Role of Plants in Climate Change-CO_2 Enrichment

Title	**Effects of Elevated Atmospheric CO_2 on Respiratory Rates in Mature Leaves of Two Rice Cultivars Grown at a Free-Air CO_2 Enrichment Site and Analyses of the Underlying Mechanisms**
Author Name	Ko Noguchi, Tomonori Tsunoda, Atsuko Miyagi, Maki Kawai-Yamada, Daisuke Sugiura, Shin-Ichi Miyazawa, Takeshi Tokida, Yasuhiro Usui, Hirofumi Nakamura, Hidemitsu Sakai & Toshihiro Hasegawa
Journal Name	Plant and Cell Physiology
Year	2018
Volume and Issue	59, 3
Pages	637–649
Abstracts	Respiratory CO_2 efflux and O_2 uptake rates in leaves change in response to the growth CO_2 concentration ($[CO_2]$). The degrees of change vary depending on the responses of cellular processes such as nitrogen (N) assimilation and accumulation of organic acids to growth $[CO_2]$. However, the underlying mechanisms remain unclear. Here, we examined the respiratory characteristics of mature leaves of two rice varieties with different yield capacities at different growth stages under ambient and elevated $[CO_2]$ conditions at a free-air CO_2 enrichment site. We also examined the effect of increased water temperature on leaf respiration. We measured the rates of CO_2 efflux and O_2 uptake, and determined N contents, primary metabolite contents and maximal activities of respiratory enzymes. The leaf CO_2 efflux rates decreased in plants grown at elevated $[CO_2]$ in both varieties, and were higher in high-yielding Takanari than in Koshihikari. The leaf O_2 uptake rates showed little change with respect to growth $[CO_2]$ and variety. The increased water temperature did not significantly affect the CO_2 efflux and O_2 uptake rates. The N and amino acid contents were significantly higher in Takanari than in Koshihikari. The enhanced N assimilation in Takanari may have consumed more respiratory NADH, leading to higher CO_2 efflux rates. In Koshihikari, the ratio of tricarboxylic acid (TCA) cycle intermediates changed and maximal activities of enzymes in the TCA cycle decreased at elevated $[CO_2]$. Therefore, the decreased rates of CO_2 efflux in Koshihikari may be due to the decreased activities of TCA cycle enzymes at elevated $[CO_2]$.
Keywords	CO_2 concentration; nitrogen (N) assimilation; CO_2 enrichment; CO_2 efflux; tricarboxylic acid (TCA) cycle; enzymes.

Title	**Elevated CO_2 compensates for drought effects in lemon saplings via stomatal down regulation, increased soil moisture, and increased wood carbon storage**
Author Name	Environmental and Experimental Botany
Journal Name	Indira Paudel, Moshe Halpern, Yael Wagner, Eran Raveh, Uri Yermiyahu, Guenter Hoch & Tamir Klein
Year	2018
Volume and Issue	148
Pages	117-127
Abstracts	Tree growth enhancement under elevated [CO_2] is much smaller than originally anticipated; yet carbon overabundance can lead to increased wood carbon storage and to stomatal down regulation and hence reduced water-use. Notably, all three outcomes increase tree drought resistance. Here we studied growth, water relations, and non structural carbohydrates of 60 lemon saplings growing in CO_2-controlled rooms at the same greenhouse, under 400, 650, and 850 ppm [CO_2]. At each [CO_2] level, 10 saplings were exposed to 1-month dry-down after 2 months of standard irrigation, followed by re-watering for another month. The other 10 saplings served as controls. Under drought, tree growth was maintained at elevated, but not ambient, CO_2, linked with mild vs. severe tree water stress (leaf water potential of −3.5 at elevated and −5.5 MPa at ambient [CO_2]). Stomatal down regulation with increasing [CO_2] meant that leaf transpiration and diurnal plant water-use were 13–46% lower at elevated vs. ambient [CO_2] but photosynthesis was still 15–25% higher. CO_2-induced increases in root and shoot starch were transient but significant. Our results suggest that when predicting tree growth in a warmer and drier future, concomitant atmospheric CO_2 concentration must be considered. In young lemon trees, elevated CO_2 partially compensated for drought effects on tree growth and water status, and might delay some of the effects of the anthropogenic climate change.
Keywords	CO_2; Storage carbohydrates; Drought resistance; Stomatal adjustment

Title	**Interactive Effects of Elevated CO_2 and N Fertilization on Yield and Quality of Tomato Grown Under Reduced Irrigation Regimes**
Author Name	Zhenhua Wei, Taisheng Du, Xiangnan Li, Liang Fang & Fulai Liu
Journal Name	Front. Plant Sci.
Year	2018
Abstracts	The interactive effects of CO_2 elevation, N fertilization, and reduced irrigation regimes on fruit yield (FY) and quality in tomato (Solanumlycopersicum L.) were investigated in a split-root pot experiment. The plants were grown in two separate climate-controlled greenhouse cells at atmospheric [CO_2] of 400 and 800 ppm, respectively. In each cell, the plants were fertilized at either 100 or 200 mg N kg−1 soil and were either irrigated to full water holding capacity [i.e., a volumetric soil water content of 18%; full irrigation (FI)], or using 70% water of FI to the whole pot [deficit irrigation (DI)] or alternately to only half of the pot [partial root-zone irrigation (PRI)]. The yield and fruit quality attributes mainly from sugars (sucrose, fructose, and glucose) and organic acids (OAs;citricacidandmalicacid)tovariousionic(NH4+,K+,Mg2+,Ca2+,NO 3−,SO42−, and PO43−) concentrations in fruit juice were determined. The results indicated that lower N supply reduced fruit number and yield, whereas it enhanced some of the quality attributes of fruit as indicated by greater firmness and higher concentrations of sugars and OAs. Elevated [CO_2] (e[CO_2]) attenuated the negative influence of reduced irrigation (DI and PRI) on FY. Principal component analysis revealed that the reduced irrigation regimes, especially PRI, in combination with e[CO_2] could synergistically improve the comprehensive quality of tomato fruits at high N supply. These findings provide useful knowledge for sustaining tomato FY and quality in a future drier and CO_2-enriched environment.
Keywords	CO_2 elevation; fruit yield (FY); split-root pot experiment; deficit irrigation (DI); partial root-zone irrigation (PRI)

Title	**Effect of elevated atmospheric CO_2 concentration on growth and leaf litter decomposition of Quercus acutissimaand Fraxinus rhynchophylla**
Author Name	Sangsub Cha, Hee-Myung Chae, Sang-Hoon Lee & Jae-Kuk Shim
Journal Name	PLoS ONE
Year	2017
Volume and Issue	12(2)
Pages	171-197
Abstracts	The atmospheric carbon dioxide (CO_2) level is expected to increase substantially, which may change the global climate and carbon dynamics in ecosystems. We examined the effects of an elevated atmospheric CO_2 level on the growth of *Quercus acutissima* and *Fraxinus rhynchophylla* seedlings. We investigated changes in the chemical composition of leaf litter, as well as litter decomposition. *Q. acutissima* and *F.* rhynchophylla did not show differences in dry weight between ambient CO_2 and enriched CO_2 treatments, but they exhibited different patterns of carbon allocation, namely, lower shoot/root ratio (S/R) and decreased specific leaf area (SLA) under CO_2-enriched conditions. The elevated CO_2 concentration significantly reduced the nitrogen concentration in leaf litter while increasing lignin concentrations and carbon/nitrogen (C/N) and lignin/N ratios. The microbial biomass associated with decomposing *Q. acutissima* leaf litter was suppressed in CO_2 enrichment chambers, while that of F. *rhynchophylla* was not. The leaf litter of *Q. acutissima* from the CO_2-enriched chambers, in contrast with F. *rhynchophylla*, contained much lower nutrient concentrations than that of the litter in the ambient air chambers. Consequently, poorer litter quality suppressed decomposition.
Keywords	global climate; carbon dynamics; elevated atmospheric CO_2 level; lignin concentrations; microbial biomass; ambient air chambers

Title	**Effects of CO_2 Enrichment and Drought on Photosynthesis, Growth and Yield of an Old and a Modern Barley Cultivar**
Author Name	I. Schmid, J. Franzaring, M. Müller, N. Brohon, O. C. Calvo, P. Högy, A. Fangmeier
Journal Name	Journal of agronomy and plant science
Year	2016
Volume and Issue	202, 2
Pages	81–95
Abstracts	Susceptibility of crops to drought may change under atmospheric CO_2 enrichment. We tested the effects of CO_2 enrichment and drought on the older malting barley cultivar Golden Promise (GP) and the recent variety Bambina (BA). Hypothesizing that CO_2 enrichment mitigates the adverse effects of drought and that GP shows a stronger response to CO_2 enrichment than BA, plants of both cultivars were grown in climate chambers. Optimal and reduced watering levels and two CO_2 concentrations (380 and 550 ppm) were used to investigate photosynthetic parameters, growth and yield. In contrast to expectations, CO_2 increased total plant biomass by 34 % in the modern cultivar while the growth stimulation was not significant in GP. As a reaction to drought, BA showed reduced biomass under elevated CO_2, which was not seen in GP. Grain yield and harvest index (HI) were negatively influenced by drought and increased by CO2 enrichment. BA formed higher grain yield and had higher water-use efficiency of grain yield and HI compared to GP. CO_2 fertilization compensated for the negative effect of drought on grain yield and HI, especially in GP. Stomatal conductance proved to be the gas exchange parameter most sensitive to drought. Photosynthetic rate of BA showed more pronounced reaction to drought compared to GP. Overall, BA turned out to respond more intense to changes in water supply and CO_2 enrichment than the older GP.
Keywords	Susceptibility; malting; hypothesizes.

Title	**Free-air CO_2 enrichment (FACE) reduces the inhibitory effect of soil nitrate on N2 fixation of Pisum sativum**
Author Name	Clayton R. Butterly, Roger Armstrong, Deli Chen and Caixian Tang1
Journal Name	Annals of Botany
Year	2016
Volume and Issue	117, 1
Pages	177-185
Abstracts	Background and Aims Additional carbohydrate supply resulting from enhanced photosynthesis under predicted future elevated CO_2 is likely to increase symbiotic nitrogen (N) fixation in legumes. This study examined the interactive effects of atmospheric CO_2 and nitrate (NO_3 –) concentration on the growth, nodulation and N fixation of field pea (Pisum sativum) in a semi-arid cropping system. Methods Field pea was grown for 15 weeks in a Vertosol containing 5, 25, 50 or 90 mg NO3 – -N kg^{-1} under either ambient CO_2 (aCO_2; 390 ppm) or elevated CO_2 (eCO_2; 550 ppm) using free-air CO_2 enrichment (SoilFACE). Key Results Under aCO_2, field pea biomass was significantly lower at 5 mg NO_3 – -N kg^{-1} than at 90 mg NO_3 – -N kg^{-1} soil. However, increasing the soil N level significantly reduced nodulation of lateral roots but not the primary root, and nodules were significantly smaller, with 85 % less nodule mass in the 90 NO_3 – -N kg^{-1} than in the 5 mg NO_3 – -N kg^{-1} treatment, highlighting the inhibitory effects of NO_3 – . Field pea grown under eCO_2 had greater biomass (approx. 30 %) than those grown under aCO_2, and was not affected by N level. Overall, the inhibitory effects of NO_3 – on nodulation and nodule mass appeared to be reduced under eCO_2 compared with aCO_2, although the effects of CO_2 on root growth were not significant. Conclusions Elevated CO_2 alleviated the inhibitory effect of soil NO_3 – on nodulation and N_2 fixation and is likely to lead to greater total N content of field pea growing under future elevated CO_2 environments.
Keywords	Nitrogen fixation; nitrate, carbon cycling; nitrogen cycling; free-air CO_2 enrichment; FACE; high atmospheric CO_2; 15N; Pisum sativum; climate change.

Title	**Effect of CO_2 enrichment and increased nitrogen supply on the induction of sunflower (Helianthus annuus L.) primary leaf senescence**
Author Name	F.J. Canales, P. de la Haba, E. Barrientos, E. Agüera
Journal Name	Canadian Journal of Plant Science
Year	2016
Volume and Issue	96 (6)
Pages	1002-1013
Abstracts	A study was made of the effect of atmospheric CO_2 enrichment and increased nitrogen availability on primary leaf senescence in sunflower (*Helianthus annuus L.*). First, markers normally used for monitoring leaf development (dry weight, leaf surface area, protein content, photosynthetic pigment levels, CO_2 fixation rate, changes in the enzymes involved in nitrogen metabolism, and plant-tissue oxidative status) were measured in plants grown for 42 days under ambient (400 µL L−1) or enriched CO_2 conditions (800 µL L−1), and with two different levels of nitrate supply (10 mM and 25 mM). Second, two-dimensional electrophoresis (2-DE) was used to compare primary-leaf protein profiles (16 and 42 days) in sunflowers grown under ambient or enriched CO_2 conditions with elevated nitrate supply. Plants grown under enriched CO_2 conditions and with high nitrogen supply displayed faster growth, a higher CO_2 fixation rate, and increased activity by antioxidative and nitrogen-metabolism- related enzymes than those grown under elevated CO_2 with low nitrogen supply. These findings indicate that CO_2 enrichment and increased nitrate availability slow down the induction of senescence, suggesting that senescence may be directly related to leaf C/N ratio. These results enhance our understanding of the sunflower's response to increased atmospheric CO_2 levels, one of the environmental factors favoring climate change.
Keywords	Development; growthparameters; Helianthusannuus L.,photosynthesis; proteins