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Selection of tree species for forests under climate change: is PSI functioning a more effective predictor for net photosynthesis and growth than PSII?

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Introduction

- Chlorophyll Fluorescence analysis (ChlF) is widely applied to assess stress condition and vitality of plants in experiments, open field and remote sensing surveys. ChlF detects the first events of the photosynthetic process (i.e. the efficiency of the electron transport chain).
- The most widely used parameter of ChlF is the "maximum quantum yield of primary photochemistry" (F_V/F_M).
- There are only limited evidences about the relationship between F_V/F_M, the actual photosynthetic performance of plants, in terms of carbon assimilation (Pn), and plant growth.
- Here the suitability of selected ChlF parameters (*prompt ChlF*) to predict Pn and plant growth is presented.

Fig. 1. The common garden at Sant'Anatolia di Narco (July 2018) and the detail of oak seedling.

Methods

- A common garden was established in April 2017 in Santa Anatolia di Narco (Perugia, Central Italy, **Fig. 1**).
- 1-year old seedlings of *Quercus ilex* L. (QI), *Quercus pubescens* Willd. (QP) and *Quercus frainetto* Ten. (QF) originated from acorns collected in selected forests in Italy and Greece, were assessed. 210 seedlings for each species and provenance (Italy, IT; Greece, GR) were planted (1260 seedlings in total).
- Parameters assessed: Plant height (H), Specific Leaf Area (SLA), leaf gas exchanges (net carbon assimilation Pn, stomatal conductance Gs, measured with gas analyzer CIRAS 2, PP System), chlorophyll a fluorescence (Prompt Fluorescence, PF, measured with HandyPEA fluorimeter, Hansatech, and evaluated by JIP-test analysis, Strasser et al. 2004), Modulated Reflectance (MR) of Photosystem I (assessed with MPEA, Hansatech Inst).
- The physiological and growth parameters were measured in September 2017 and 2018.

Results

- The physiological state of the oak seedlings has been assessed by F_V/F_M and ΔV_{IP}. In the first year of the experiment (2017), no differences between species and provenances were detected for F_V/F_M. ΔV_{IP} was lower in *Q. frainetto* with respect to the other species. In the second year (2018) also F_V/F_M was lower in *Q. frainetto* (**Fig. 2A**).
- Considering all the three species together, ΔV_{IP} (but not F_V/F_M) was positively (significantly) correlated to plant growth (i.e. height, **Fig. 2B**) and net photosynthesis (**Fig. 2C**).
- The positive strong correlation between ΔV_{IP} and the Modulated Reflectance (MR) parameter V_{red} shows the relationships between the thermal phase of the photosynthetic processes and the content of PSI (**Fig. 2D**).
- Pn was lower in *Q. frainetto* (2018) respect to the other species (**Fig. 3A**). Stomatal conductance (Gs, **Fig. 3B**) and Water Use Efficiency (WUE) were, respectively, higher and lower in this species (**Fig. 3C**) respect to QI and QP. The higher values of Ci/Ca indicated failures in the leaf mesophyll cells (i.e. carbon is not fixed) (**Fig. 3D**).

Conclusions

- The stability of F_V/F_M in relation to environmental factors and genetic variability of plants was confirmed in this study. ΔV_{IP} resulted more effective than F_V/F_M as early indicator of stress and acclimation of plants to the environmental conditions.
- ΔV_{IP} is the more efficient indicator for plant growth and net photosynthesis.
- Contemporary measurements of prompt fluorescence and modulated reflectance indicate the role of PSI, rather than PSII, in plant stress responses.
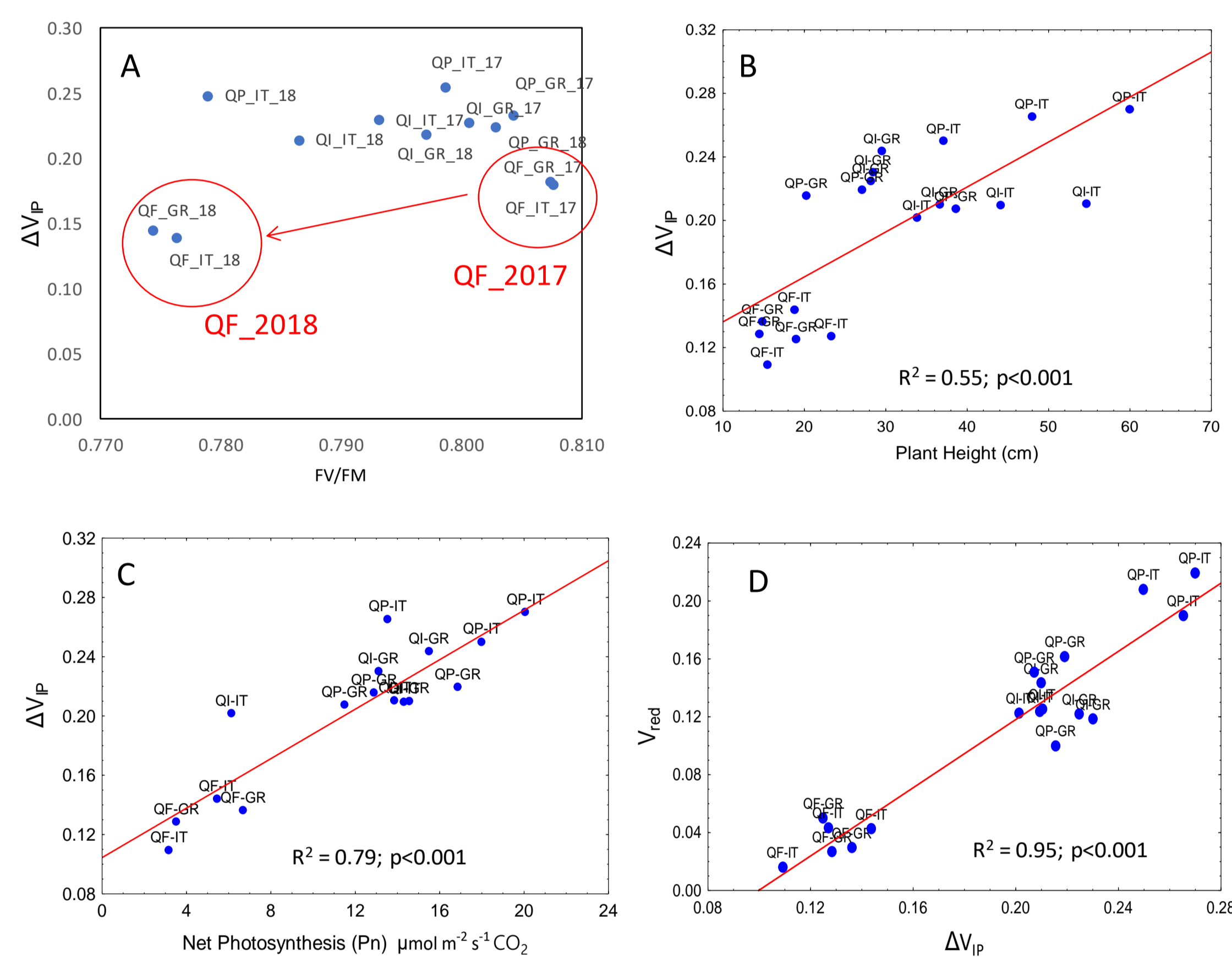
Fig. 2. QI = *Quercus ilex*; QP = *Quercus pubescens*; QF = *Quercus frainetto* provenances from Italy (IT) and Greece (GR).[A] Distribution of species and provenances (years 2017 and 2018) in a cartesian space according to the values of F_V/F_M (x-axys) and ΔV_{IP} measured in September 2017 (17) and 2018 (18). *Quercus frainetto* is marked. [B] Correlation between plant height and ΔV_{IP} (year 2018). [C] Correlation between net photosynthesis and ΔV_{IP} (year 2018). [D] Correlation between the parameters related to PSI, ΔV_{IP} and V_{red}, assessed, respectively ,with HandyPea and Mpea (year 2018).
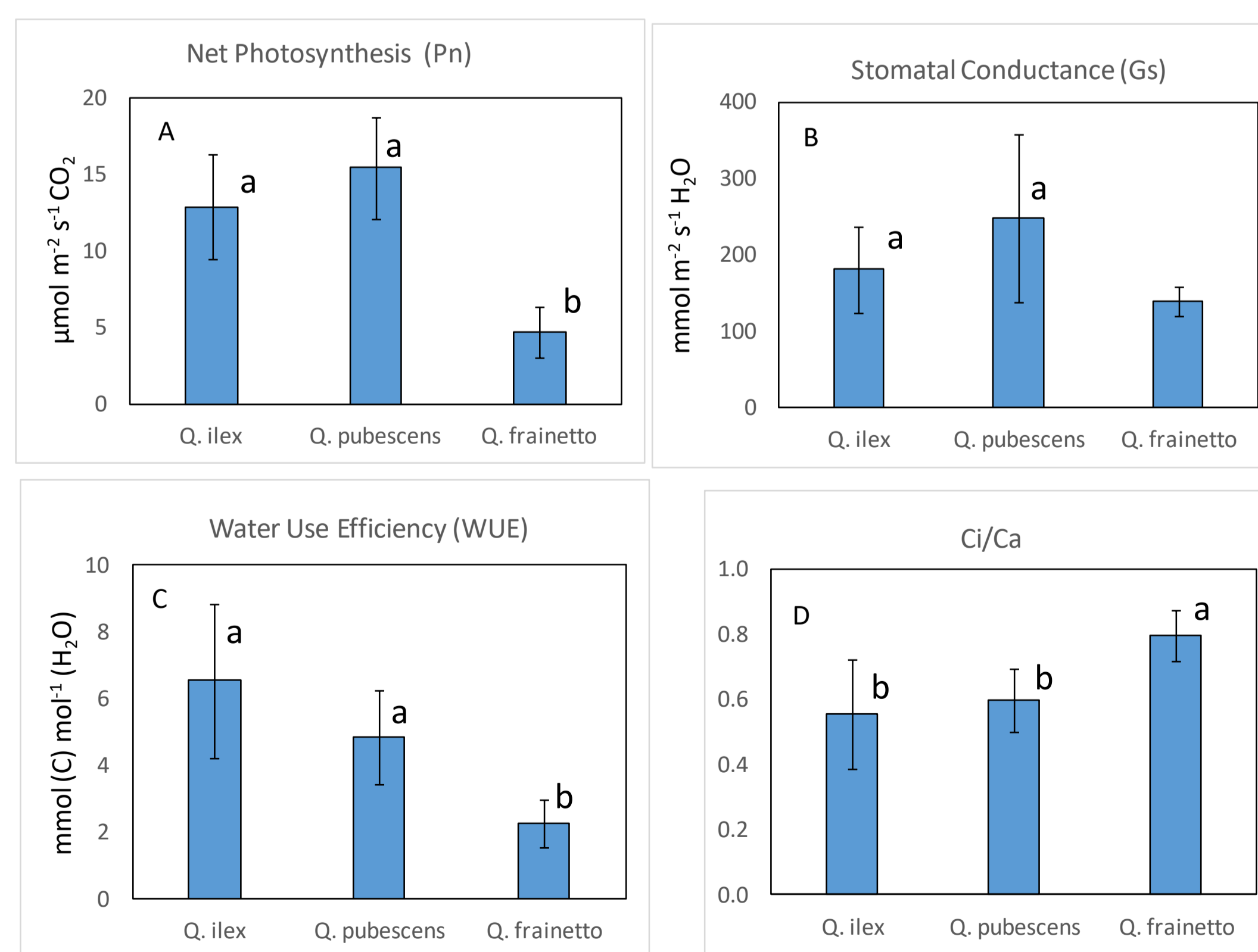

Fig. 3. Gas exchanges parameters. WUE is instantaneous water use efficiency. Ci/Ca is the ratio between intercellular and ambient CO_2 (adimensional). The plant species include Italian and Greek provenances. Bars indicate standard deviation. Different letters indicate significant differences with $p < 0.05$.

References
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