

## Introduction

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Published online: 30 April 2010  
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Photosynthesis occurs in vastly different forms, for e.g. some prokaryotes perform anoxygenic photosynthesis, and on the other hand, cyanobacteria, algae and land plants use oxygenic photosynthesis. Likewise, in land plants, most organisms rely on so-called C<sub>3</sub> photosynthesis, but several tropical species as maize or sugarcane use a variant called C<sub>4</sub> photosynthesis in which the first photosynthetic product is malate, a 4 carbon compound, rather than phosphoglyceric acid the more classical 3 carbon compound. Another example of the variation of the photosynthetic mode is found in so-called CAM (crassulacean acid metabolism) plants where CO<sub>2</sub> fixation takes place at night rather than during the light, enabling these plants to resist extreme climatic conditions.

As far as land plants are concerned, trees constitute a very different physiological model than herbaceous plants. First they are perennial species while the others are generally annual or biannual species that do not survive individually on a long term. On the other hand, for many trees, the possibility to sexually reproduce appears only after 10 years or more and many species can survive over a span of several centuries. Moreover, most angiosperm trees of temperate regions are deciduous i.e. they lose their leaves in winter (this is also true for some rare gymnosperms as larch). In these species, photosynthesis stops in winter and the tree goes to a less active metabolic state with concomitant storage of useful compounds and

subsequent remobilization in the spring. Finally, some tree species as poplar can also reproduce non-sexually via vegetative propagation resulting in large clonal populations. The capacity for trees to survive over very long periods also means that they have to cope with repeated environmental stresses as drought or flooding, heat, fire or freezing temperatures, excess light etc. In addition, the clonal nature of many populations makes them more susceptible to various pathogens. Many of these stresses (be there biotic or abiotic) are accompanied by an oxidative stress as in other living species. In order to withstand environmental constraints, trees rely on antioxidant networks and signalling pathways that are generally exacerbated in plants compared to other living organisms, perhaps because plants also perform photosynthesis and thus produce excess oxygen in their chloroplasts leading to larger concentrations of reactive oxygen species. Perhaps as a consequence but also because of additional duplication events, the genome of poplar contains a much larger number of genes (ca. 45,000) than non photosynthetic genomes (human 20,000–25,000 genes) but also some non perennial plants as arabidopsis (26,000 genes) (Tuskan et al. 2006). Despite the duplication events, many of these genes are orphan (i.e. there is no equivalent in other species), suggesting that trees may have vastly different metabolic activities compared to other species, even photosynthetically active herbaceous species.

The recent deciphering of the poplar genome revealing a higher gene complexity in trees, the increasingly harsh environmental and biotic constraints that plants are experiencing linked to global warming and pollution have led us to propose a special issue of Photosynthesis Research with the topic ‘Stress in Trees, the Poplar Model’. Many colleagues have enthusiastically endorsed this project and contributed. This special issue contains seven different

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articles that all deal with poplar, photosynthesis and stress. In an article entitled ‘Isoprene emission protects photosynthesis in sunfleck exposed Grey poplar’, Behnke and colleagues have combined transient temperature and light stress and analysed photosynthetic gas exchange in grey poplar which has been genetically modified in isoprene emission capacity. They demonstrate that the ability to emit isoprene is crucial to maintain photosynthesis when exposed to sunflecks and provide also experimental evidence indicating that the antioxidant system is adjusted in isoprene non-emitting poplars. The second article by Silim et al. is entitled ‘Temperature responses of photosynthesis and respiration in *Populus balsamifera* L.: acclimation versus adaptation’. They have investigated photosynthesis and respiration parameters in poplar cultivars collected from warm and cool habitats and grown at warm and cool temperatures. They conclude that primary carbon metabolism clearly acclimates to growth temperature in *P. balsamifera*, but that the ecotypic differences suggest that global warming scenarios might affect populations at the northern and southern edges of the boreal forest in different ways. The third article is by Rood et al. and it is entitled ‘Effects of flooding on leaf development, transpiration, and photosynthesis in narrowleaf cottonwood, a willow-like poplar’. They have investigated the flood response of narrowleaf cottonwoods and a related native hybrid, jackii cottonwood. It is described that flooding reduces stomatal conductance and net photosynthetic rate, and reduced transpiration particularly in *P. x jackii*. They conclude that narrowleaf cottonwoods are flood-tolerant, and that these trees could provide traits to increase the flood tolerance of fast-growing hybrid poplars. The fourth article by Major et al. ‘Photosynthetic and respiratory changes in leaves of poplar elicited by rust infection’ describes the relations between poplar and one of its major pathogens, rust which sporulates on leaves and disseminates readily in suitable clonal populations. Large-scale expression studies of poplar–rust interactions show concerted transcriptional changes during defence responses, as in other plant pathosystems and surprisingly, besides the traditional antioxidant network response modulation, photosynthesis and respiration are also important components of the poplar response to rust infection. It is concluded that the defence reactions impose substantive demands for resources and energy that are met by reorganization of the primary metabolism. The fifth article by Possel et al. is entitled ‘Effects of fosmidomycin on plant photosynthesis as measured by gas exchange and chlorophyll fluorescence’. It describes the effect of fosmidomycin, an antibiotic/herbicide compound which inhibits isoprene emission on photosynthesis in *Populus alba*. They conclude that the diminution of photosynthesis after fosmidomycin treatment is likely a complex effect that includes the inhibition of

multiple methyl-erythritol phosphate (MEP) pathway products, resulting in photoinhibition and photo-damage. The sixth article by Farel et al. describes the ‘Volatile emissions and phenolic compound concentrations along a vertical profile of *Populus nigra* leaves exposed to realistic ozone concentrations’. It deals with the effects of ozone, a modern prevalent pollutant on the physiology of poplar trees. They have especially investigated the changes in physiological parameters (photosynthesis and stomatal conductance), the ozone uptake, the emission of volatile organic compounds, the concentration of antioxidant surface compounds, the concentration of phenolic compounds in plants treated with high ozone concentrations likely to arise naturally in future environments. They observed that the emission of isoprene and C6 volatiles were inhibited by ozone, whereas methanol emission was increased, especially in developing leaves. In addition, most surface and phenolic compounds showed a declining trend in concentration from the youngest to the fully expanded leaves. Ozone reduced the concentrations of chlorogenic acid derivatives at the leaf surface, whereas in total leaf extracts a metabolic shift towards phenolics with higher antioxidant capacity was observed. Phenolic compounds seem to play a major and dynamic role as antioxidants in response to moderate increase of atmospheric ozone. Many of the above-mentioned articles deal with various stresses that are accompanied by an oxidative burst, and so we found it desirable to include an article that discusses the various antioxidant systems in trees (especially poplar) and compares them to herbaceous plants. This is described in the last article of this volume by Chibani et al. entitled ‘The chloroplastic thiol reducing systems: dual functions in the regulation of carbohydrate metabolism and regeneration of antioxidant enzymes, emphasis on the poplar redoxin equipment’. This article focuses in particular on two multigenic families (thioredoxins and glutaredoxins) and associated protein partners in poplar and on their involvement in the regulation of some major chloroplastic processes such as stress response, carbohydrate and heme/chlorophyll metabolism.

We believe that this volume devoted especially to stress and photosynthesis in poplar is the first of the kind. We thank all the authors who have willingly contributed to it and hope that together these articles will be precious to the poplar community but also more widely to the photosynthetic community.

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