LEAF MORPHOLOGY AND PHOTOSYNTHESIS OF COTTON SEEDLINGS AS INFLUENCED BY SPECTRAL BALANCE OF LIGHT REFLECTED FROM THE SOIL SURFACE

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Abstract

Narrow row cotton production is now a possible management option for picker-type cotton growers. Decreasing the distance between plants will influence the FR/R ratio of the reflected light plant leaves receive. Our objective was to determine the influence of the FR/R light ratio received by cotton leaves on leaf morphology and photosynthesis. Plants were grown over green (higher reflected FR/R light ratio relative to incoming sunlight) and white (reflected FR/R light ratio similar to the ratio found in incoming sunlight) soil surface colors in 1992. Photosynthesis was determined on 9 July and 13 July when the plants had about five fully expanded leaves. Representative leaves were collected on 10 July for leaf area, leaf weight, and stomate number determinations. Leaves that developed over the white had higher specific leaf weight and more stomates per unit area than leaves that developed over the green. Photosynthesis per unit leaf area was generally higher for leaves that developed over the white than leaves that developed over green. However, when calculated on a leaf weight basis, photosynthesis was greater in the leaves that developed over the green on 13 July and there was no difference between the surface colors on 9 July. These preliminary findings suggest that the FR/R light ratio can influence both cotton leaf morphology and photosynthesis.

Introduction

Determining the optimum row width and within row plant spacing has long been of interest to producers and agronomists. Since the introduction of harvesters that can pick cotton in narrow rows, many research projects have been initiated to investigate cotton's response to plant population and row spacing. Even though cotton lint yield can be the same over a wide range of plant populations, (Bauer, 1988; Bridge et al., 1973; Hawkins and Peacock, 1970; Hawkins and Peacock, 1971), information about physiological plant responses to increasing populations will provide guidelines for developing optimum cotton management systems.

Cotton plants grow taller, thinner, and have fewer branches at high plant density levels (Fowler and Ray, 1977). These morphological responses are indicative of a higher far-red to red (FR/R) light ratio within the canopy. Plants growing in high populations receive more light reflected from other leaves than plants in less dense spacings. Light reflected from leaves contain more FR and a higher FR/R ratio than incoming sunlight (Kasperbauer and Karlen, 1986). Kasperbauer and Hunt (1992) found similar morphologic responses in cotton plants grown over green plastic mulch (high reflected FR/R ratio) to plants grown at high populations.

Individual leaf morphology is influenced by the FR/R ratio. It has long been known that leaves that develop in shade are thinner than leaves that develop in full sunlight. Bradburne et al. (1989) studied the influence of soil surface color on leaf morphology and chemical concentrations of compounds important to photosynthesis. They found that, compared to leaves grown over a white soil surface color, leaves grown over a green surface color weighed less per unit area, had a higher chlorophyll concentration, and had a higher concentration of the major light-harvesting chlorophyll a/b binding protein complex of photosystem II (LHC-II).

Increasing plant population density causes increased competition between plants for nutrients, water, CO_2, and light, which can influence leaf photosynthetic rates. Growing plants over the green surface mulches to increase the FR/R ratio results in similar plant morphological responses to high populations, without these competitions. Our objective was to determine the influence of relected FR/R light ratios received by cotton plants on leaf photosynthesis.

Materials and Methods

The study was conducted in 1992 on a Norfolk loamy sand soil near Florence, SC. Conventional tillage was used to prepare the field, including forming beds which were centered at 1.0 m. Trickle tubing was placed on top of each bed and the plots were covered with 6-m X 20-m sheets of black plastic. Four rows in each replicate, 5.5 m long, were painted green or white. 'PD-1' cotton seeds were planted in 5-cm diameter holes in the plastic spaced 0.3 m apart. There were three replicates of each soil cover color.

Leaf photosynthesis was determined on 9 July and 13 July when the cotton seedlings had four to six fully expanded true leaves. Measurements were made with a Li-Cor model 6200 Portable Photosynthesis System at 0800, 1000, and 1200 EST on fully expanded leaves that had developed exposed to reflected light from the painted plastic mulches on the soil surface. Three leaves were measured at each measurement time per plot (nine leaves/soil surface color/measurement time). All measurements were collected within 1 hr.

Leaves from each plot, representative of those used for the photosynthesis measurements, were collected on 10 July for leaf area, leaf weight, and stomate number determinations. Stomate counts were made on the upper and lower surfaces of each leaf.

Results and Discussion

On each measurement day, no cloud cover occurred between sunrise and the time the last leaf measurement was made. Environmental conditions for the two days on which photosynthesis measurements were taken are given in Table 1. All measurements were collected with the same instrument used for determining photosynthesis. Incoming photosynthetically active radiation (PAR), air temperature, and leaf temperature were similar for both soil surface color treatments at each measurement time.

Leaf photosynthesis measurements were taken to coincide with a similar stage of crop development and time of day to those leaves measured by Bradburne et al. (1989). Averaged over the three measurement times, net photosynthesis (leaf area basis) was significantly greater ($P = 0.10$) on the cotton leaves that developed over the white soil surface color than those that developed over the green on 13 July (Table 2). On 9 July, although no significant differences occurred, average photosynthesis was higher on leaves over the white soil surface color at each measurement time (Table 2).

Our results (on a leaf area basis) appear contrary to those expected since Bradburne et al. (1989) found a higher leaf chlorophyll content and a higher LHC-II protein concentration in the leaves that developed over the green soil surface color. However, leaves which developed over the green soil surface color had lower specific leaf weight and fewer stomates per unit area than those which developed over the white (Table 3). When calculated on a leaf weight basis, there was no difference in photosynthesis rate between leaves grown over the green surface color and leaves grown over the white on 9 July (Table 4). On 13 July, photosynthesis rates per gram of leaf tissue (averaged over the three measurement times) were greater ($P = 0.05$) for the leaves that developed over the green soil surface color (Table 4). Most of the difference between the two surface colors on 13 July was at the 1000 measurement time (Table 4), which was the only measurement time of the six that green had numerically higher photosynthesis rates on a leaf area basis
(Table 2).

These preliminary findings suggest that the FR/R light ratio from soil surface colors can influence cotton leaf morphology and photosynthesis without the confounding plant competition factors associated with high plant densities. They also imply that the morphological and chemical constituent changes of cotton leaves induced by the FR/R ratio of light reflected by other leaves may impact single leaf photosynthesis. Perhaps this should be accounted for in simulating crop development in high plant population or narrow row production systems.

Acknowledgement and Disclaimer

We thank W. Sanders for excellent technical support. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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Table 1. Environmental conditions at the time leaf photosynthesis was measured. Values are means of nine leaf measurements per treatment per measurement time.

Variable	Soil Surface Color	0800	1000	1200
July 9				
PAR	Green	1548	1924	2050
	White	1521	1963	2036
Air Temperature	Green	31.7	35.2	38.5
	White	31.9	35.7	39.2
Leaf Temperature	Green	30.6	33.4	35.5
	White	30.7	33.7	36.0
July 13				
PAR	Green	1432	1900	1940
	White	1434	1918	1934
Air Temperature	Green	32.2	36.7	38.8
	White	32.4	36.7	39.0
Leaf Temperature	Green	30.9	34.0	36.1
	White	31.3	34.5	35.7

Table 2. Leaf photosynthesis rates on a leaf area basis for cotton leaves that developed over green or white soil surface colors.

Soil Surface Color	0800	1000	1200	$\bar{X}$
	-------- μmol CO_2 m^{-2} s^{-1} ---------			
July 9				
Green	33.36	34.84	30.57	32.93
White	35.58	36.89	33.75	35.41
LSD[†]		NS		
July 13				
Green	28.54	35.16	31.86	31.85[‡]
White	30.41	33.09	36.34	33.28
LSD[†]	NS			

[†] NS indicates nonsignificant color x measurement time interaction.
[‡] Means are significantly different (P = 0.10) from ANOVA.

Table 3. Morphological characteristics of leaves collected on July 10, 1992.

	Soil Surface Color			
	Green	SE[†]	White	SE
Specific Leaf Weight mg cm^{-2}	25.7	1.0	27.6	0.9
Stomates (no. cm^{-2})				
Upper Surface	11,300	190	12,190	250
Lower Surface	22,130	450	27,290	380
Total	33,430	-	39,480	-

† SE indicates standard error of mean.

Table 4. Leaf photosynthesis rates on a leaf weight basis for cotton leaves that developed over green or white soil surface colors.

Soil Surface Color	0800	1000	1200	$\bar{X}$
	-------- μmol CO_2 gm^{-1} s^{-1} --------			
July 9				
Green	0.130	0.136	0.119	0.128
White	0.129	0.137	0.122	0.128
LSD[†]		NS		
July 13				
Green	0.111	0.137	0.124	0.124[‡]
White	0.110	0.120	0.132	0.121
LSD[†]		NS		

[†] NS indicates nonsignificant color x measurement time interaction.
[‡] Indicates means are significantly different (P = 0.05) from ANOVA.