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COTTON PHOTOSYNTHESTIC RESPONSES TO ULTRAVIOLET-B RADIATION AND ELEVATED CO2

M. A. Razack, K. Raja Reddy, Duli Zhao and V.G. Kakani
Mississippi State University
Mississippi State, MS

Abstract

Changes predicted in our climate such as losses in stratospheric ozone and the resultant increase in ground level UV-B radiation and increases in atmospheric CO_2 concentration have profound direct and indirect impacts on crop production. Studies were conducted on the interactive effects of atmospheric CO_2 and ultraviolet-B (UV-B) radiation on cotton growth and physiology, particularly on photosynthesis processes. Upland cotton, cv. Nucotn-33b, was grown in Soil-Plant-Atmospheric-Research units at 30/22°C day/night temperatures from planting until 3-weeks after flowering. Three SPAR units were maintained at ambient (360 µL L^{-1}) CO_2 and other three at twice the ambient (720 µL L^{-1}) CO_2 throughout the experiment. Three UV-B treatments of 0 kJ m^{-2} d^{-1} (No UV-B), 8 kJ m^{-2} d^{-1} (moderate UV-B) and 16 kJ m^{-2} d^{-1} (high UV-B) were imposed at each CO_2 treatment soon after emergence till harvest for a period of 8 hours per day. The plants were irrigated with half-strength Hoagland's nutrient solution three times a day. Leaf net photosynthetic rate (P_{net}) and light use efficiency (LUE) were measured or estimated from the measurements on three top most fully expanded leaves at weekly intervals during the treatment period using LI-6400 portable photosynthesis system. Leaf age and photosynthesis relationships were also measured on 10^{th} leaf on the mainstem at 5-day intervals. At the final harvest, 66 DAE, plant component weights and leaf area were measured. Boll numbers were counted on 9 plants.

Plants grown at 16 kJ UV-B radiation showed a severe decline in photosynthetic activity compared to plants grown at 8 kJ UV-B radiation or the controls when measured in the top most fully expanded leaves on the mainstem grown at ambient and elevated CO_2. Light use efficiency calculated from the light responses curves, declined by 49% in the 16 kJ UV-B treatment for plants grown at ambient CO_2 level, compared to the control plants. The LUE was not affected by moderate doses of UV-B. Similar trends were observed for high-CO_2 grown plants. Averaged over the treatment period, the P_{net} at 1500 PPFD declined significantly, 40% in the 16 kJ UV-B treatment, compared to controls, for plants growth in both CO_2 levels. Similar to LUE, maximum photosynthesis (P_{max}) was not affected by moderate levels of UV-B radiation when measured in the fully expanded topmost canopy leaves. The decrease in photosynthetic capacity may not be related to stomatal limitation, as internal co_2 concentration was not affected by UV-B treatments.

The P_{max} increased up to 10 days of leaf unfolding in the control and in the moderate levels of UV-B radiation treatment, and then declined linearly as leaf aged. Photosynthesis capacity for the high UV-B radiation treatment showed continuous and substantial decline with age in in plants grown at both CO_2 levels. By 30 days after leaf unfolding, the P_{max} declined to nearly half of the maximum capacity in the control and in the moderate UV-B radiation treatments, and to nearly one third of the maximum in the high UV-B radiation treatment. These photosynthesis parameters indicated that higher doses of UV-B radiation accelerates the leaf aging processes, and elevated CO_2 did not ameliorate this aging processes in cotton.

Average canopy photosynthesis estimated from the light response curves and corrected for 1200 PPFD when the plants were intercepting almost 90% of the incoming solar radiation at the end of the experimental period declined quadratically with an increase in UV-B radiation both in the ambient and elevated CO_2 levels. As canopy photosynthesis integrates leaf photosynthetic capacities of various age groups, it was positively and linearly correlated with biomass accumulation rates. Similar to canopy photosynthesis, dry weight per plant decreased by 40% in the 16 kJ UV-B treatment and by 10% in the moderate levels of UV-B radiation treatment, compared to controls. The rate of decline was almost the same in high CO_2 grown plants in response to UV-B radiation. Similar declines in plant height and leaf area were observed in response to UV-B radiation. Node numbers on the mainstem were not affected by either UV-B radiation or elevated CO_2. Boll retention showed a trend similar to that of declines in the rates of canopy photosynthesis and whole plant biomass accumulation. Boll retention declined by 50 and 70% at the highest UV-B radiation for plants grown in 360 and 720 µL L^{-1} CO_2, respectively. The decline in boll retention was much greater than declines in any of the other processes. Our results indicate that cotton photosynthesis and growth are responsive to both elevated CO_2 and higher solar UV-B radiation.