by Arne Saatkamp (Université Paul Cézanne, France), whereas microenvironmental conditions that influence secondary dormancy in the highly invasive cheatgrass were illustrated by Phil Allen (Brigham Young University, USA). Germination ecology served as a factor to explain the distribution of species of Melastomataceae in neotropical montane savannas (Fernando Silveira, Universidade Federal de Minas Gerais, Brazil), a narrow endemic in Spain (Borja Jimenez-Alfaro, University of Oviedo, Spain) and an endemic eucalypt in Australia (Megan Hirst, Royal Botanic Gardens Melbourne, Australia). Hana Skálová (Czech Academy of Sciences, Czech Republic) reported that invasive *Impatiens* in Europe germinate earlier and have lower frost resistance as compared to native congeners.

The fifth session entitled 'Seed community ecology/consumer relations' chaired by Jerry Baskin included talks on dynamic relationships between seeds and dispersers, predators and pathogens. Peter Kotanen (University of Toronto, Canada) explored the impacts of fungal pathogens on soil seed-bank dynamics in his plenary lecture. Julie Beckstead (Gonzaga University, USA) reported that both the seed-bank pathogen and its host cheatgrass are well-adapted to frequent and low-intensity wildfires, allowing for post-fire cheatgrass expansion. While Bram D'hondt (Ghent University, Belgium) concluded that 'hardseededness' evolved in response to control dormancy and germination, Ken Thompson showed that it served as an anti-predator device, i.e. dry seeds release few volatile chemicals making it difficult (or impossible) for predators to locate seeds by smell. During this session, we learned that rodents determine the distribution of blue fan palm (Elisabet Wehncke, San Diego Natural History Museum, USA), earthworms are attracted to seeds as a food source (Emilie Regnier, Ohio State University, USA), terrestrial isopods are granivores as well as detritovores (Stanislava Koprdova, Crop Research Institute, Czech Republic) and nutcrackers play a pivotal role in dispersal of *Cembrae* pines (Eila Tillman-Sutela, Finnish Forest Research Institute, Finland). Carlos Carmona (Universidad Autónoma de Madrid, Spain) showed that germination and root growth of grazing increasers were unaffected by the presence of cow dung, whereas those of decreasers declined.

The last session entitled 'Restoration and conservation seed ecology' chaired by Phil Allen, showcased efforts of seed ecologists to restore damaged ecosystems and stem biodiversity loss. The plenary speaker David Merritt (Kings Park and Botanic Garden, Australia) spoke on managing seed resources to deliver large-scale biodiverse restoration projects, with examples drawn from Australia. In the light of climate change, Costas Thanos discussed its effect on germination in an alpine Cretan endemic and Andrea Mondoni (University of Pavia, Italy) highlighted *ex situ* seed banking for halting alpine biodiversity loss. The role of *ex situ* seed banking in Hawaiian rare plant reintroductions was covered by Lauren Weisenberger (University of Hawaii, USA), whereas seedling production for restoration in the Brazilian cerrado region was discussed by Henk Hilhorst (Wageningen University, The Netherlands). Alvin Yoshinaga (University of Hawaii) spoke about the correlations between longevity of seeds in wet and dry storage and John Dickie (Royal Botanic Gardens, Kew) shared his model for predicting optimum germination conditions for wild species in the Millennium Seed Bank. Todd Erickson and Lucy Commander (Kings Park and Botanic Garden) characterized seed-germination strategies for arid-zone species and showed how this information can be used to restore mine sites in Australia.

The meeting concluded with an awards banquet, and closing remarks by Susan Meyer at the picturesque Red Butte Gardens and Arboretum. Student awards went to Jacqueline Betsch (Arizona State University) for best poster and Bram D'hondt (Ghent University) for best oral presentation. The next meeting in the series is tentatively planned to be held in China in 2013.

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MEETING REPORT

Air pollution and climate change effects on forest ecosystems*

Anthropogenic-driven elevated CO_2 levels in the atmosphere and consequent climate change are likely to affect the forest ecosystems. According to some studies, under elevated CO_2 conditions decomposition was more than the net primary production (NPP). Certain other studies predicted greater increase in NPP than decomposition, leading to carbon storage. Projecting to larger scales, the responses of forest ecosystems to elevated CO_2 may be highly variable temporally and globally. In areas where nitrogen is limiting, elevated CO_2 levels should not increase the growth of trees even though there may be an increase in photosynthesis. Excess nitrogen deposition in forests is likely to increase productivity. On the other hand, increase in ambient ozone has negative effect on forest ecosystem, including foliar damage, decreased productivity and elevated sensitivity. Presentations and deliberations in the recently held International Union of Forest Research Organizations Conference were about these major issues, where the parti-

*A report on the Five-day IUFRO (International Union of Forest Research Organizations) Conference for Specialists in Air Pollution and Climate Change Effects on Forest Ecosystems held at Antalya, Turkey during 22–26 March 2010.

cipants shared their research findings in temperate forests of Europe, USA and Canada. The conference was attended by 155 scientists across the world, who presented their recent findings.

Anthropogenic anionic depositions in forest ecosystems, particularly sulphur and nitrogen compounds having varying effects on plant growth coupled with other climatic factors were discussed exhaustively in the conference. Based on the outcome of the observations of the Pan-European programme that commenced in 1994, Wim De Vries (Wageningen University, The Netherlands) reported that nitrogen deposition has affected foliar chemistry and species diversity of ground vegetation. According to Badea, phytotoxic agents (SO_2, NO_2, NH_3) registered damaging effects with forest ecosystems. Norway spruce is the most affected species with more than 27.7% of trees damaged. In Finland, Nevalainen reported that defoliation of pine increased slightly wherever modelled sulphur and nitrogen deposition was the highest. Forest edges receiving higher levels of nitrogen deposition than interiors was highlighted by Wuyts in four deciduous and coniferous forests in Belgium, leading to enhanced nitrogen leaching to groundwater. Knoepp observed that due to implementation of Clean Air Act of 1990 in the US, sulphate deposition has decreased by 20% whereas nitrogen remained more or less constant. However, in contrast ammonium inputs have increased by 50% over the last 35 years. Kozlov *et al.*, after detailed examination of various reports concluded that acidic polluters cause strong effects on biota than alkaline polluters and the effect of metals is detrimental compared to sulphur dioxide.

Paoletti and Manning opined that ozone and other acidic depositions are likely to induce a number of responses in trees, including leaf injury, gas-exchange aberrations, growth reduction, altered biomass allocation, impaired water balance and biodiversity changes, which in turn affect the provisioning services of these ecosystems. Braun emphasized that ozone can disturb plant growth and the productivity presumably by causing oxidative stress in the leaf apoplast and the photosynthetic process. In the control experiments ozone correlated negatively with shoot growth in beech forests. In Califorian black oak and blue oak species, a delay in stomatal response was found due to ozone uptake. According to Bohler, ozone-induced exposure appeared after 14 days with visual symptoms of chloroses and necroses in *Populus tremula*. Kasurinen noticed that elevated ozone treatments in silver birch (*Betula pendula*) decreased the total above-ground biomass in the fastest growing genotypes. Zaple observed a negative correlation between net ecosystem productivity and ozone in a 31-year-old Norway spruce forest, North East Czech Republic. Ozone risk assessments in forest regions of southern Germany also predicted 5% growth reduction. Further, it has also been concluded that soil and water availability was a decisive factor for ozone uptake via the stomata.

According to Oksanen, *P. tremula* (European aspen) exposed to climatic stress of dry, optimum and wet treatments, interestingly showed wet conditions inducing more changes in gene expression pattern than drought stress. In a similar experiment on oak species, Dobbertin observed that drought treatment reduced stem basal area growth, while shoot growth remained unchanged under warming effect. Pinto in his experimental analysis of heat stress on cork oak, showed survival of plants in extreme temperatures of 55°C. The climatic effects on forest ecosystems of Nantahala Mountain Range, northwestern Carolina, USA observed by Laster suggested that drought conditions have occurred more frequently over the past 20 years and trees are more susceptible to disease, pest and fungal outbreaks under water-stress condition leading to higher mortality. Bradford *et al.* in their PnET-CN ecological simulation model predicted that in north-central North America, increasing temperature and CO_2 enhance productivity rates while increasing weather variability decrease productivity rates.

Zengin reported that to cope with climate change, rural people preferred certain adaptive strategies in agro-forestry practice like diversification of crop production, raising drought-tolerant species, introducing short-rotation species, etc. In Turkey energy forestry has been realized as an option for carbon sequestration by fast-growing trees and short-rotation ages. Raftoyannis mentioned that in forest ecosystems which are highly prone to climate change, adaptation strategies such as modification of forest structure (clearing, thinning, biomass removal, prescribed burning, grazing) change in species composition and active post-fire management (reforestation, slope restoration, salvage logging) are possible options. In conclusion, it is recognized that nitrogen-saturated forests will have to prevent the risk of excess nitrogen. The conference emphasized the need to understand the genetic/genomic basis of responses and adaptation of forest trees to climate change and air pollution. An approach to compare the effects of growth stressors (drought, strong oxidants and excess nitrogen deposition) and growth enhancers (elevated CO_2 and low nitrogen deposition) across varying landscapes and time is emphasized. Importance of multifactor analysis to validate model outputs was insisted by Anderson. Palotti suggested antioxidant applications to protect sensitive plants from ozone injury. Such holistic monitoring approaches and adaptive strategies are important on a regional scale to minimize the serious hazards due to climate change.

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