Genetic variation of photosynthetic capacity in wheat

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Introduction

With harvest index approaching a plateau in some regions and countries, future genetic improvement in grain yield of wheat (*T. aestivum* L.) will increasingly depend on raising above-ground biomass. Therefore, a key breeding target is enhancing photosynthetic capacity to boost biomass. In bread wheat, there are to date relatively few reports of genetic variation in light-saturated leaf photosynthetic rate (A_{max}) in field investigations within adapted elite germplasm (Richards, 2000; Foulkes *at al*., 2009). This study therefore aims to identify novel variation for photosynthetic capacity and biomass by screening diverse wheat germplasm (landraces and synthetic-derived hexaploids) for flag-leaf photosynthetic rate and associated traits and biomass.

Materials and methods

Field experiments were carried out in 2010-11 and 2011-12 at University of Nottingham farm, Leicestershire UK (52°50' N, 1º14' W) on 50 wheat genotypes (20 wheat landraces from the AE Watkins collection, 20 synthetic-derived hexaploid wheats in a spring wheat Paragon background (BC1S3) and 10 UK elite wheat cultivars). The experiments were grown with optimal inputs and there were 3 replicates. Genotypes in the present analysis were selected to have similar anthesis dates. Flag-leaf A_{max} was measured using a Li-Cor 6400XT Photosynthesis System weekly from GS39 to mid grain fill on three flag leaves per plot in a subset of 15 genotypes. Grain yield, harvest biomass and relative chlorophyll content (SPAD) at anthesis on three flag leaves per plot were recorded in 50 genotypes.

Results

Significant genetic variation in biomass (P<0.001) was found in the 50 genotypes with higher biomass overall recorded in the synthetic derivative (1874 g m^{-2}) and elite UK cultivar (1756 g m^{-2}) groups compared to the Watkins landrace group (1543 g m^{-2}) (P< 0.05). Genotypes differed in A_{max} (P<0.001) averaged across readings and years with synthetic hexaploid wheat (22.3-25.0 µmol m^{-2} s^{-1}) and elite cultivars (23.2-25.3 µmol m^{-2} s^{-1}) generally expressing higher A_{max} than the Watkins landrace group (18.0-21.5 µmol m^{-2} s^{-1}). The year x genotype effect was not statistically significant.

Flag-leaf A_{max} was positively associated with biomass at harvest (pre-anthesis A_{max} (R^2=0.80 , P< 0.001); post-anthesis A_{max} (R^2 = 0.61 , P< 0.001) Fig. 1). Similarly, flag-leaf A_{max} pre-anthesis (R^2 = 0.87, P<0.001) and post-anthesis (R^2 = 0.74, P<0.001) was positively associated with grain yield. A significant and positive correlation was observed between biomass and grain yield (Fig. 2). A positive association was also found between flag-leaf SPAD value at GS61 and pre-anthesis A_{max} (R^2 = 0.82; P< 0.001, Fig. 3).

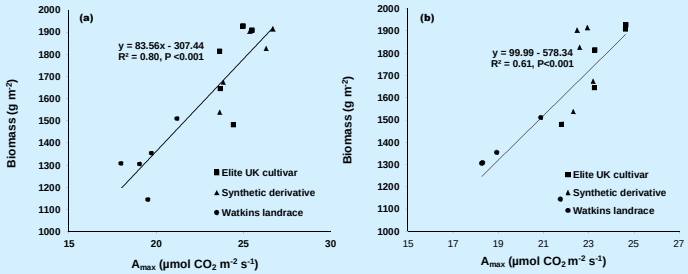

Figure 1: Relationship between pre-anthesis (a) and post-anthesis (b) flag-leaf A_{max} and biomass (Mean 2010-11and 2011-12). LSD (5%) for biomass = 562 g m^{-2}.

Field experiment at University of Nottingham Farm in 2011-12.

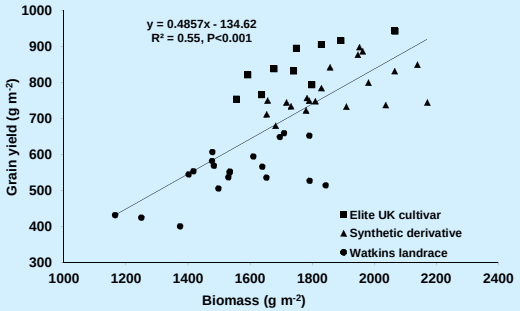

Figure 2: Relationship between grain yield and biomass (Mean 2010-11 and 2011-12).

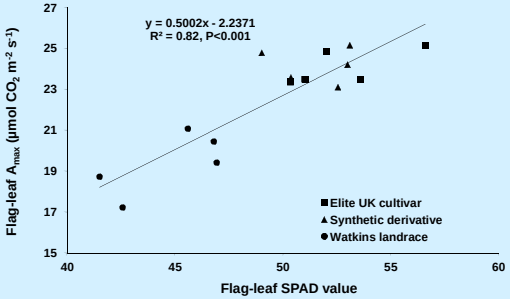

Figure 3: Relationship between pre-anthesis A_{max} and chlorophyll content (SPAD) (Mean 2010-11 and 2011-12). LSD (5%) for SPAD = 4.81.

Conclusions

Novel genetic variation in biomass was identified amongst groups of synthetic-derived wheats (1653-2170 g m^{-2}), UK elite cultivars (1555-2066 g m^{-2}) and AE Watkins landraces (1163-1842 g m^{-2}). Genetic variation in flag leaf A_{max} in the range 18.0 – 25.3 mol µCO_2 m^{-2} s^{-1} was positively associated with biomass and grain yield amongst the genotypes. The elite UK cultivars and synthetic-derived wheats generally showed higher A_{max} compared to AE Watkins landraces. In the present study results showed a linear relationship between flag-leaf N concentration (as indicated by SPAD) and A_{max} amongst genotypes, in contrast to previous reports of an asymptotic relationship, e.g. Evans (1983). Work is ongoing screening a wider range of synthetic derivatives and landraces for biomass and underlying traits. The strong correlation between A_{max} and SPAD indicates that SPAD could be used as a selection criteria for high throughput phenotyping.

References

Evans, J.R.1983. Nitrogen and photosynthesis in the flag leaf of wheat (*Triticum aestivum*, L.). *Plant Physiology*, 72, 297-302.

Richards, R.A.2000. Selectable traits to increase crop photosynthesis and yield of grain crops. *Journal of Experimental Botany*, 51, 447-458.

Foulkes, M.J., Hawkesford, M.J., Barraclough, P.B., Holdsworth, M.J., Kerr, S., Kightley, S., Shewry, P.R. 2009. Identifying traits to improve the nitrogen economy of wheat: Recent advances and future prospects. *Field Crops Research*, 114, 329-342.