LOW LIGHT CONDITIONS COMPROMISE THE QUALITY OF FIBER PRODUCED

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Abstract

There can be considerable variation in the fiber quality produced by a particular cotton (*Gossypium hirsutum* L.) genotype, depending upon the variation in environments under which the genotype is grown. The purpose of this series of experiments was to clarify the role of the amount of sunlight in determining various fiber quality traits. Altering the canopy light environment by a variety of techniques in 1991 and 1992 showed that lint yield increased or decreased as the canopy light level increased or decreased. Changes in the number of bolls per unit ground area was the yield component responsible for these lint yield differences. Light enhancement did not consistently improve fiber quality. However, a 30% shade treatment reduced both fiber strength and micronaire (MIC) by 6%. Periods of fiber development that were sensitive to low light conditions were not conclusively established by altering the timing and duration of exposure to shaded conditions in 1993 and 1994. However, the fiber data trends in 1993 tended to indicate that fiber strength developed from 0 to 21 days post anthesis (DPA) and MIC developed after 21 DPA. Both the yield and quality of lint produced would benefit from techniques that either increase the amount of sunlight intercepted by a canopy or that utilize the intercepted sunlight more efficiently.

Introduction

Cotton fiber quality varies considerably among years and locations, depending upon the prevailing environmental conditions. This variation can occur even if the same genotypes are grown. Because the plant reproductive structures ultimately derive the assimilates needed for growth and development from photosynthetic tissues, the location and year effects on fiber quality may be related to variations in the photo assimilate supply among the environments. Although certain other environmental factors have been reported to influence fiber quality, such as the temperature effect (Gibson and Joham, 1968; 1969) or moisture effect (Eaton and Ergle, 1952; Marani and Amirav, 1971) on length and micronaire (MIC), sunlight is the most predominant climatic factor determining the supply of photosynthetic assimilates available to developing bolls. The objectives of these studies were to document how alterations in the availability of sunlight (amount, timing, and duration) during periods of boll development affect the quality of lint produced.

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Materials and Methods

Field studies were conducted at Stoneville, MS during the growing seasons from 1991 through 1994 to investigate the effect of sunlight on fiber quality. In 1991 and 1992, four treatments altering the canopy light level were imposed upon the cotton genotypes 'Acala Prema', 'DES 119', and 'DPL 5690'. A randomized complete block with five replicates and a factorial arrangement of treatments and genotypes was the experimental design used. The four treatments were as follows: (i) open canopy: plants in adjacent rows to the harvest row were bent away from the harvest row and held back with wire to increase the light environment of the harvest row; (ii) reflectors: reflective aluminum strips were placed on the ground on either side of the harvest row to increase the light environment of the harvest row; (iii) shaded plot: harvest rows were covered by shade cloth cages (30% reduction in visible sunlight or photosynthetic photon flux density); and (iv) untreated control. Lint yield and yield components were determined on all plots. Fiber quality was determined for lint collected from bolls that had previously been tagged as white blooms (blooms at anthesis) on the same day in each plot.

In 1993 and 1994, in a field of 'MD 51 ne', the shaded plot treatment was imposed at different stages of development and for different durations during the development of bolls tagged on the same day. These time frames [defined relative to the day of flowering (anthesis)] were as follows: (i) -7 to 0 days post anthesis (DPA); (ii) 0 to 7 DPA; (iii) 7 to 21 DPA; (iv) 21 to 35 DPA; (v) 0 to 42 DPA; and (vi) untreated control. The experimental design was a randomized complete block with six replications. Fiber quality was determined from lint collected from the tagged bolls in each plot.

Results and Discussion

Lint yield results from the 1991-92 study demonstrated that plots from the open canopy and reflectors treatments produced 17% and 6% greater lint yields than the control plots respectively (Table 1). The shaded plot treatment yielded 20% less than the control. As shown by these results, lint yield increased or decreased as the canopy light levels increased or decreased. The response of the number of bolls / unit ground area to changes in light levels essentially mirrored that of the lint yield response. These differences in bolls / unit ground area appeared to be the primary yield component contributing to the lint yield differences. Using different genotypes did not statistically change the treatment effects on lint yield, any of the yield components, or fiber quality traits measured. Therefore, the treatment means were averaged across genotypes for these traits.

Both fiber strength and MIC were reduced by the low light in the shaded plot treatment. Fiber strength and MIC from the shaded plots were both 6% lower than that of the control (Table 2). Light enhancement from the reflectors and open canopy treatment had no consistent beneficial effect on fiber quality. The decreased fiber strength under shade conditions was consistent with the observations of Eaton and Ergle (1954), who observed lower fiber strength under 70% reduced light conditions. The data indicate that the assimilate supply available to the developing boll must play a prominent role in the determination of the fiber quality of that boll. This idea is reinforced by the positive associations found between photosynthesis and fiber strength and MIC reported by Pettigrew and Meredith (1994). However, there may also be a genetic upper limit precluding further fiber strength increases when assimilates are in abundant or excessive supply, as would be the case under light enhanced conditions.

Altering the timing and duration of the exposure to shaded conditions in 1993 and 1994 provided only limited insight as to when during boll development various fiber quality traits are sensitive to the effects of low light conditions (Tables 3 and 4). In 1993, only the 0 to 42 DPA shade exposure appeared to consistently affect fiber strength and MIC (Table 3). Although periods of fiber development that were sensitive to low light levels (periods when quality is determined) were not conclusively established, the data trends hinted that fiber strength developed from 0 to 21 DPA and MIC developed after 21 DPA. This period of MIC determination closely matches that reported for the period of secondary wall deposition for a fiber cell (Benedict, 1984).

The low light exposure treatments had no real or significant effects on fiber quality in 1994 (Table 4). This lack of response is possibly due to lower than normal sunlight levels (numerous cloudy days) during July and August in 1994. This cloudy weather may have naturally reduced the fiber quality produced in 1994 and masked the response of the artificially imposed shade treatment. Solar radiation received in July and August in 1994 totaled 1305 MJ m^{-2} as compared to 1426 MJ m^{-2} received during the same period in 1993. The average total solar radiation received during the same period in 1991 and 1992 was 1526 MJ m^{-2}.

Data from this study indicate that cotton grown in the southeastern USA under normal production systems is light-limited. Protracted periods of cloudy weather can lower both the amount and quality of lint produced. The lack of consistency between years highlights the complex nature of the interaction among the various environmental factors and fiber quality development. Nonetheless, the data suggest that manipulations of the crop either to increase the amount of light penetrating to the lower canopy leaves or to utilize the intercepted light more efficiently may lead to improvements in lint yield and consistently good fiber quality.

References

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Table 1. Cotton lint yields, % first harvest, and number of bolls / unit ground area averaged across 1991 and 1992.

TREATMENT	LINT YIELD	FIRST HARVEST	BOLL NUMBER
	kg ha^{-1}	%	no. m^{-2}
Open Canopy	1397	95.6	83
Reflectors	1261	93.6	76
Control	1190	92.7	72
Shaded Plot	957	84.0	57
LSD (0.05)	68	1.9	4

Table 2. Cotton fiber strength and micronaire averaged across 1991 and 1992.

TREATMENT	FIBER STRENGTH	FIBER MICRONAIRE
	kN m kg^{-1}	
Open Canopy	216	3.91
Reflectors	212	3.77
Control	212	3.73
Shaded Plot	200	3.52
LSD (0.05)	5	0.19

Table 3. Cotton fiber strength and micronaire as affected by the timing and duration of a 30% shade treatment in 1993.

TREATMENT	FIBER STRENGTH	FIBER MICRONAIRE
	kN m kg^{-1}	
-7 to 0 DPA †	227	4.85
0 to 7 DPA	219	4.88
7 to 21 DPA	220	4.63
21 to 35 DPA	228	4.58
0 to 42 DPA	208	4.45
Control	223	4.72
LSD (0.05)	12	0.33

† DPA = Days post anthesis

Table 4. Cotton fiber strength and micronaire as affected by the timing and duration of a 30% shade treatment in 1994.

TREATMENT	FIBER STRENGTH	FIBER MICRONAIRE
	kN m kg^{-1}	
-7 to 0 DPA †	204	4.13
0 to 7 DPA	201	4.17
7 to 21 DPA	201	4.33
21 to 35 DPA	200	4.23
0 to 42 DPA	202	4.18
Control	200	4.35
LSD (0.05)	NS	NS

† DPA = Days post anthesis