Oxidative stress injury in tomato plants induced by supplemental UV-B radiation

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Abstract

Tomato (Lycopersicon esculentum Mill. cv. PKM 1) plants growing under field conditions were exposed for 15 d to solar radiation with UV-B component (280 - 320 nm) enhanced to 6.3 kJ m⁻² d⁻¹. This simulated a 15 % stratospheric ozone depletion over Madurai (9° 50' N latitude). Lipid peroxidation in the leaves of UV-B treated plants was 32 % higher compared to the control. Superoxide dismutase (SOD) and catalase activities registered parallel promotion by 126 and 50 %, respectively, in the UV-B treated plants. Further, the contents of total phenols and anthocyanins in the leaves have also been enhanced by 40 and 156 %, respectively. On the contrary, polyphenol oxidase activity demonstrated a 58 % inhibition in the leaves of UV-B treated plants. While anthocyanins and phenols are proposed to act as antioxidants, the reduction in polyphenol oxidase activity may maintain the turnover of phenols in the UV-B treated plants.

Additional key words: lipid peroxidation, oxidative stress, phenols, superoxide dismutase.

Introduction

The direct consequence of the stratospheric ozone depletion is increase in the input of mid band solar ultraviolet radiation (UV-B, 280 - 320 nm) reaching the earth's surface. Therefore, the stratospheric ozone depletion is gaining attention both in the

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Abbreviations: UV-B - ultraviolet-B radiation (280 - 320 nm); SOD - superoxide dismutase.
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This paper is dedicated to Prof. Dr. M.R. James, Head of the Department of Botany, the American College, Madurai 625 002, India, on the occasion of his retiring after three decades of botany education.
scientific community and in the perspective of man. UV-B radiation inhibits a variety of growth and metabolic processes in crop plants, consequently diminishing the agricultural productivity (Caldwell et al. 1989, Tsvi and Teramura 1989, Balakumar 1992, Stapleton 1992, Tsvi 1993). Albeit a large body of literature is available on the UV-B effects, most of the investigators have addressed these effects at the whole plant level. Less information on the UV-B induced damages at the cellular level are found, e.g., at the chloroplast level (Nedunchezhian and Kulandaivelu 1991, Renger et al. 1989) and at the enzyme level (Balakumar 1992, Dohler 1988, Jordan et al. 1992). UV-B radiation induces a wide range of oxidative stress injuries in plant cells (Balakumar et al. 1993, Larson 1988). Therefore, we decided to envisage the mechanism of tolerance of the oxidative injuries caused by UV-B radiation in vegetable crops. Tomato has been chosen as the model system.

The main objective of the present study is: (1) to characterize the kinds of oxidative stress injuries elicited by UV-B radiation in tomato leaves; (2) to identify the kinds of enzymatic antioxidants which serve as defence agents against the oxidative stress injury mediated by UV-B radiation; and (3) to elucidate as to whether the metabolism of phenols plays any protective role against the oxidative stress injury.

Materials and methods

Plants: Seeds of tomato (Lycopersicon esculentum Mill. cv. PKM 1) obtained from the local market, were surface-sterilized by immersing in 0.01 % HgCl₂ solution for 1 min, thoroughly rinsed in running water and soaked overnight. Seedlings were grown in small plastic troughs containing a mixture of garden soil and sand (1:1), or 15-d-old seedlings raised in the garden beds were transplanted to field in plots adopting a completely randomized block (CRB) design.

UV-B treatment (cf. Balakumar et al. 1993 for details): The source of supplemental UV-B radiation was FS-40 sunlamps (Westinghouse Co., Bloomfield, USA). Distance between the light source and the plants was 300 mm. The spectral characteristics of the sunlamps and the transmittance characteristics of the filters used are presented in Fig. 1. Irradiance in the UV-B wavelength (mainly 290 - 320 nm) was measured using a factory calibrated double-holographic-grating spectroradiometer (model 742, Optronic, Orlando, USA). The radiation filtered through cellulose acetate filters supplied a weighted irradiance of 6.0 kJ m⁻³ d⁻¹ of biologically effective enhanced UV-B using the generalized plant action spectrum (Caldwell 1971) normalized at 300 nm, simulating a 15 % ozone depletion over Madurai (9° 50' N). During UV-B treatment, the control plants also were kept under the FS-40 sunlamps wrapped with mylar type D plastic films which prevent any radiation below 320 nm to be transmitted. The supplemental UV-B was given around the noon time every day for 15 d. On the 15th day, measurements of growth parameters and biochemical analyses were carried out.

Growth parameters: Shoot and root lengths and fresh and dry masses of the plants were measured. Leaf area was measured using a LiCOR 3100 leaf area meter.