Effect of elevated CO_2 and nitrogen supply on biometry, wood density and wood structure of young sessile oak trees (*Quercus petraea* (Matt.) Liebl.)

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INTRODUCTION

Since the Industrial revolution, atmospheric CO_2 has increased by more than 45 %, reaching slightly above 410 parts per million (ppm) in 2018. Nevertheless, growth stimulation by eCO_2 may be limited by progressive scarcity of nutrients, in particular nitrogen. To summarize, at the same time with increase in CO_2 and nitrogen deposition, forest ecosystems will face challenges in the next few decades as plants will need to cope with warmer temperature, higher evaporative demand and as well as increases in frequency and severity of extreme droughts. Adaptation to these abrupt new conditions represents the main future challenge for the forest ecosystems, however, it is very hard to predict how the forest will respond to these simultaneous changes.

METHODOLOGY

The experiment was carried out inside two glass domes in the Bílý Kříž experimental ecological station situated in the Moravian-Silesian Beskydy Mountains (49°30'77" N, 18°32'28" E, 908 m a.s.l.). A total of 144 two-years-old sessile oak trees per glass dome were planted in 2017 following specific fertilization experimental design (Fig. 1). Each glass dome was split into twelve blocks: six blocks were not fertilized (control) and six blocks were enriched with N (fertilization). At the end of vegetation season 2019, we pulled out all young sessile oak trees to compare their biometric characteristics. For determination of oven-dry wood density, 5-8 cm long of wood segments from 10 cm above the ground/base from all trees - were taken. The biomass of segments was weighted with a digital scale, while volume was measured using the water displacement method according to Archimedes' principle. Subsequently, the sample oven-dry wood density (WD, g cm^{-3}) was calculated based on the wood sample oven-dry mass divided by volume. Immediately after tree harvesting, microcores with a thickness of 1.8 mm were collected from the base of a stem using Trephor increment borer. Two to three sectors of an outermost ring formed in 2019 (third year of CO_2 enrichment experiment) from each cross-section were obtained for the width of the growth ring (RW) and vessel characteristic measurements.

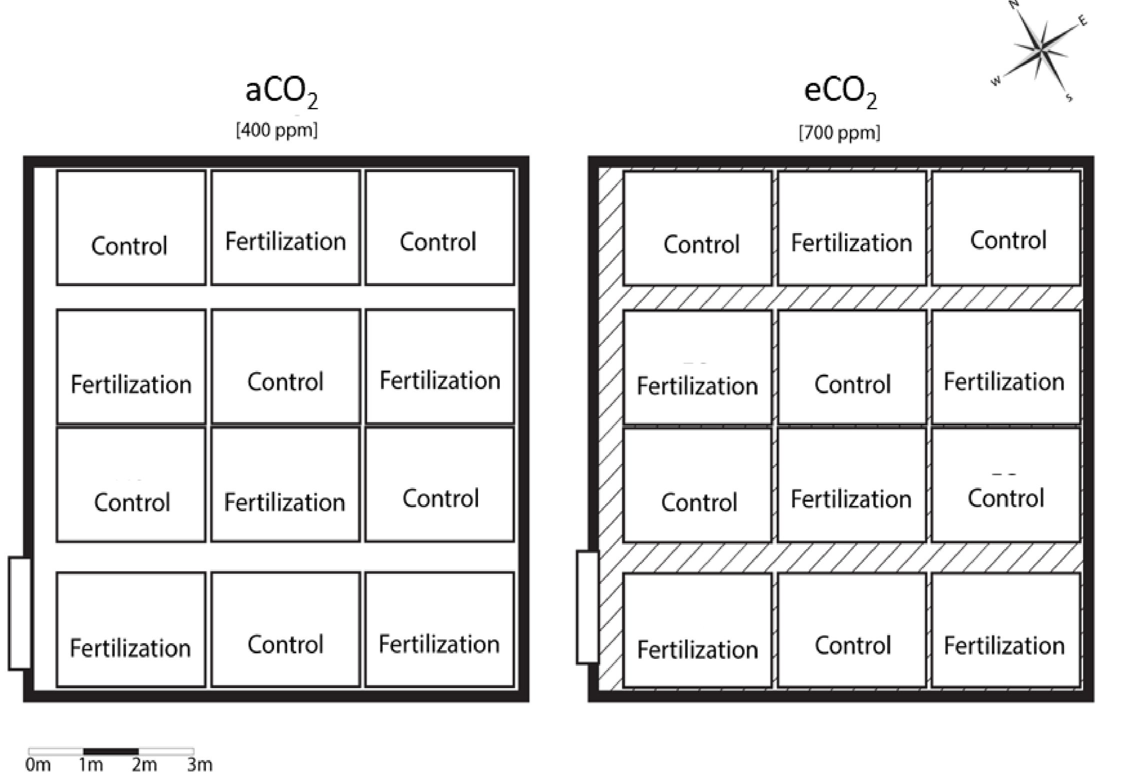

Figure 1: Experimental design scheme.
aCO_2 - ambient CO_2 concentration, eCO_2 - elevated CO_2 concentration, Control - plots without N fertilization, Fertilization - plots with N fertilization.

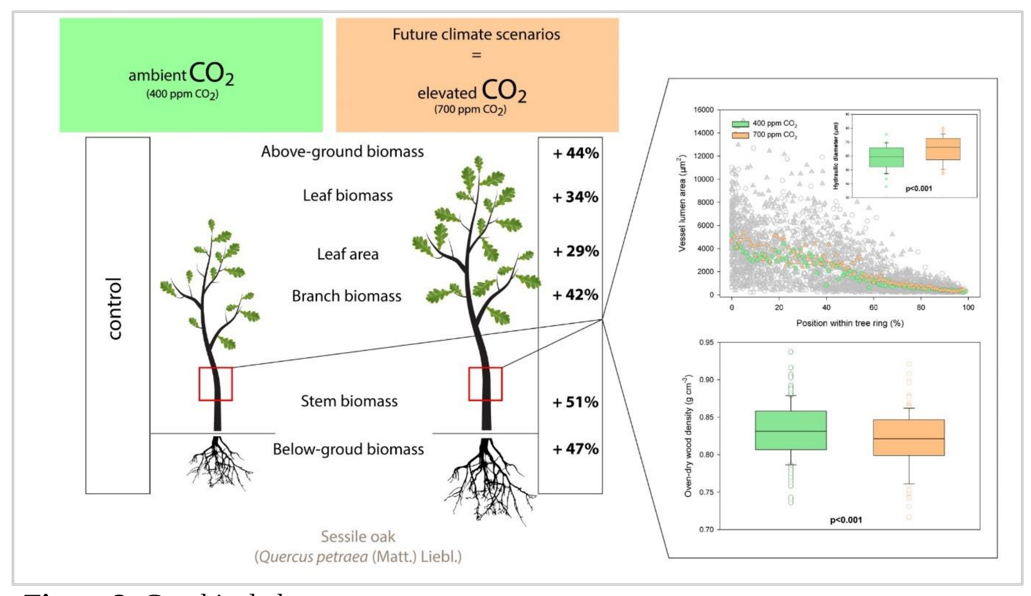

Figure 2: Graphical abstract

RESULTS

All investigated above-ground morphological parameters showed to be highly significantly ($p \leq 0.005$; Fig. 2 and 3) affected by (elevated CO_2) eCO_2 concentration, whereas nutrient supply had no statistically significant effect. The eCO_2 concentration had a highly positive effect on below-ground biomass (Fig. 2 and 4). The eCO_2 concentration had a positive effect on the total biomass of young sessile oak trees, the observed increase was, for above-ground biomass +44 % (Fig. 2 and 3), and respectively for below-ground biomass + 47 % (Fig. 2 and 4). All wood anatomical parameters except (total vessel area) TVA, (the proportion of the total vessel lumen area per analyzed sector) PTVA, and (potential specific hydraulic conductivity) K_s showed significant changes under eCO_2 while nutrient supply and combination $[CO_2] \times$ nutrient supply had no influence (Fig. 5). In young sessile oak trees, the (vessel lumen area) VLA was significantly larger under eCO_2 concentration, whereas (vessel density) VD was significantly lower (Fig. 5.) All traits related to hydraulic conductivity tended to increase under eCO_2 (Fig. 5). Overall, trees growing under eCO_2 had significantly lower densities -1.7 %, (Fig. 6), however, no effect of nutrient supply or combination of $[CO_2] \times$ fertilization was observed.

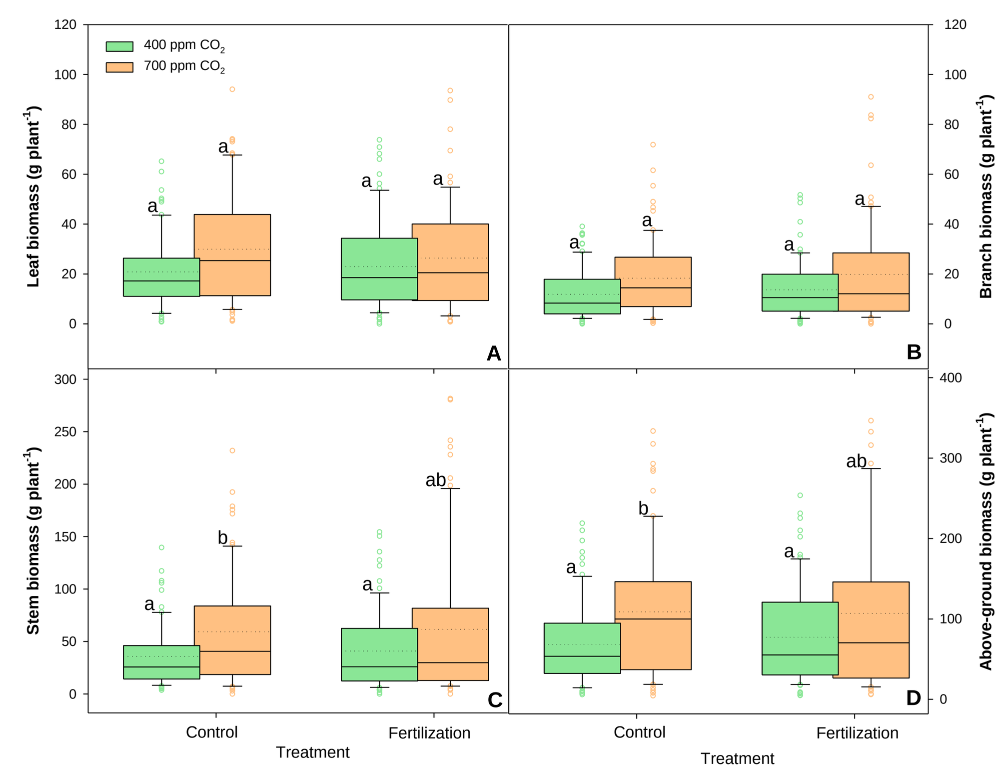

Figure 3: Changes in leaf biomass (**A**), branch biomass (**B**), stem biomass (**C**), and above-ground biomass (**D**) of (*Quercus petraea* (Matt.) Liebl.) trees treated under ambient (400 ppm CO_2) and elevated (700 ppm CO_2) and different nutrient supplies.

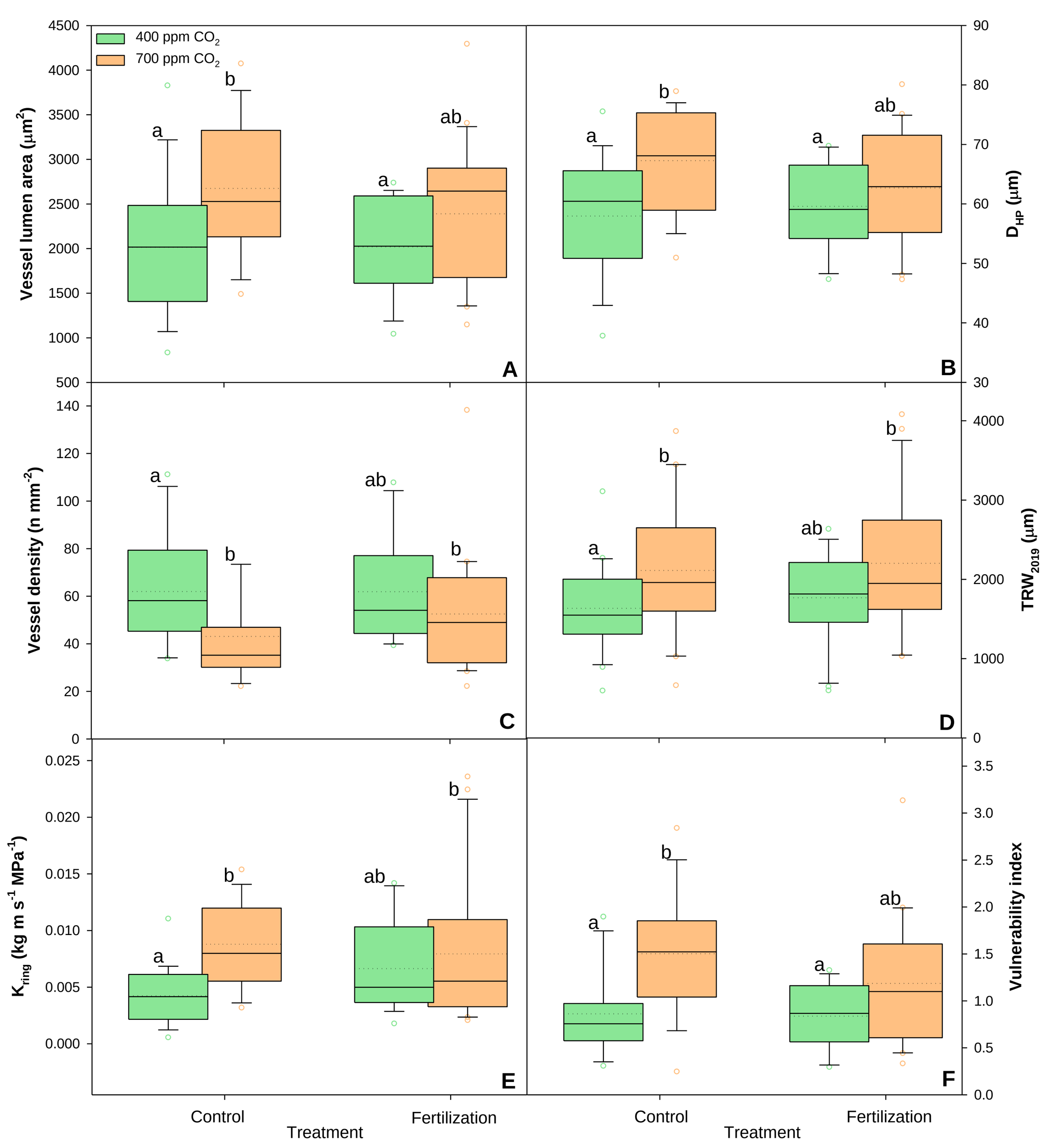

Figure 5: Changes in vessel lumen area (**A**), D_{hp} (**B**), vessel density (**C**), TRW_{2019} (**D**), K_{ring} (**E**), and Vulnerability index (**F**) of (*Quercus petraea* (Matt.) Liebl.) trees treated under ambient (400 ppm CO_2) and elevated (700 ppm CO_2) and different nutrient supplies. The data are expressed as medians (solid lines) and means (dotted lines) of measurements. The box boundaries mark the 25[th] and 75[th] percentiles and whiskers the 10[th] and 90[th] percentiles. Circles mark outliners. Different letters indicate significant differences ($p \leq 0.05$) estimated on the base of Duncan's ANOVA post-hoc test.

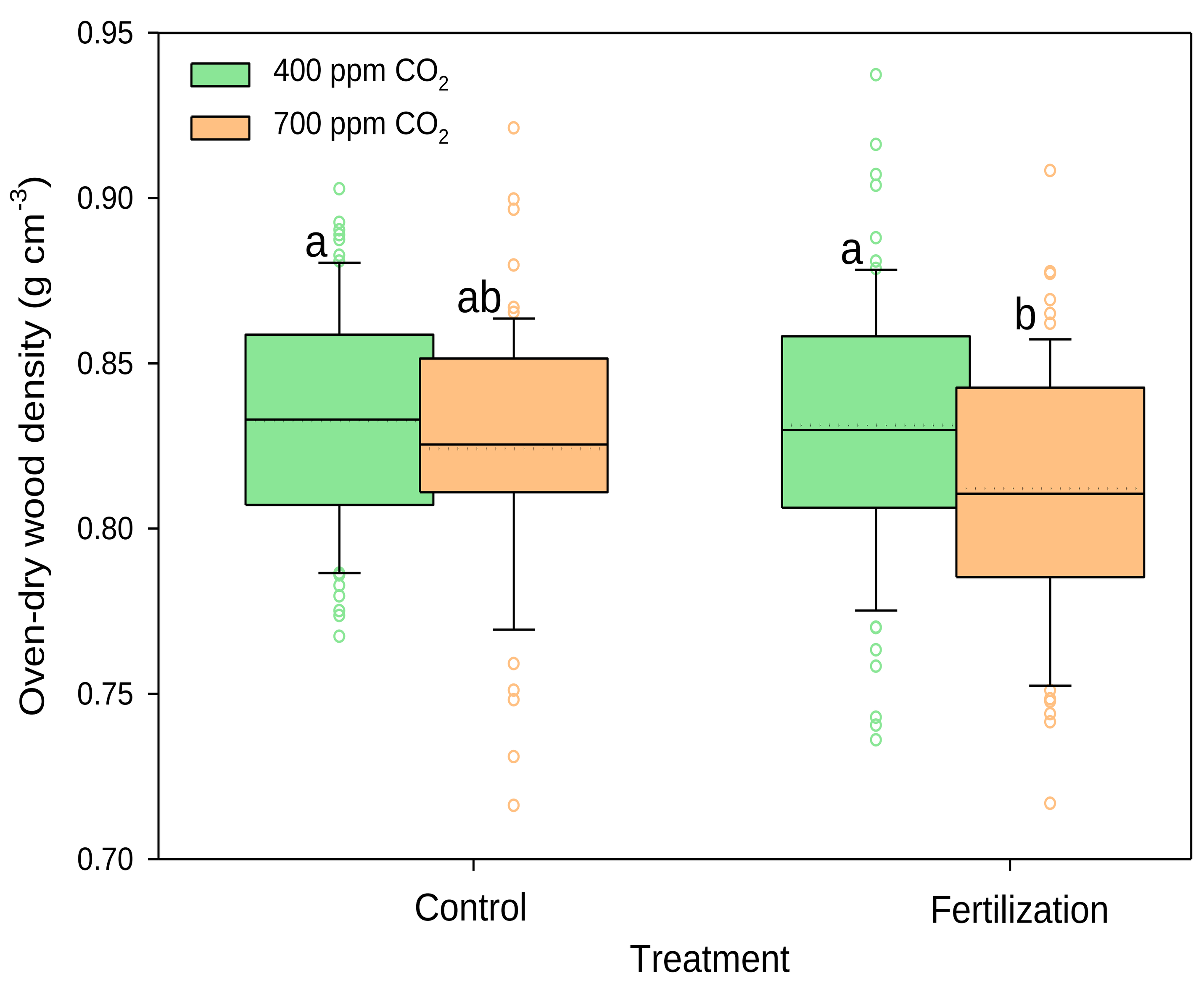

Figure 6: Changes in over-dry wood density of (*Quercus petraea* (Matt.) Liebl.) trees treated under ambient (400 ppm CO_2) and elevated (700 ppm CO_2) and different nutrient supplies. The data are expressed as medians (solid lines) and means (dotted lines) of measurements. The box boundaries mark the 25[th] and 75[th] percentiles and whiskers the 10[th] and 90[th] percentiles. Circles mark outliners. Different letters indicate significant differences ($p \leq 0.05$) estimated on the base of Duncan's ANOVA post-hoc test.

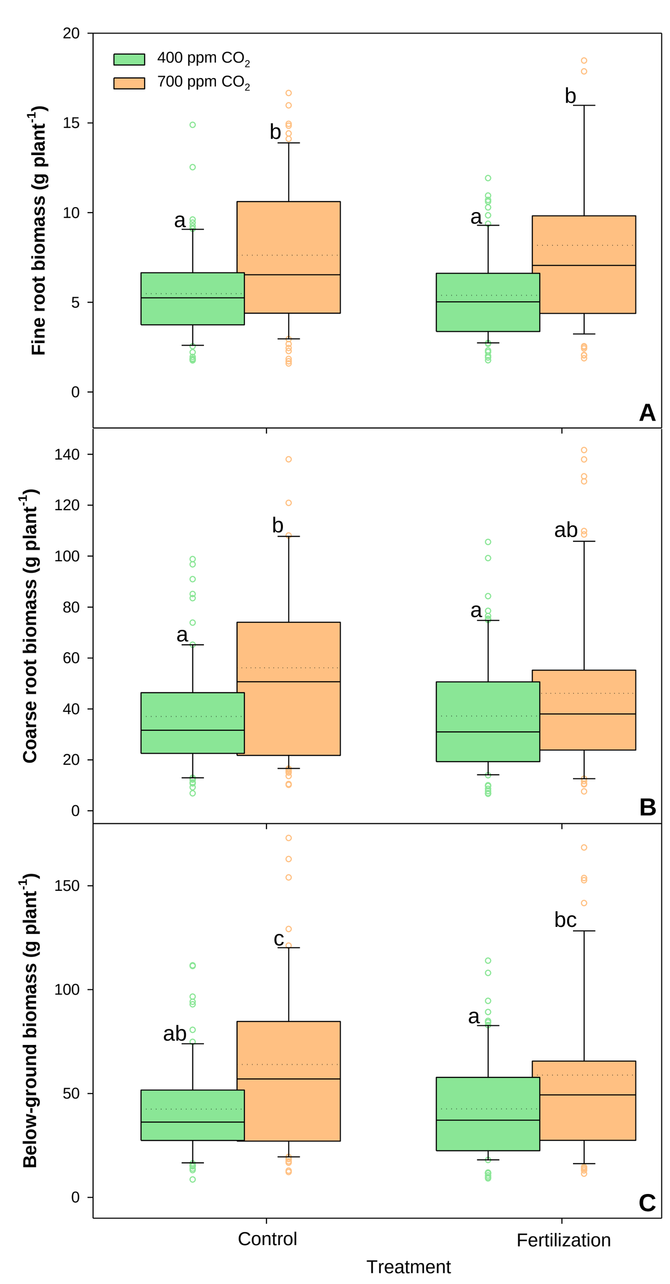

Figure 4: Changes in fine roots biomass (**A**), coarse roots biomass (**B**), and below-ground biomass (**C**) of (*Quercus petraea* (Matt.) Liebl.) trees treated under ambient (400 ppm CO_2) and elevated (700 ppm CO_2) and different nutrient supplies. The data are expressed as medians (solid lines) and means (dotted lines) of measurements.

CONCLUSIONS

Our research found that higher biomass production of young sessile oak trees under eCO_2 was supported by more efficient xylem hydraulic system. Nonetheless, the trade-off between the hydraulic efficiency and safety suggests that xylem consisted of larger vessels might be less resistant to embolism during severe droughts. However, larger absorptive area of root system indicated by higher biomass, both fine and coarse roots found in this study (Fig. 2 and 3), might be able to compensate aforesaid xylem susceptibility and increase resistance of young sessile oak trees to drought. This study also reported a significant effect of eCO_2 on (wood density) WD (Fig. 5), which is well related to many wood quality properties. Low WD generally means lower stiffens and therefore higher susceptibility of tree damage by different abiotic factors. It should be emphasised that our study focused on juvenile wood, however, reasonably good correlations between quality of juvenile and mature wood has been reported by different authors, thus the wood of young trees may indicate the wood quality in mature trees. In spite of the increase of biomass production at eCO_2 in this economically and ecologically important tree species in Europe, mechanical strength indicated by lower density and more vulnerable xylem to drought may lead to earlier mortality offsetting the positive effect of future eCO_2.

ACKNOWLEDGEMENTS

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