Is a reduced-tillering trait (tin) beneficial under elevated CO_2 in four FACE environments?

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Abstract
The number of heads per m^2 is an important yield component in wheat, and high yielding wheat types often produce many tillers and heads. Elevated CO_2 (eCO_2) generally promotes growth and yield of wheat, and this 'CO_2 fertilisation effect' is commonly linked to increased production of biomass and tillers, and less to other yield components. In water limited environments where crops mature under increasingly dry conditions, high biomass productivity early in the season may lead to an early depletion of soil water reserves, and inability of the crop to fill grains. A restricted tillering trait, through a 'tiller inhibition gene' ('tin'), has therefore been suggested in pre-breeding research and proven to be beneficial in such environments. In this study, we address the potential trade-offs between the response of yield to eCO_2 and the restricted tillering trait. Two near-isogenic wheat lines, the freely tillering cultivar cv. Silverstar and a Silverstar line containing the 'tin' gene (Silverstar T65 "SSR T65"; CSIRO) conferring limited tillering ability, were grown side by side in four different environments (created by two different water supply levels – rainfed and supplemented by limited irrigation – during 2011 and 2012 growing seasons) in the Australian Grains Free Air Carbon dioxide Enrichment (AGFACE) facility in Horsham, Victoria. Our results indicate that eCO_2 promoted tillering in both lines, that the responsiveness of yield and growth was not restricted by tin. The tin-line showed greater depression of leaf N under eCO_2, but this did not translate to a CO_2-related depression in grain protein.

Key words
Wheat, Free-Air Carbon dioxide Enrichment (FACE), tillering trait (tin), multi-environment experiment, dryland.

Introduction

Future climates, as predicted by IPCC (2014), will provide challenging environments for wheat growth. Rising CO_2 levels in combination with the increased occurrence of dry conditions have to be considered to ensure successful crop yield. In dryland environments, crops have to cope with increasingly limited water availability towards the end of the growing season. In terminal water deficit environments, it was suggested to limit the number of heads per area (Mitchell et al. 2012). This balances the increased growth of wheat under eCO_2 due to the 'CO_2 fertilisation effect' with the increased demand for water to sustain such an increased biomass it number of heads per area. A 'tiller inhibition gene' ('tin'), has been suggested in pre-breeding research and proven to be beneficial in such environments (Dreccer et al. 2013, Mitchell et al. 2012).

In this study, the freely tillering wheat cultivar cv. Silverstar and a line containing the 'tin' gene with limited tillering ability were grown side by side in four different environments. The environments were established at the Australian Grains Free Air Carbon dioxide Enrichment (AGFACE) facility via rainfed-only and supplemental irrigation and two growing season (2011 and 2012) which provided growing seasons) in the AGFACE facility.

We tested the following hypotheses:
(1) Elevated CO_2 will promote growth and yield of the freely tillering line more than growth and yield of the restricted tillering one.

(2) Elevated CO_2 will increase tiller numbers in all cultivars, thus potentially limiting the expression of the 'tin' trait.
(3) Leaf nitrogen concentrations will be more depressed by elevated CO_2 in the restricted tillering line due to sink limitations and corresponding down-regulation of photosynthesis (Kirschbaum 2011).

Methods

The AGFACE facility is located outside of Horsham, Victoria, Australia. Annual rain fall for the two years covered in this study was 507 mm in 2011, and 287 mm in 2012. The two near-isogenic wheat (*Triticum aestivum* L.) lines, the freely tillering "Silverstar" and a Silverstar line containing the 'tin' gene (Silverstar T65 "SSR T65"; CSIRO) conferring limited tillering ability, were grown in four rings under prevailing ambient CO_2 (aCO_2) conditions and in four FACE rings under eCO_2 conditions (sample size n = 4). Half of these rings received supplemental water (Sup), whereas the other half was rainfed only (Rain). The design and operation of the Free Air CO_2 Enrichment system is described by Mollah et al. (2009).

Results

In general, SSR T65 had 50% less tillers m^{-2} compared to Silverstar, the low-tillering trait was expressed (Fig. 1). A trend for more tillers m^{-2} under eCO_2 was not statistically significant. Consistent with literature, eCO_2 increases yield (Fig. 2). Grains per head were not affected by eCO_2. At flowering, leaf nitrogen concentrations decreased significantly under eCO_2. Elevated CO_2 lead to decreased grain protein in general. eCO, decreased %N in leaves at flowering, and more so for 'tin'.

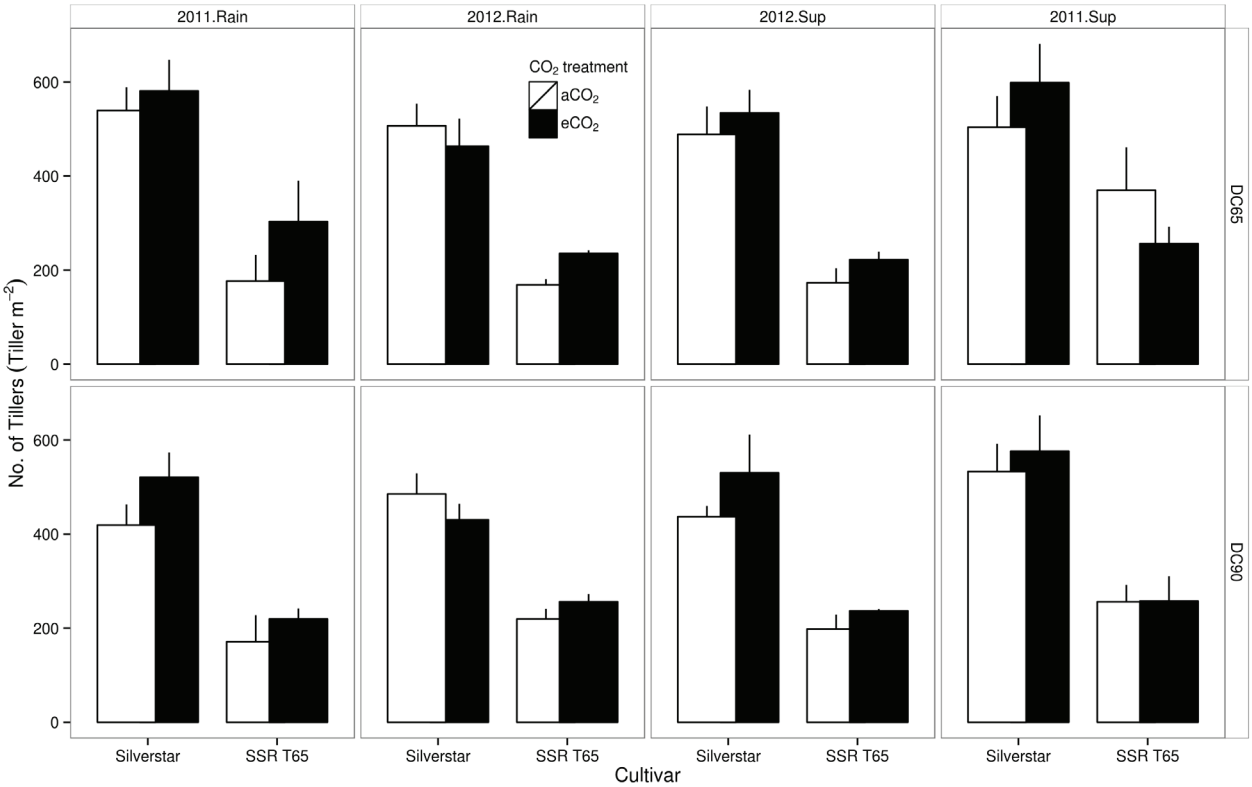

Fig. 1: Number of tillers m^{-2} in the four environments and two developmental stages (DC65, DC90) for Silverstar and the reduced-tillering 'tin' line SSR T65. The environments are ordered from left to right according to increasing yield (Fig. 2) of Silverstar in ambient CO_2. Mean and standard error.

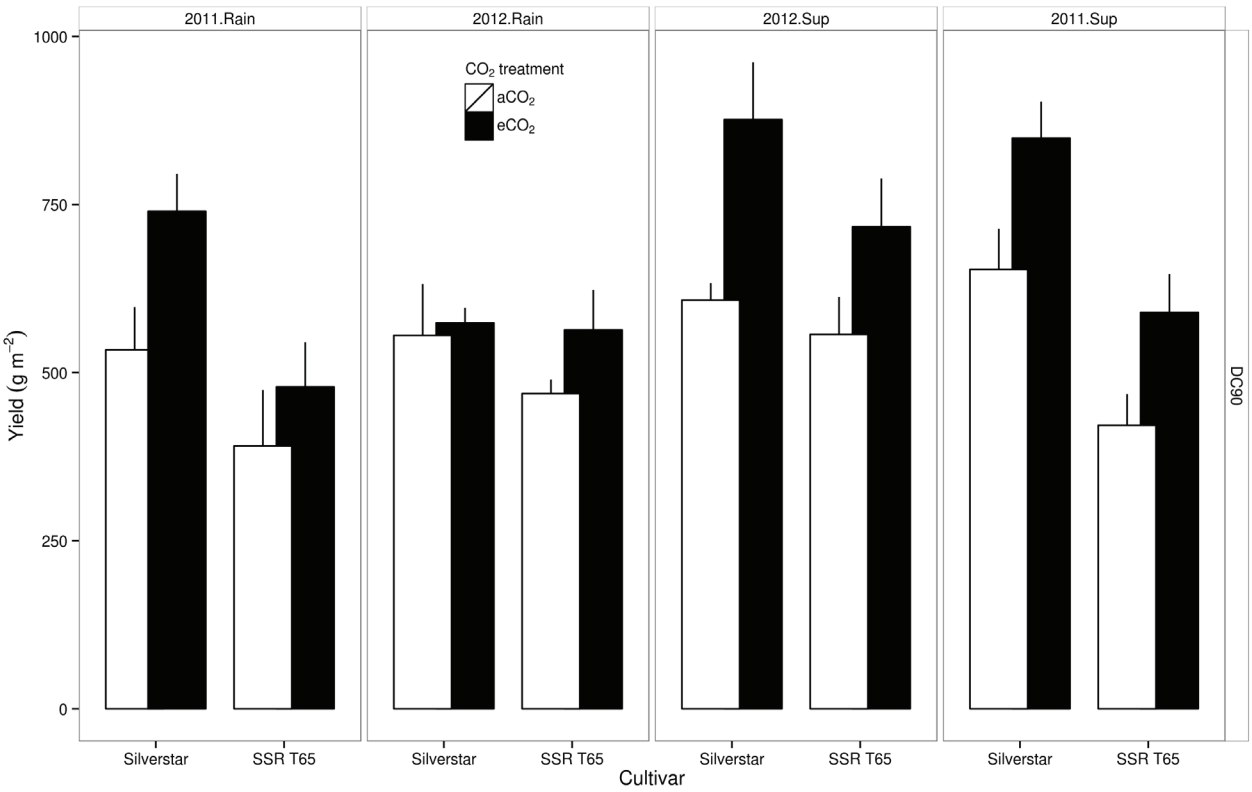

Fig. 2: Yield in the four environments for Silverstar and the 'tin' line SSR T65. See Fig. 1 for further details.

Conclusions

There was no evidence that the restricted tillering trait 'tin' limited CO_2 responsiveness of yield and growth in the tested environments. As a trend, eCO_2 promoted tillering in both lines (incl. the low tillering one), but the effect was moderate and non-significant in our data-set. The free-tillering line did not benefit more from eCO_2 compared with the 'tin' line as suggested in hypothesis 1. The relative ranking between the cultivars (high – low tillering) was maintained at both CO_2 levels. The expression of the 'tin' trait was therefore not limited due to eCO_2. Hypothesis 2 was therefore rejected.

The restricted tillering line showed greater depression of leaf N under eCO_2 (confirming hypothesis 3), but this did not translate to greater CO_2-related depression in grain protein (not shown), probably due to trade-off effects between N available in leaves for remobilisation and differences in harvest index (different amounts of leaf mass available per grain).

Acknowledgments

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