INFLUENCE OF ULTRAVIOLET-B RADIATION AND ATMOSPHERIC CO2 ON LEAF MORPHOLOGY

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Abstract

Cotton in the future will be grown under elevated atmospheric carbon dioxide concentration (540 to 700 compared to 360 ppm of the current levels) and enhanced solar UV-B radiation (4-7% higher in the mid-latitudes of the Northern hemisphere relative to the 1970's) if present anthropogenic activities continue well into the coming decades. Cotton growth, development and form are being affected by these two environmental factors. The objective of this study is to test the hypothesis that elevated CO_2 will ameliorate the damaging effects of higher UV-B radiation on cotton growth and development, particularly on leaf morphology.

Upland cotton (c.v. Nucot 33B) was seeded 1 August 2001 in one meter deep soil bins of temperature-controlled plant growth chambers in a nearly natural environment. Each chamber was filled with fine sand, and seeds were placed 10 cm apart in three 66-cm rows. Throughout the experiment, the temperature in the chambers was maintained at 30/22°C, day/night. During the whole season, two carbon dioxide treatments, 360 (ambient) and 720 ppm, were imposed during the daylight hours. Half-strength Hoagland's nutrient solution was applied daily to each growth chamber via a drip irrigation system.

Three Ultraviolet-B radiations of control (No UV-B), and a total daily flux of biologically effective UV-B radiation of 8, and 16 kJ m^{-2} d^{-1} were imposed soon after emergence. The UV-B doses selected and imposed simulate ambient and certain percent (10 and 20%) depletion of stratospheric ozone. The UV-B radiation from fluorescent sun-lamps were delivered to plants for eight hours from 0800 to 1600 h by UV-313 lamps driven by 40 W dimming ballasts. To filter out UV-C radiation (<280 nm), the lamps were wrapped with solarized 0.07 mm cellulose diacetate (CA) film. The CA on the lamps was changed at regular intervals to account for the degradation of the CA properties. The UV-B energy delivered at the top of the canopy was checked daily with a radiometer. Rack height and lamp power were adjusted, as needed, to maintain the respective UV-B radiation levels. Lamps were always at 0.5 m above the plants.

When leaf nine on the mainstem was fully expanded, stomatal and epidermal cells were counted from the clear nail varnish impressions on both surfaces of each leaf midway between the midvein and the leaf margin, and midway between the apex and base of each leaf on nine plants. The 'stomatal index' was calculated as the ratio of stomata to epidermal cells plus the stomata per unit area. The leaf areas of all leaves were measured with an automatic leaf area meter. Scanning images of the leaves were also taken to examine stomatal and epicuticular wax morphology. Leaf epicuticular wax was extracted with chloroform, evaporated, weighed and expressed on unit leaf area basis. At the final harvest, 66 DAE, plant growth components were measured or counted on nine plants.

Plants grown in elevated UV-B radiation (particularly at the highest dosage) were smaller in stature in every aspect: shorter plants (40% reduction at 16 kJ), smaller individual leaf sizes and total leaf area and shorter branches. Elevated UV-B radiation increased stomatal density (56% on the upper and 23% on the lower leaf surface at the 8 kJ of UV-B, and by 34% in the upper and 10% in the lower leaf surface at the 16 kJ of UV-B), and stomatal index (an increase of 54% in 8 kJ and 23% 16 kJ on the upper surface) and decreased leaf size by 15% at 8 kJ of UV-B and by 30% at 16 kJ of UV-B radiation. The length and width of the stoma, however, were not affected by elevated UV-B radiation compared to the control. Leaf epicuticular waxes increased by 149 and 107% in 8 and 16 kJ of UV-B, respectively at square and by 71 and 87% in 8 and 16 kJ of UV-B, respectively at flower stage in response to elevated UV-B radiation.

The time of life cycle events such as first square and first bloom, and mainstem node addition intervals were not affected by elevated UV-B radiation. Similarly, the node at which the first fruiting branch appears was unaffected by elevated UV-B radiation. However, the number of bolls retained was severely affected by UV-B radiation, and decreased linearly with increases in UV-B radiation. The net result was reduced crop growth and lower biomass in elevated UV-B radiation environment.

Elevated atmospheric CO_2, on the other hand, did not ameliorate all the negative effects of UV-B radiation. Plant height and growth were enhanced in elevated CO_2 concentration at all UV-B levels, but the response to elevated UV-B radiation was similar to that of the ambient CO_2 conditions. Plants grown in high CO_2 did not produce as much quantity of wax as that of the ambient CO_2 levels, and response to elevated UV-B radiation was minimal in the high CO_2 environments.

The damage to reproductive structures (bolls and squares) by UV-B radiation was not ameliorated by elevated CO_2. Breeding UV-B-tolerant cotton cultivars will be more productive in the future higher solar UV-B radiation and higher atmospheric CO_2 concentration environments.