Influence of supplemental UV-B radiation on photosynthetic characteristics of rice plants

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Abstract

In a field experiment with rice (Oryza sativa L. cv. Saket 4) grown under ambient and supplemental ultraviolet-B (UV-B) radiation at 20% ozone depletion, differences in gas exchange, concentrations of photosynthetic pigments, anthocyanins and flavonoids, biomass accumulation, catalase and peroxidase activities, and contents of ascorbic acid and phenol were determined. Decline in photosynthesis was associated with reductions in stomatal conductance and concentrations of photosynthetic pigments. Enhanced UV-B radiation (eUV-B) increased the contents of flavonoid and phenolic compounds in leaves. Peroxidase activity increased and catalase activity was always lower at eUV-B. The total plant biomass decreased at eUV-B.

Additional key words: biomass; carotenoids; catalase; chlorophyll; flavonoids; Oryza sativa; peroxidase; phenols; stomatal conductance; transpiration rate.

Introduction

Most of the reports on effect of eUV-B on rice plants are from those grown in greenhouses and growth chambers where the irradiance is totally different from the normal sunlight, and therefore the sensitivity of plants may vary (Teramura et al. 1991, He et al. 1993, Dai et al. 1994, 1995, Murthy and Rajagopal 1995). Rice is variably sensitive to eUV-B under growth chambers (Krupa and Kickert 1989, Teramura et al. 1991, Huang et al. 1993, He et al. 1993, Dai et al. 1992) and Barnes et al. (1993) have shown drastic reduction in the net photosynthetic rate ($P_N$) in rice plants grown in a greenhouse. Teramura et al. (1991) found a reduction in total plant biomass in six out of 16 cultivars exposed to UV-B simulating 20% ozone depletion at the equator in a glasshouse.

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Tropics receive higher UV fluxes as compared to temperate regions. Rice is one of the major food grain crops of the world particularly in Asia, so the present investigation was conducted to quantify the physiological and biochemical responses of rice (Oryza sativa L., cv. Saket 4) plants to eUV-B grown in the field at natural photosynthetically active radiation (PAR).

Materials and methods

Plants: The experiments were performed from July through September in 1993 and 1994 at the Botanical Garden of Banaras Hindu University, Varanasi (25°18'N latitude and 83°18'E longitude, at an elevation of about 70 m a.s.l.), situated in the eastern part of Gangetic plains in India. The climate of the region is tropical monsoon. The soil of the study site was sandy loam (sand 45%, silt 28%, and clay 27%) and neutral in reaction (pH 7.0 to 7.2). During the experiment, average temperature ranged from 25 to 38°C, relative humidity from 70 to 98% and rainfall was 642 mm. The PAR averaged 827 μmol m⁻² s⁻¹. In six field plots of 1.5×1.5 m, each prepared using standard agronomic practices, rice bunches of three seedlings (25 d-old) were transplanted in rows spaced 0.5 m apart. Recommended doses of nitrogen, phosphorus, and potassium as urea, superphosphate, and muriate of potash (8:4:2 g m⁻²) were added to all plots as basal dressing at 40 d. At 60 and 80 d ages, urea was twice amended (0.6 g m⁻²) as top dressing. Watering was done at regular intervals to maintain the moisture at field capacity. For the control and eUVB treatments, always three replicate plots were maintained.

eUV-B was artificially provided by Q Panel UV-B 313 fluorescent lamps (Q Panel, Cleveland, U.S.A.). Four lamps per bank fitted 30 cm apart on a wooden frame were suspended above and perpendicular to the planted rows. The lamp banks were equipped with dimming ballasts and dimmer switches to control the UV-B irradiance. Each lamp was covered with 0.13 mm thick cellulose diacetate film (Cardillo Plastics, Baltimore, U.S.A.) which absorbed radiation emitted by lamps below 290 nm. For control, lamps were covered with 0.13 mm thick polyester film (Cardillo Plastics Baltimore, U.S.A.) which absorbed radiation emitted by lamps below 320 nm. Plastic filters were aged 5 h under unfiltered Q Panel UV-B lamps prior to use and changed twice a week to avoid ageing effects on the spectral transmission of UV-B. The 0.45 cm distance between the top of plant canopy and UV-B lamps was kept constant. Plants were artificially irradiated after 5 d of transplantation for 5 h per day in the middle of the photoperiod till the maturity.

The UV-B irradiance at the top of the canopy under the lamps was measured by an Ultraviolet Intensity Meter (UVI, San Gabriel, U.S.A.). The readings were converted to UV-Bge values by comparing with the Spectro Power Meter (Spectrom, Boulder, U.S.A.). Plants under polyester filtered lamps received only ambient UV-B (9.6 kJ m⁻² UV-Bge) on the summer solstice weighted against the generalised plant response action spectrum of Caldwell (1971). The plants beneath cellulose diacetate film received eUV-B (∼7.1 kJ m⁻²) that mimicked 20% reduction in stratospheric ozone at Varanasi (25°N) during clear sky condition on the summer solstice (Green et al