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*Prof. Elżbieta Skórska, dr. hab.; Magdalena Witczak, mgr inż. –
West Pomeranian University of Technology, Szczecin, Poland*

INFLUENCE OF ENHANCED ULTRAVIOLET-B RADIATION ON SOME PLANT SPECIES RESPONSES

Main targets and mechanism of UV-B (280-320 nm) affect on plants are described in the paper. Plants species show differentiation in susceptibility on this environmental stress factor what resulted from many experiments. Plants can protect against UV-B radiation damages in various ways, including increase synthesis of flavonoids and phenylpropanoids, DNA photorepair and excision.

Targets and mechanisms of UV-B affect on plants. UV-B radiation (280-320 nm) has long been known to be damaging to life. It affects plants by modifying both their biological and chemical environment. Damage may occur in many places, including the direct destruction of the DNA, deactivation of protein and enzymes, disruption of membranes and other cell structures and the generation of highly reactive chemical agents known as 'free radicals' (Caldwell 1971, Rozema 1997, Jansen 1998, Björn et al. 2002, Hollosy 2002). DNA is one of the most notable targets of ultraviolet radiation, which can be damaged directly after absorption of UV-B photons. UV-B irradiation induces two of the most abundant mutagenic and cytotoxic DNA lesions, cyclobutane dimers and pyrimidine pyrimidone photoproducts. Kravets et al. (2008) showed that irradiation of barley seedlings by ultraviolet-B radiation affected the growth and development of the sexual elements of the spike, accelerating differentiation of the sporogenous tissue of the anther and the male gametophyte. Influence of UV-B on the reproductive system of the plant is expressed in genotoxic, through damage to the DNA of meristemic cells, and photo-inductive, through acceleration of efflorescence and differentiation of gametophytes, effects. DNA can be also damaged indirectly as a result of formation of free radicals by absorption of photons (Rozema 1997). UV-B can cause damage of cell membranes by photo-absorption and peroxidation of unsaturated fatty acids and changes in the membrane lipid composition (Jansen 1998).

The direct effect of enhanced UV-B radiation in sensitive plants are the following: impairment of photosystem II (PS II) and to lesser extent photosystem I (PS I), decrease in Rubisco activity, decreased carbon dioxide fixation and oxygen evolution; reduction in dry weight, starch and chlorophyll content (Bormann 1989, Jansen 2008). The water-oxidizing complex of PS II is an important target of ultraviolet-B radiation (Skórska 2000 a, Szilárd et al. 2007). Inhibition of water oxidation is caused either by direct absorption within the catalytic manganese cluster or by damaging intermediates of the water oxidation process. However, van Rensen et al. (2007) showed that the damage by UV-B radiation occurs first at the acceptor side of photosystem II, and only later at the donor side. In addition to the direct effect of UV-B radiation, photosynthesis may also be indirectly affected: induction of stomata closure may reduce the efficiency of gas exchange, changes in leaf thickness and anatomy may alter light environment within the leaf, and modification in canopy morphology may also indirectly affect whole plant photosynthesis (Nogue et al. 1999, Hollosy 2002, Fagerberg & Bornman 2005). Damage induced

by UV-B can be diverse to morphogenetic changes in plants: decrease of height, leaf length, leaf area, increase of leaf thickness, axillary branching, altered leaf angle, plant architecture, canopy structure, altered emergence, phenology, senescence, seed production (Rozema 1997, Hollosy 2002, Kakani 2003, Jansen 2008). Consequences of UV-B damages can be reduction in growth yield, changes in levels and effects of plant hormones and alteration of periods of dormancy or flowering (Teramura et al. 1990, Heisler et al. 2003, Kakani 2003).

Differentiation in susceptibility of plant species. Studies of more than 300 plant species and cultivars have been carried out, and about 50 % have been considered sensitive, 20-30 % moderately sensitive, and the rest insensitive to UV-B radiation (Teramura et al. 1990, Hollosy 2002). In many sensitive plant species (e.g. wheat, rice, maize, rye, sunflower, and cucumber), reduced leaf area and/or stem growth has been found. Visual symptoms consisting of chlorosis or necrosis on leaves exposed to UV-B were not unique (Jansen et al. 1998, Hollosy 2002, Kakani 2003). Both vegetative and reproductive morphology were altered by UV-B radiation. Enhanced UV-B generally decreased chlorophyll content (10-70 %), whereas it increased UV-B absorbing compounds (10-300 %) in many crops. Decrease in photosynthesis (3-90 %), particularly at higher UV-B doses, was due to both direct (effect on photosystem) and indirect (decrease in pigments and leaf area) effects. The decreases in chlorophyll pigments and photosynthesis resulted in lower biomass and yield of most crop plants. Genotypes of crop species exhibited variability in leaf wax layer thickness, loss of chlorophyll, and increase in phenolics as mechanisms of tolerance to enhanced UV-B radiation resulting in changes in biomass/yield (Rozema 1997, Hollosy 2002, Kakani 2003, Caldwell 2007). For example, pea plants were more susceptible to long-wave UV-B irradiation (305-320 nm) in comparison with the triticale, and the difference was more apparent from the changes in total area of leaves and dry mass of shoots rather than from photosynthesis reactions (Skórska 2000 b). Generally cereals plant seems to be more tolerant to UV-B than dicotyledon plants due to vertical position of leaves, which are less exposed to harmful radiation (Caldwell et al. 1998, Kakani et al. 2003, Lizana et al. 2009). There are evidenced experiments about UV-B effects on orientation movements of wheat seedlings (Tendel & Häder 1995). The plants were turned into a horizontal position and irradiated. Wheat seedlings irradiated with white light showed curvature angles of 80 ° -90 °, while the UV-B irradiated plants changed curvature angles of 0 ° -20 °.

Conifers are considered as the most resistant species to the UV-B because of their thick epidermis and wax layer on needles which are particularly effective in attenuating the radiation (Hollosy 2002, Caldwell et al. 2007).

Protective responses of plants against UV-B radiation. Physically avoiding UV-B radiation (scattering and reflection) from penetrating into the plant system is the first line of strategy to counter UV-B stress; this can be done by manipulating epidermal and cuticular layers of the leaf (wax, hairs). In the experiments of Skórska & Szwarc (2007) showed that RAH 336 line of triticale, which wax cover is lesser than that of traditional cultivar Magnat, was more susceptible to UV-B radiation, considering primary photosynthesis reactions, recorded by

chlorophyll a fluorescence, and also morphology and physiology of the young plants. The second line of plant defense against UV-B radiation involves increasing UV-B absorbing pigments such as flavonoids and anthocyanins after the actual entry of UV-B into the outer layer of leaf surface (Rozema 1997, Jansen et al. 1998). Both these methods involve manipulation at molecular genetic levels and are expensive in terms of metabolic energy. The third line is to ameliorate or alleviate UV-B stress using various mechanisms. One of them is photoreactivation with enzymes DNA photolyases, which directly repair lethal and carcinogenic UV-light-induced DNA lesions in the genome plants. It is a rapid process and needs sufficient photosynthetically active radiation (Björn 2007). Other defense mechanism in plants is excision repair of DNA damage caused by UV-B. It is a slow process, also occurring in the dark, relies on that the damaged sections of DNA are cut away, and new sections are synthesized using the complementary strand as template (Jansen et al. 1998, Hollosy 2002). Moreover, plants have also free radicals scavenging system using such enzymes as superoxide dismutase, catalase or peroxidase. Flavonoids and phenylpropanoids are also involved in neutralizing radicals (Mahdavian et al. 2008). Polyamines may ameliorate UV-B damage to membranes (Rozema 1997, Jansen et al. 1998). Plants raised under natural radiation conditions are generally better protected from the potentially detrimental effects of UV-B radiation (Jansen 2008).

Some compounds named as biostimulators can not only cause better growth and development, and also ameliorate physiological state of the plants subjected to environmental stress factors, including UV-B radiation. In own experiments on plants of cucumber and basil exposed to relative high dose of UV-B and treated as well as biostimulator NanoGro (Fig. 1) and Asahi SL (Fig. 2) significant higher content of flavonoid in leaves, respectively by 25 % and 56 % compared to the control, were observed. These results showed better protection response against the applied UV-B radiation.

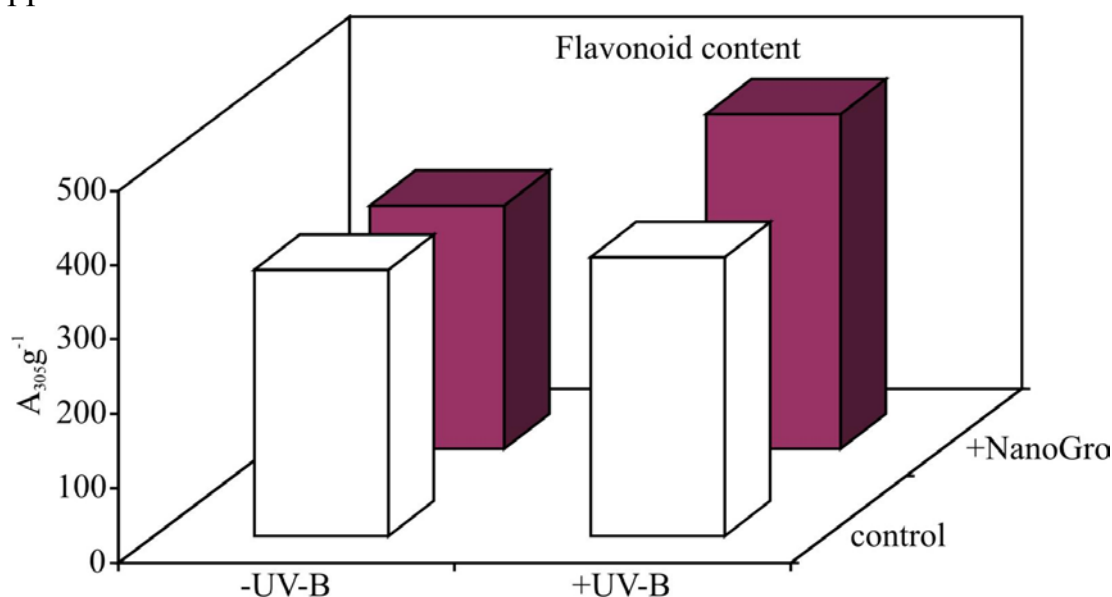


Fig. 1. Flavonoid content in leaves of cucumber cv. Polan F1 plants subjected (+UV-B, dose $UV-B_{BE}=3,2 \text{ kJ}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) of broadband lamp Vilber Lourmat VL-115 and not subjected to UV-B (-UV-B), treated with NanoGro or not treated (control)

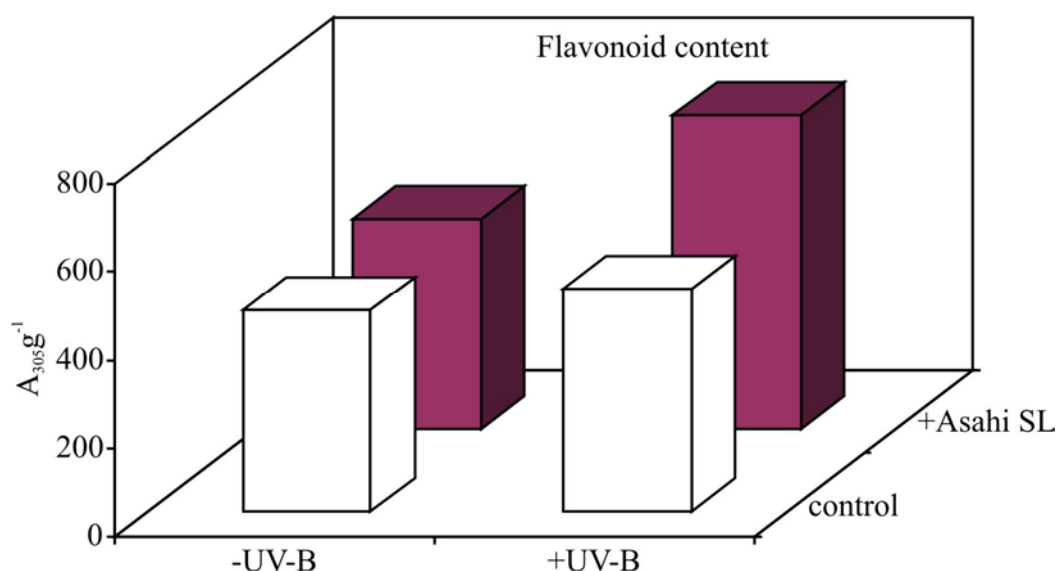


Fig. 2. Flavonoid content in leaves of *Ocimum basilicum* plants subjected (+UV-B, dose UV-B_{BE}=3,2 kJ·m⁻²·d⁻¹) of broadband lamp Philips TL40/12 and not subjected to UV-B (-UV-B), treated with Asahi SL or not treated (control)

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Скурска Е., Вітчак М. Вплив збільшення випромінювання ультрафіолету-В на деякі рослинні види

Описано головні цілі і механізм афекту ультрафіолету-В (280-320 нм) на рослини. Рослинні види показують диференціювання в сприйнятливості до цього впливового стресового чинника довкілля, що підтверджено багатьма експериментами. Рослини можуть захищатися від шкідливого впливу ультрафіолету-В різними шляхами, зокрема збільшенням синтезу флавоноїдів і фенілопропаноїдів, фоторепаруванням і вирізуванням ДНК.

Скурска Е., Вітчак М. Влияние увеличения излучения ультрафиолета-В на некоторые растительные виды

Описаны главные цели и механизм аффекта ультрафиолета-В (280-320 нм) на растения. Растительные виды показывают дифференцирование в восприимчивости к этому влияющему стрессовому фактору окружающей среды, что подтверждено многими экспериментами. Растения могут защищаться от вредного влияния ультрафиолета-В различными путями, в частности увеличением синтеза флавоноидов и фенилопропаноидов, фоторепарированием и вырезанием ДНК.

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Prof. Elżbieta Skórska, dr. hab. –

West Pomeranian University of Technology, Szczecin, Poland

MONITORING OF ULTRAVIOLET-B RADIATION IN POLAND

Two independent networks of UV-B radiation monitoring in Poland are described. One of them, Geophysical Observatory at Belsk of the Institute of Geophysics of the Polish Academy of Sciences, from over 30 years has performed monitoring of sun ultraviolet radiation. The second UV-B network of the Institute of Meteorology and Water Management has carried out continuously sun ultraviolet measurements in the erythema range in three stations (Łeba, Legionowo, Zakopane) since 1994. In last years studies on forecast for agriculture and forestry are continued.

Keywords: Diffey, dose, erythema action, measurement, spectrum, sun, UV index

Analysis of changes of stratospheric ozone in atmosphere under Poland is a part of the coordinated international action for protection of ozone layer. Significant decrease of ozone concentration in the stratosphere under Poland observed