DURUM WHEAT GRAIN YIELD AND QUALITY UNDER ELEVATED CO_2
RESA IN GRANELLA E QUALITÀ DI FRUMENTO DURO A CO_2 ELEVATA

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Abstract
We present results on the aboveground biomass production, grain yield and quality of 12 durum wheat genotypes grown under elevated atmospheric CO_2 studied with a FACE experiment. The FACE (Free Air Carbon Dioxide Enrichment) system, installed in the experimental farm of the Genomics Research Centre of CRA in Fiorenzuola d'Arda, allows to study the effect of increased atmospheric CO_2 mixing ratios, expected for the mid of the 21st Century on crop yield and quality. Increases in biomass and grain yield and decreases in grain crude nitrogen content due to elevated CO_2 were comparable to those reported in the literature for soft wheat. A high genetic variability was observed for all of these traits.

Keywords: Free Air Carbon dioxide Enrichment (FACE), *Triticum durum*, grain quality, grain yield, aboveground biomass
Parole chiave: Arricchimento in CO_2 all'aria aperta (FACE), *Triticum durum*, qualità della granella, resa in granella, biomassa

Introduction
The continuously rising atmospheric CO_2 content is a major element of the ongoing anthropogenic global changes. Future agricultural yields depend on the changing physical climate but also on the stimulation of photosynthesis by elevated levels of atmospheric CO_2, the main direct effect of CO_2 on plants (Badeck et al., in press). The response of durum wheat (*Triticum durum*) to increasing atmospheric CO_2 is currently not well known and needs to be characterised for the purpose of selection of varieties well suited for the atmospheric conditions expected for Mid-21st Century. We report on growth, yield and grain quality of durum wheat studied with a FACE (Free Air Carbon Dioxide Enrichment) experiment.

Materials and Methods
Twelve durum wheat genotypes were grown within the FACE facility of the Genomics Research Centre of the Consiglio per la Ricerca e sperimentazione in Agricoltura (CRA-GPG) at Fiorenzuola d'Arda (44.927°N, 9.893°E) applying a split plot design with FACE and control octagons distributed at random within the experimental field (4 FACE, 4 controls). The single FACE and control systems contained two blocks (northern and southern side) with plots (1.32 x 2.2 m) for the twelve genotypes as split plots. The genotypes include modern high yielding varieties (Simeto, Ciccio, Claudio, Anco Marzio, Saragolla), modern varieties with high protein content (Svevo and Aureo), varieties with a prominent role in Italian durum wheat breeding (Cappelli, Creso, Ofanto) and two lines of the Ofanto x Cappelli mapping population (RIL11 and RIL28). Sowing at optimal sowing time (October 19th 2011) was assured by a pre-harrowing irrigation due to dry soil conditions. The CO_2 mixing ratio for the FACE treatment target was fixed at 570 ppm representing a value within the upper range of scenarios for the mid Century atmospheric mixing ratio. FACE treatment was started on November 16th, 2011 and stopped when leaves were senescent at June 14th, 2012. The FACE treatment was interrupted for 20 days in February 2012 when the plots were covered with snow.
Apart from the CO_2 fumigation, the experiment was performed according to standard local agronomic practice and with the objective to avoid major pests and diseases. The plots were fertilised with application of an N:P:K fertiliser at pre seeding and two top dressings with ammonium nitrate for a total of 149 kg N ha^{-1}. At final harvest (July 2nd, 2012) 1.5 linear meters per plot were harvested for determination of yield components. Subsequently, the whole plots were harvested manually and aboveground biomass as well as grain yield were determined. Grain nitrogen content determined with the Kjedahl method, and grain crude protein content calculated as 5.7*N.

Results and Discussion
All traits related to growth showed a more vigorous development under elevated CO_2 (Badeck et al., 2012). Flag

Fig. 1 - Two of the durum wheat FACE octagons in April 2012 with the CO_2 tank in the background.
Fig. 1 - Due degli ottagoni FACE con frumento duro e in fondo il serbatoio per la CO_2, aprile 2012.

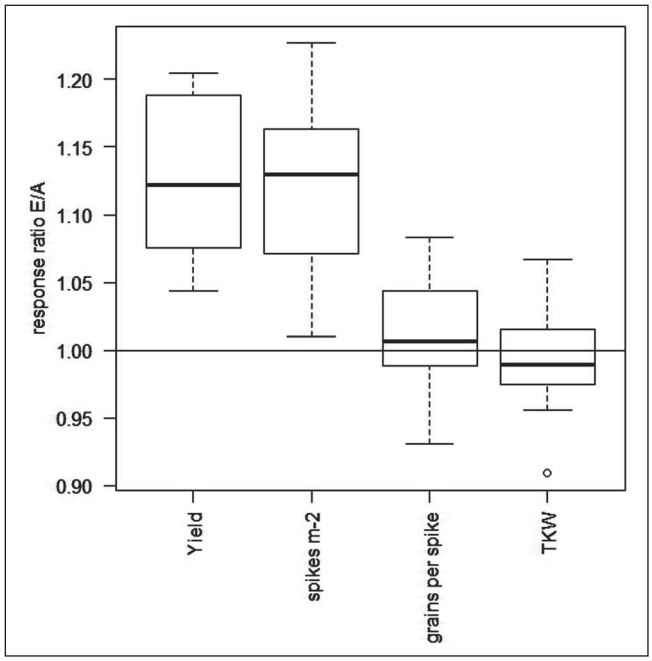

Fig. 2 - Effect of elevated CO_2 on grain yield and yield components. The box plots show the distribution of genotype means.
Fig. 2 - Effetto dell'aumento della CO_2 atmosferica sulla resa in granella e suoi componenti.

leaf light saturated photosynthesis was higher under elevated CO_2 when measured at growth conditions and stomatal conductance substantially reduced leading to an increased instantaneous water use efficiency (+30 to +60%) at the leaf level (Badeck et al., in press). The increased leaf level water use efficiency was not fully compensated by the higher transpiring surface area, as evidenced by measurements of soil water content in the uppermost 6 cm of soil (data not shown), that showed a slightly higher water content in the elevated CO_2 treatment.

An exceptionally good growing season led to high yield in the ambient as well as the elevated CO_2 treatments. The average grain dry mass yield was 7.91 t DM ha^{-1} under ambient CO_2 and the FACE treatment increased the average yield significantly ($p<0.01$) to 8.91 t DM ha^{-1}. Total aboveground dry biomass at harvest was 18.5 t DM ha^{-1} under ambient CO_2 and increased ($p<0.01$) to 21.6 t ha^{-1} under FACE. There is a considerable and statistically significant genetic variability of yield as well as of the CO_2 response of yield. Grain dry matter yield was increased between 4.4% (var. Ciccio) and 20.4% (RIL28). The average increase in grain yield of durum wheat by 16.7% due to elevated CO_2 was similar to the medium effect of 14.4 % reported by Ainsworth and Long (2005) for bread wheat based on a meta-analysis of five FACE experiments. The variability between the durum wheat cultivars (+4.4 to +20.4%) filled a substantial part of the confidence range found for the effect in bread wheat (-1.6 to +33.1%). The increase in grain yield of durum wheat was mainly due to increased tillering, while the number of grains per spike and the thousand kernel weight changed only marginally (Fig. 2).

Averaged across all genotypes, the crude grain protein content decreased by 7.0% for plants grown in elevated CO_2 relative to the controls with a substantial variation between genotypes (-2.2% for Ofanto to -10.8% for Aureo).

Conclusions

Atmospheric CO_2 content elevated to 570 ppm led to a stimulation of grain yield in durum wheat that is comparable to results obtained on bread wheat, whereas crude grain protein content decreased indicating potential losses in grain quality. Substantial between genotype variability in the yield and quality response to elevated CO_2 hints to genetic variability that can be exploited for selection of varieties best suited for the mid-Century atmospheric CO_2 content.

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