APGC Symposium

'Plant Functioning in a Changing Global Environment'

December 7-11, 2008

Department of Forest and Ecosystem Science
Melbourne School of Land and Environment
University of Melbourne
Water Street
Creswick, Victoria 3363
Australia

Organising Committee:

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David Tissue, University of Western Sydney, Richmond, Australia

Content:

APGC Symposium

'Plant Functioning in a Changing Global Environment'

P R O G R A M M E

The Organising Committee would like to dedicate this Symposium to the memory of

David F. Karnosky († 24 October 2008),

Professor of Forest Genetics and Biotechnology and Robbins Chair in Sustainable Management of the Environment, Director of the Ecosystem Science Center, School of Forest Resources and Environmental Sciences of Michigan Technological University, who passed away unexpectedly in October this year. His outstanding contributions to the field, such as his leadership of the unique Aspen-FACE project in Rhinelander, Wisconsin, or his research on the Central Park "Splendor" Chinese elm, to name but few, will continue to shape our understanding of climate change effects on forest ecosystems and are guaranteed to inspire future research.

Sunday, December 7, 2008

18:30 - 21:00 Registration, welcome and get-together party

Monday, December 8, 2008

08:45 - 09:00 Opening

Interaction between plant functioning and the atmosphere (I)
(Chair: Kenji Omasa, University of Tokyo & Michael Tausz, University of Melbourne)

09:00 - 09:30 Why and how plants exchange gases with air: a review - *Stanislaw Cieslik, Joint Research Centre, Ispra, Italy*
09:30 - 10:00 Negative versus positive functional plant responses to sulfurous air pollutants - *Luit J. De Kok, University of Groningen, The Netherlands*
10:00 - 10:30 Molecular aspects of air pollutant impacts on plants with emphasis on sulfur dioxide - *Ralf R. Mendel, Braunschweig University of Technology, Germany*

10:30 - 11:00 *Coffee break + Poster viewing*

Interaction between plant functioning and the atmosphere (II)
(Chair: Heinz Rennenberg, University of Freiburg & David Ellsworth, University of Western Sydney)

11:00 - 11:30 Air pollution problems in developing countries - increasing pollutants production in East Asia would be a great anxious influence on eco-environment in 21st century - *Hideyuki Shimizu, National Institute for Environmental Studies, Tsukuba, Japan*
11:30 - 12:00 Ozone, a dominant air pollutant, and its role in climate change - *Rainer Matyssek, Technical University of Munich, Germany*
12:00 - 12:30 Elevated O_3 and CO_2 and belowground processes - *Sirkku Manninen, University of Helsinki, Finland*

12:30 - 14:00 *Lunch break + Poster viewing*

Interaction between plant functioning and the atmosphere (III)
(Chair: Rainer Matyssek, University of Munich & Stefan Arndt, University of Melbourne)

14:00 - 14:15 Elevated CO_2 on yield and yield quality of wheat - evidence from three years of field studies involving FACE technology - *Petra Högy, University of Hohenheim, Germany*
14:15 - 14:30 Photosynthetic acclimation to elevated p[CO_2] of 100 Pa occurs during all stages of leaf development in rice (*Oryza sativa* L. cv. Notohikari) canopy - *Saman Seneweera, University of Melbourne, Australia*
14:30 - 14:45 3D visualization of plant response to ozone exposure - *Ryosuke Endo, Nihon University, Tokyo, Japan*
14:45 - 15:00 Stem wood properties of mature Norway spruce after 3 years of continuous exposure to elevated CO_2 and temperature - *Katri Kostiainen, Finnish Forest Research Institute (METLA), Finland*
15:00 - 15:15 Impact of tropospheric ozone on yield and quality of *Brassica napus* - *Karine Vandermeiren, Veterinary and Agrochemical Research Centre, Tervuren, Belgium*

15:15 - 15:30 The coupling of reducing power and stomatal conductance could improve the effective ozone uptake concept in a risk assessment model - *Didier Le Thiec, University HP, Nancy, France*

15:30 - 16:00 *Tea break + Poster viewing*

Interaction between plant functioning and the atmosphere (IV)
(Chair: Sirkku Manninen, University of Helsinki & Ralf R. Mendel, Technical University of Braunschweig)

16:00 - 16:15 O_3, CO_2 and chemical fractionation in ponderosa pine saplings - *David Olszyk, Environmental Protection Agency (EPA), Corvallis, USA*

16:15 - 16:30 Which are the leaf colors, elemental compositions and phenolic contents of beech leaves and spruce needles in a future with elevated CO_2 concentration and nitrogen deposition? - *Madeleine Günthardt-Goerg, Swiss Federal Research Institute (WSL), Switzerland*

16:30 - 16.45 Ecophysiological responses of lichen *Physia* sp to sulfur dioxide polluted air - *Taufik Taufikurahman, Institut Teknologi Bandung, Indonesia*

16:45 - 17:00 Atmospheric sulfur nutrition and copper toxicity in Chinese cabbage - *Muhammad Shahbaz, University of Groningen, Netherlands*

17:00 - 17:30 General discussion

Tuesday, December 9, 2008

Interaction between plant functioning and climate change (I)
(Chair: Ineke Stulen, University of Groningen & Kouki Hikosaka, Tohoku University)

09:00 - 09:30 Drought and water use efficiency - *Erwin Dreyer, INRA, Nancy, France*
09:30 - 10:00 Interactive effects of temperature and atmospheric CO_2 on plant function - *David Tissue, University of Western Sydney, Australia*
10:00 - 10:30 Nutrient acquisition - *Malcolm J. Hawkesford, Rothamsted Research, Harpenden, U.K.*

10:30 - 11.00 *Coffee break + Poster viewing*

Interaction between plant functioning and climate change (II)
(Chair: Ewald Schnug, Julius Kühn-Institut, Braunschweig & John L. Innes, University of British Columbia)

11:00 - 11:30 Nutritional limitation of plants under climate change stresses: nitrogen balance in forests - *Heinz Rennenberg, University of Freiburg, Germany*
11:30 - 12:00 Economics of N and its use in photosynthesis - *Charles Warren, University of Sydney, Australia*
12:00 - 12:30 Climate change at the timberline of the Central European Alps - *Gerhard Wieser, Federal Research and Training Centre for Forests, Innsbruck, Austria*

12:30 - 14:00 *Lunch break + Poster viewing*

14:00 - 14:45 **Poster introductions: "Interaction between plant functioning and the atmosphere"** (Chair: Luit J. De Kok, University of Groningen & Andrew Merchant, University of New South Wales)

- Risk assessment of ozone for *Fagus crenata* in Japan - consideration of atmospheric nitrogen deposition - *Makoto Watanabe, Hokkaido University, Sapporo, Japan*
- Modelling stomatal ozone flux for forests in East Asia - *Yasutomo Hoshika, University of Tokyo, Japan*
- Eco-physiological effects of polycyclic aromatic hydrocarbons (PAH) on plants: exposure experiments using fluoranthene - *Ilemobayo Oguntimeh, Hiroshima University, Japan*
- Combination of elevated CO_2 and nitrogen deposition changed photosynthetic traits in Boston fern - *Satoshi Kitaoka, Hokkaido Research Center, Japan*
- Estimation of net ecosystem exchange of forests by terrestrial ecosystem model - *Tomohiro Hajima, University of Tokyo, Japan*
- Arabidopsis transcriptional responses differentiate between O_3 and herbicides - *David Olszyk, EPA, Corvallis, USA*
- The effect of elevated carbon dioxide on the growth and yield of wheat in the Australian grains free air carbon dioxide enrichment (AGFACE) experiment - *Saman Seneweera, University of Melbourne, Australia*
- Influence of air pollution on needles of *Pinus amamiana*, in Yakushima Island, Japan - *Osamu Nagafuchi, University of Shiga Prefecture, Japan*
- Effects of acid deposition on forest and its watershed - *Koyomi Nakazawa, University of Shiga Prefecture, Japan*
- Increasing ozone concentration may affect production in certain ozone sensitive rice cultivars under a global warming condition - *Yoshihisa Kohno, Central Research Institute of Electric Power Industry, Japan*

- Differential ozone sensitivity evaluated by visible injuries or grain yield among rice (*Oryza sativa* L.) varieties - *Hiroko Sawada, Central Research Institute of Electric Power Industry, Japan*
- Effects of O_3 and SO_2 on semiarid plant species in Mu Us Sandyland, Inner Mongolia, China - *Hideyuki Shimizu, National Institute for Environmental Studies, Tsukuba, Japan*
- Contribution of plant-emitted VOCs to the atmosphere with increasing prevalence of fire - *Tina Bell, Department of Forest and Ecosystem Science, University of Melbourne, Australia*

14:45 - 15:00 *Tea break*

15:00 - 15:45 **Poster introductions: "Interaction between plant functioning and climate change including mitigation"** (Chair: Malcolm J. Hawkesford, Rothampsted Research, Harpenden & David Olszyk, EPA, Corvallis)

- Temperature adjustment among six Eucalyptus species in Hawkesbury Forest Experimental common garden - *Yan-Shih Lin, University of Western Sydney, Australia*
- Assessment of transpiration efficiency in peanut (*Arachis hypogaea* L.) under drought by lysimetric system - *P. Ratna Kumar, International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), India*
- A preliminary study of the impact of climatic changes on thirty species of garden trees in Central Shanxi, China - *Liangmin Wang, Shanxi Agricultural University, China*
- Impact of supra-optimal copper levels and UV irradiation on Chinese cabbage - *Mei-Hwei Tseng, Taipei Municipal University of Education, Taiwan*
- Salt resistance and change of antioxidative enzyme activity in transgenic rice plants overexpressing glycine-rich RNA-binding protein (AtRZ1a) and dual positional specific lipoxygenase genes - *Keumhwa Kim, Chonnam National University, Gwangju, Korea*
- Constitutive expression of aquaporin and lipoxygenase genes leads to the enhancement of salt, heat, and mannitol stress resistance in transgenic rice plants - *Eunji Um, Chonnam National University, Gwangju, Korea*
- Recent effects of global warming on agricultural production in Japan - *Toshihiko Sugiura, National Institute of Fruit Tree Science, Japan*
- Is faster growth related to enhanced photoprotective or antioxidative defense capacity in seedlings of six *Pinus radiata* families? - *Sabine Posch, Department of Forest and Ecosystem Science, University of Melbourne, Australia*
- *Deschampsia antarctica* desv. at changing environment - *Nataliya Taran, Taras Shevchenko National University, Ukraine*
- Simulation study to assess the impact of biomass allocation characteristics of plants on the carbon sequestration in forest ecosystems - *Endah Sulistyawati, Institut Teknologi Bandung, Indonesia*
- Carbon sequestration efficiency of vetiver grass, Nakhon Ratchasima, Thailand - *Piyanut Khanema, Suranaree University of Technology, Thailand*
- Flooding induced alterations in the lipid peroxidation, membrane permeability, reactive oxygen species generation and the antioxidative response systems in *Zea mays* leaves - *Rashid Jamei, Urmia University, Iran*
- Fluorescence measurement as an assessment method for the anaerobic digestion activity - *Ryosuke Endo, Nihon University, Japan*

15:45 - 17:30 Poster discussion + drinks

Wednesday, December 10, 2008

Interaction between plant functioning and climate change (III)
(Chairmen: Erwin Dreyer, INRA, Nancy & Gerhard Wieser, Federal Research and Training Centre for Forests, Innsbruck)

09:00 - 09:15 Changes in the stress sensitivity of plants and ecosystems in a future climate: interactions between stressors - *Kim Naudts, University of Antwerp, Belgium*

09:15 - 09:30 Changes in the stress sensitivity of plants and ecosystems in a future climate: dose-response relations - *Joke Van der Berge, University of Antwerp, Belgium*

09:30 - 09:45 A multiscale analysis of resource allocation in cyanogenic plants in response to drought and elevated CO_2 - *Ros Gleadow, Monash University, Australia*

09:45 - 10:00 High resistance of Eastern Mediterranean plant communities to climate change - lessons from seven years of precipitation manipulation - *Katja Tielbörger, University of Tübingen, Germany*

10:00 - 10:15 Effect of sulfate availability on plant metabolism - *Rainer Höfgen, Max Planck Institute of Molecular Plant Physiology, Potsdam-Golm, Germany*

10:15 - 10:30 Phyllode shape and water use in Mulga woodlands: how important is diversity in a changing climate? - *Gerald Page, University of Western Australia, Crawley, Australia*

10:30 - 10:45 Bud break of Norway spruce in relation to temperature sum: usefulness of microscopy in evaluation and improvement of phenological model - *Sirkka Sutinen, Finnish Forest Research Institute (METLA), Finland*

10:45 - 11:15 *Coffee break + Poster viewing*

Plant functioning and mitigation of global change factors (I)
(Chairman: Mark Adams, University of Sydney & Hideyuki Shimizu, National Institute for Environmental Studies, Tsukuba)

11:15 - 11:30 Consequences of sulfur deficiency in higher plants for proximal soil ozone levels - *Elke Bloem, Julius Kühn-Institut, Braunschweig, Germany*

11:30 - 11:45 Outstanding functions of SunPatiens (*Impatiens hybrida* hort.) in air purification and cooling effect - *Yutaka Urano, University of Tokyo, Japan*

11:45 - 12:00 Drought stress effects on chlorophyll fluorescence, gas exchange and antioxidative defense in *Allocasuarina luehmannii* seedlings - *Lauren Bennett, Department of Forest and Ecosystem Science, University of Melbourne, Australia*

12:00 - 12:15 Temperature effects on the metabolism of ectotherms: does Darwin break the Arrhenius Law? - *Cordula Schmitz, University of Groningen, Netherlands*

12:15 - 12:30 The role of ecophysiological and phenological processes during regeneration in increasing tree species sensitivity to climate change in British Columbia, Canada and south-east Victoria, Australia - *Craig Nitschke, University of British Columbia, Canada*

12:30 - 12:45 Changes in *Leptospermum myrsinoides* stomatal behaviour along a microclimate gradient as affected by adjacent land-use - *Tom Wright, University of Melbourne, Australia*

12:45 - 14:00 *Lunch break + Poster viewing*

Plant functioning and mitigation of global change factors (II)
(Chair: Rodney Keenan, University of Melbourne & David Tissue, University of Western Sydney)

14:00 - 14:30 Barking up the wrong tree - energy and nutrient use efficiency of biofuel plants - *Ewald Schnug, Julius Kühn-Institut, Braunschweig, Germany*
14:30 - 15.00 Role of sustainable forestry in climate change - *John L. Innes, University of British Columbia, Canada*
15:00 - 15:30 Carbon sequestration efficiency of trees - *David Ellsworth, University of Western Sydney, Australia*

15:30 - 16:00 *Tea break + Poster viewing*

Plant functioning and mitigation of global change factors (III)
(Chair: Michael Tausz, University of Melbourne & Luit J. De Kok, University of Groningen)

16:00 - 16:30 Interspecific variations in photosynthetic nitrogen-use efficiency - *Kouki Hikosaka, Tohoku University, Japan*
16:30 - 17:00 Why growth and carbon models are wrong: a new way forward - *Mark Adams, University of Sydney, Australia*

17:00 - 17:30 General discussion

18:30 Conference dinner

Thursday, December 11, 2008

Excursion

APGC Symposium

'Plant Functioning in a Changing Global Environment'

A B S T R A C T S

“OVERVIEW AND FOCUSED LECTURES”

(in order of appearance)

Why and how plants exchange gases with air - a review

Stanislaw Cieslik[1*], Kenji Omasa[2] and Elena Paoletti[3]
[1]Joint Research Centre, Ispra, Italy; [2]University of Tokyo, Tokyo, Japan; [3]Centro Nazionale delle Ricerche, Florence, Italy

This presentation is intended as focused on the plant-atmosphere gaseous exchange processes. For more than two centuries photosynthesis has been discovered and is now well known and described as an exchange of carbon dioxide, water vapour and molecular oxygen between plants and the air, whose role is to build up the vegetal tissues, and constituting a governing and regulating factor of global atmospheric chemistry, e.g. explaining the presence of molecular oxygen as secondary and resulting from the onset of photosynthesis in remote geological times. If water vapor penetrates in the plant for photosynthesis, it is also emitted as a thermal regulator and also to eliminate excess water in the plant. Besides this, a number of organic substances like isoprene, monoterpenes, aldehydes and ketones, etc., are emitted by vegetation into the atmosphere, some of these substances (e.g. isoprene) playing an important role in atmospheric chemistry. Most of these processes take place at stomatal level, and are regulated by stomatal aperture. Unfortunately for the plants, air pollutants like ozone, nitrogen oxides, etc., can use the stomatal pathway to penetrate into the plant tissues. The chemical, plant physiological and geophysical aspects of plant-atmosphere gas exchange are reviewed in detail.

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Negative versus positive functional plant responses to sulfurous air pollutants

Luit J. De Kok* and Ineke Stulen
Laboratory of Plant Physiology, University of Groningen, P.O. Box 14, 9750 AA Haren, The Netherlands

Throughout the world natural and agro-ecosystems still at risk from sulfurous air pollutants. However, their paradoxical effects on plant functioning complicate the establishment of cause-effect relationships of these air pollutants and their acceptable atmospheric concentrations. Sulfurous air pollutants may act as both toxin and nutrient for plants. Nevertheless, it is unclear to what extent metabolism contributes to the detoxification of foliarly absorbed sulfur gases, since there is no clear-cut transition in the level/rate of metabolism of the absorbed sulfur gases and their phytotoxicity. Moreover, the effects of sulfurous air pollutants on plant functioning are most probably strongly dependent on the soil sulfur status.

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Molecular aspects of air pollutant impacts on plants with emphasis on sulfur dioxide

Ralf R. Mendel[1*], Robert Hänsch[1] and Heinz Rennenberg[2]
[1]Department of Plant Biology, Braunschweig University of Technology, D-38106 Braunschweig, Germany, [2]Department of Tree Physiology, University of Freiburg, D-79085 Freiburg, Germany

Air pollutants exert manifold impacts on plants, and our understanding of these processes on the molecular level is growing tremendously. With the advent of the "omics"-technologies, a multitude of genes regulated by ozone and by NO_x became uncovered. This talk will focus on SO_2 as the third major air pollutant and on the novel plant enzyme sulfite oxidase that detoxifies this compound. For a long time, occurrence and nature of sulfite oxidase activity in higher plants were controversially discussed. During primary sulfate assimilation in the chloroplast, sulfate is reduced via sulfite to organic sulfide, which is essential for cysteine biosynthesis. However, it has also been reported that sulfite can be oxidized back to sulfate, e.g. when plants were subjected to SO_2 gas. Recently, work from our laboratory has identified sulfite oxidase as the fourth member of molybdenum-enzymes in plants, which seems to be the most important way to detoxify excess of sulfite. Recombinant protein could be purified from *E. coli*, crystallized and investigated biochemically. The enzyme is localized in peroxisomes where H_2O_2, the second end product in addition to sulfate, can be easily eliminated by catalase. Sulfite oxidase occurs in a wide range of plant species and is expressed in all plant organs tested. Fumigation with SO_2 gas induces the expression of the enzyme as demonstrated by promoter-reporter gene fusion, by immuno-blot analysis of sulfite oxidase protein and by induction of enzyme activity. T-DNA tagged *A. thaliana* plants lacking the enzyme showed a decrease in vitality during SO_2 fumigation and a change in their S metabolites. On the contrary, overexpression of SO helped the plant to survive SO_2 concentrations that were detrimental for non-transformed wildtype plants, as was shown with transgenic poplar plants, which are known to be particularly sensitive to SO_2.

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Air pollution problems in developing countries - increasing pollutant production in East Asia would be a significant influence on the eco-environment in the 21st century

Hideyuki Shimizu
Asian Environment Research Group, National Institute for Environmental Studies, Tsukuba, Japan

In recent years, not only developed countries but also developing countries exhausted high levels of air pollutants, along with the rapid increases in industrialisation and motor vehicle number. Asia has already exceeded other regions in NO_x emission. We recognised that East Asia including China is the hottest area for considering global atmospheric environment in 21st century. Acid Deposition Monitoring Network in East Asia (EANET) was established in 1998 as a regional cooperative initiative to promote environmental sustainability and protection of human health in the East Asian region, with Cambodia, China, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Philippines, Republic of Korea, Russia, Thailand and Vietnam. One of major activities of EANET is wet/dry acid deposition monitoring in each country, and high concentrations of O_3 were observed in some sites. Ecological monitoring including soil, vegetation and inland water has also been conducted by ADORC. Catchments studies have been conducting in Thailand, Malaysia and Japan, and forest decline was studied in Mongolia. With increasing emissions of primary air pollutants, O_3 concentration in East Asia has been predicted to increase rapidly. From monitoring data, emission inventory and chemical transport model, the forecast system was developed in the National Institute of Environmental Studies (NIES) in Japan. As compared with 2000, O_3 concentration in 2020 will increase according to several predicted scenarios. In East Asia, not only O_3 but also dust and sandstorm (DSS) are significant air pollution phenomena. NIES also predicts DSS occurrence by collaborating with East Asian countries. Increased concentration of O_3 would damage several crops such as wheat, rice, etc. Several experiments using open-top chambers (OTC) have been conducted in Asia, especially in China and Japan. They estimated yield reduction of some crops by current O_3 concentrations, and the reduction in these areas will increase in near future. To address the potential overestimation of yield reduction in chamber experiments, the field experiment of "Free-Air Concentration Enrichment with Ozone (FACE)" in China has been conducting recently. Preliminary results showed that some rice cultivars will be more damaged in near future with increasing O_3 concentration. Apart from crop species, several grass and shrub species grown in Northeast Asian semiarid area have been exposed to air pollutants such as O_3 and/or SO_2. Relative to plants grown in temperate region, it is assumed that stomatal conductance of plants growing in semi-arid environments is lower, which limits the uptake of gaseous pollutants and thereby limit the damage. However, experimental results showed visible injuries and growth reductions in some plant species grown in semiarid East Asian region. More precise chamber/field studies should be conducted.

Ozone, a dominant air pollutant, and its role in climate change

Rainer Matyssek[1*] and Gerard Wieser[2]
[1]*Ecophysiology of Plants, Technical University of Munich, Am Hochanger 13, D - 85354 Freising, Germany; Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), Unit Alpine Timberline Ecophysiology, Rennweg 1, A - 6020 Innsbruck, Austria*

Amongst air pollutants, ground-level ozone (O_3) is potentially the most detrimental to vegetation. Spreading globally, enhanced levels are predicted to increase, in particular, in rapidly developing countries, and O_3 must now be considered in climate change scenarios and post-Kyoto policies. Combined free-air CO_2 and O_3 enrichment studies have shown O_3 to counteract C sequestration, especially in pioneer trees, with implications for renewable resource management. O_3 can lower C sink strength to an extent similar to the limited increases, which may occur at most under elevated CO_2. Interaction between these gases may be modified by further environmental stress as by plant competition. Such latter impact can alter tree performance to a larger extent than does the stress by the gases – both in pioneer and in climax tree species. Similarly important is the O_3/pathogen interaction, both agents causing oxidative stress and being affected by climate change-related moisture and temperature variation along with nitrogen supply. Hardening against pathogens may be promoted by chronic O_3 stress, as such examples will be presented from juvenile and adult trees. O_3 stress can indirectly alter belowground C flux in ways contrasting across tree ontogeny and growth conditions, inciting risk of turning soils from C sinks to C sources. This context requires the mycorrhizosphere to be viewed as a component of O_3, temperature and moisture interactions, which is relevant in ecotones like the alpine timberline, which are limited by temperature rather than moisture. Episodic stress as by severe drought does fundamentally change factorial interactions and limit the predictability of chronic pollutant effects. Such examples underline that the risk posed by pollutants can only be assessed realistically when covering interactions with other site factors. This latter demand provides the rationale of this presentation. Assessing risks by pollutants under climate change requires mechanistic understanding of factorial biotic and abiotic interactions.

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Elevated O_3 and CO_2 and belowground processes

Sirkku Manninen[1*], Teri Kanerva[1], Hermanni Aaltonen[2], Kristiina Regina[3], Ansa Palojärvi[3], Kaisa Rämö[1], Katinka Ojanperä[3] and Martti Esala[3]
[1]Department of Biological and Environmental Sciences, University of Helsinki, Finland; [2]Department of Forest Ecology, University of Helsinki, Finland; [3]MTT, Agrifood Research Finland, Jokioinen, Finland

One of the prominent weaknesses in our understanding of how natural vegetation will respond to increases in O_3 and CO_2 concentrations is our limited knowledge of the responses of belowground processes such as greenhouse gas fluxes, nitrogen cycling and the microbial community structure. We studied the direct and indirect effects of elevated O_3 (40-50 ppb) and CO_2 (ambient + 100 ppm) on meadow plants grown in both multispecies mesocosms and in pot monocultures of *Agrostis capillaris* and *Lathyrus pratensis* using open-top chambers in the summers of 2002-2004. Elevated O_3 (alone and combined with elevated CO_2) decreased the total microbial, bacterial, actinobacterial and fungal biomasses as well as the fungal/bacterial biomass ratio, analyzed by PLFA (phospholipid fatty acid) method. These changes also translated into decreased soil NH_4^+-N and mineral N concentrations and into decreased fluxes of N_2O, CH_4, and CO_2. The effects of elevated CO_2 alone were negligible. The observed changes in the mesocosm total microbial PLFA biomass did not correlate with plant biomass, whereas marked positive and negative correlations were found between the plant biomass and the microbial PLFA biomasses in the soil of the grass and legume monocultures. The pot experiment showed that the effects of elevated O_3 and CO_2 varied depending on the host plant, the soil sample (rhizospheric versus bulk soil) and climatic factors. Climatic factors were also significant variables in the mesocosm experiment, in which air and soil temperatures and soil water content contributed markedly to the N_2O and CO_2 fluxes. The soil in our experiments was low in N and this is also assumed to have modified the responses. The biotic and abiotic factors that modify plant growth and belowground processes and their interactions under elevated O_3 and CO_2 will be further discussed in the oral presentation in the light of results from other studies.

Acknowledgements: The work was supported with funds from University of Helsinki, Maj and Tor Nessling Foundation, and Finnish Cultural Foundation. We thank the personnel of the Plant Production Research, MTT Jokioinen, for their valuable technical assistance.

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Elevated CO_2 on yield and yield quality of wheat – evidence from three years of field studies involving FACE technology

Petra Högy[1*], Herbert Wieser[2], Peter Köhler[2], Klaus Schwadorf[3], Jörn Breuer[3], Jürgen Franzaring[1] and Andreas Fangmeier[1]

[1]Landscape and Plant Ecology, University of Hohenheim, Germany; [2]German Research Centre for Food Chemistry and Hans-Dieter-Belitz-Institute for Cereal Research, Germany; [3]Landesanstalt für Landwirtschaftliche Chemie, University of Hohenheim, Germany

Atmospheric CO_2 enrichment is known to alter the carbon- and nitrogen-metabolism of important C_3 crops such as wheat during vegetative development. Therefore, the availability of metabolites for the developing grain may be altered. To identify the specific response patterns of wheat during grain filling and element redistribution, a spring wheat cultivar (*Triticum aestivum* L. cv. TRISO) was grown for three consecutive seasons in a free air CO_2 enrichment (FACE) field experiment. CO_2 enrichment had beneficial impacts on aboveground biomass and yield, contrasted by predominantly negative effects on wholegrain quality aspects, which have to date received less attention. Although the thousand grain weight remained unchanged, the size distribution was significantly shifted to smaller grains, which may directly relate to a lower market value. Elevated CO_2 resulted in significant decreases of the total grain protein concentration and changes in the protein composition. Concentrations of minerals such as potassium, molybdenum and lead were increased, while manganese, iron, cadmium and silicon were decreased, suggesting that adjustments of agricultural practices may be required to achieve current grain quality standards. CO_2 enrichment resulted in an overall decrease of the concentrations of proteinogenic amino acids per unit flour weight. In addition, the amino acid composition on a protein basis was changed. The concentration of fructose and fructan as well as the amounts per area of total and single non-structural carbohydrates except for starch were significantly increased in the grains. The same holds for the amounts of lipids. With regard to mixing and rheological properties of the flour, a significant increase in gluten resistance under elevated CO_2 was observed. Elevated CO_2 is obviously affecting grain characteristics important for human and animal nutrition and industrial processing such as bread-making. Experimental evidence for these changes is still poor but deserves further attention.

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Photosynthetic acclimation to elevated p[CO_2] of 100 Pa occurs during all stages of leaf development in rice (Oryza sativa L. cv. Notohikari) canopy

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Photosynthetic (*A*) capacity of C_3 plants is often reduced after long-term exposure to elevated CO_2 and is closely associated with a decline in leaf nitrogen (N) and ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco, E.C.4.1.1.39) content. The reduction in Rubisco content at elevated CO_2 is thought to be mediated through carbohydrates signalling mechanism. In order to gain new insight into photosynthetic acclimation to elevated CO_2, a study was conducted to test the hypothesis that *A* acclimation to elevated CO_2 is associated with factors other than accumulation of carbohydrates using leaf blades from different positions of the rice *Oryza sativa* L. cv. Notohikari) canopy. Plants were grown for 70 days hydroponically in artificially illuminated growth chambers at a *p*[CO_2] of either 39 or 100 Pa. The relationships between *A*, Rubisco, leaf N, carbohydrate concentrations and the mRNA for ribulose-1,5-bisphosphate carboxylase/oxygenase small subunit (*rbc*S) and large subunit (*rbc*L) in leaves at different positions in the canopy were determined. Plant dry mass, total N uptake and N allocation to leaf blade, sheaths and roots were also calculated. Growth at *p*[CO_2] of 100 Pa suppressed light saturated *A*, $V_{c.max}$ and J_{max} in leaf blades at all positions in the canopy. *A* was suppressed at elevated *p*[CO_2] by approximately 25% in the lower leaf blades as compared to 17% in the upper leaf blades. This was associated with a similar reduction in leaf N and Rubisco concentration. Plant growth at elevated *p*[CO_2] resulted in an increase in sucrose concentration all leaf positions. However, the transcript abundance for *rbc*S and *rbc*L decreased only in the expanding leaf blade and found no relationship between *A* acclimation and sucrose concentration. We conclude that *A* acclimation to elevated p[CO_2] occurs through mechanisms other than the sugar sensing.

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3D visualization of plant response to ozone exposure

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Ozone in troposphere is one of the worst global air pollutants and its concentration at the ground surface appears to be stable or increasing in many industrialized countries. Plant productivity decreases due to ozone inhibition of photosynthesis. This inhibition can be the result of changes in stomatal conductance or photosynthetic enzymatic activities. Changes in stomatal conductance may be associated with changes in the plasmalemmae of guard cells, and changes in photosynthetic enzymatic activities may be due to the effect of oxygen radicals generated by ozone. Plants will show spatially non-uniform distribution of photosynthetic activity upon an environmental challenge such as ozone exposure. Therefore, to specify the effects of ozone on photosynthetic activity, a spatial measurement method is better suitable than a traditional non-imaging method. Especially, chlorophyll fluorescence imaging is one of the most effective methods for analysing photosynthetic activity in in-situ plant leaves. Recently, microscopic fluorescence imaging systems have been developed for cellular- and chloroplast-level analyses. On the other hand, high-resolution imaging with a microscope causes the inevitable problem of limited depth of observable field. This problem can be solved by reconstructing an extended-focus image from a series of images captured at different focal planes (shape from focus). This method provides not only an extended-focus image but also a 3-D image. Confocal scanning laser microscopy is a similar system in point of the view of constructing 3-D images. However, the system in this study provides light irradiance with low intensity to apply the fluorescence method. In contrast, confocal scanning laser microscopy uses high intensity irradiance. Therefore, this system can offer more suitable light conditions to investigate plants.

In this study, the method of more effective 3-D reconstruction based on LR operator have been designed to produce microscopic extended-focus images of the chlorophyll fluorescence of ozone-injured leaves.

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Stem wood properties of mature Norway spruce after 3 years of continuous exposure to elevated CO_2 and temperature

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The objective of the study was to investigate the interactive effects of elevated atmospheric CO_2 concentration and temperature on the wood properties of mature field-grown Norway spruce (*Picea abies* (L.) Karst.) trees. Material for the study was obtained from an experiment in Flakaliden, northern Sweden, where trees were grown for 3 years in whole-tree chambers at ambient (365 ppm) or elevated CO_2 (700 ppm) and ambient or elevated air temperature (ambient + 5.6 °C in winter and ambient + 2.8 °C in summer). Elevated temperature affected both wood chemical composition and structure, but had no effect on stem radial growth. Elevated temperature decreased the concentrations of acetone-soluble extractives and soluble sugars, while mean and earlywood cell wall thickness and wood density were increased. Elevated CO_2 had no effect on stem wood chemistry or radial growth. In wood structure, elevated CO_2 decreased earlywood cell wall thickness and increased tracheid radial diameter in latewood. Some significant interactions between elevated CO_2 and temperature were found in the anatomical and physical properties of stem wood (e.g. microfibril angle, latewood cell wall thickness and density). Our results show that the wood material properties of mature Norway spruce were altered under exposure to elevated CO_2 and temperature, although stem radial growth was not affected by the treatments.

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Impact of tropospheric ozone on yield and quality of *Brassica napus*

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Nearly one-quarter of the Earth's surface is currently at risk from mean tropospheric O_3 in excess of 60 ppb during midsummer with even greater local concentrations occurring. This is well above the mean concentration of 40 ppb that has been determined for damage to sensitive plant species and several scenarios indicate that concentrations of tropospheric O_3 will further increase throughout the 21st century. O_3 damage to plant tissues includes visible leaf injury, decreased photosynthesis and increased senescence, which has significant repercussions for the yield of major agricultural crops. Due to changes in pool size of metabolites, also the effects on crop quality can be significant. In this study we will present the preliminary results of an open-top chamber experiment on the effects of a daily 8h increase in O_3 concentrations with 20 and 40 ppb on photosynthesis and yield of oilseed rape (*Brassica napus* cv Ability). This crops is becoming increasingly important as so-called 'bio-fuel'. It is the third most important source of vegetable oil with the lowest amount of saturated fatty acids. After removal of the oil, the residual rapeseed meal is also an inexpensive protein supplement for animal feed. Most interestingly, Brassica species contain glucosinolates that have potential value as cancer chemo-preventive agents, but have also proven to cause toxic effects when fed to animals in too high quantities. Glucosinolate metabolism is dependant on the cross-talk between methyl jasmonate and salicylic acid, that are both involved in antioxidative defence responses. As such the glucosinolate profile and quantity may alter in response to both biotic and abiotic stress. Elevated ozone exposure clearly induced a reduction of CO_2 assimilation towards the end of the growing season. The investigated yield and quality parameters include total seed yield, 1000 seed weight, protein content, fatty acid composition, oil percentage and glucosinolate composition of the final oilseed harvest.

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The coupling of reducing power and stomatal conductance could improve the effective ozone uptake concept in a risk assessment model

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The tropospheric level of the phytotoxic air pollutant ozone has considerably increased during the last century and is expected to continue to rise. Long-term exposures of higher plants to low ozone concentrations affect biochemical processes prior to any detectable symptoms of visible injury. On the other hand, the current critical level of ozone used to determine the threshold for damaging plants (biomass loss) is still based on the seasonal sum of the external concentrations of the pollutant above 40 nl l^{-1} (AOT40). Taking into account the stomatal conductance, a more relevant concept is based upon the actual ozone flux in the leaf through the stomata (cumulative uptake of ozone = CUO). CUO however ignores the internal capacity of leaf defense, which led to the concept of "effective ozone flux", balance between stomatal flux and the intensity of cellular detoxification, with the aim to propose an improved threshold for ozone risk. Although the direct detoxification of ozone (and ROS issued from its decomposition) can primarily be carried out by cell wall ascorbate, the existing level of this antioxidant is not sufficient to indicate the degree of cell sensitivity. The capacity for regeneration of the antioxidant barrier is needed, implying the knowledge of the increased production of reducing power (NAD(P)H), primary supplier for detoxifying processes. It is made possible through the increased participation of the catabolic pathways and associated shunts which can provide NAD(P)H. In addition, the large change in the rubisco/PEPcase ratio, due to a huge increase in activity of the latter enzyme, leads to changes in carbon isotopic discrimination, which could be related to water use efficiency. Some results will be presented knowing that the challenge is to integrate the possible indicators in a leaf model to be used, through an upscaling process, in a tree and forest stand model.

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O_3, CO_2 and chemical fractionation in Ponderosa pine saplings

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Environmental factors can affect plant tissue quality, which is important for quality of organic matter inputs into soil food webs and decomposition of soil organic matter. Thus the effects of increases in CO_2 and O_3 and their interactions were determined for various chemical fractions in needles, branches, stems, and roots of ponderosa pine (*Pinus ponderosa*) saplings. Tissue samples were obtained after three growing seasons of treatment, dried and processed through a series of extractions and analyses to quantify non-polar, polar, cellulose, lignin, ash, phenolic, sugar and amino nitrogen fractions. The % carbon and nitrogen in the starting material; and polar, non-polar, and acid hydrolysis residues were measured. Needle and stem ages, and root size class all had significant effects on chemical fractionation, but the pollutants had little impact. The significant ($p<0.05$) effects were O_3-induced reductions in needle amino nitrogen and non-polar residue nitrogen concentrations, and CO_2 x O_3 interactions on amino nitrogen and non-polar residue carbon in needles which had senesced from the saplings. Thus, this study indicated that while O_3 affected some forms of leaf nitrogen, a doubling of CO_2 coupled with O_3 did not affect woody tissues or roots.

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Which are the leaf colors, elemental compostitions and phenolic contents of beech leaves and spruce needles in a future with elevated CO_2 concentration and nitrogen deposition?

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In the context of the current discussion of increasing anthropogeneous carbon dioxide (CO_2) concentrations and nitrogen (N) depositions, an interdisciplinary model ecosystem experiment was carried out at WSL with a full factorial design with four treatments using 16 large open top chambers, split each in two soil compartments containing acidic or calcareous forest soil. Young beech (*Fagus sylvatica*) and spruce (*Picea abies*) trees (in total 16 trees per each soil compartment) were studied during four years under ± elevated CO_2 (374 vs. 590 µl l^{-1}) and ± elevated N (5 vs. 50 kg ha^{-1} a^{-1}). As both CO_2 and N have been reported to stimulate CO_2 assimilation, a particular focus of this study was given to changes in visible leaf or needle color, to their calibration with chloroplast pigments (indicating the state of the chloroplasts), to their correlation with phenolic leaf contents (mechanisms of the plant secondary metabolism) and how they reflect the leaf nutritional state. The hypothesis of earlier leaf senescence under elevated CO_2 was particularly investigated and confirmed for beech, whereas this process was less evident in needle color or phenolic content than in needle cell structures of spruce. The soil type was a more important modifying factor than N deposition.

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Ecophysiological responses of lichen *Physia sp* to sulfur dioxide polluted air

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Colonies of the lichen *Physcia sp* growing on the bark of *Vaccinium varingiaefolium* trees around the crater of mount Tangkuban Parahu, Bandung, West Java, were examined for their ecophysiological responses to sulfuric gas which is released continuously by the crater. Three sampling locations were taken, from the site close to the crater (5 m) to far end sites, i.e. 75 m and 150 m. At the location closer to the crater, the level of ambient sulfur dioxide in three research locations increased (from 0.0234 to 0.0519 ppm), and the level of sulfate ions in soil also increased (from 323 to 539 ppm), also matched by the increase of acidity of the tree bark (from 3.59 to 3.17 pH). As a result sulfur dioxide absorption directly from the air, total sulfur content in tissues of *Physcia sp* also increased (from 0.112 to 0.188 % of plant dry weight). Sulfur accumulation reduced chlorophyll content of the lichen. The content of chlorophyll a decreased from 110 to 34 μg g^{-1} fresh weight; while that of chlorophyll b decreased from 54 to 15 μg g^{-1} fresh weight. This in turn reduced the photosynthesis rate of the lichen. As direct consequence, the lichen reduced its length of thalli (from 0.56 to 0.39 cm), thalli coverage within 400 m^2 (from 60.8 to 33.6 %), and number of colonies per 400 cm^2 (from 69 to 45). Proline concentration in lichen tissue increased (from 51.9 to 85.8 μg g^{-1} fresh weight) as stress level from the polluted atmosphere increased. It can be concluded that sulfur reduced growth of lichen by reducing its rate of photosynthesis as the content of chlorophyll was significantly reduced. As the lichen experienced stress conditions, it produced more proline, which might contribute to adaptive physiological mechanism of the lichen.

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Atmospheric sulfur nutrition and copper toxicity in Chinese cabbage

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Copper is an essential plant nutrient and it functions as redox-active transition metal in enzymes in many physiological processes, e.g. photosynthesis, respiration, oxidative stress response. Supra-optimal levels of copper are phytotoxic and the general symptoms of toxicity are chlorosis and a stunted growth. Copper may negatively affect chlorophyll integration into the photosystems and may affect photosynthesis. It also may react with sulfur metabolites and oxidize thiols, resulting in the production of radical oxygen species, lipid peroxidation and membrane injury. Copper induces the synthesis of thiol-rich peptides, so-called phytochelatins, which may play a role in the homeostatic control of potential toxic metal ions in plants. It has been presumed that sulfur metabolism might play an essential role in the detoxification of copper in plants. In the current study, Chinese cabbage was exposed to supra-optimal levels of copper (1 to 10 μM Cu^{2+}) in the root environment. The impact of sulfur nutrition *viz.* sulfate-deprivation and H_2S exposure on growth, the activity and expression of the sulfate transporters and sulfur assimilation in the presence of supra-optimal Cu^{2+} levels was investigated.

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Water-use efficiency in trees: techniques, scales and diversity

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Water-use efficiency is an important functional trait that can be defined at very different temporal and spatial scales in trees as well as in crops. Transpiration efficiency (TE) is usually defined at tree or even stand level as the ratio between transpired water and accumulated biomass. Intrinsic water-use efficiency (W_i) is defined at instant leaf scale as the ratio net CO_2 assimilation rate vs. stomatal conductance (A/g_s). W_i is usually estimated by isotopic discrimination against $^{13}CO_2$ during photosynthesis (Delta). Delta can be measured at the instantaneous time-scale on-line with new spectroscopic techniques, but is usually recorded from the isotopic composition of different metabolic pools (bulk leaf matter, soluble sugars, cellulose in leaves and wood). Delta is a plastic trait and is therefore largely used as an index for short term (interannual) changes in water availability and for climate constraints. Delta is also under tight genetic control in trees like in many other species and shows a large diversity. This was shown for populations from different origins, within populations on ecological clines, and among clones. Furthermore, quantitative genetics approaches identified a few highly significant QTLs for Delta in full-sib offsprings of oaks, maritime pine, chestnut and poplars, and thus identified a small number of genomic regions that are active in the control of Delta. The range of genotypic values identified in these approaches encompasses up to 3-4 ‰, which would translate into 30-50% difference in intrinsic water-use efficiency. Due to technical difficulties, much less evidence is available about the genetic control of W_i and of TE. Moreover, the parameters of the model relating Delta to W_i may also display some degree of genotypic variability, and the suitability of Delta as an index for W_i has been questioned. In this presentation, some evidence will be produced in support for the tight correlation between Delta and W_i in support of the use of Delta as a screening tool for W_i and even TE. Based on the accumulated data demonstrating the large diversity of W_i as well as the tight genetic control over this trait, a few research perspectives will be identified and discussed.

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Interactive effects of temperature and atmospheric CO_2 on plant function

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Since the industrial revolution, global climate has changed dramatically as a function of human activity. In the past 150 years, atmospheric [CO_2] has risen from 280 ppm to approximately 385 ppm, air temperature has risen at different rates (greater at the poles and lesser at the equator), and precipitation patterns have changed significantly. Individually and in combination, these climate factors have substantially affected plant function including vegetative and reproductive growth, and rates of carbon and water exchange. In this talk, I will address the general growth and physiological responses of plants to changes in atmospheric [CO_2] and air temperature. In addition, I will present data from our recent experiment in which we grew from seed a slow- and fast-growing *Eucalyptus* species and exposed them to three [CO_2] treatments (280, 400, and 640 ppm) and two air temperatures (ambient, ambient + 4 C) for 8 months in environmentally controlled glasshouses. I will discuss the implications of the significant temperature and [CO_2] effects on growth, stomatal anatomy, and carbon and water exchange across the six treatments.

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Nutrient acquisition

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Fertilizers are amongst the most critical determinants of crop production, but are costly inputs and inappropriate over-use can have many ecologically damaging affects, making efficient use of fertilizers a major challenge for agriculture. Nitrogen use in agriculture results in a major fraction of anthropogenic nitrous oxide emissions, which contribute substantially to climate change; inefficient nutrient uptake can result in pollution of inland and coastal waters; as a result, both agriculture and plant breeding have a responsibility to optimize nutrient, and particularly nitrogen, use in crop systems. Furthermore, crop improvement to anticipate changing patterns of water availability and temperature must include an anticipation of nutritional demands influenced by changing cropping systems and crop ideotypes. Worldwide, fertilizer use efficiency for nitrogen in cereals may be as low as 33 %. Both management and genetic improvement must be applied to improve this. Considerable variation in the complex nitrogen use efficiency (NUE) trait, including the nitrogen uptake efficiency component, is apparent even within the relatively small germplasm pools found in modern wheats. A goal will be to combine varieties with optimum component traits by conventional or genetic manipulation technology. In either instance, identification of genes and underlying mechanisms will facilitate the isolation of new more efficient varieties better able to exploit resources and minimize the damaging environmental consequences of inefficient uptake. This will include modification of root traits, both in terms of architecture or functionality (transporter operation) or the capacity to convert nutrients taken up into crop production (which may include short term storage, photosynthetic capacity/patterns of senescence coupled with nutrient remobilization). De-convolution of the complex traits involved and the observed genetic variation will be presented along with speculation on targets and mechanisms for improvement. The genetic complexity of uptake systems will be illustrated with reference to both nitrogen and sulfur nutrition.

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Nutritional limitation of plants under climate change stresses: nitrogen balance in forests

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Nutritional limitations as a consequence of climate change stresses are of particular significance for natural vegetation and forests that often have developed on marginal soils and are not subjected to extensive management practices such as cropland, pastures and plantations of woody plants. In this context, nitrogen balance of forests not exposed to nitrogen deposition of anthropogenic origin is of high vulnerability, because it is achieved by a relatively closed ecosystem cycle with low rates of input and output, but high rates of internal turnover. Besides direct effects of increasing gas mixing ratios of radiatively active gases in the atmosphere, i.e. of CO_2, CH_4, N_2O, O_3, $H_2O_{(v)}$, the meteorological consequences of this increase, esp. enhanced surface temperature and elevated frequency and intensity of heat, drought and flooding events interact with processes of central importance for the nitrogen balance of ecosystems. These processes include (a) the uptake capacity of roots for different forms of nitrogen; (b) the capability to adapt this uptake capacity to changing meteorological conditions; (c) nutrient mobilisation and nutrient availability; and (d) competition for nitrogen between root uptake of adult trees and natural regeneration, between root uptake of different tree species, and between root uptake and microbial nitrogen consumption. The effects of temperature, drought, and flooding on these processes will be discussed and compared. The interactive effects of different climate stresses will be addressed.

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Economics of N and its use in photosynthesis

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Central paradigms of ecophysiology are that plants can only access inorganic nitrogen and there are recognizable patterns among species, and life forms in the economics of water and nitrogen use in photosynthesis. A range of studies have cast doubt on the first assumption that plants can only access inorganic nitrogen. However, in many cases while the potential for uptake of organic N has been demonstrated via experiments with roots in solutions, we do not know whether this potential is realized in soil. Experiments with *Eucalyptus* show that solution experiments grossly overestimate the importance of organic N for nutrition. Nevertheless, *Eucalyptus* can and do have access to more N than suggested by the traditional paradigm of N cycling. Most examinations of N economy of photosynthesis have implicitly assumed an infinite internal conductance (g_i) and/or that internal conductance scales with the biochemical capacity for photosynthesis. Examination of published data for 54 species show both of these assumptions are incorrect. The reduction in concentration of CO_2 between the sub-stomatal cavity (C_i) and the site of carbon fixation (C_c) varies greatly among species and limitations to photosynthesis due to g_i are not constant among species. Importantly, there is a general trend for plants with low g_i to have a larger draw-down from C_i to C_c, further confounding efforts to scale photosynthesis and other attributes with g_i. Variation in the g_i - photosynthesis relationship contributes to variation in photosynthetic use efficiency of N (PNUE) and water (WUE).

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Climate change at the timberline of the Central European Alps

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We consider about possible effects of climate change on high elevation forests in the Central European Alps. However, as temperature, elevated CO_2, and elevated ozone act in concert it is impossible to break up their impacts. Therefore, we first describe the impacts of climate warming on the carbon and water balance of timberline associated trees and forests, followed by a section outlining the effects on altered atmospheric chemistry ending up with changes in tree growth and tree-line dynamics. Moreover, physiological responses to climate change are strongly dependent on the limiting factor of a particular forest site. Thus, in regions with ample soil water availability such as the "*kampfzone*" with their shallow soils an upward advancement of trees might be critically questioned, although growth of trees below their current upper limit may of course increase.

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Changes in the stress sensitivity of plants and ecosystems in a future climate: interactions between stressors

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In almost all ecosystems plants are subjected to stress. In the future, these stressors will occur under a modified atmospheric background, with higher CO_2 concentrations and elevated average air temperatures. Will this future climate alter the stress response of plant communities and their composing plant species? To answer this question grassland mesocosms were exposed to several stressors in an experimental platform consisting of 10 computer-controlled, air conditioned, sunlit growth chambers. Half of these chambers tracked ambient temperature at ambient CO_2 concentration, the other half was exposed to a predicted climate scenario with elevated CO_2 and temperature. The stressors included one acute stressor (drought) and two chronic stressors (nitrogen deficiency and zinc toxicity). During the summer of 2008 these stressors were applied separately and in combination in order to examine the interactive impact and the effect of climate change on these interactions. In July 2008 an extensive set of measurements was conducted from leaf scale to ecosystem scale. Data collection included: gas exchange, leaf chemistry (C/N ratio) and chlorophyll fluorescence at leaf scale; survival and above ground biomass at plant scale; below and above ground biomass and soil water content at ecosystem scale. Preliminary results indicate a lower water consumption caused by a lower biomass production in the mesocosms subjected to chronic stressors. Therefore, these stressors are expected to have an antagonistic effect on drought stress. These and other results will be presented and discussed in relation to possible effects of a future climate.

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Changes in the stress sensitivity of plants and ecosystems in a future climate: dose-response relations

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The central research question of this experiment is whether the resistance of species-rich plant communities to different stress factors will change in a future climate. To this end grassland mesocosms, composed of three functional groups, were grown in sunlit controlled chambers under either the present CO_2 concentration and air temperatures, or future climate conditions with a higher CO_2 concentration and a 3°C warming. Equal amounts of water were added to all of the mesocosms, so that warming could imply drier soils if evapo-transpiration was higher. In addition the mesocosms were exposed to a range of abiotic stressors: drought, waterlogging, nitrogen deficiency and heavy metals (zinc). In the growing season of 2007 stressors were applied separately to assess dose-response relations. Higher CO_2 concentrations will stimulate growth and productivity. Moreover the higher availability of carbon could stimulate defense mechanisms and improve stress resistance. Higher air temperatures on the other hand can change the energy balance and the amount of water lost through transpiration. Growth in a warmer climate could reduce stress resistance and any possible increase in productivity from elevated CO_2 might be overturned. To quantify the dose-response relations of plants and communities, measurements were conducted from leaf scale to community (mesocosm) scale. The measurements contained: (eco)-physiological reactions to stress derived from water relations, from chlorophyll fluorescence and from CO_2 exchange (leaf scale); loss of productivity as an integrative response to stress (plant and community scale); and the relative abundance of species (community scale). Preliminary analysis shows that (1) with increasing zinc stress biomass decreased while the photosynthetic capacity (A_{max}) was unaffected. (2) Drought stress affected A_{max} and biomass differently per functional group but reduced total community biomass. (3) Increasing nitrogen shortage changed the proportion of functional groups per mesocosm. Overall the effects of climate change on the stress responses seemed moderate.

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A multiscale analysis of resource allocation in cyanogenic plants in response to drought and elevated CO_2

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Two of the most pressing social issues facing the world at the moment are climate change and food security. Predicting the impact of the current shifts in atmospheric CO_2, and the concomitant changes in climate on plant growth and composition are essential if we are to anticipate the necessary changes that will be required in plant breeding and agricultural practice. The results presented here focus on the regulation of cyanogenic glycosides in response to drought and elevated CO_2, secondary metabolites that break down to release toxic cyanide (HCN) when plant tissue is damaged. Around 10% of all plants and 60% of crop species produce such cyanogens, primarily for protection against generalist herbivores. Three cyanogenic crops (*Trifolium repens*, *Sorghum bicolour*, *Manihot esculenta*) were compared with two species of *Eucalyptus*, one cyanogenic and one not. The concentration of both cyanogenic glycosides and phenolics increased in leaves of plants suffering water stress. Genes governing cyanogen synthesis were moderately up-regulated but the change in concentration may also, in part, be a passive consequence of reduced growth rates. In elevated CO_2-grown C3 crop plants there was a significant increase in the concentration of cyanogenic glycosides on a per mass basis in the leaves. We also found a highly significant difference between species in growth rate production at the different levels of CO_2 and N supply. Surprisingly, there was a highly significant decrease in biomass in cassava which may be linked either to the role of cyanogens in nitrogen transport in this species or to its highly sensitive stomata. Coupled with the decrease in leaf protein and increase in all measures of C-based defense it is likely that climate change is will reduce the nutritional value of the plants. This needs to be considered when attempting to mitigate the effects of climate change.

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High resistance of Eastern Mediterranean plant communities to climate change- lessons from seven years of precipitation manipulation

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Global circulation models are consistent in their climate scenarios for the Mediterranean and predict increasing aridification with higher temperatures, lower average precipitation and higher inter-annual variability in rainfall. At the same time, species-rich Eastern Mediterranean ecosystems are mainly limited by water availability, and they should be particularly vulnerable to climatic changes. We tested this assumption with an interdisciplinary study designed to predict the effect of regional changes in precipitation on Eastern Mediterranean ecosystem structure and function. We combined monitoring of ecological processes along a steep climatic gradient ranging from extreme desert to mesic Mediterranean conditions with manipulation of annual rainfall at two of the stations. After seven years of climatic manipulation there was almost no response of the annual plant communities to climate change. Precipitation change had no effect on overall plant community structure and species composition, there was no clear response of single plant species irrespective of plant functional type, and plant growth and community productivity were affected to a much smaller extent than expected. We suggest that environments characterized by large natural climatic variability may be highly resistant against climate change. However, management (i.e. grazing) may modify the resistance of the annual plant communities to change. We discuss our findings within the framework of adaptation of annual plants to extreme and variable climatic conditions.

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Effect of sulfate availability on plant metabolism

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Plant development, growth and yield are directly related tot he availability of plant nutrients in the environment, especially water, light and macro and micro nutrient ions. Together with nitrate, phosphate and potassium, sulfate is an essential macronutrient for plant metabolism being reduced to sulfide after uptake from soil and channelled into plant metabolism via cysteine, the first organic sulfur compound, being involved in numerous metabolic processes, such as amino acids, protein structure, co-factors, C1 metabolism, and hormone synthesis. Sulfur compounds are essential for food and feed as amino acid and vitamin sources or provide flavour and aroma components. Thus, insufficient supply of sulfate, impairs plant metabolism in a pleiotropic manner. Through transcriptome and metabolome analysis of Arabidopsis plants under sulfate starvation we described the network of responses triggered by withdrawal of sulfate and searched to identify essential processes and genes involved.

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Phyllode shape and water use in mulga woodlands: how important is diversity in a changing climate?

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Mulga (*Acacia aneura* and associated species) occurs across a range of landscape positions and soil types in the Pilbara region of Western Australia and is extremely variable in phyllode shape, the functional significance of which is not known. However, mulga with greater specific leaf area (SLA) dominate in valleys, while mulga with smaller SLA's are more common on hill slopes. In the Pilbara, rainfall has increased since the 1970's; however, rainfall is also predicted to become more episodic in coming decades meaning that drought periods may lengthen. As less specific leaf area (SLA) often correlates with decreased water availability among many plant species, we investigated if differences in SLA of mulga were reflected in tree water relations. We simulated a 100 mm rainfall event by irrigating nine trees over 24 h in the Hamersley Ranges. Three replicate trees of three phyllode types that encompassed SLA 1.8 – 3.8 mm^2 mg^{-1} were measured for water potential, foliar relative water content (RWC), stomatal conductance (g_s) and $\delta^{13}C$. We also established pressure-volume relationships for each of the phyllode types. Trees with a larger SLA were more water stressed, used more water, and were less water use efficient both pre- and post-irrigation. We speculate that predicted changes in rainfall patterns will result in increased dominance of mulga types with more terete phyllodes across the landscape.

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Bud break of Norway spruce in relation to temperature sum: usefulness of microscopy in evaluation and improvement of phenological models

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Timing of bud development in ecodormancy has always been critical for the trees growing in boreal and temperate regions with seasonally alternating climates. The predicted global warming over the mid- and high latitudes of northern continents can make the boreal forests more sensitive to frost damage due to temperature fluctuations in early spring. At present, the beginning of "invisible" phase of vegetative bud development in phenological models, used to forecast the possible consequences due to the global climate warming, is fixed on theoretical assumptions or it is estimated using visible bud burst observations. Our study aims to clarify, if microscopic, "invisible" developmental phases in vegetative buds of Norway spruce (*Picea abies* L. Karst.) could be used to evaluate and improve the phenological models. To achieve the aim, microscopic development of the buds of Norway spruce was followed during two consequent springs in relation to bud phenology and to accumulated temperature. The results showed that certain morphological changes in the primordial needles occurred before any visible changes in the buds, and at the same calendar day in both springs, not depending on the accumulated temperature. Instead, the elongation of primordial shoots that began before visible changes, as well as the visible bud development followed the accumulated temperatures, but the timing of both of these events differed between the years. The results, if only from two years, showed the importance of temperature in timing of early, "invisible" bud elongation, and are promising in respect to evaluation and improvement of phenological models. In addition, the same morphological changes in the primordial needles at the same calendar day of two consequent springs are very interesting. If this simultaneity refers to the importance of light conditions in bud development will be tested in the following years.

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Consequences of S deficiency in higher plants for proximal soil ozone levels

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Desulfurization of fumes caused a drastic decline of atmospheric sulfur (S) depositions into agricultural systems in northern Europe and average in rural areas meanwhile <10 kg ha^{-1} yr^{-1}. Based on physico-chemical soil properties and climatic conditions about 31% of the arable land in Germany is subjected to a high risk of S deficiency. The predicted climate change implies scenarios with higher temperatures and precipitation over winter, or summer and increase the risk of S deficiency by another 11 % in the next 70 years. The soil proximal ozone level increased in northern Germany from 33 µg m^{-3} in 1980 up to 50 µg m^{-3} in 2007. The German alert value of 180 µg m^{-3} ozone was regularly exceeded during the last years. Schnug proposed already in 1997 that the level of S supply is positively correlated with the release of H_2S by plants and that this process is relevant for the degradation of ozone. The S supply is of high ecological importance with view to climate relevant gases. S metabolism is closely related to the natural resistance of crops against pests and diseases. The emission of H_2S by oilseed rape plants increased by more than 150 pg g^{-1} min^{-1} in a field experiment after application of 150 kg ha^{-1} S. In addition, the S nutritional status of a crop is directly related to the utilization of nitrogen and thus gaseous losses of NO_x from soils. It is the aim of the presented contribution to outline the significance of the S supply of higher plants for proximal soil ozone levels in the context of climate change.

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Outstanding Functions of SunPatiens (*Impatiens hybrida hort.*) in air purification and cooling effect

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SunPatiens® (*Impatiens hybrida hort.*) is an interspecies hybrid garden plant of Impatiens produced by Sakata Seed Corporation in 2006. This study shows SunPatiens® has outstanding abilities in air purification and cooling effect compared with traditional garden plants. Based on empirical data, it has 5 - 8 times higher absorption rate per unit of time in nitrogen dioxide (NO_2) and 3 - 4 times higher in formaldehyde (HCHO) than traditional garden plants. Both are resulted by the experiments in 1 m^3 chambers and common rooms. In addition, it has superior cooling effect. By measuring surface temperature of SunPatiens® bed in summertime, it showed about 10 degrees Celsius lower than bare ground temperature and showed 3.0 - 4.5 degrees Celsius lower than the surface temperature of traditional garden plants. Using these functions, we may suggest that SunPatiens® will help to improve our environment factors such as reducing air pollutions (NO_2, HCHO) and preventing urban heat island phenomenon.

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Drought stress effects on chlorophyll fluorescence, gas exchange and antioxidative defence in *Allocasuarina luehmannii* seedlings

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Buloke (*Allocasuarina luehmannii*) communities in central and northern Victoria, Australia, have been cleared to less than 3 % of their original distribution. They are listed nationally as endangered. Re-vegetation of this species is critical to mitigate soil degradation and salinity associated with its clearing. However, seedling regeneration is infrequent because seedling persistence relies on above-average seasonal rainfall, a rare event in an increasingly drier Australia. To reduce uncertainty about effects of variable water availability on seedling persistence, we studied the physiological and biochemical drought tolerance mechanisms of buloke seedlings in a controlled glasshouse experiment. We simulated two different stages of water deficit (moderate and severe) and monitored effects on stomatal conductance, photosynthesis and the efficiency of photochemistry. Since plant water stress is often accompanied by the development of reactive oxygen species due to an imbalance of the light and dark reactions of photosynthesis, we also monitored concentrations of ascorbic acid and glutathione, both important antioxidants protecting plants against oxidative stress. At the end of the drought treatments, all seedlings were re-watered and the same physiological and biochemical responses monitored. Here we examined whether recovery was dependent on the severity of the previous stress. This knowledge will deepen our understanding about the survival strategies of this species, since seedling regeneration might not only depend on its adaptations during periods of stress, but also on its ability to recover after re-watering.

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Temperature effects on the metabolism of ectotherms: does Darwin break the Arrhenius Law?

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The metabolism of plants is dependent on temperature, which has a physical impact on the enzyme kinetics that causes changes in the metabolism. The respiratory temperature dependency, which reflects the metabolic change at different temperatures, is considered to be universal (Gillooly *et al.* 2001). The respiratory temperature dependency may be described by the Arrhenius relation $A \bullet e^{-kE/T}$. The universality of the temperature dependency is based on the assumption that both the activation energy (E) of the limiting key-enzymes and the baseline respiration (A), which is given by the enzyme and substrate availability of the limiting key-enzymes, are similar for all organisms. Those assumptions exclude that various organisms may have developed differences in the enzymatic network, which exclude furthermore thermal acclimation and adaptation within extended temperature exposure duration. Variations in the enzymatic network might result in differences of the respiratory temperature dependency. Differences in the respiratory temperature dependency could occur in the activation energy (E) reflected by the slope and the baseline respiration (A) that is given by the intercept. Our results showed that the Arrhenius relation predicted the immediate respiratory temperature response, which appeared to be highly variable. For different plant species and plants acclimated to different temperatures, the slope of the immediate respiratory temperature response differed, showing that the activation energy cannot be considered to be universal. Furthermore, the acclimation and adaptation temperature had a high impact on the baseline respiration. Upon acclimation and adaptation of plants to warm temperatures the baseline respiration decreases. This decrease resulted from compensatory modifications of the enzymatic network, which counteracted the increased immediate respiratory temperature response. It was evident that the acclimated and adapted respiratory temperature response, by comparing the basal metabolism of plants grown in different temperatures, was relatively independent of temperature. However, other ecosystem limitations like water and nutrient availability may become important limiting factors.

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The role of ecophysiological and phenological processes during regeneration in increasing tree species sensitivity to climate change in British Columbia, Canada and south-east Victoria, Australia

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Tree species are most sensitive to changes in environmental conditions during the regeneration phase of their life cycle. Climate-driven changes in phenology and resource availability can affect the spatial and temporal breadth of a species regeneration niche which in turn could increase the sensitivity of species to projected climate change. To examine species sensitivity to climate change we investigated the influence of projected change on the ecophysiological and phenological mechanisms that govern the breadth of a species regeneration niche. We used the tree and climate assessment model, TACA, to examine species sensitivity within two regions of British Columbia, Canada and in southeast Victoria, Australia. Although, the species of British Columbia and Australia differ in many ways, similarity was found to exist in the mechanisms that influence regeneration success. The results from the three case studies suggest that similar responses may be exhibited by species within British Columbia and Victoria to projected climate change as warmer conditions allow for the expansion of species regeneration niches into higher elevations but warmer and drier conditions force their contraction from lower elevations and/ or to sites with more suitable edaphic conditions. The results also highlight that multiple factors exist that will cause these shifts which differ between species and species-groups. The findings highlight the need to initiate field trials of tree species across climatic gradients with detailed climatic and soil moisture monitoring to investigate regeneration response and the subsequent roles of competition and biotic factors in order to develop and/ or validate ecological models suitable for assessing species sensitivity.

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Changes in *Leptospermum myrsinoides* stomatal behaviour along a microclimate gradient as affected by adjacent land-use

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Native temperate woodlands in western Victoria are currently under pressure by agricultural and forestry land-use, and by the predicted shift to a drier and warmer climate, combined with generally more extreme weather events in these areas. In a landscape mosaic, microclimatic conditions in remnant woodlands may be dependent on the distance from the edge of the woodland and the adjacent land-use, be it forestry plantation, or pastures. Environmental gradients from woodland edges to the interior may also serve as proxies for changing climate conditions. As part of an ongoing study investigating the effect of adjoining land-use on native woodland microclimate in south-western Victoria, Australia, edges of native woodlands were found to be 0.5°C cooler than the interior of woodlands in winter, but had similar temperatures in summer, with adjoining land-use (*Eucalyptus globulus* plantation versus pasture) having no impact on this temperature gradient in either season. We studied gas-exchange of *Leptospermum myrsinoides,* the dominant understorey species in south-eastern Australia's native heathy woodlands, in both winter and summer. Such data help to determine the response of stomatal behaviour to temperature shifts across time and space. Boundary-line analysis was then performed to determine stomatal conductance and photosynthesis response to temperature when other microclimate variables were non-limiting. This presentation will discuss how responsive *Leptospermum myrsinoides* stomatal behaviour is to temperature shifts comparing it with other species, and what might be the implications given current climate change predictions.

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Barking up the wrong tree - energy and nutrient use efficiency of biofuel plants

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Fact is that a worldwide continuously increasing energy demand cannot be met by fossil fuels at reasonable prices and on a long-term basis. Cultivation and processing of special energy crops such as *Miscanthus giganteus* for incineration and oilseed rape for biofuel production have been explored since the 1980s. The extended growth of biofuel plants more than 20 years later has been reinforced in industrial countries as a counter-measure against increasing energy costs and a contribution to lessen the burdens of climate change. A decision with global impact on food security. The reason is simple: Increasing product prices in the non-food sector will globally not only promote conversion of natural land, forests and grasslands into agricultural land, but also cause an intensification of plant production for the non-food segment. Undesired side effects on nature and environment are inevitable and imply carbon debts, which have been calculated to take several centuries before being balanced theoretically by biofuel production. In addition, a higher input of fertilizers will diminish nutrient use efficiency and may increase nutrient losses to the environment, which contribute for instance to the eutrophication of water bodies. This contribution will evaluate the overall potential of biofuel plants to satisfy the demand for fuel in Germany, it will assess energy and nutrient use efficiency of selected agricultural crops, and it will provide an estimate on the demand for environmental clean-up.

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The role of sustainable forestry in climate change

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Since the publication of the Stern Review in 2006, forests have returned to the international political agenda. The role of forests in mitigating climate change received relatively minor attention during the drafting of the Kyoto Protocol, but it is certain that they will be play a more prominent role in the Kyoto Protocol's successor, currently being negotiated. The most important aspect of forests in this respect is the reduction of carbon emissions from deforestation and forest degradation (REDD). Fortunately, action in this area is consistent with a number of other aims, such as the conservation of biological diversity. However, a number of vested interests may argue against the incorporation of forests in any future agreement, so a strong presence by the forest community is needed in the negotiations. Forests will only help mitigate climate change if they can survive the changes in climate. Consequently, any attempts to consider mitigation must also consider adaptation. A forthcoming report from the Collaborative Partnership on Forests has examined adaptation in detail. It is very difficult, if not impossible, to take a prescriptive approach to forest management when considering climate change. Instead, there are a wide range of possible actions that could be taken, and the precise combination will depend on the local conditions, the anticipated changes in climate, and the objectives for the forest (which may themselves have to be changed because of climate change). Many tools exist that can be used to aid this sort of decision analysis, but few to date have incorporated the uncertainties that climate change introduce to long-term forest management.

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Carbon sequestration efficiency of trees

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Questions about how much carbon trees sequester from the atmosphere, and how this sequestration varies with multiple limitations by environmental conditions and resources, are central to national programmes for global change mitigation. One issue that is cogent to forest ecosystems, which frequently occupy more resource-poor portions of the landscape, is whether growth capacity and carbon sequestration capacity response to climate and atmospheric perturbations is largest when nutrient and water resources are more abundant, or more scarce, or depend on the particular limiting resource. Using examples from research on elevated atmospheric CO_2, including from global FACE experiments, I ask whether C sequestration is limited by atmospheric CO_2. I also seek to test whether the atmospheric CO_2 response of photosynthesis and tree C sequestration is greater on high-nutrient versus nutrient-poor sites. Understanding what conditions maximise these responses is important to developing strategies to allocate effort for C sequestration from the atmosphere under current and futuristic conditions, and determine how to best manage for maximises C sequestration.
I review recent literature on stand C sequestration for different tree types (deciduous, coniferous evergreen, and broadleaf evergreen) that characterise managed forest vegetation worldwide. I also review the ecosystem C sequestration responses to elevated CO_2 alone or in combination with other environmental factors. Overall, C sequestration is greatest on high-nutrient or fertilised sites, but C sequestration efficiency is also low under such conditions. Results and arguments advocated here can help provide a framework for natural resource management decisions for increasing C sequestration using native species, including native Eucalypts in Australia.

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Interspecific variations in photosynthetic nitrogen-use efficiency

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Photosynthetic capacity is known to vary considerably among species. Its physiological cause and ecological significance have been one of the most fundamental questions in plant ecophysiology. Photosynthetic nitrogen-use efficiency (PNUE, photosynthetic rate per unit leaf nitrogen) has attracted much attention to understand the inherent variation in photosynthetic capacity among species. Previous studies have demonstrated that leaf nitrogen is less allocated to Rubisco in low-PNUE species. It was considered that there is a trade-off in nitrogen partitioning between photosynthesis and cell walls. We studied contents of Rubisco (key enzyme of photosynthesis) and cell walls in leaves of 26 species with a large variation in photosynthetic rates, which covered almost half of its global variation. Our results demonstrated that Rubisco-use efficiency (RUE, photosynthetic rate per Rubisco) explained most of the interspecific variation in photosynthetic rates, while nitrogen allocation to Rubisco had a significant but smaller contribution. Our analyses suggested that RUE was altered by the content of cell wall, which probably affected mesophyll conductance for CO_2 diffusion. Cell wall nitrogen increased with increasing leaf mass per area, but it did not directly affect the variation in photosynthetic rates. Species with low photosynthetic rates invest more resources in cell walls at the expense of RUE.

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Why growth and carbon models are wrong: a new way forward

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(P1) **Risk assessment of ozone for *Fagus crenata* in Japan - consideration of atmospheric nitrogen deposition**

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We investigated the effects of ozone (O_3) on the whole-plant growth of *Fagus crenata* seedlings under different nitrogen (N) loads. The seedlings were grown in potted andisol supplied with N at 0, 20 and 50 kg ha^{-1} $year^{-1}$. In each N treatment, the seedlings were exposed to charcoal-filtered air or O_3 at 1.0, 1.5 and 2.0 times the ambient concentration for two growing seasons from April 2004 to October 2005. The sensitivity to O_3, which was defined as absolute value of slope of the regression line between AOT40 (accumulated exposure over a threshold of 40 nmol mol^{-1}) of O_3 and the relative whole-plant dry mass increment during the second growing season, was increased with increasing the amount of N load. Based on the relationship between the amount of N load and the sensitivity to O_3 obtained from the experimental study, we assessed the risk of O_3 for *F. crenata* throughout Japan with consideration of atmospheric N deposition. AOT40, total (wet plus dry) N deposition (TN_{dep}) and habitat of *F. crenata* were integrated by geographic information system. The relative growth reduction (RG_{red}, %) of *F. crenata* at each habitat with different AOT40 (μmol mol^{-1} h) and TN_{dep} (kg ha^{-1} $year^{-1}$) was calculated according to the following formula: $RG_{red} = (0.0055*TN_{dep} + 0.230)*AOT40$. The average and maximum of the RG_{red} were estimated as 3.2% and 9.7%, respectively. The TN_{dep} greatly affected the RG_{red}. When the TN_{dep} was assumed as zero, the estimated average and maximum of the RG_{red} were 2.3 % and 5.7 %, respectively. This indicates that the estimated average and maximum of the RG_{red} were increased by the consideration of atmospheric N deposition at the rate of 38 % and 71 %, respectively. Therefore, we concluded that atmospheric N deposition must be taken into account the risk assessment of O_3 for *F. crenata* in Japan.

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(P3) **Modelling stomatal ozone flux for forests in East Asia**

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O_3 impacts on vegetation are becoming a serious problem in East Asia. The stomatal flux-based method was recently developed to assess O_3 impacts in Europe because O_3 uptake was closely related to O_3 effects. This method would also be useful for O_3 risk assessment in East Asia. However, the method should be modified to apply in East Asia because of an interaction between regional climate and species-specific stomatal response effect on stomatal O_3 uptake. Moreover, growing season for deciduous forests was also one of the determining factors in O_3 uptake. In Europe, the length of the growing season was defined by a fixed time period when O_3 uptake was estimated. However, the fixed time period may bring about uncertainty in the estimation of O_3 uptake. Therefore, initially, stomatal response for deciduous forests was parameterized from scientific literature in East Asia. In addition, we made comparisons of simulated cumulative stomatal ozone flux (F_{st}) for deciduous forests in East Asia (20° N, 100° E ~ 45° N, 150° E) between the following two cases: 1) using a fixed time period and 2) using a phenological model for leaf development. The distribution of potential deciduous forest area was identified using warmth index. Meteorological and O_3 concentration data in 2000 were used as the input data. The result showed a significant difference in F_{st} between both cases of the growing season length in East Asia. In Case 2, high F_{st} was estimated not only in highest O_3 concentration area but also in the moderately high O_3 concentration area, Japan and southern part of China. This showed that O_3 effects might spread to wide areas in East Asia.

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(P5) **Eco-physiological effects of polycyclic aromatic hydrocarbons (PAH) on plants: exposure experiments using fluoranthene**

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Polycyclic aromatic hydrocarbons (PAHs) have been widely studied with respect to their carcinogenic and mutagenic effects on animals and human cells. In chamber exposures between April 2006 and July 2008, we have illustrated the effects of these groups of organic compound on plants, using a four-ring member, fluoranthene as a model. Firstly, phenanthrene and fluoranthene effects on the needle photosynthetic traits of 2 year-old Japanese red pine (*Pinus densiflora* Sieb et Zucc.) seedlings were investigated in a long term (105 days) fumigation study. Fluoranthene (10μM) negatively affected the net photosynthesis rate measured at near saturated irradiance (A_{max}), stomatal conductance (g_s), initial chlorophyll fluorescence (F_o), needle chemical contents and ribulose 1,5-bisphophate carboxylase (Rubisco) of current-year needles. Also, 10μM phenanthrene effects were comparable to those for fluoranthene, but with lesser damage severity. Secondly, we investigated and compared the effectiveness of scavenging reactive oxygen intermediates/species (ROI) in fluoranthene pre-fumigated Japanese red pine seedlings in a short term (5-14 days) exposure. The ecophysicological status of 1- year-old pine seedlings was assessed with emphasis on dosage and period of fluoranthene fumigation. Peroxidase, superoxide dismutase and mannitol were effective scavengers of ROI. Finally, the interactive effect of simultaneous ozone and fluoranthene fumigation on the eco-physiological status of the evergreen conifer, *P. densiflora* in a 90-day fumigation period was assessed. The interaction indicated that O_3 exacerbated the phytotoxicity of fluoranthene, even at low concentration. Likewise, a similar experiment was carried out on Cherry tomato (*Lycopersicon esculentum* Mill) in a 34 d fumigation study. The plants were fumigated with ten fumigants until the fruiting stage of the plant. Results comparable to those from *P. densiflora* were observed on tomato. Mannitol addition to the treatments mitigated the negative effects of the fumigants in all these experiments.

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(P7) Combination of elevated CO_2 and nitrogen deposition changed photosynthetic traits in Boston fern

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Fern species have notable characteristics: 1) they are one of the main components of the forest floor in temperate region, 2) photosynthetic down regulation was not observed at elevated CO_2 concentrations ($[CO_2]$). At 2100, there would be possibilities of atmospheric $[CO_2]$ reaching around 1000 ppm and approximately 2.5 g N m^{-2} nitrogen depositions in both Europe and East Asia. How do growth and photosynthesis traits of Boston ferns respond to the combination of high $[CO_2]$ and nitrogen deposition? To determine the effects of high $[CO_2]$ and nitrogen deposition on the photosynthetic traits of fern species, we grew Boston fern (*Nephrolepis exatata* var. *bostoniensis*) under elevated $[CO_2]$ and high nitrogen ($(NH_4)_2SO_4$) loading. Four regimes were studied: control (grown at 360 ppm CO_2); nitrogen deposition treatment alone (grown at 360 ppm CO_2 and 3.0 g N m^{-2} with $(NH_4)_2SO_4$ fertiliser); elevated $[CO_2]$ treatment alone (grown at 1200 ppm $[CO_2]$); and elevated $[CO_2]$ with nitrogen supply (grown at 1200 ppm CO_2 with 3.0 g N m^{-2} $(NH_4)_2SO_4$ fertilizer). In each regime we determined growth and photosynthetic responses of Boston fern. Aboveground biomass of the fern treated with alone or combination of both elevated $[CO_2]$ and nitrogen was significantly higher than that at the control. P_{growth} (light saturated photosynthetic rates at grown $[CO_2]$) of elevated $[CO_2]$ treatment alone was higher than P_{growth} of control. Leaf nitrogen content and V_{cmax} were significantly lower in elevated $[CO_2]$ treatment alone than in the control, even though no clear fall of J_{max} was found in elevated $[CO_2]$ treatment alone. In nitrogen deposition treatment, P_{growth}, V_{cmax} and J_{max} showed higher than those of controls. Based on these results, Boston fern shows no clear photosynthetic down regulation, even at very high $[CO_2]$, and nitrogen deposition would increase the P_{growth} by way of the changes of leaf biochemical characters.

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(P9) **Estimation of net ecosystem exchange of forests by terrestrial ecosystem model**

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Carbon budgets between atmosphere and terrestrial ecosystems have been measured and estimated by various ways for the purpose of understanding the mechanism of ecosystems and global warming, including the way of terrestrial ecosystem models. The purpose of this research is 1) to develop an above ground flux model that can estimate the diurnal change of CO2 flux from atmosphere to forest ecosystem, 2) to couple the above ground flux model with a carbon cycle model that can calculate the long-term carbon cycling with the flow of nutrients and water, and 3) comparing the NEE (Net Ecosystem Exchange) estimated by the model with the observed NEE in flux tower sites. Seasonal GPP variation and its magnitude in boreal coniferous forests and temperate deciduous forest is well represented by above ground water and carbon flux model, comparing with the estimated GPP from tower flux measurement. The above ground flux model is coupled tightly with a terrestrial ecosystem model, which can calculate long-term carbon, nitrogen, and water cycling in forest ecosystems. Estimated value of annual and seasonal NEE by the coupled model is compared to the tower observed NEE. The seasonal variation of NEE in flux tower sites with different climate and vegetation are well represented by the model and long-term carbon stocks are matched to the measurement.

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(P11) *Arabidopsis* transcriptional responses differentiate between O_3 and herbicides

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Using published data based on Affymetrix ATH1 Gene-Chips we characterized the transcriptional response of *Arabidopsis thaliana* Columbia to O_3 and a few other major environmental stresses including oxidative stress. A set of 101 markers could be extracted which provided a composite diagnostic signature that differentiated the transcriptional responses of *A. thaliana* to these stresses. Cluster analysis reveals greater similarity between the expression responses to four ALS-inhibiting herbicides and O_3. In contrast, responses to glyphosate were more similar to UV-A and UV-B. While this research primarily was carried out to identify herbicide-specific expression patterns, the comparison to published data for O_3 indicates that O_3-specific markers may be evaluated and developed. This proof-of-concept study indicates that microarray approaches may useful to identify additional ozone-specific gene expression changes.

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(P13) **The effect of elevated carbon dioxide on the growth and yield of wheat in the Australian Grains Free Air Carbon dioxide Enrichment (AGFACE) experiment**

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Current predictions indicate that Australia is likely to be particularly challenged by the impacts of rising atmospheric carbon dioxide and the consequent perturbations in climate. The Australian Grains Free Air Carbon dioxide Enrichment (AGFACE) project in Horsham, Victoria was designed to simulate predicted atmospheric carbon dioxide levels in the year 2050. The experiment measures the interacting effects of carbon dioxide (ambient aCO_2 ~380 ppm, elevated eCO_2 ~550 ppm), irrigation (rainfed, irrigated), higher temperatures during grain fill (time of sowing), nitrogen (0, +), and variety (Yitpi, Janz) on wheat growth and production. Carbon dioxide was injected over the crop in open-air 12 m rings from emergence (July) until maturity (December) in 2007. Crop development was not affected by eCO_2. The effect of eCO_2 was to increase crop biomass at maturity by 20 % ($P<0.001$) and anthesis root biomass increased by 49 % ($P=0.004$). Harvest index was not affected but mean grain yield across all treatments increased from 2.68 ton ha^{-1} under aCO_2 to 3.23 ton ha^{-1} under eCO_2. Both sowing time and additional water affected growth and yield but there were no significant interactions among these factors and eCO_2. The effect of higher carbon dioxide was to slightly increase the number of kernels per spikelet ($P = 0.055$). Water use, the sum of rainfall and change in soil water from sowing to maturity was 387 mm with no differences among the treatments other than irrigation. There were no significant interactions between carbon dioxide and genotype or nitrogen treatment on growth or yield. These data will be used to calibrate crop simulation models to assist with developing strategies to assist the grains industry adapt to the changing climate.

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(P15) **Influence of air pollution on needles of *Pinus amamiana*, in Yakushima Island, Japan**

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With the progress of industrialization in East Asian countries, enormous amounts of yellow dust, ozone and acidic aerosol are transported to Japan. Yakushima island (30˚ 22'N 130˚ 23'E) is affected directly by the long-range transport of air pollutants from continental China, because there are no industrial areas and sources of pollution between the continent and this island. Recently, significant decline of *Pinus amamiana* is observed in this island. Significant effects of long-range transport of air pollution were detected in winter. Large amounts of SO_4^{2-} ion originated from acidic aerosol (nss-SO_4^{2-}) transported from the continent adhered to the needle surface. The amount of adhered nss-SO_4^{2-} was larger on the trees growing on the ridge and caused acidic through-fall. The accumulation rates of NO_3^- and SO_4^{2-} were similar in November, but the rates of SO_4^{2-} remarkably increased in February. About half of the increase in SO_4^{2-} was nss-SO_4^{2-} and the rate in February was over 4 to 5 times as high as that in November. These stresses caused severe damage to the surface of pine needles and potassium leakage from needles significantly increased. On the other hand, although the daily mean O_3 concentration was nearly 100 ppb in winter, the effect of O_3 was not clear under the present conditions. *Pinus amamiana* was the most sensitive tree species compared with other trees to the increase of nss-SO_4^{2-} flux because of its growth characteristics.

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(P17) **Effects of acid deposition on forest and its watershed**

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To examine the influence of air pollution on the forest watershed, we have studied the stream water, precipitation, and gaseous elements at the site of Aburahi-R located in Shiga pref., Japan. Annual average nitrate-nitrogen concentration of stream water was 2 mg l^{-1}, which is more than 3 times higher than in other watersheds. Average annual loads of NO_3^- from 1991 to 1999 and from 2000 to 2007 were 16 and 25 kg ha^{-1} yr^{-1}, respectively. It was increasing gradually in this period. There is the national highway (the traffic was 60,000 a day) and a tea plantation (240 ha^{-1}) near the site. Nitrogen and sulfate from these emission sources may affect the stream water, plant functioning, and forest ecosystems. On the other hand, the average ambient concentration of NO_X and SO_2 monitored by Ogawa passive samplers (Ogawa & Co.) from November 2007 until October 2008 were 10.6 and 1.2 ppb, respectively. These concentrations were slightly less than in the suburban area, such as Hikone City, Shiga pref., where our university is located. In order to estimate the dry deposition onto the canopy, the precipitation and the through-fall of the Hinoki trees (*Japanese Cypress*) were measured approximately every hour. Total precipitation was 44 mm, and continued from May 19, 5.00 p.m. till May 20, 5.00 a.m. Each concentration of NO_3^- for the first one and half hour was 2.5 and 34 mg l^{-1}, respectively. Those concentrations for NO_3^- decreased rapidly and reached a constant value seven hours after the beginning of rainfall (precipitation of the period was 24 mm). These results indicate that the dry deposition affects the plant functioning and forest ecosystems.

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(P19) **Increasing ozone concentration may affect production in certain ozone sensitive rice cultivars under a global warming condition**

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To estimate ozone threat for food production in Asian countries under global warming conditions, we conducted ozone exposure experiments under a current ambient temperature condition or +3 °C using glass house type open top chambers (OTCs). In 2007, total of 14 rice cultivars including representative Japanese (Japonica) cultivars and some Indica-types grown in pots were exposed to ozone at an ambient temperature condition. Designated daily mean ozone concentrations in the OTCs were 2, 19, 32, 45, 58 ppb and daytime AOT40 (12 h) were 0, 0, 8,576, 33,525, and 61,114 ppb•h, respectively for 5 months. In 2008, designated daily mean ozone concentrations were 2, 23, 28, 42, and 57 ppb. Those daytime AOT40 (12 h) were 0, 0, 8, 640, 83,700 and 146,610 ppb•h, respectively. Global warming condition of + 3C with ambient air temperature were combined with ozone treatment at 0, 28 and 57 ppb of daily mean in 2008. Japanese representative rice cultivars Koshihikari and Akitakomachi were relatively tolerant to ozone stress based on the rice yield reduction in 2007. However, Kirara 397 and Takanari were classified into relatively sensitive cultivars. In 2008 Akitakomachi and Kirara 397 were exposed to ozone under mean global warming condition. Akitakomachi did not show any significant yield reduction at any ozone and temperature stress schemes. Ozone sensitive Kirara 397 significantly reduced grain yield by high ozone concentration as in the 2007 experiment. Temperature stress did not have significant effects on Kirara 397. However, combined treatment with temperature and ozone dramatically reduced rice yield. These results suggest that certain ozone sensitive varieties may experience greater threats under global warming conditions.

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(P21) **Differential ozone sensitivity evaluated by visible injuries or grain yield among rice (*Oryza sativa* L.) varieties**

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Ozone sensitivity in rice varieties is often evaluated based on visible leaf injuries at early growing stage. However, it is not clear that the reduction of rice yield relates to visible injuries. Therefore, visible damage and the reduction of grain yield in 20 Japanese and 20 Asian varieties exposed to ozone was examined. Experiment 1: Two weeks-old rice seedlings were exposed to ozone (min.: 20 nl l^{-1}, max.: 120 nl l^{-1}) for 12 h from 06:00 to 18:00 in open top chamber (OTC). Visible leaf injuries were quantified by assigning a leaf bronzing score (LBS) to the leaves. Experiment 2: Rice plants were exposed to ozone in OTC throughout the growing seasons of 2008. Ozone concentration was maintained at 0, or the above-mentioned level. At harvest, samples were taken to determine grain yield and yield components. *Indica* varieties (mean LBS: 3.0) were more sensitive to ozone induced leaf injuries than *Japonica* varieties (mean LBS: 1.8). Among the tested varieties, *Indica* variety Kasalath was tolerant to visible ozone damage (LBS 0.5), and *Japonica* variety Kirara 397 was one of the most sensitive cultivar (LBS 5.8). Ozone exposure reduced rice yield. The reduction rates of the grain yield by the ozone exposure were 20 % in Kasalath, and 22 % in Kirara 397. It is suggested that Kasalath is not tolerant to ozone in terms of grain yield. These results showed that ozone sensitivity in rice evaluated by visible injuries did not coincide with an evaluation by the reduction of grain yield. Current results suggest that the mechanisms responsible for acute short term leaf injury development will be insufficient to explain those of chronic long-term ozone toxicity effects.

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(P23) Effects of O_3 and SO_2 on semiarid plant species in Mu Us Sandyland, Inner Mongolia, China

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Increasing air pollution level in East Asia, especially China, has caused great attention in the stability of some semiarid grassland ecosystems. However, there is almost no experimental data available for assessing the effects of air pollutants on the native plant species in these regions. The objective of the present study was to investigate the growth responses of seven plant species from semiarid Mu Us Sandyland, Inner Mongolia to O_3 and SO_2 in controlled environmental cabinets, in order to provide baseline data for assessing the potential effects of air pollution to the grassland in semiarid East Asia. Seeds of seven plant species (*Agriophyllum squarrosum*, *Artemisia ordosica*, *Artemisia sphaerocephala*, *Astragalus adsurgens*, *Caragana korshinskii*, *Hedysarum fruticosum* subsp. Laeve, *Medicago sativa*) grown in semiarid Mu Us Sandyland, Inner Mongolia, China were collected, and were sown in the artificial soil (Engei-baido). Seedlings were transplanted to pots packed with sand and Engei-baido (7:3), and were grown in the environment-controlled greenhouse for several weeks. They were moved into the naturally lighted gas exposure cabinets, in which temperature was 25/15°C (day/night) and relative humidity was 55/75% (day/night). Plants were exposed to 0.1 ppm SO_2 (constant), 0.05 ppm O_3 in average (0.02-0.1 ppm) or nothing (control) for 4 weeks. After stem length, leaf number and area were measured, each organ (leaf, stem, root) was dried and weighted. Growth in each treatment was compared by statistically with Duncan's multiple range test (5% level). A typical visible symptom (reddish brown small dots) caused by O_3 was observed to the surface of the leaf of *A. adsurgens*, and leaf senescence was accelerated on several species exposed to O_3 or SO_2. Growth of *A. squarrosum*, *A. ordosica* and *H. fruticosum* was reduced by SO_2 and that of *A. ordosica*, *A. sphaerocephala*, *A. adsurgens*, and *M. sativa* was reduced by O_3, while *A. squarrosum* exposed to O_3 grew more than control. In these plant species, decreases in net assimilation rate, changes in assimilate partitioning, leaf morphological changes, etc. were induced by O_3 or SO_2. The present research showed that even in the semiarid grassland, some species showed visible injuries by O_3 or SO_2, and different species showed different sensitivities to the two air pollutants. These species responses should be the important basic information for the deterioration of grassland and the recovery of desertification according to atmospheric environmental changes, especially O_3 increase, in near future in East Asia.

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(P25) **Contribution of plant-emitted VOCs to the atmosphere with increasing prevalence of fire**

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The frequency and size of wildfires is expected to increase in Australia with global warming. It is widely accepted that the number of days of extreme and high fire danger will increase and will extend beyond the period of the traditional fire season throughout the continent. Forest and savannah fires are frequent in the dry season in Australia and occasionally cause loss of life and damage to property. Fire plays an important role in many Australian ecosystems but our knowledge of how these ecosystems will respond to changes in fire regimes is limited. The associated increase in risks is not only restricted to greater ecological, economic and social losses but also to substantial additions to air pollution and therefore changes in atmospheric chemistry. Volatile organic compounds (VOCs) are released through burning of vegetation. VOCs are also produced naturally by many plants and up to 10% of plant carbon may be devoted to the production of volatile secondary metabolites. This paper explores the potential impact of increased fire frequency and size on the nature of emissions of plant-emitted VOCs to the atmosphere in Australia.

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(P2) **Temperature adjustment among six *Eucalyptus* species in Hawkesbury Forest Experimental common garden**

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There are persistent questions regarding how climate controls the geographical distribution of species that highlight a lack of understanding of their ecology. Addressing these questions is a high priority in Australia given the strong possibility of changes in temperature and precipitation that are expected as a result of greenhouse gas accumulation forcing climate. It is hypothesized that species originally from warmer regions and more likely to be exposure to a wide range of temperatures show higher photosynthetic temperature optima or high temperature tolerance than species from cooler regions. This hypothesis was tested using leaf gas exchange and chlorophyll *a* fluorescence measurements of six contrasting *Eucalyptus* species at the Hawkesbury Forest Experimental site. Photosynthetic heat tolerance of six species was investigated in a common environment. Measurements for each species at three temperature levels (18, 25 and 32°C) along with photosynthetic parameters were used to evaluate heat tolerance. The initial dataset suggests that *E. dunnii* from a geographically narrow and cooler region of Qld. has the less heat tolerance than other five species. This was true in terms of its optimal temperature for photosynthesis and in terms of its critical temperature of chloroplast function. Further measurements will evaluate: 1) the magnitude of adaptability of heat tolerance from winter to summer conditions, and 2) how other climate change factors like elevated [CO_2] and drought affect the thermotolerance of *Eucalyptus*. Information from this study will be used to refine models of species distributions in the face of climate change.

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(P4) **Assessment of transpiration efficiency in peanut (*Arachis hypogaea* L.) under drought by lysimetric system**

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Transpiration efficiency (TE) is an important trait for drought tolerance in peanut (*Arachis hypogaea* L.). The variation of TE was assessed gravimetrically in nine peanut genotypes (Chico, ICGS 44, ICGV 00350, ICGV 86015, ICGV 86031**,** ICGV 91114, JL 24, TAG 24 and TMV 2) grown in lysimeters (PVC tubes of 1.2 m length with 20 cm diameter) under well-watered and drought conditions. The transpiration was measured by regular weighing of the lysimeters whose soil surface was mulched with 4-cm thick polythene beads. Transpiration efficiency in the nine genotypes used varied from 1.4 to 2.9 g kg^{-1} under well watered and 1.7 to 2.9 g kg^{-1} under drought conditions. Consistent variation for TE existed among the nine genotypes across the crop growing period was studied. Higher TE was found in ICGV 86031 in both well-watered and drought condition and lower TE was found in TAG-24 under both the water regimes. ICGS 44 had high TE under well-watered conditions but had one of the lowest TE under drought condition. Compared to well-watered condition, TE increased under drought in genotypes except ICGV 91114, ICGS 44 and JL 24. Transpiration efficiency was significantly correlated with stem dry weight (r^2 = 0.47), vegetative dry biomass (r^2 = 0.76) and pod weight (r^2 = 0.48) under drought condition. Total whole plant leaf area was negatively associated with transpiration efficiency (r^2 = 0.26) under well watered condition. Our data showed that under drought that was imposed, TE appeared to be the most important trait of the yield architecture that contributed to an enhanced yield and warrants further effort to breed for TE in peanut.

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(P6) **A preliminary study of the impact of climatic changes on thirty species of garden trees in Central Shanxi, China**

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Shanxi is located in Northern China. The climatic change is characterised by increasing temperature and decreasing rainfall in Shanxi over the recent 50 years. Thirty species of main garden trees were chosen from the Botanic Garden of Shanxi Agricultural University to study the impact of the climatic changes on the trees. The preliminary results showed: 1) Some introduced species which had hardly survived the winter period 30-40 years ago could grow normally now, such as *Magnolia liliflora*, *M. biondii*, *Liriodendron chinense*, *Firmiana simplex* etc. 2) There has been no significant impact of climatic changes on the indigenous species distributed widely in the local area, such as *Platycladus orientalis*, *Quercus wutaishanica*, *Populus tomentosa*. 3) Some introduced species which are in favour of cool weather have been affected significantly by the warming climate, showing reduced survival rates and growth of young trees and death of adult trees, such as *Betula platyphylla*, *Betula albo-sinensis*, *Fraxinus americana.* Suggestions are proposed for the selection of garden trees suitable to deal with the warming and drying climate in Shanxi, China.

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(P8) **Impact of supra-optimal copper levels and UV irradiation on Chinese cabbage**

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Soils may be contaminated with high copper levels as the result of mining, smelting and other industrial activities, but also by the application of manure and other copper-rich organic fertilizers or copper-containing fungicides. Copper is an essential micro-nutrient for plants, however, it is potentially toxic at supra-optimal levels and the general symptoms of toxicity are chlorosis and a stunted growth. In order to get more insight into the physiological basis for the toxicity of copper, Chinese cabbage (*Brassica pekinensis*) was grown at supra-optimal levels of copper (1 to 10 μM Cu^{2+}) in the root environment. The pigment content of the shoot already started to decrease at levels >2 μM Cu^{2+} after 2 days of exposure. However, both the photosynthesis expressed on chlorophyll basis and Fv/Fm ratio were hardly affected upon Cu^{2+} exposure even not after leaves had become severely chlorotic. Plant biomass production was stunted at levels ≥5 μM Cu^{2+} after 3 days of exposure. It was evident that the copper toxicity was strongly reduced if UV was filtered out. In addition to enhanced levels of Cu in the root and to a lesser extent in the shoot, exposure of plants to ≥5 μM Cu^{2+} resulted in an altered mineral composition, especially of that in the root. Exposure of plants to Cu^{2+} resulted in a strongly increased level of water-soluble non-protein thiols in the root and slight increase of that in the shoot with increasing Cu^{2+} concentration. The uptake of nitrate by the root was decreased at >2 μM Cu^{2+}, whereas the uptake of sulfate and the sulfate uptake capacity were slightly enhanced at >2 μM Cu^{2+}. The latter was accompanied with an increase in total sulfur content of the shoot, which could pre-dominantly be ascribed to an accumulation of sulfate. The nitrogen content was hardly affected at supra-optimal Cu^{2+} levels.

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(P10) Salt resistance and change of antioxidative enzyme activity in transgenic rice plants overexpressing glycine-rich RNA-binding protein (AtRZ1a) and dual positional specific lipoxygenase genes

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Glycine-rich RNA-binding proteins (GRPs) and Lipoxygenases (LOXs) have been implicated in the responses of plants to changing environmental conditions. Transgenic rice plants constitutively expressing Arabidopsis GRP (AtRZ1a) and Maize LOX (MzLOX1) genes were generated and the responses to various stresses were examined at the flowering stage of T0 plants. Tolerances toward salt and mannitol stress were observed in double transgenic rice plants compared with the wild type plants. Kinetics of dehydration and rehydration experiment indicated that the transgenic rice plants lost water faster than wild-type plants under dehydration stress conditions. However, the resistance to cold stress was not increased in transgenic rice plants. Analysis of antioxidative enzyme activities indicated that GRP may be involved in the down regulation of catalase and superoxide dismutase. Our results suggest that GRP may function as an important determinant in water stress and oxidative stress response pathway.

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(P12) **Constitutive expression of aquaporin and lipoxygenase genes leads to the enhancement of salt, heat, and mannitol stress resistance in transgenic rice plants**

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Water movement across cellular membranes is regulated largely by aquaporins (AQPs). Plant AQPs are divided into four subfamilies PIPs (plasma intrinsic proteins), TIPs (tonoplast intrinsic proteins), NIPs (NOD26-like intrinsic proteins) and SIPs (small basic intrinsic proteins). TIP is known to be involved in water stress response. Transgenic rice plants constitutively expressing Arabidopsis TIP (AtTip4;1) and Maize LOX (MzLOX1) genes were generated and the responses to various stresses were examined at the flowering stage of T0 plants. Transgenic rice plants showed remarkable resistance to salt and mannitol stress. The dehydration experiment indicated that water transport across the membranes is more rapid in transgenic rice plants. Interestingly, the sensitivity in heat stress due to the overexpression of LOX could be recovered by the expression of TIP. Analysis of antioxidative enzyme activities indicated that the activities of peroxidase and superoxide dismutase are inversely correlated under wound stress. Our results suggest that the water movement across tonoplast mediated by TIP is involved in responses to salt, mannitol, heat stress, which may be correlated to the regulation of antioxidative enzyme system.

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(P14) **Recent effects of global warming on agricultural production in Japan**

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The Japan Meteorological Agency reported that the mean temperature in Japan rose at a rate of 1.1º C per 100 years during the 20th century and this rise clearly accelerated after 1990. Therefore, general effects of global warming can be estimated by collecting and analyzing data from various agricultural systems on changes in production due to this recent temperature rise. We conducted a survey of the public institutes of agricultural research in all 47 prefectures in 2005. Over 70 % of prefectures recognized effects of warming on rice, vegetable, and flower cultivation. Horticultural crops and rice are likely to be more sensitive to global warming than other agricultural crops. Our survey elucidated many effects of recent warming, such as changes in the length of crop-growing periods, increases in the abundance of milky white kernels of rice, reductions in feed intake and feeding efficiency of livestock, and reductions in yields of wheat, barley, vegetables, flowers, milk, and eggs. This survey indicates that agricultural production has been greatly affected by recent global warming. If global warming continues to increase, both the frequency and scale of the variety of effects and problems reported in this study will increase.

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(P16) **Is faster growth related to enhanced photoprotective or antioxidative defence capacity in seedlings of six *Pinus radiata* families?**

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The state of the photoprotective and antioxidative system can serve as an indicator of the stress resistance of a plant. Enhanced photoprotective and antioxidative defence capacity may allow plants to maintain faster rates of photosynthesis under a wider range of environmental conditions. This may result in faster growth. Plantation trees often grow in environments to which they are not well adapted and enhanced ability to cope with stress may well be an important contributing factor to sustained growth. Stress tolerance seems likely to become increasingly important as climates and atmospheric conditions continue to change. In this study we examined the photoprotective and antioxidative defence capacity in seedlings of six, glasshouse-grown families of *Pinus radiata* with contrasting growth potential. We chose *Pinus radiata* because it is the dominant softwood species in southern Australia and it is planted across wide ranges of soils and climates. Using stem volume increment as a surrogate for growth, we tested correlations with growth of a range of photoprotective and antioxidative leaf traits. In particular, we obtained data on photoprotective and light harvesting chloroplast pigments (chlorophylls, xanthophylls and carotenes) as well as on the antioxidants ascorbic acid, α-tocopherol and glutathione. We also determined the specific leaf area (SLA) and measured the light saturated gas exchange rates of the seedlings (A_{max}). Compared to slower growing families, faster growing families had greater SLA and chlorophyll content but slightly less ascorbic acid and α-tocopherol. There were no differences among families in A_{max}, glutathione or any of the remaining chloroplast pigments. We conclude that faster growth by measured seedlings was not due to greater photoprotective or antioxidative defense capacity but rather seemed to be related to cumulative effects of increased light harvesting capacity and differences in SLA.

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(P18) *Deschampsia antarctica* desv. in a changing environment

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The Antarctic geobotanical zone is a hostile environment for plant growth. Low temperatures, high light and stratospheric ozone depletion (causing increases in solar UV-B irradiation) cause the formation of active oxygen species. *Deschampsia antarctica* Desv. (Poaceae) is the only native Gramineae found in the Antarctic, where it is restricted to the Antarctic Peninsula and its offshore islands. Throughout its Antarctic distribution the plant exhibits successful reproduction. Its population increased in numbers during the current trend of climate warming. Our investigations performed with *D. antarctica* plants delivered from various islands of Antarctic showed that it was characterized by quantitative differences in total LHCII (light harvesting complex; its oligomeric ($LHCP^1$) and monomeric ($LHCP^3$) forms) and in chlorophyll content in zone CPa where close antenna pigment-protein complexes are situated. Protein bioinformatic search showed the fragment of amino acid sequence of *D. antarctica* PSII has high similarity with *A. thaliana* and *O. sativa* sequences related to PcbC protein family thus being fragment of psbC family gene product. Besides, C-terminal part of sequence equal to one or a few is absent in this fragment. Lipid composition was characterized by diminished galactolipid ratio (MGDG/DGDG ≈1,3) and high enough SQDG content. Also unusual was low PG content (comparatively with other plants). Action UV-B radiation caused changes mainly in pigment composition - chlorophyll *a* and carotenoids - increase of *β*-carotene and decrease of violoxanthin content with stable lutein, neoxanthin and zeaxanthin level. Lipid composition was characterized by accumulation of TAG and SQDG, whereas MGDG quantity decreased. H_2O_2 treatment did not cause any reliable changes in SOD activity but its mean was higher at *D. antarctica* compared with *D. caespitosa*. There are increases in carotenoid and SQDG concentrations in *D. antarctica* plants and chlorophyll *a* content increased in both species.

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(P20) **Simulation study to assess the impact of biomass allocation characteristics of plants on the carbon sequestration in forest ecosystems**

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In reforestation projects for climate change mitigation, it is important to select species with characteristics that can maximise the amount of carbon sequestered into the ecosystem. In this study, we used the CENTURY model to study how plant characteristics in terms of biomass allocation to different parts of plant, i.e. leaves, stem, fine branch, coarse root and fine root, affect the rate of carbon sequestration in a reforestation setting. Firstly, CENTURY was parameterised for *Acacia mangium* (acacia). Then, simulation was conducted for acacia and two other "hypothetical species" in which all characteristics are the same with *A. mangium* except biomass allocation, i.e. representing that of *Pinus merkusii* and *Gmelina arborea*. The biomass allocation to leaves, stem, fine branch, coarse root and fine root for acacia, pine-like and gmelina-like trees was 0.052, 0.048, 0.139, 0.664, 0.097; 0.17, 0.15, 0.1, 0.52, 0.06; and 0.04, 0.11, 0.1, 0.65, 0.1, respectively. The result showed that the total carbon sequestered in the forest ecosystem (aboveground biomass, belowground biomass, litters and soil) in acacia, pine-like and gmelina-like stand after 50 years of planting were 171, 164 and 163 ton ha^{-1}, respectively. When the distribution of carbon according to its pool was analysed, it showed that the source of difference was mainly in the carbon accumulation in aboveground biomass pool.

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(P22) **Carbon sequestration efficiency of vetiver grass, Nakhon Ratchasima, Thailand**

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Deep rooting plants like vetiver grass (*Vetiveria* spp.) cause increasing carbon transfer from the global atmosphere to the pedosphere. The comparative study on carbon sequestration among 11 ecotypes of vetiver grass, namely Prachuap Khiri Khan, Kamphaeng Phet 1, Kamphaeng Phet 2, Sri Lunka, Ratchaburi, Songkla 3, Praratchathan, Roi Et, Naskorn Sawan, Surat Thani and Loei was conducted at Regional Office 3, Land Development Department, Nakhon Ratchasima, Thailand, on loamy sand. The results showed that Loei gave the best belowground biomass, while the worst was found in Ratchaburi. In contrast, Ratchaburi showed the highest of carbon storage in soil at 1 meter depth (11 ton C ha^{-1} yr^{-1}), but the lowest was found in Loei (4 ton C ha^{-1} yr^{-1}). Although Loei gave the lowest rate of carbon storage among 11 ecotypes, it was greater than *Acacia mangium* reforestation, perennial ryegrass, wheat, barley and oat. From leaf cross section analysis, in addition, it was found that there were big intercellular spaces presented in all 11 ecotype leaves suggesting interactions between water and air storage and circulation and carbon sequestration capability. In conclusion, Loei and Ratchaburi ecotypes exhibited the great efficiency of carbon sequestration in form of belowground biomass and soil carbon storage, respectively.

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(P24) **Fluorescence measurement as an assessment method for the anaerobic digestion activity**

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In recent years, biomass is brought to attention as an alternative to conventional fossil fuels, which increase carbon dioxide (CO_2) in the atmosphere, likely causing global warming. Anaerobic digestion is one of the major and earliest biomass conversion technologies. Anaerobic digestion is widely used to treat organic wastes such like wastewater sludge, municipal solid wastes and agricultural wastes because (1) it provides a renewable energy source as biogas including methane, suitable for energy production helping replace fossil fuels, (2) the nutrient-rich solids left after digestion can be used as compost for agriculture. Resulting from the progress in studying anaerobic digestion, the digestion system has become more complex and the efficiency has increased strongly. On the other hand, it has been necessary to monitor the state in the digester accurately and to keep the best condition to prevent the deactivation of the process. Consequently, a simple but informative method of monitoring the situation is required. Fluorescence measurement is one of the most effective methods to detect traces of materials that emit fluorescence. Therefore, excitation-emission matrices (EEMs) of anaerobically digested sludge have been measured by spectrophotofluorometer to analyse relationships between fluorescence characteristics and biogas evolution. EEM plots of the sludge showed at least three peaks. The first and more intense region was centred at Ex/Em = 285 nm/335 nm. The second and less intense region was centred at 235 nm/330 nm. The third was centred at 360 nm/425 nm. Furthermore, separation of liquid and solid phase of the sludge showed the first two peaks are derived from liquid phase and the third fluorescence peaks are derived from solid phase. These results indicate that the first two peaks are attributed to volatile fatty acid and the third peak is attributed to F_{420} of methanogenic archea.

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(P26) **Flooding induced alterations in the lipid peroxidation, membrane permeability, reactive oxygen species generation and the antioxidative response systems in *Zea mays* leaves**

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Effects of hypoxia on the activities of some enzymes of antioxidative, non-enzymatic scavenging systems, membrane permeability, lipid peroxidation and some reactive oxygen species (ROS) in leaves of *Zea mays* were investigated. Samples were taken 48, 96, 144 and 192 hours after the start of hypoxia treatment. A 192 h hypoxia treatment resulted in a significant rise in membrane permeability, lipid peroxdation (malondialdehyde level), and the production of hydrogen peroxide (H_2O_2) and superoxide (O_2^-) in *Zea mays* leaves. A short duration hypoxia enhanced the activity of superoxid dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), and glutathione reductase (GR), while further hypoxia scinificantly lowered the enzyme activity but increased the cotent of reduced form gluthatione (GSH) and ascorbic acide (ASA). It was observed that the reduction in SOD activity was greater than that in GR and APX (H_2O_2 scavengers). Our results showed that O_2^- induced membrane damage and lipid peroxidation, and that excessive accumulation of O_2^- is due to the reduced activity of SOD under hypoxia.

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