Effect of nitrogen fertiliser application on canopy architecture in the MAGIC wheat population

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Abstract

The role of agronomic management in improving canopy architecture has received relatively little attention, particularly in the novel Multi-parent Advanced Generation Inter Cross (MAGIC) wheat population developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Yet understanding the impact of the different agronomic practices such as soil nutritional management and careful varietal selection is key to improving canopy radiation-use efficiency (RUE), which is associated with greater biomass, canopy productivity and grain yield in cereals. To address this research gap, a factorial experiment with 10 different F-line genotypes selected from the MAGIC wheat population and two commercial lines and two soil types with two nitrogen (N) fertiliser levels applied at a rate of 348 and 180 kg N/ha was setup under controlled glasshouse conditions. Different canopy attributes were evaluated during crop growth and at harvest (anthesis, GS69). Leaf chlorophyll content, plant height, tiller number and leaf erectness were determined during crop growth. At harvest, plant height, tiller and ear number, green leaf area and total above-ground dry matter (AGDM) were also determined. Study findings showed a significant interaction between N fertiliser application and genotype for growth measurements ($P < 0.05$). At harvest, N fertiliser application and genotype had a significant effect on plant height, ear number and total AGDM ($P < 0.05$), while tiller number was significantly affected by N fertiliser application only ($P < 0.05$). Differences between planophiles and erectophiles were evident, particularly for leaf erectness, green leaf area, ear number and total AGDM.

Keywords: Canopy efficiency, leaf erectness, nitrogen fertiliser, *Triticum aestivum*, genotypic variation.

Introduction

Canopy architecture plays a significant role in photosynthetic efficiency, which influences canopy productivity and resultant grain yield (Fischer & Edmeades 2010). Agronomic management is important in improving canopy architecture. Practices such as nitrogen (N) fertiliser application and careful varietal selection are key to improving canopy duration and productivity. Despite the various physiological and molecular studies conducted on the novel Multi-parent Advanced Generation Inter Cross (MAGIC) wheat population developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Cavanagh et al. 2008; Huang et al. 2015), limited research has been conducted to understand the influence of agronomic practices on the canopy architecture of the F-line genotypes (Merry et al. 2017). Yet understanding the impact of the different agronomic practices such as nutrient management and careful varietal selection is key to improving canopy radiation-use efficiency (RUE), which is associated with greater biomass, canopy productivity and grain yield in cereals. In this study, we hypothesised that N fertiliser application will significantly improve canopy architectural traits and yield attributes of selected genotypes and significant variations will be evident among erectophiles (erect/vertical leaf structure) and planophiles (flat/horizontal leaf structure).

Materials and methods

Location of the experiment

The experiment was conducted under glasshouse conditions at the Tasmanian Institute of Agriculture (TIA), University of Tasmania, Sandy Bay Campus located 42^0 91'S and 147^0 32'E from April to September 2018. Air temperature and relative humidity inside the glasshouse were monitored using a data logger, Tinytag Ultra 2. The average minimum and maximum air temperatures were 12 ^{0}C and 23 ^{0}C, respectively with a relative humidity of 75%.

Experimental setup
The factorial experiment was a randomised complete block design (RCBD) with three replicates. The 10 F-line genotypes selected from the novel Multi-parent Advanced Generation Inter Cross (MAGIC) wheat population developed by the CSIRO included: F0883, F1587, F1181, F1579, F0597, F1265, F1183, F0589, F0853 and F0746, including two commercial lines, Bolac and Beaufort (both erectophiles). The MAGIC population F-lines were selected as either erectophile or planophile leaf habit.

Four seeds of each genotype were sown in 150 mm diameter pots (2.6 litre volume capacity) filled with the standard premium potting mix or a soil mix (mixture of coarse sand and sandy loam soil in a ratio of 3:1). The seedlings were thinned to two per pot after emergence. N fertiliser, urea (46-0-0) was applied at a rate of 348 and 180 kg N/ha for the premium potting mix and soil mix, respectively following nutrient analysis results. The fertiliser was split-applied with 50% applied shortly after sowing and the remaining 50% top-dressed at 45 days after the first application.

Agronomic practices such as weeding, and pest and disease control were carried out according to standard practice; pheromone traps were used to prevent whiteflies and aphids. A controlled-release fertiliser, Osmocote Exact was applied to each pot at a rate of 3 kg/m^3, 7.95 g/pot to prevent nutritional deficiencies. The pots were regularly watered using an over-head sprinkler irrigation system.

Measurements
Leaf chlorophyll content was estimated in the middle of the youngest fully expanded leaf using a chlorophyll meter (SPAD-502, Osaka, Japan), while tiller number was established through visual counting. Plant height was determined using a meter-rule and leaf erectness was scored from visual assessments on a scale of 1 – 5, with 1 being all leaves erect and 5 all leaves completely drooped over (Richards et al. 2019). These non-destructive measurements were taken over a period of six weeks through different growth stages (seedling growth, tillering, stem elongation, booting, ear emergence and anthesis).

At harvest (anthesis, GS69), tiller and ear number were established through visual counting and green leaf area was determined using a Leaf Area Meter (Li-3000C, John Morris Scientific Pty Ltd, LI-COR Biosciences). The ears were weighed to determine ear weight per plant. The ears, green leaf, dead leaf and stem were oven-dried at 60^{0}C for 48 hours and weighed to determine their dry matter (DM) and compute the total above-ground DM (AGDM).

Data analysis
Growth measurements were analysed using repeated-measures ANOVA whilst harvest data were analysed using univariate ANOVA. The treatment effects and interactions were deemed significant at a least significant difference, LSD of 5% using SPSS statistical package where the ANOVA-F was significant (IBM SPSS Statistics Version 22).

Results
There was a significant interaction between N fertiliser application and genotype for plant height, leaf chlorophyll content, leaf erectness and tiller number during crop growth ($P < 0.05$). Significant variation among genotypes was evident for plant height and leaf erectness ($P < 0.05$). No significant differences were observed among genotypes for tiller number and leaf chlorophyll content ($P = 0.05$). At harvest (anthesis, GS69), N fertiliser application and genotype had a significant effect on plant height, ear number and total AGDM ($P < 0.05$) as single main effects. Tiller number was significantly affected by N fertiliser application ($P < 0.05$), and a significant interaction between N fertiliser application and genotype was observed for total green leaf area ($P = 0.004$) (Figure 1). The N fertiliser treatment at 348 kg N/ha significantly increased plant height, tiller and ear number, green leaf area and total AGDM of both planophiles and erectophiles. For instance, the average plant height, green leaf area and total AGDM were 79 cm, 505 cm^2 and 18 g, respectively compared with the 50 cm, 71 cm^2 and 1.3 g at 180 kg N/ha.

Differences between planophiles and erectophiles were evident, particularly for leaf erectness, green leaf area, ear number and total AGDM (Table 1). Commercial lines Bolac and Beaufort were more erect, with an average score of 2.0. They were not significantly different from the erectophilic F-lines, which also had an average score of 2.0, except for F0589 and F1265, which had an average score of 3.0. Interestingly, there were no significant statistical differences between planophiles and erectophiles for leaf chlorophyll content (Table 1). Overall, the erectophiles had a higher green leaf area, with an average of 302 cm^2 compared with

246 cm^2 of the planophiles. The commercial lines were significantly different with Bolac and Beaufort having 189 cm^2 and 524 cm^2 of green leaf area, respectively. No significant statistical differences were evident between planophiles and erectophiles for tiller and ear number and total AGDM.

Table 1. Canopy and yield attributes of different genotypes at anthesis (GS69)

Genotype		**Canopy and yield attributes**					
Planophiles	Plant height (cm)	Leaf erectness	Leaf chlorophyll content	Green leaf area (cm^2)	Tiller number	Ear number	Above-ground DM (g)
F0597	64.0ab	3.3c	37.8a	268.4abc	2.6a	2.2ab	10.7ab
F0853	68.4ab	3.3c	39.1a	338.6abc	2.5a	2.1ab	12.7b
F0883	69.3b	3.3c	37.6a	239.6ab	2.5a	2.1ab	11.8ab
F1181	55.9a	2.8bc	34.1a	138.4a	2.7a	2.6ab	9.3ab
F1579	65.1ab	3.1c	38.1a	246.4ab	3.0a	2.8b	9.9ab
Erectophiles							
F0589	68.0ab	2.6abc	35.6a	337.9abc	2.7a	2.4ab	10.0ab
F0746	71.9b	2.0ab	36.4a	480.3bc	3.1a	2.8b	12.2ab
F1183	64.2ab	2.1ab	38.8a	256.6ab	3.1a	2.2ab	9.5ab
F1265	62.9ab	2.6abc	37.3a	255.3ab	2.1a	1.9a	8.9ab
F1587	55.5a	1.9a	39.7a	180.4a	2.8a	2.5ab	7.4a
Bolac	64.9ab	2.1ab	36.6a	188.6a	2.1a	2.1ab	7.7a
Beaufort	63.8ab	1.8a	35.7a	524.5c	2.8a	2.0a	10.6ab

*Genotypes followed by the same letter are not significantly different (*P* > 0.05).

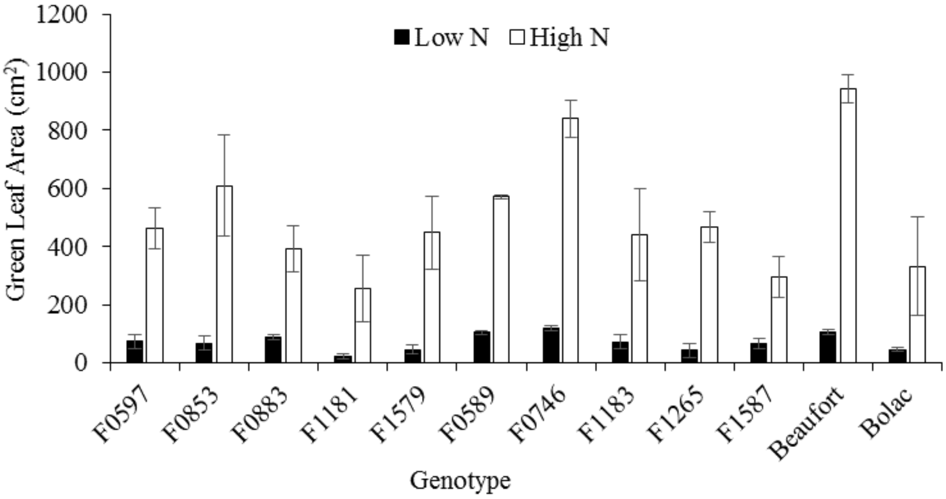

Figure 1. Green leaf area of different genotypes under different nitrogen treatments

Discussion

Nitrogen is a vital macronutrient for plant growth. For instance, 75% of the total leaf N is allocated to the chloroplasts for synthesis of components for the photosynthetic apparatus particularly Ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO), which facilitates CO_2 assimilation (Cai et al. 2012; Fois et al. 2009). This boosts canopy productivity through increased leaf chlorophyll content and photosynthetic capacity (Wang et al. 2012). Improvement in photosynthetic efficiency increases canopy size and duration, which improves plant growth through increased plant height, tiller number, ear number and overall, above-ground DM.

Genotypic differences particularly between erectophiles and planophiles could be attributed to their leaf growth habits. Planophiles tend to have a larger proportion of their leaves exposed to intercept more sunlight (Yunusa et al. 1993), resulting in improved canopy productivity and resultant biomass. However, given the flat nature of the leaves, there is a possibility of leaf shading particularly for the lower leaves, which can compromise the photosynthetic efficiency of the canopy. Erectophiles on the other hand, provide for improved radiation-use efficiency (Merry et al. 2017), which increases canopy productivity through improved plant height, green leaf area and resultant grain yield.

Conclusion

In conclusion, proper agronomic management strategies such as nitrogen fertiliser application play a vital role in improving the productivity of both erectophilic and planophilic plants. Exploiting this genotype and environmental interaction for key lines is crucial for improving the productivity potential of the MAGIC population and development of resource-use efficient wheat varieties through generating a genetic resource population with substantial phenotypic diversity suitable for high-resolution trait mapping. Field studies exploring various agronomic strategies for instance appropriate sowing time under different environmental conditions will provide an in-depth understanding of how the genotype x environment x management (GxExM) interactions impact on the productivity of the MAGIC population and establish the suitability of desirable genotypes to the diverse regions across Australia and global agro-ecological zones.

Acknowledgements

We acknowledge financial assistance from the University of Tasmania, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for the 10 F-line genotypes and two commercial lines seed provided and Rebecca Fish for the technical support rendered particularly with scoring the leaf erectness.

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