

Supplementary material

Physiological and molecular responses of woody plants exposed to future atmospheric CO₂ levels under abiotic stresses

Number of Tables: 1

Table S1. Overview of studies with woody species exposed to elevated [CO₂] alone or combined with abiotic stresses.

*Studies involving molecular approaches. Description of the abbreviations present in the table: **WUE**: Water use efficiency; **gs**: stomatal conductance; **E**: transpiration rate; **Chl**: Chlorophyll; **ABA**: Absciscic acid; **iWUE**: Intrinsic water use efficiency; **PS**: Photosystem; **GLO**: Glycolate oxidase; **PPP**: Pentose phosphate pathway

Species	e[CO ₂]	Interaction with other abiotic stress	Main effect of e[CO ₂] sole or combined with abiotic stress	Reference
<i>Acacia karroo</i> and <i>Acacia nilotica</i>	180 - 1000 (1 year, OTC)	No	↑ Photosynthesis, WUE, and overall biomass ↓ gs Light photosynthesis acclimation in the second season	[22]
<i>Alnus hirsuta</i>	360 x 720 (>1 year, GC)	Phosphorus and drought	↑ Nodule biomass and N ₂ fixation under high P availability	[137]
<i>Anacardium occidentale</i>	380 x 760 (15 days, GC)	Salt	↓ Photosynthesis without affecting gs and E ↓ Photosynthesis, gs, E, GLO activity and the contents of H ₂ O ₂ , NH ₄ ⁺ , and glyoxylate under salinity ↑ NPQ, K ⁺ /Na ⁺ ratio, and the content of anthocyanin, sucrose, amino acid and total soluble proteins under salinity	[126]
Angiosperm and gymnosperm tree species (57)	340-980	No	↓ gs according to the evolutionary scale (evergreen gymnosperms < deciduous angiosperms < evergreen angiosperms)	[20]
<i>Aulonemia aristulata</i>	380 x 760 (3 weeks, OTC)	No	↑ Photosynthesis, WUE, and overall biomass ↓ gs	[58]
<i>Betula papyrifera</i>	380 x 550 (Long-term, FACE)	O ₃	↑ Photosynthesis, specialized compounds, expression of glycolysis-related genes and farnesyl-PP and phytyl-PP ↓ Expression of pre-squalene and squalene synthesis genes, and leaf senescence	[135]
<i>Betula papyrifera</i> and <i>Populus tremuloides</i>	380 x 560 (Long-term, FACE)	O ₃	↑ Photosynthesis, monosaccharides ↓ gs, leaf senescence	[136]
<i>Betula pendula</i>	380 x 760 (~ 1 year, OTC)	O ₃	↓ Oxidative stress and senescence-related gene expression and proteins.	[135]*
<i>Betula pendula</i>	360 x 720 (3 years, OTC)	O ₃	↑ Photosynthesis, leaf dry weight, leaf area ↓ Photosynthetic protein content, Chl and PS density	[59]
<i>Betula pendula</i>	360 x 720 (3 years, OTC)	O ₃	↑ Photosynthesis, starch, leaf area, stem diameter, biomass, and C/N ratio ↓ Total leaf N, Rubisco amount and activity, and leaf senescence	[60,134]
Betulaceae species	370 x 500 (2 years, FACE)	Soil nutrition	↓ Photosynthesis by lower C/N ratio	[56]
<i>Coffea arabica</i>	400 x 700 (7 months, OTC)	Drought	↑ Photosynthesis, WUE, respiration, overall biomass, and root length ↓ Photorespiration rates and oxidative pressure	[49]
<i>Coffea arabica</i>	400 x 700 (5 months, OTC)	Drought	↑ Faster stomatal closure, water potential, plant hydraulic conductance, aquaporin gene expression	[112]

			↓ Whole plant transpiration No association with g_s or leaf ABA levels	
<i>Coffea arabica</i>	390 x 600 (4 years, FACE)	No	↑ Photosynthesis, g_s , WUE, growth, and soil carbon concentration ↓ Leaf area, diameter of the second-order axes	[25]
<i>Coffea arabica</i>	400 x 550 (4 years, FACE)	Seasonal drought	↑ Photosynthesis in summer and winter, and the concentration of soluble carbohydrates, organic acids, and amino acids in leaves	[68]
<i>Coffea arabica</i>	400 x 760 (44 days, OTC)	Drought	↑ Photosynthesis, WUE, leaf water potential and carbohydrate concentration	[111]
<i>Coffea arabica</i>	400 x 800 (40 days, OTC)	Drought	↑ Photosynthesis, iWUE, leaf concentration of 5-O-caffeoylquinic acid and caffeine	[113]
<i>Coffea arabica</i>	390 x 550 (~2 years, FACE)	No	↑ Photosynthesis ↓ Photorespiration No changes in stomatal and mesophyll conductance, leaf nitrogen and phosphorus concentrations	[24]
<i>Coffea arabica</i>	380 x 700 (4.4 years, GC)	Heat	↓ Impact on physical and chemical traits of coffee beans Preserved bean quality	[100]
<i>Coffea arabica</i> and <i>Coffea canephora</i>	380 x 700 (1 year; GC)	No	↑ Photosynthesis, WUE, stomatal size, photosynthetic and respiratory proteins ↓ Stomatal density No changes in PSII efficiency, non-structural carbohydrates, photosynthetic pigment and membrane permeability	[40]
<i>Coffea arabica</i> and <i>Coffea canephora</i>	380 x 700 (7 years, GC)	Drought	↑ Photosynthesis, photosynthetic proteins ↓ Energy dissipation and PSII impact No correlation with stomatal closure and leaf ABA level	[114]
<i>Coffea arabica</i> and <i>Coffea canephora</i>	380 x 700 (7 years, GC)	Drought	↑ Leaf amino acid concentration in <i>C. arabica</i> Little effect in leaf metabolite levels in <i>C. canephora</i>	[115]*
<i>Coffea arabica</i> and <i>Coffea canephora</i>	380 x 700 (10 months, GC)	Heat	No clear pattern between transcriptomic data and the mitigating role of $e[CO_2]$ suggesting post-transcriptional modifications	[99]*
<i>Coffea arabica</i> and <i>Coffea canephora</i>	380 x 700 (10 months, GC)	Heat	↑ Gene expression and activity of glutathione reductase, catalase, Cu- and Zn-superoxide dismutase, ascorbate peroxidase and gene expression of HSP70, ELIPs, and chaperonins ↓ Reactive oxygen species and PSII photoinhibition	[98]
<i>Coffea arabica</i> and <i>Coffea canephora</i>	380 x 700 (10 months, GC)	Heat	↑ Photosynthesis (photochemical efficiency, energy use and biochemical functioning) and WUE.	[96]
Deciduous trees	FACE	No	↑ Leaf area index, WUE ↓ Photosynthesis (except in alder), light compensation point, g_s of most species	[41]
Ecosystem-scale relationship	FACE	No	↑ Plant productivity and N acquisition positive correlation ↓ Plant N concentration regardless of productivity	[53]
Eucalyptus forest	400 x 550 (5 years, FACE)	No	↑ N/P ratio in sapwood ↓ N concentration and N/P ratio in young leaf No changes in P concentraation	[51]
<i>Eucalyptus saligna</i>	380 x 680 (5 months, GC)	Seasonal drought	↑ Leaf day respiration No changes in seasonal acclimation	[65]
<i>Eucalyptus saligna</i> and <i>Eucalyptus sideroxylon</i>	290 x 400 x 650 (~4 months, GC)	Drought and temperature	Contrasting photosynthetic response between genotypes under drought No beneficial effect under elevated temperature and drought	[19]
Eucalyptus species	290 x 400 x 650 (~4 months, GC)	Heat	↑ Photosynthesis, maximal electron transport rate and carboxylation rate, and growth	[93,97]
<i>Eucalyptus tereticornis</i>	400 x 640 (4 months, GC)	Heat x Phosphorus	↑ Total dry biomass, leaf number, leaf area under high P supply	[138]
Forest species	long-term field-based studies	Review	↓ g_s mostly in young, deciduous and water-stressed trees No acclimation of g_s	[35]
<i>Liquidambar styraciflua</i>	Long-term FACE	Seasonal drought	↓ Sap flow, g_s , leaf senescence	[108]
<i>Liquidambar styraciflua</i>	370 x 570 (2 years; FACE)	No	↑ Number of mitochondria, mass per area, and starch in leaves No changes in leaf respiration	[66]
Mature forest	ambient x +150 ppm (FACE)	No	↑ C uptake through gross primary production and soil respiration	[70]

<i>Morus multicaulis</i> Perr.	410/460 x 710/760 ppm (4 months, GC)	No	↑ Plant height, stem diameter, number of leaves, biomass production, and P and K uptake ↓ Photosynthesis, gs, transpiration and concentration of chlorophyll, and N and P in leaves and roots	[52]
<i>Olea europaea</i>	360 x 700 (3 months, GC)	Salt	↑ Photosynthesis, and WUE ↓ NaCl content in plant tissue, PSII efficiency and chlorophyll	[125]
(<i>Populus tomentosa</i> x <i>P. bolleana</i>) x <i>P. tomentosa</i>	385x550x720 (3 months; GC)	No	↑ Stem diameter, gibberellic acid, cytokinin zeatin riboside ↓ Photosynthesis, abscisic acid DEGs in leaves were involved in metabolic processes (77.55%) and response to stimulus of external environment (14.29%). Aldehyde dehydrogenase and pyruvate kinase were the core interconnected with other genes.	[76]*
<i>Pinus densiflora</i>	350 x 700 (73 days; GC)	Phosphorus	↑ P requirement, and shoot growth No changes in photosynthesis and stomatal conductance	[37]
<i>Pinus halepensis</i>	421 x 867 (18 months, GC)	Heat and drought	↑ Photosynthesis, WUE, root protein stability ↓ Respiration Little effect in combined stress	[110]*
<i>Pinus massoniana</i>	400 x 800 (0 to 24 h, GC)	No	↑ Expression of glycolysis, carboxylic acid cycle, PPP pathway, sucrose synthesis, gibberellin, salicylic acid, brassinolide and methyl jasmonate pathways related genes ↓ Expression of photosynthetic, and abscisic acid-related genes	[67]*
<i>Pinus radiata</i>	370 x 650 (3 years, OTC)	Nitrogen	↑ Stem basal area in high-N supply, and sapwood density No changes in N status and lignification	[77]
<i>Pinus sylvestris</i>	380 x 580 (5 months, OTC)	Heat and nitrogen	↑ Radial growth, latewood density and maximum intra-ring density, thicker (alone) or thinner (+heat) tracheid walls ↓ Cellulose concentration, number of tracheids	[78]
<i>Pinus sylvestris</i> and <i>Pinus nigra</i>	390 x 570 (4 months, FACE)	Drought	No changes in starch concentrations, biomass production and mortality	[109]
<i>Pinus taeda</i>	380 x 600 (4 months; FACE)	Seasonal drought	↑ Photosynthesis under eCO ₂ , except at peak drought No changes in water-saving and gs	[36]
<i>Populus</i>	380 x 550 (2 years, FACE)	No	↑ Photosynthesis ↓ Leaf senescence, leaf area index, and chlorophyll content	[73]
<i>Populus</i> × <i>euramericana</i>	380 x 550 (6 years, FACE)	No	↑ DEGs in young leaves (developmental response related – xyloglucan endotransglycosylase and calcium-signalling) ↓ DEGs in semimature leaves (Photosynthesis, chloroplast biogenesis- and function-related)	[61]*
<i>Populus deltoides</i>	400 x 800 x 1200 (3 years; FACE)	No	↑ Leaf area, stem biomass, expression of genes involved with storage proteins, cell wall expansion in leaves and lignin formation and polymerisation or ethylene response factors in stems.	[74]*
<i>Populus deltoides</i>	400 x 800 (3 years, GC)	Drought and VPD	↑ Leaf area, leaf loss under drought, stomatal density ↓ Woody density	[107]
<i>Populus tremuloides</i>	372 x 560 (~3 months, FACE)	No	↑ Photosynthesis and stem volume, expression of genes related to active defense/response to stress, carbohydrate/starch biosynthesis and growth in the CO ₂ -responsive clone, and passive defense (e.g. lignin, phenylpropanoid) and cell wall thickening in the CO ₂ -unresponsive clone	[62]*
<i>Populus tremuloides</i>	360 x 560 (5 years; FACE)	O ₃	↑ Expression chloroplast 30S ribosomal, PSII, and auxin-binding related genes ↓ Expression of Rubisco activase genes	[72]*
<i>Populus tremuloides</i>	380 x 560 (~4 months, FACE)	O ₃	↓ Chlorophyll and carotenoid concentration, activity of antioxidant enzymes and PAL and expression of 1-aminocyclopropane-1-carboxylic acid (ACC)-oxidase transcript	[21]
<i>Populus</i> × <i>euramericana</i>	380 x 550 (2 years, FACE)	No	↑ Pathways for secondary metabolism (anthocyanin biosynthesis) and glycolysis during senescence, LDOX (leucoanthocyanidin dioxygenase) and DFR (dihydroflavonol reductase) related transcripts	[75]*
<i>Populus</i> × <i>euramericana</i>	370 x 550 (Long-term, FACE)	No	↑ Cell expansion and production, basipetal gradient of leaf development	[81]
(<i>Quercus mongolica</i> and <i>Kalopanax septemlobus</i>) (<i>Betula maximowicziana</i> and <i>Acer mono</i>)	370 x 500 (4 years, FACE)	No	↑ Plant height, photosynthesis and vessel area in <i>K. septemlobus</i> and vessels in all species, except <i>B. maximowicziana</i> and number of cambial cells in two ring-porous species	[57]

<i>Quercus rubra</i>	380 x 700 (4 months, GC)	Heat and drought	↑ Photosynthesis and biomass in heatwave	[139]
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