## COTTON YIELD AND FIBER QUALITY AS AFFECTED BY LOW LIGHT F.R. Echer C.A. Rosolem R. Werle E. N. Gomes São Paulo State University Botucatu, São Paulo – Brazil

## <u>Abstract</u>

Cotton exposure to periods of shade might decrease yields and fiber quality. The study aimed to evaluate the effect of shade at different growth stages and it's interaction with row spacing on cotton yield and fiber quality. The experiment was carried out in Paranapanema, SP, Brazil. Treatments resulted from combinations of row spacings (0.48, 0.75 and 0.96m) and 7-day shade periods(pin head square – B1, first white flower – F1,one white flower at the reproductive branch 7 – F7, one boll open in the reproductive branch 3 – C3, and without shade). A shade cloth was used to reach a 50% reduction in PPFD. Leaf net photosynthesis decreased as row with decreased, and were higher on no-shade treatments during F1 and C3 stages. There was no interaction between row spacing and shading periods on cotton seed and fiber yields, boll weight, micronaire and fiber length. However, cotton grown in row spacings of 0.75 m (4514 kg ha<sup>-1</sup>) and 0.48 m (4296 kg ha<sup>-1</sup>) yielded more seed cotton than in 0.96m (4114kg ha<sup>-1</sup>). Shading during seven days from C3 decreased cotton yields as a result of a lower boll weight. Lint percentage was not affected by treatments and ranged from 34 to36%. The wider spacings resulted in heavier bolls and fiber yield was1466 kg ha<sup>-1</sup>, 1625 kg ha<sup>-1</sup> and 1473 kg ha<sup>-1</sup>, at 0.48, 0.75 and 0.96 m rows, respectively. There was no effect of treatments on micronaire; however, the fiber was shorter in the smallest row spacing.

### **Introduction**

Cotton, similar to other species bearing C3carbon fixation route, has low photosynthetic efficiency, with high rates of photorespiration and low affinity of the carboxylation enzyme for  $CO_2$ . Besides, its  $CO_2$  compensation point is high, between 60 and 120 mL L<sup>-1</sup> (Krizek, 1986), which makes it responsive and highly dependent on solar radiation.

Although the leaf area index may be two to three times higher at high plant populations, net photosynthesis, and consequently the accumulation of dry matter per plant may be lower, mainly due to decreased light interception resulting from self-shading (Fowler& Ray, 1977). However, dry matter yield per hectare has not been affected by row spacings or plant populations (Rosolem et al., 2011).

Zhao and Oosterhuis (2000) concluded that a low photosynthetic photon flux density (PPFD) during the first flower stage (FF), full flowering (PF) and boll development (BD) increased fruit abscission and decreased fiber quality, especially micronaire and fiber length. The same authors also found that the shade imposed in FF, PF and BD decreased fiber yields by18 to 52%, depending on the year. This is important mainly in cotton production regions located in tropical areas with high rainfalls, where overcast weather is common during the growing season. These cloudy, overcast periods for one to two weeks may have detrimental effects on cotton growth and boll retention.

The effect of PPFD on cotton has been documented before, as well as the plant responses to self-shading. However, there is no research on the effect of self-shading associated with the shade caused by clouds (simulated shade) on cotton yield and fiber quality. We evaluated the effect of self-shading caused by row spacings (0.48, 0.75 and 0.96 m) and time of artificial shade imposed at several growing stages on photosynthesis, seed cotton and lint yield, fiber percentage, boll weight, micronaire and fiber length.

### **Materials and Methods**

The experiment was carried out on farm conditions, in Paranapanema, Sao Paulo State, Brazil. Treatments consisted of cotton cropped in rows 0.48, 0.75 and 0.96 m apart, and 7-day shade periods starting at B1, F1, F7 and C3 (Marur and Ruano, 2001), plus one treatment without shade. B1 corresponds to pinhead square, F1 to first white flower, F7 to first white flower on the seventh branch and C3 the first open boll in the third node. After plant emergence the crop was thinned to 9.9 plants per meter of row. The plots were of 6.0 m long and 4.5 m wide. A black shade cloth was used to reduce light intensity around 50% for seven days from the beginning of each phenological stage of

cotton plants (B1, F1, F7 and C3). The experimental design was a 3 x 5 (row spacing x shading stage) factorial in complete randomized blocks with four replications.

Crop management followed the procedures adopted in commercial cotton farming, including pest and disease monitoring and control, chemical weed control, plant height monitoring and application of growth regulators. Growth regulator application time and rates were specific for each row spacing, aiming to a plant height correspondent to1.5 times the row spacing. We evaluated seed cotton yield, fiber percentage, fiber yield, boll weight, micronaire, and fiber length. Net photosynthesis was measured using a LI-6400 portable photosynthesis system (LiCor, Lincoln, NE, USA), on the sixth main-stem leaf from the plant top. At each stage (B1, F1 and C3) photosynthesis was measured in shaded and no-shaded leaves. All readings were made between 9:00 and 11:00 hours, using the ambient photosynthetic photo flux density. Global and PAR (radiation photosynthetically active) was measured by LI190SB (Campbell Scientific) for PAR and CM3 pyranometer (Kipp & Zonen) for global radiation, and data are showed in table 1.

Statistical analysis consisted of analysis of variance, and experimental data means were compared using the t test (LSD, P < 0.05).

Table 1. Global radiation and PAR accumulation during 7-days shade in each stage.								
	Global Sun*	Global Shade	PAR Sun**	PAR Shade				
	MJ m <sup>-2</sup>							
B1	118.0	49.4	52.3	23.4				
F1	138.0	57.7	65.2	31.0				
F7	153.0	63.2	80.1	42.7				
C3	127.7	53.9	58.0	26.6				

\*global ultraviolet; \*\*photosynthetically active-PAR

### **Results and Discussion**

Seed cotton yield decreased when shade was imposed at F1 and C3 (Table 2). The lower cotton seed yield when the shade was applied in F1 stage was due to a decrease in the number of fruiting sites (data not shown). The decreased yield when shade was applied from C3 was due to a lower boll weight (Table 2). The lowest boll weight was observed in this treatment.

Table 2. Seed Cotton and lint yields, boll weight and lint percentage as affected by shading stage.

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Shading*	Seed cotton	Boll weight	Lint percentage	Lint yield
	kg ha <sup>-1</sup>	g	%	kg ha <sup>-1</sup>
No Shade	4575 a**	7.3 a	35.8	1663
B1	4356 ab	7.3 a	35.6	1550
F1	4130 b	7.3 a	35.0	1451
F7	4288 ab	7.4 a	34.6	1483
C3	4194 b	7.0 b	35.5	1493
LSD	290 (P>0.01)	0.3 (P>0.04)	2.5 (P>0.86)	146 (P>0.12)

\*B1 (pinhead square), F1 (1<sup>st</sup> white flower at 1<sup>st</sup> sympodia), F7 (1<sup>st</sup> whiteflower at the7<sup>th</sup> sympodia), C3 (1<sup>st</sup> openbollat 3<sup>rd</sup> sympodia). \*\* Different letters show significant difference (P>0.05).

Zhao &Oosterhuis (2000) observed a decrease in cotton boll weight when shade occurred during the boll development stage, due to a decreased leaf photosynthetic rate and limited carbohydrate supply. In this experiment, bolls sampled to determine boll weight were taken from the plant half-height; hence they developed under shade applied at C3 (first boll opened at 3<sup>rd</sup>sympodia).

Lint percentage was not significantly affected by periods of shade (Table 2). Lint percentage is a genetically controlled characteristic (Godoy &Palomo, 1999), but may be affected by some factors like incident light (Roussopoulos et al., 1998), which was not the case in the present experiment. Periods of shade had no significant

effect on lint yield if the P>0.05 threshold level is considered. However, at lower level of probability there was a decrease in lint yield whenever a shade was imposed. Dusserre et al. (2002) showed no effect of shade (light decrease by 40%) imposed before anthesis onwards on fiber weight, because the lower growth rates were compensated by a longer growth period. However, when shade was imposed 178 degree-days after anthesis onwards, final fiber weight decreased because there was no such compensatory effect. Therefore, in this experiment reduced fiber yield when shade was imposed from F1 stage may be due to poor carbohydrate storage, as a result of low photosynthesis in this treatment (data not showed).

It was expected a negative effect of shade on cotton quality (Zhao and Oosterhuis, 2000, Pettigrew, 2001). Micronaire is a result of secondary wall thickening by carbohydrates deposition; therefore, any stress that reduces carbohydrate availability could hinder fiber quality as well as boll weight. However, in this experiment there was no effect in micronaire index due to low light (average 4.2). Fiber length was also not affect by periods of shading (average 28.1 mm). Fiber length is defined up to three weeks after anthesis, and after this begins the cellulose deposition in the fiber, which lasts for about 25 to 30 days. In this experiment, a shade lasting just one week was not long enough to impair fiber growth and maturation, showing that, if there are no environmental or nutritional limitations, normal fiber development is resumed after a short period of low PPDF.

Seed Cotton yield was higher when grown in 0.75 m rows than in 0.96 m, but cotton boll weight decreased with decreasing row spacings (Table 2) and was lowest when cotton was grown in 0.48 m rows. This behavior may be a result of competition among fruits when cotton is grown under high plant populations, even though lint yield is not affected (Boquet, 2005). Lint percentage was not affected by row spacing, but lint yield was, and was higher in the 0.75 m row spacing. Jos t& Cothren (2000) also observed no differences in lint percentage between cotton planted in conventional and ultra-narrow row spacings. Hence, the differences observed in lint yield were due to different seed cotton yields. Similar results were obtained by Boquet (2005) growing cotton at wider rows as compared with narrow rows. Row spacing did not affect micronaire (average 4.2), but fiber length decreased when cotton was grown in 0.45 rows. Jost & Cothren (2000) observed a tendency of decreasing fiber length when row spacing was reduced to 0.19 m. However, Boquet (2005) observed just a little effect of row spacings on fiber length.

Leaf net photosynthesis decreased as row with decreased, likely due to higher competition for resources on 0.45 m row spacing, like high incident light (PPFD) on wider row spacing (Table 3). Similar data were found by Arriaga et al. (2009), which net photosynthesis was higher on 1.02m row spacing than 0.20 m.

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Row widt	th Seed cotton	Boll weight	Lint	Lint yield	Fiber length	Photosynthesis	$PPFD^1$
			percentage				
М	kg ha <sup>-1</sup>	g	%	kg ha <sup>-1</sup>	mm	$mmolCO_2 m^{-2}$	µmol m <sup>-2</sup> s <sup>-1</sup>
						$s^{-1}$	
0.45	4297 ab	6.9 b	34.1	1467 b	27.8 b	9.77 b	751 ab
0.75	4514 a	7.3 a	36.1	1626 a	28.3 a	13.33 a	644 b
0.96	4114 b	7.5 a	35.7	1474 b	28.3 a	14.79 a	933 a
LSD	224 (P>0.03)	0.23 (P>0.01)	1.9 (P>0.08)	113 (P>0.01)	0.33 (P>0.01)	2.33(P>0.01)	221(P>0.04)

Table 3.	Seed	Cotton	and lint	vields.	boll	weight	and l	int p	ercentag	e as	affected	bv	row	widt	h
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\*B1 (pinhead square), F1 (1<sup>st</sup>white flower at 1<sup>st</sup>sympodia), F7 (1<sup>st</sup> whiteflower at the7<sup>th</sup>sympodia), C3 (1<sup>st</sup>openbollat the3<sup>rd</sup>sympodia). \*\* Different letters show significant difference (P>0.05).<sup>1</sup> Photosynthetic Photon flux density at sixth fully youngest expanded leaf.

Shading decreased PPDF, photosynthesis and stomatal conductance (Fig. 1). According with Smith & Longstreth (1994) cotton leaf photosynthesis at high PPFD has the potential to assimilate 2.2 times the amount of  $CO_2$  as leaves at a lower PPFD (only 17% of high PPFD), however in the present experiment, leaves in the no-shaded treatment assimilated 1.4 times the amount of  $CO_2$  as leaves from the shaded treatment, due to the lower PPFD.



Figure 1. Photosynthesis, stomatal conductance and incident PPFD in shaded and no shaded treatments. LSD 1.87(P>0.01); 0.04(P>0.05); 178 (P>0.01) for photosynthesis, stomatal conductance and incident PPFD, respectively.

Furthermore, stomatal conductance decreased on shaded treatment as a result of lower PPFD. Stomatal conductance is related with photosynthesis rate; however cotton leaf conductance in excess to 0.3-0.4 mol  $CO_2 \text{ m}^{-2} \text{ s}^{-1}$  did not result in increases in net photosynthesis (Hutmacher& Krieg, 1983). At low PPFD stomata tend to close, reducing stomatal conductance (Farquhar & Sharkey, 1982). Despite that, Zhao & Oosterhuis (1998a) found lower stomatal conductance in shaded treatments at pin-head square, first flower and peak flower stages, but no differences when the shade was imposed at boll stage. They argued that stomates and intercellular  $CO_2$  concentrations were not the major factors that decrease leaf photosynthetic rate of shaded treatments, but in this experiment the tendency for both parameters was the same.

Leaf photosynthesis rates were higher (P>0.01) under sun light F1 and C3, but the effect was not significant at B (data not showed). Similar results were reported by Zhao & Oosterhuis (1998b), even though values were different, the relative decrease was similar (88 and 39% in their study and 77 and 43% in our study at F1 and C3). A possible explanation for this difference is the degree of shading, which was 50% in our study against 63% in theirs.

#### **Summary**

Cotton shading for 7 days from F1 (first white flower) stage decreased cotton seed yield, however the lowest boll weight was obtained when the shade was applied at C3stage (the first open boll at 3<sup>th</sup> sympodia) to plants grown in 0.48 m rows. Micronaire was not affected, but fiber length decreased in narrow-row spacing. Leaf net photosynthesis decreased as row with decreased, and was higher on no-shade treatment in F1 and C3 stages.

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