PHYSIOLOGICAL RESPONSES OF COTTON LEAVES TO SHADING AND AGING

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Abstract

Shading causes early stomatal closure, decreasing gas exchange and photoassimilate production. Additional changes in leaf photosynthetic rates result from its aging. We aimed to show the effects of leaf aging with short and long term shading on cotton physiological response. Cotton plants were grown in 12 L pots in a greenhouse. Measurements were made in 15 and 60 day old leaves. The leaves were preconditioned receiving or not shade for 4 days before measurement (long term shading). Each leaf was shaded or no-shaded at the measurement (short term shading), using a black shade cloth (50%). Long term shading (4 days) decreased leaf net photosynthesis in 15 day old leaves but did not in under the short term shading. Shading in leaves over 60 days old did not affect gas exchange. Stomatal conductance was higher in younger leaves. Stomatal conductance in 60 days old leaves declined while intercellular CO_2 concentration increasing. Transpiration rates decreased and vapor pressure deficit based on leaf temperature (VpdL) increased with leaf aging.

Introduction

Incident light affect cotton photosystem, but is a factor poorly controlled or cannot be controlled. It is important to know the physiological limitations caused by shading for future advances in productivity (Wells & Stewart, 2010). The loss of photosynthetic capacity limits photo assimilate supply to the developing fruit, and under conditions of extreme shade can result in ovule abortion and fruit abscission (Pettigrew, 1994; Zhao &Oosterhuis, 1998).

Shading causes early stomatal closure, decreasing gas exchanges and photoassimilate production (Hesketh, 1968). Additional changes in leaf photosynthetic rates result from aging, due to chlorophyll breakdown, observed as a yellowing of photosynthetic tissues and chloroplast degradation (Sassenrath-Cole et al., 1996; Woolhouse, 1987). We aimed to show the interactive effects of leaf aging with short and long term of shading on cotton physiological performance.

Materials and Methods

The experiment was conducted in a greenhouse at Botucatu, São Paulo State, Brazil (22º51' S, 48º26'O). Cotton plants (cv. FMT 701) were grown between November 2009 and January 2010, in 12 liter pots with soil from the arable layer of a Rhodic Ferralsol (FAO, 2006). Plants were watered daily with half-strength Hoagland's nutrient solution. The experimental design was a factorial 2 x 2(leaf age x preconditioning) with two sub-plots (condition at the measurement), in randomized blocks with four replications. Measurements were taken in 15 and 60 day old leaves there were or preconditioned under shade for 4 days before evaluations (long term shading). Sub-plots were leaves shaded or no-shaded at the time of measurement (short term shading). A black shade cloth was placed approximately 2 centimeters above the leaf to reduce light intensity around 50%.

Measurements of CO_2 assimilation, stomatal conductance (g_s), transpiration , intercellular CO_2 concentration and vapor deficit pressure of cotton leaves were done using a Li-COR 6400 gas exchange system (LI-COR Inc., Lincoln, NE). Measurements were made from 09:00 to 11:00 am. Temperature was monitored (Figure 1). Leaf incident PAR at measurement is showed in Table 1. For statistical analysis, means were compared using t test (DMS, $P<0.05$).

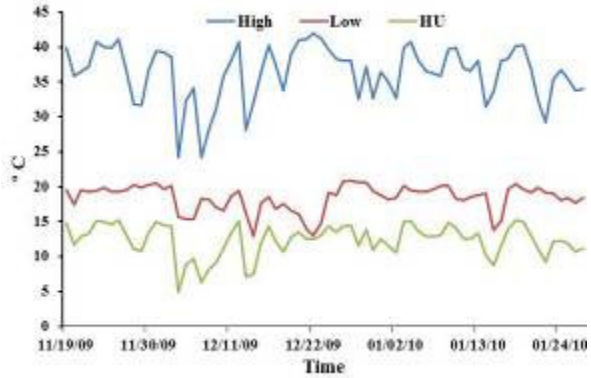

Figure1. High and low daily temperatures and heat units (HU) observed during the experiment.

Table 1. Leaf incident PAR at the measurement according with treatment. Preconditioning with shade was done 4 days before the measurement, the shadow being held at the measurement (Shaded) or removed (full sunlight).

Preconditioning	Condition at the measurement			
	Shaded		Full sunlight	
	Leaf age (days)		Leaf age (days)	
	15	**60**	**15**	**60**
	μmol m^{-2} s^{-1}			
Shaded	228	117	523	254
Full sunlight	371	204	394	139

Results and Discussion

Long term shading decreased leaf net photosynthesis by 22.5% in leaves 15 days old (Figure 2-A), but no differences were observed for short term shading (Figure 2-B). Shading in leaves over 60 days old did not affect gas exchange, regardless of shading duration (Figures 2-A and B). In both situations (shading or full sunlight and short or long term) 15 day old leaves showed higher photosynthetic rates than 60 day old leaves (Figure 2 – A and B). Leaf aging is one of the main causes of reduced photosynthetic rates (Constable & Rawson, 1980), irrespective of the shade levels received during leaf aging (Sassenrath-Cole et al., 1996).

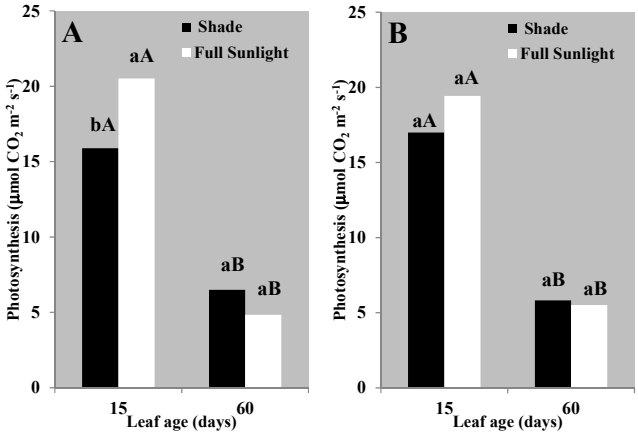

Figure 2. Photosynthetic response to cotton leaf age and preconditioning. (A) Long term shading - full sunlight or shaded for four days before measurement and (B) Short term shading – full sunlight or shaded at the measurement. LSD 2.78 (P<0.01). Small letters compares shade and capital letter compares age.

Stomatal conductance was higher in younger leaves, but the behavior was altered in short term shading (Figure 3B). These results are similar to those found by Bauer et al. (1997) where the imposition of a 6 min shade decreased g_s by

43%, but the immediate effect of shade was a sensible increase on g_s following by decrease, as we found in long term shading (Figure 3-A) and short term shading (Figure 3-B). Stomatal conductance in 60 day old leaves declined due to increasing intercellular CO_2 concentration (data not showed) (Messinger et al, 2006). Ci was not affected by shading, but leaf aging was (data not showed). Perry et al. (1983) also observed that intercellular CO_2 concentrations were lowest in youngest leaves (284 µl CO_2L^{-1} air) and increased to 296 µl CO_2L^{-1} in 35 day old leaves. However, Constable & Rawson (1980) found little or no differences in Ci with leaf aging, but with a slight tendency for C_i to rise as leaf aged.

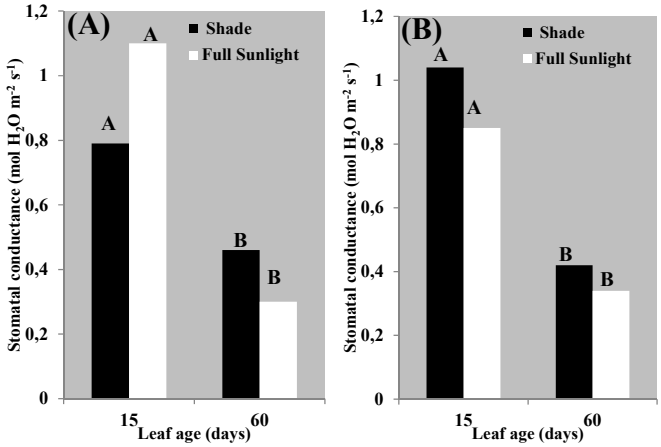

Figure 3. Stomatal conductance (g_s) as response of leaf age and long (A)or short term shading (B).LSD 0.39 ($P<0.01$). Capital letter compares leaf age.

Leaf aging from 15 to 60 days decreased transpiration rates by 24%, but little effect was observed due to shading (data not showed). As showed by Constable & Rawson (1980), transpiration changes with leaf age followed a similar pattern as photosynthesis, reaching maximum values around 13 days. By 60 days, rates of transpiration had fallen by approximately 50%.

Vapor pressure deficit based on leaf temperature (VpdL) increased with leaf aging (data not showed). Increasing in VpdL has been associated with reductions in leaf conductance and photosynthetic capacity of well-watered plants, and therefore to radiation use efficiency reductions (Stockle and Kiniry, 1990), as it was observed in the present experiment (Figures 1-A,B and 2-A,B).

Summary

Long term shading (4 days) decreased leaf net photosynthesis in 15 day old leaves but did not in short term shading (at the measurement). Shading in leaves over 60 days old did not affect gas exchange. Stomatal conductance was higher in younger leaves, but the behavior was altered in short term shading, in which g_s was higher on shaded leaf. In 60 days old leaves g_s declined due to increased intercellular CO_2 concentration. Transpiration rates decreased and Vapor pressure deficit based on leaf temperature (VpdL) increased with leaf aging.

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