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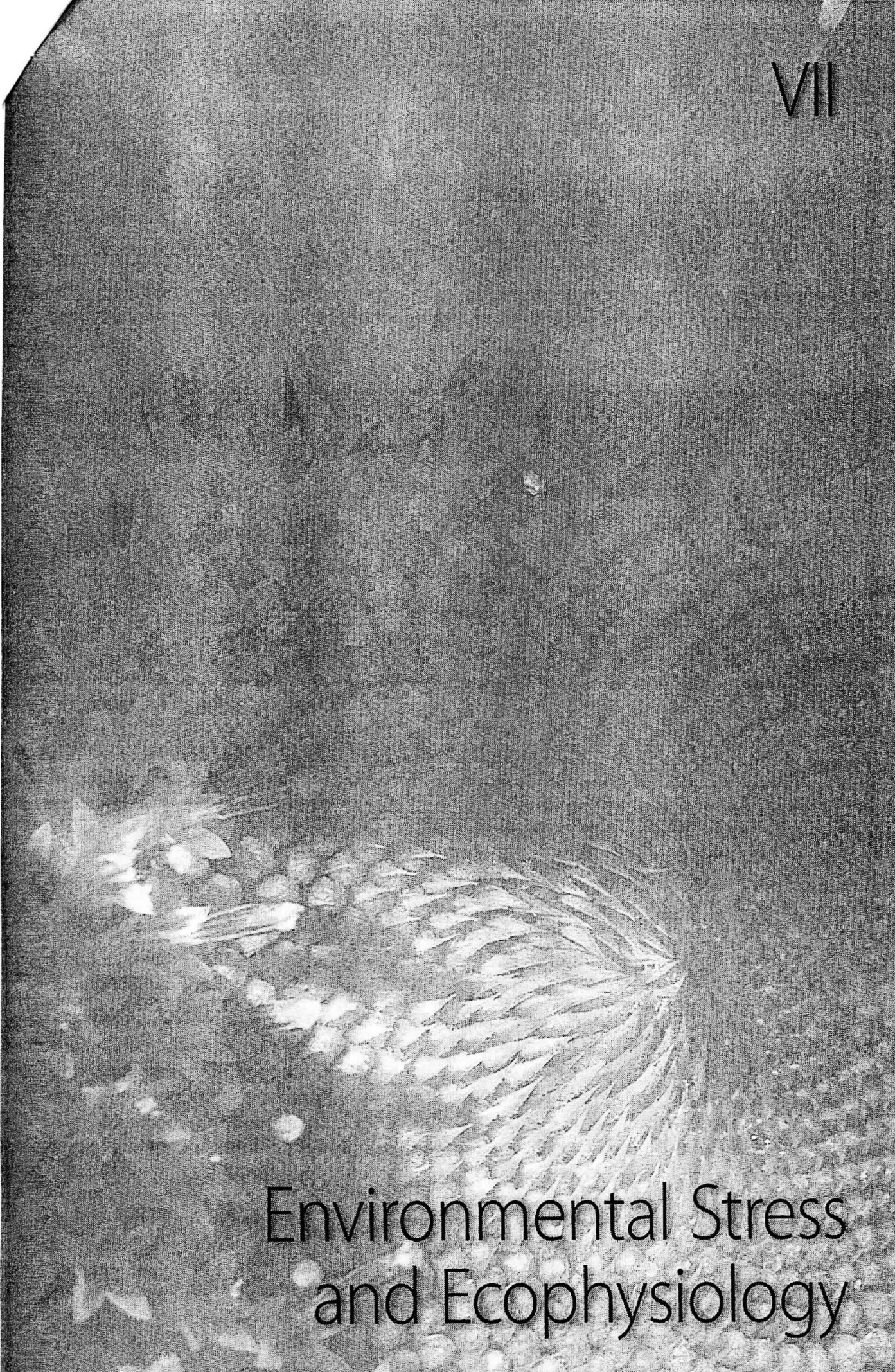

VII

Environmental Stress and Ecophysiology

Silicon mitigates oxidative stress in cucumber at copper excess

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Beneficial effects of silicon (Si) are well demonstrated for many crop species, although its essentiality is still not proven. Some mechanisms of Si-mediated alleviation of different stresses in plants have been proposed in the literature, however the molecular bases of these mechanisms are poorly understood. Metal toxicity is considered as an important environmental problem in many agricultural soils worldwide. Copper (Cu) is an essential microelement for plant growth and development. As a redox-active transition metal, Cu is a cofactor in many proteins involved in electron transfer chains including respiration and photosynthesis. However, in excess Cu can induce oxidative stress via several proposed mechanisms, including direct generation of reactive oxygen species (ROS) through the Fenton reaction. The aim of this study was to elucidate the molecular mechanism of Si-mediated alleviation of oxidative stress caused by excess Cu in cucumber. Hydroponically grown plants were subjected to different Cu concentrations, with or without Si supply. The high Cu treated plants showed higher biomass and better root growth when Si was applied. The parameters of oxidative stress lipid peroxidation, total phenolics and tissue Cu concentrations were measured. Expressions of the genes involved in antioxidative defense and biosynthesis of phenolics were in accordance with the biochemical findings, clearly demonstrating the multiple role of Si in alleviation the harmful effects of ROS in cucumber.

Photosynthetic efficiency and leaf morphology of (*Pinus nigra* Arn.) under variable urban pollution conditions

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To date an unprecedented, rapid change in urban environment is observed, which is likely to exceed the adaptive potential of plants, especially that of tree species with their long reproductive cycles. Changes in chlorophyll fluorescence parameters is considered as an reliable approach for evaluating the state of plant vitality and provides a rapid and accurate technique for detecting and quantifying the tolerance of plants to stress. In order to consider the different pollution sources, photosynthetic efficiency (Fv/Fm) of Austrian pine (*Pinus nigra* Arn.) in urban areas of four cities in Serbia, characterized by different sources of pollution, was assessed. The sampling sites were urban parks in the cities exposed to airborne pollutants from industrial activities, waste disposal and heavy traffic: Belgrade (traffic), Pančevo (factory of nitric fertilizers and a refinery), Obrenovac (thermoelectric power plant and fly ash disposal site), Smederevo (iron smelter), and Košutnjak forest in Belgrade (without direct source of pollution).

Site-dependent variations were found in photosynthetic efficiency (Fv/Fm) of pine trees. A reduced vitality was observed in all the examined sites in relation to control: Pančevo ($p<0.001$), Obrenovac ($p<0.001$), Smederevo ($p<0.001$), and Belgrade ($p<0.01$) followed by toxicity symptoms in form of tip necrosis and decline of the needles, which was the most pronounced in the city of Smederevo.

The results obtained in this study demonstrate that the two-years-old pine needles expressed both physio-

al and morphological injuries and that the measured reductions in photosynthetic capacity can be attributable to increased uptake and accumulation of the pollutants in the examined sites.

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Effects of pollution on Norway maple (*Acer pseudoplatanus* L.): chlorophyll fluorescence and photosynthetic pigments

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Many urban areas are polluted by industrial activities and waste disposal. The role of vegetation in mitigating the effects of airborne pollution has been highlighted as one potential benefit of urban green space. Sycamore maple (*Acer pseudoplatanus* L.) is often used for urban landscaping because it is considered to be tolerant to different ecological conditions. The ecophysiological behavior of maple trees in urban areas of four cities in Serbia, characterized by different sources of pollution, was studied. The sampling sites were urban parks in the cities exposed to airborne pollutants from industrial activities, waste disposal and traffic: Belgrade (traffic), Pančevo (factory of nitric fertilizers and a refinery), Obrenovac (thermoelectric power plant and fly ash disposal site), Smederevo (iron smelter), and Košutnjak forest in Belgrade (without direct source of pollution). Site-dependent variations were found in photosynthetic efficiency (Fv/Fm) of maple trees. A reduced vitality was observed in Obrenovac ($p<0.001$), Smederevo ($p<0.001$), and Belgrade $p<0.05$) in relation to control, followed by toxicity symptoms in form of leaf chlorosis and marginal necrosis. Differences in total chlorophyll (Chla+b) levels between sites were as follows: Pančevo ($p<0.001$), Obrenovac ($p<0.001$), Smederevo ($p<0.001$), and Belgrade (ns).

The results clearly demonstrate that the individuals of maple from city parks in Obrenovac with the thermoelectric power plant in its vicinity, in Smederevo with iron smelter and Belgrade with dominance of traffic pollution have lower adaptation response to the pollution. This work highlights the possibility of using a fast and low-cost procedure to evaluate the pollution level through data obtained from plant species growing within an urban environment.

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The effect of drought on photosynthesis of *Q. robur* and *Q. cerris*: use of light response curve as indicator of stress

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Seedlings of *Q. robur* and *Q. cerris* were grown in in the greenhouse pot experiment during one vegetation period. Acorns were collected in natural populations at Mt Fruška gora National park in 2011 and sown