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The influence of development on early growth in wheat

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Abstract

Genotype has a large influence on the development pattern of wheat, largely due to the response to vernalisation and photoperiod. There is a general belief that development and growth are uncoupled, however there are some reports that early maturing crops grow faster than late maturing crops. A field experiment was conducted in 2011 at Wagga Wagga, southern New South Wales to explore differences in dry matter production of 12 wheat genotypes with known vernalisation and photoperiod genes. Results indicate an association between developmental rate and biomass accumulation, showing later flowering genotypes grew slowly, whilst earlier flowering genotypes showed significant variation in biomass production. Further analysis of the data using genetic characterisation for *Vrn-A1, Vrn-B1, Vrn-D1* and *Ppd-D1* suggest a possible interaction between this developmental rate-biomass association and vernalisation responsiveness

Introduction

It is important to distinguish between development and growth of plants. Phasic development can be defined as a sequence of phenological events controlled by environmental conditions, which determine changes in plant morphology and/or function of some organs; whilst growth refers to the accumulation of crop biomass (Miralles and Slafer, 1999; Hay and Porter, 2006). Optimum phasic development ultimately determines the 'fit' of a particular cultivar in a particular growing environment (Snape *et al*. 2001). In southern NSW, the optimum wheat flowering window is bounded by early frost damage and late water deficit and heat stress (Gomez-Macpherson and Richards, 1995). The role of vernalisation (and photoperiod) genes in influencing the developmental rate of wheat is a well researched, though evolving (e.g. Pugsley, 1983; Eagles *et al.* 2009; Trevaskis *et al.* 2010; Eagles *et al.,* 2011). The development of diagnostic markers have enabled the classification of alleles associated with *Vrn-A1, Vrn-B1, Vrn-D1* and *Ppd-D1* genes, with new markers for additional genes continually being updated. A spring genotype is characterised by the presence of at least one dominant *Vrn* allele, whilst a winter genotype requires recessive *Vrn* alleles at all *Vrn* loci in wheat (Pugsley, 1983). From a physiological perspective, a winter cultivar requires a period of exposure to low temperatures to satisfy the vernalisation requirement, to make the transition from vegetative to reproductive development. In contrast, a spring cultivar has no such requirement and will grow and develop in response to increasing temperature and day length.

The objective of this study was to confirm an association between development and biomass production shown in studies by Davidson *et al.* (1990) and Gomez-Macpherson and Richards (1995). A second objective was to provide additional information to further understand the above association, and the developmental interaction with responsiveness to vernalisation.

Methods

A field experiment located at Wagga Wagga, NSW (35.05°S, 147.35°E, 520 mm AAR) was conducted. Ten doubled haploid (DH) lines derived from the cross between cv. Janz and cv.

Diamondbird (NSW DPI, Wagga Wagga) were used. The parental lines were also included in the field experiments. The selected genotypes showed allelic variance for *Vrn-A1*, *Vrn-B1*, *Vrn-D1* and *Ppd-D1* (Table 1). The experiment used three times of sowing (12th July; 15th August, 26th September), though only results from the July and August sowings are presented. The plots were observed to obtain time of anthesis (Growth Stage (GS)61) for each genotype, defined as when visible anthers were apparent in 50% of the plot area, and biomass was measured by destructive dry matter samplings of each genotype. Dry matter samplings for the July sowing time were targeted at specific growth stages (GS12, GS14/21 and GS16/30). At each sampling time, thermal units (ºCdays, above a base temperature of 0ºC) were recorded (258ºCdays, 399ºCdays, 520ºCdays respectively), with the subsequent sowing times being assessed based on thermal units rather than growth stage.

Table 1. Experimental genotypes classified for *Vrn-A1*, *Vrn-B1*, *Vrn-D1* and *Ppd-D1*.

Genotype grouping	Number of genotypes	*Vrn-A1*	*Vrn-B1*	*Vrn-D1*	*Ppd-D1*	Habit
A	3	*a*	*v*	*v*	*a*	Spring
B	3	*v*	*a*	*v*	*a*	Spring
C	2	*a*	*a*	*v*	*a*	Spring
D	4	*v*	*v*	*v*	*a*	Winter

Results

Association between development and biomass accumulation

Results indicate a negative association between biomass accumulation and later flowering time. Figure 1 illustrates the correlation between shoot biomass (DC30~520ºCdays) and flowering time for the July sowing, whilst Figure 2 shows the correlation between shoot biomass (DC31~520ºCdays) and flowering time for the August sowing. It is important to note the distinct variation amongst earlier flowering genotypes for biomass production, and the limited variation in biomass for the later flowering genotypes.

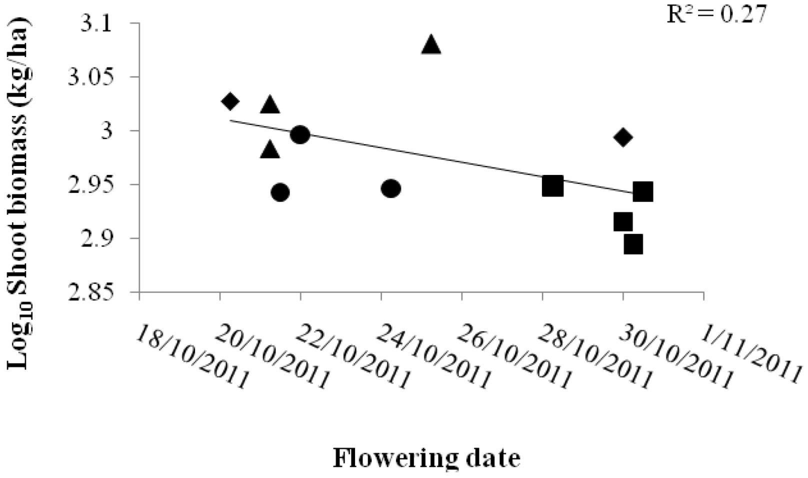

Figure 1. Relationship between shoot biomass (DC30~520ºCdays) and flowering date of July sowing (Symbols represent genotype grouping as indicated in Table 1. ● = A, ▲= B, ♦ = C and ■ = D).

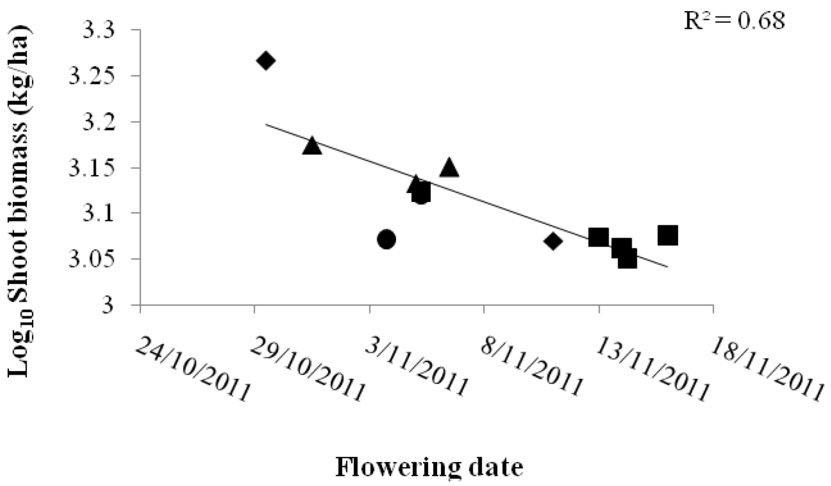

Figure 2. Relationship between shoot biomass (DC30~520°Cdays) and flowering date of August sowing (Symbols represent genotype grouping as indicated in Table 1. ● = A, ▲= B, ♦ = C and ■ = D).

The role of vernalisation responsiveness

The genetic classification of the genotypes for *Vrn-A1*, *Vrn-B1*, *Vrn-D1* and *Ppd-D1* (Table 1) enable further analysis according to genotype grouping and habit in an attempt to better understand the above association. Figure 3 shows shoot biomass according to genotype grouping (a) and habit (b) for the July sowing, whilst Figure 4 shows these for the August sowing. As indicated in Figure 1 and 2 above, the later flowering genotypes were predominately genotype D (winter habit), and when biomass accumulation is expressed in these groupings, and further in habit there is a significant (P<0.05) association between genotypes possessing a response to vernalisation and biomass production.

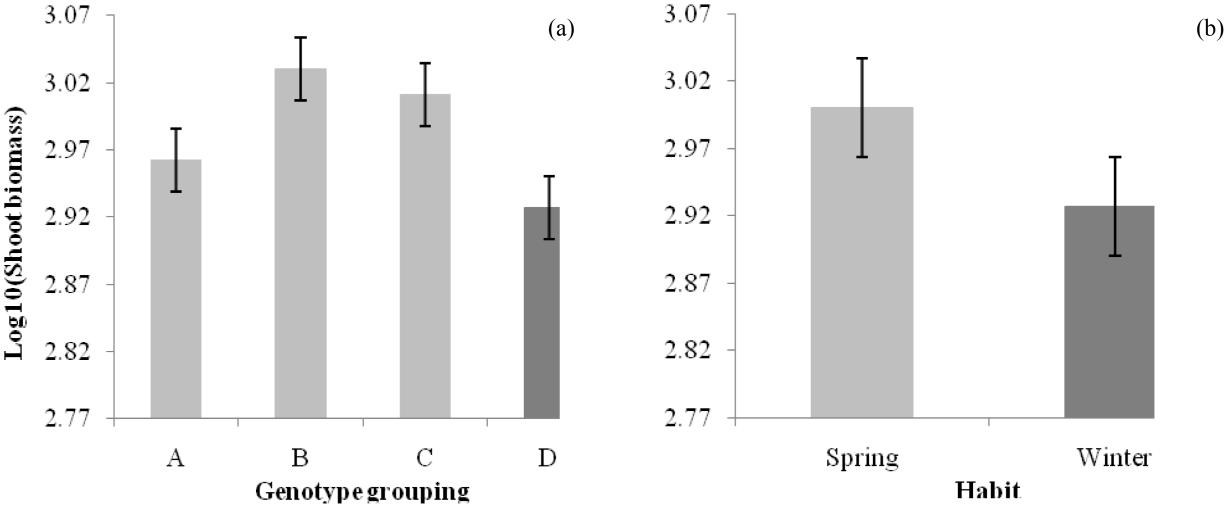

Figure 3. Shoot biomass expressed in genotype grouping (a) and habit (b) for the July sowing.

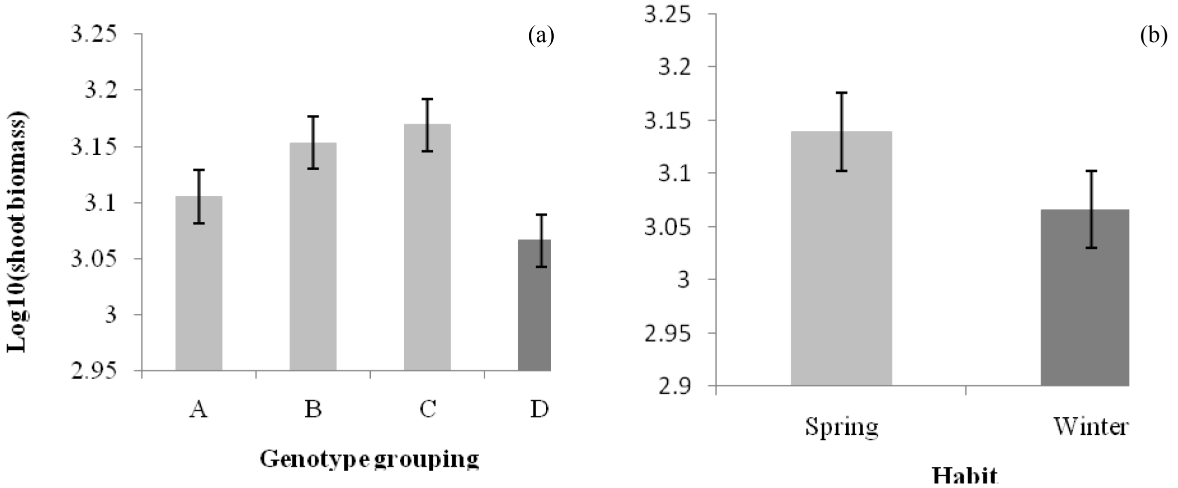

Figure 4. Shoot biomass expressed in genotype grouping (a) and habit (b) for the August sowing.

Conclusion

The results of this study indicate a relationship between developmental stage and biomass accumulation in wheat. All late flowering genotypes grew slowly, whereas growth in early flowering genotypes varied considerably (Figures 1 & 2). Further, utilising molecular markers for *Vrn-A1*, *Vrn-B1*, *Vrn-D1* and *Ppd-D1* for the genotypes examined, enabled additional analysis of the data according to groupings for the different allelic combinations for these genes and, more simply, according to spring or winter habit (Figures 3 & 4). Hence, the results suggest that the association between developmental rate and early biomass production in wheat may be related to vernalisation or some closely linked character.

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