatures at the end of the season frequently reduce grain yield and also impact on end-use quality. With global warming, extreme heat events are expected to become more frequent in the southern Australian wheat belt, making heat stress an increasing concern. Clearly, varieties with improved heat tolerance would be highly desirable. The extent of genetic variation for heat tolerance in Australian durum wheat germplasm is largely unknown and anecdotal evidence suggests that Australian durum wheat varieties may be uniformly heat susceptible. We obtained durum genotypes from various sources and plants were grown at an irrigated field site in NSW in 2011. A late-sown trial was used to expose plants to heat stress during flowering and seed set, and a second trial was sown at the normal time to provide a control. Both trials were flood irrigated to minimize water stress. Observed effects of heat on yield, single grain weight and quality will be presented and a list of potential heat tolerant lines suggested.

Keywords. Heat stress – Durum – Screening.

Sélection du blé dur pour la tolérance à la chaleur

Résumé. *Dans la ceinture de blé d'Australie, les périodes de températures modérées à extrêmement élevées à la fin de la saison réduisent souvent le rendement en grain et ont également un impact sur la qualité d'utilisation finale. Avec le réchauffement climatique, les vagues de chaleur extrêmes devraient être plus fréquentes dans la ceinture de blé de l'Australie du Sud, faisant du stress thermique une préoccupation croissante. De toute évidence, il serait très souhaitable d'obtenir des variétés plus tolérantes à la chaleur. La mesure de la variation génétique de la tolérance à la chaleur du matériel génétique de blé dur australien est largement inconnue et des preuves anecdotiques suggèrent que les variétés de blé dur australien peuvent être uniformément sensibles à la chaleur. Nous avons obtenu des génotypes de blé dur provenant de diverses sources et les plantes ont été cultivées sur un site irrigué dans le NSW en 2011. Dans un premier traitement, un semis tardif a été effectué pour exposer les plantes au stress thermique lors de la floraison et de la grenaison alors que pour un second traitement, utilisé comme témoin, le semis a été réalisé dans la période normale. Dans les deux traitements, on a utilisé l'irrigation par inondation pour minimiser le stress hydrique. Les effets de la chaleur sur le rendement, le poids d'un grain unique et la qualité seront illustrés et une liste de lignées potentiellement tolérantes à la chaleur sera présentée.*

Mots-clés. *Stress thermique – Blé dur – Sélection.*

I – Introduction

In Australian wheat growing environments, heat stress days (>30 °C) begin occurring at the flowering stage and become more frequent and severe during grain fill (Wardlaw and Wrigley, 1994). Yield losses due to heat stress have been estimated at 10 to 15% in Australia and the USA (Wardlaw and Wrigley, 1994) and can be attributed to reductions in both grain number and size. Heat stress can also impact quality traits that relate either to harvest value (e.g. increased % screenings) or processing (e.g. dough mixing characteristics). In this study, we surveyed the extent and variability of tolerance to the yield and quality effects of heat stress in a collection of tetraploid wheat (*Triticum turgidum* L. *subsp. durum*) lines, including landraces and Australian durum varieties and breeding lines. Two years of field trials were performed in central NSW, in which relative performance under late sown (heat stressed) vs. normal sown (control) conditions were used as a measure of heat tolerance.

II – Material and methods

1. Germplasm

Heat tolerance was assessed in 34 tetraploid genotypes, including 10 varieties, 17 breeding lines (BL codes) and 7 Ethiopian landraces (AUS accessions). Except for AtilC2000 and Kronos, all of the named varieties were Australian. The breeding lines were provided by Durum Breeding Australia. The same trials also included 252 hexaploid (*Triticum aestivum*) varieties and landraces but their performance will be described in detail elsewhere

2. Field trials

Field trials were conducted in Leeton in 2011 and in Wagga Wagga in 2012. At each location, duplicate trials were sown close to the optimal time (1^{st} and 8^{th} June, respectively) and late (1^{st} and 8^{th}August, respectively). Flood irrigation was applied to late- and normal-sown trials to minimize drought stress. Gypsum blocks were used to monitor soil moisture levels, and irrigation scheduled as needed. Genotypes had two (occasionally one) 7.5 m^2 replicate plots per trial, arranged randomly. Propiconazole (Throttle) was applied at a rate of 250-500 ml/ha as needed to control stripe rust infection. Weather data for the trial periods were obtained from the Bureau of Meteorology web site, for the weather stations located closest to the field sites (Yanco Agricultural Institute 074037 and Wagga Wagga AMO 072150).

3. Analysis of yield, physical grain and processing quality traits

Each plot was assessed for days to anthesis, grain yield and % screenings (2 mm sieve; corrected for visually assessed % of fragmented grains), and the overs fraction analysed for 1000-grain weight, hectolitre weight and grain number. Additional analyses were performed on the Leeton-2011 grain. These included % grain protein (using NIR; adjusted to 11% moisture basis), single kernel hardness index (SKHI; measured using SKCS 4100 device), % semolina milling yield (Buhler MLU202) and semolina yellowness (b*; Minolta chromameter). Semolina dough was also analysed in a 10g mixograph to determine time to peak resistance (mix time) and resistance breakdown (RBD; based on reduction in envelope width at 8 minutes vs. at peak resistance). A standard semolina sample (Jandaroi) was analysed at intervals to allow for temporal and operator effects. Gluten index was determined using a Glutomatic (Perten Instruments). Five genotypes had insufficient grain for milling from one or both sowing dates (either as single or pooled sample) and were therefore not analysed for semolina and mixograph traits.

III – Results and discussion

1. Flowering time and physical grain traits

Warmer conditions experienced by the late-sown plots accelerated development relative to the normal sown plots (Table 1), but the 60 day delay in sowing still set back anthesis date appreciably (relative to normal-sown plots), by an average of 26 and 18 days, at Leeton and Wagga Wagga, respectively. Consequently, more hot (>30 °C) days were experienced in the critical developmental period during the first 30 days of grain filling by the late sown plots vs. normal sown plots: 15.1 vs. 2.6 days at Leeton, and 7.7 vs. 3.9days at Wagga Wagga.

Late sown plots yielded less total grain than the normal sown plots, for all genotypes/trials. Per cent screenings was increased by the late sowing and reductions in single grain weight and number of grains/ha accounted for roughly equal proportions of the yield loss in the overs fraction. Hectolitre weight was also reduced.

Flowering times well correlated between the normal and late sowings(r=0.96 and 0.79 at Leeton and Wagga Wagga, respectively). Genotypes that took longer to flower tended to suffer greater losses with late sowing, for yield (Figure 1), and for the other physical grain traits (not shown), as these genotypes experienced more days of heat stress late in development. Hexaploid wheat genotypes of similar flowering times were less affected by late sowing (e.g., for yield, Figure 1), consistent with anecdotal reports that durum wheat in Australia is generally more heat sensitive than bread wheat.

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Genotypes that were least affected by late sowing were regarded as potentially possessing heat tolerance. After accounting for the effects of flowering time, elite tetraploids that showed the most consistent tolerance to the effects of heat on yield across the two trials were Jandaroi, Saintly and BL15,while the lines with best tolerance to grain size related effects were Jandaroi, Caparoi, BL3 andBL5.These and the best performing exotic lines could be used in genetic analysis to identify chromosome regions controlling heat tolerance, with the ultimate aim of providing molecular markers for heat tolerance to breeders.

Table 1. Traits measured in tetraploid accessions in the heat tolerance trials. t-test probability refers to the comparison of means for June vs. August sowing at each location.

	Leeton 2011				Wagga Wagga 2012			
Trait	**June sown**	**Aug sown**	**Aug/ June**	**t-test prob.**	**June sown**	**Aug sown**	**Aug/ June**	**t-test prob.**
Days to anthesis.	114	80	0.70	<0.001	122	80	0.66	<0.001
Grain yield (t/ha)	6.57	3.95	0.60	<0.001	4.84	3.14	0.65	<0.001
1000-g wt. (g)	48.2	36.7	0.76	<0.001	45.1	37.2	0.82	<0.001
% screenings	0.55	4.73	8.60	<0.001	0.67	1.85	2.76	<0.01
Grain no./ha ($\times 10^6$)	135	103	0.76	<0.001	107	83	0.78	<0.001
Hectolitre wt. (kg)	80.6	76.1	0.94	<0.001	81.2	76.6	0.94	<0.001
% grain protein	12.7	14.6	1.15	<0.001	-	-	-	-
SKHI	84.0	89.2	1.06	<0.001	-	-	-	-
% milling yield	70.9	70.2	0.99	<0.001	-	-	-	-
b*	23.6	26.1	1.11	n.s.	-	-	-	-
Mix time (min)	3.88	3.60	0.93	n.s.	-	-	-	-
RBD	56.4	45.3	0.80	n.s.	-	-	-	-
Gluten index (%)	72.7	72.9	1.00	n.s.	-	-	-	-

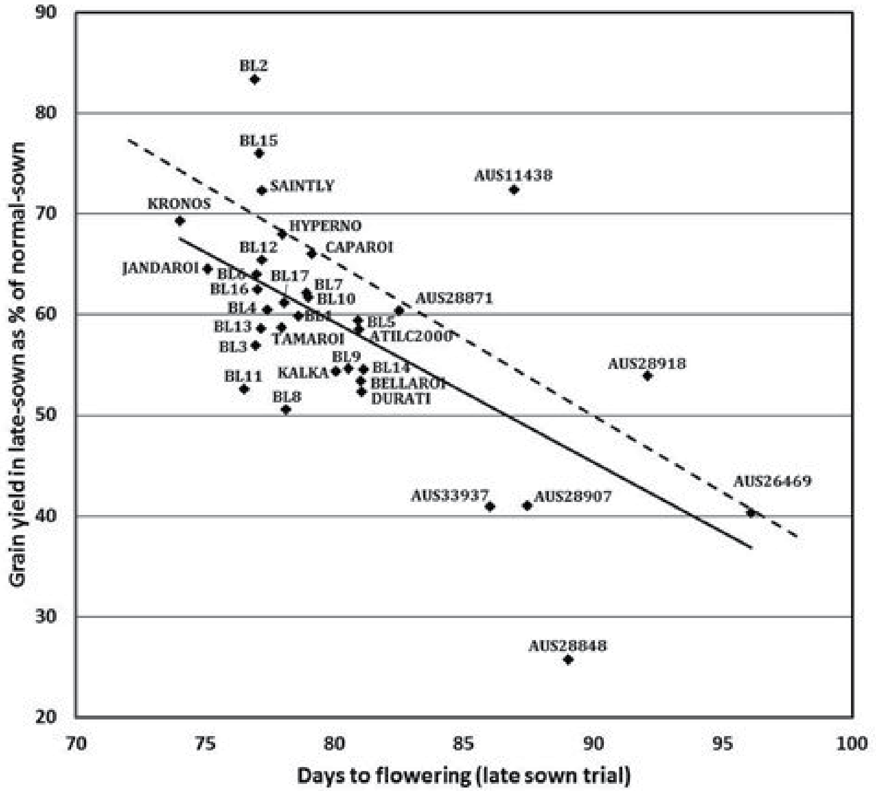

Figure 1. Relative grain yield under heat stress versus flowering time (Leeton 2011). The solid line shows the linear regression for the tetraploid accessions, and the dotted line shows the linear regression for the hexaploids (for which data points are not shown).

2. Processing quality traits

Late sowing reduced semolina milling yields, probably due to a reduced endosperm: germ ratio expected in the smaller grains (Table 1). The heat-affected grains contained elevated concentrations of protein. This is a typically observed effect of heat stress (e.g., Blumenthal *et al*. 1995) and presumably derives from a reduction in starch quantities caused by the particular heat-sensitivity of the starch biosynthetic machinery in the developing wheat grain (Zahedi *et al*. 2003). Grain from late sown plots also had harder grain (higher SKHI) which may relate to the elevated protein concentration, since interactions between starch granules and the protein matrix is regarded as a determinant of hardness (Pauly *et a*l. 2013). Heat stress did not significantly alter yellowness (b*).

On average, late sowing did not significantly alter mix time or resistance breakdown (Table 1). These mixograph traits are indicators of processing quality and can be responsive to heat. They are correlated with the proportion of glutenin that is highly polymerized, but their behaviour is largely independent of the concentration of protein *per se* (Blumenthal *et al*. 1995). Gluten index, another indicator of glutenin polymerization, was also not significantly affected (Table 1). The presence and direction of heat effects on dough physical and biochemical characteristics can depend on the timing and severity of heat stress as well as the wheat genotype (Blumenthal *et* *al.* 1995; Corbellini *et al.* 1998; Stone and Nicolas 1996). The absence of a sowing time effect on dough traits could therefore be due to insufficient levels of heat stress (timing and number of days over 30 °C) and/or the presence of a high proportion of genotypes that were resistant to the quality effects of heat stress.

Ongoing quality testing of grain from these trials, including pasta making and biochemical analyses, may shed further light on the effects of heat stress on quality in durum wheat, including its biochemical basis.

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