YIELD AND FIBER QUALITY OF COTTON CULTIVARS IN RESPONSE TO SHADING

Fábio Rafael Echer

Universidade do Oeste Paulista – UNOESTE, Programa de Pós-Graduação em Agronomia, Presidente Prudente, SP. E-mail: fabioecher@unoeste.br

ABSTRACT

Shading is an environmental stress that affects cotton production areas, especially under tropical and rainfed conditions. The aim of this research was to evaluate the tolerance of cotton cultivars to shading. A field experiment was carried out in Primavera do Leste - MT, Brazil in the 2014 growing season. The experimental design was a 2 x 4 factorial (shading x cultivars) in randomized blocks with 4 replications. Cotton cultivars included late (TMG 82WS) and mid-early (IMA 5675B2RF, IMA 5672B2RF and IMA 5822B2RF). Shading (50% light reduction) was imposed at flowering onset (F2/F3 - Stage) for 2 weeks. Node number, boll number and fiber yield decreased by shading by 18.5, 36 and 25% on mid-early cultivars (average), respectively, as compared to the late cultivar. Boll weight was not affected by shading. For fiber quality parameters, shading reduced micronaire by 6.0% in the mid-early cultivars and fiber strength was increased by 6.4% on cultivar IMA 5672B2RF under shading and it was associated with the lowest boll number in such cultivar. It was concluded that in a season with no water or temperature limitation, the late cultivar could recovery the yield in the top of the plant. Shading decrease micronaire index, but the response depends on cultivar. Fiber properties such as length and strength were affected by shading but this response was related to the number of fruits retained by the plant.

Keywords: boll number; boll weight; micronaire; length; strength.

PRODUTIVIDADE E QUALIDADE DA FIBRA DE CULTIVARES DE ALGODÃO EM RESPOSTA AO SOMBREAMENTO

RESUMO

O sombreamento é um estresse ambiental que limita a produção de algodão, especialmente em condições tropicais e não irrigadas. O objetivo deste trabalho foi avaliar a tolerância de cultivares de algodão ao sombreamento. O experimento foi conduzido á campo, em lavoura comercial de algodão em Primavera do Leste-MT, na safra 2014. O delineamento experimental foi um fatorial 2x4 (sombra x cultivares) em blocos ao acaso com 4 repetições. As cultivares de algodão utilizadas foram uma tardia (TMG 82WS) e três de ciclo médio-precoce (IMA 5675B2RF, IMA 5672B2RF e IMA 5822B2RF). A sombra (50% de redução da incidência luminosa) foi imposta no início do florescimento (estádio F2/F3) durante 2 semanas. O número de nós, número de capulhos e a produtividade de algodão em fibra foram reduzidos em média 18,5, 36 e 25%, respectivamente, nas cultivares de ciclo médio-precoce sob sombreamento, comparado á cultivar tardia. O peso médio do capulho não foi afetado pelo sombreamento. A sombra reduziu em média 6% o índice micronaire nas cultivares médio-precoce, mas não afetou a tardia, enquanto que a resistência da fibra aumentou em 6,4% no cultivar IMA 5672B2RF sob sombreamento e isso foi associado ao menor número de capulhos nesse cultivar. Conclui-se que em uma safra sem restrição hídrica e de temperatura, o cultivar tardio pôde compensar a carga frutífera abortada. As características da fibra como o comprimento e a resistência foram afetados pelo sombreamento, porém essa resposta foi associada á menor retenção de capulhos pela planta.

Palavras-chave: número de capulhos; peso do capulho; micronaire; comprimento; resistência.

INTRODUCTION

Shading is an environmental stress that affects cotton production areas, especially under tropical and rainfed conditions. Cotton is a perennial shrub native from tropical and subtropical regions, and in these conditions, the lack of light is not a significant problem. Cloudy days can affect plant yield and fiber quality as a result of the high abscission rates (GUINN, 1974) or the low availability of carbohydrates for boll filling (ZHAO; OOSTERHUIS, 2000).

Studies from Echer and Rosolem (2015a) reported that a short-term shade decreased net photosynthesis (Pn), especially in 15 and 30 days old leaves. Additionally, Pn response to PAR in older leaves (45 and 60 days) was lower than younger leaves, which suggests a low effect of self-shading on Pn for those old leaves.

The length of the crop window can be a strategy to deal with the deleterious effects of shading, especially when cotton is grown in tropical areas, where the temperature window and rainy season are longer, the plant growing season can be lengthened by adjusting the planting time or cultivar type in an attempt to avoid yield loss.

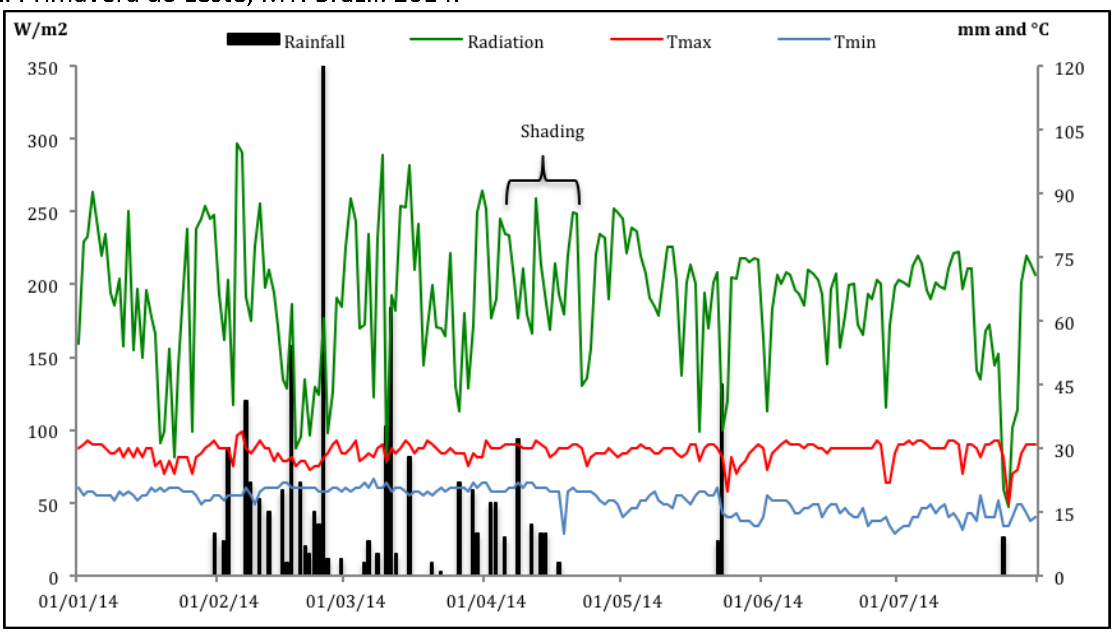
In a tropical environment, Echer and Rosolem (2015b) reported the flowering onset as the most sensitive stage to yield losses induced by shading, but no effects were observed on fiber quality. According to the authors such yield losses are due to a combination of declining water availability late in the season, temperature and radiation preventing full yield compensation following fruit shedding during shading.

One of the options to growers deal with shading is the cultivar tolerance/recovery to shading, however a few number of studies have reported the cultivar performance under low irradiance levels, especially in tropical areas, where the temperature window and rainy season are longer, and a yield recovery can happen. The hypothesis of this work was that late cotton cultivars could compensate the yield loss as a response of shading early in the flowering. The aim of this work was evaluate the performance of cotton cultivars under artificial shading at field conditions.

MATERIAL AND METHODS

The experiment was carried out at field conditions in Primavera do Leste, MT – Brazil, during 2014 growing season in a Ferralsol (IUSS WORKING GROUP/WRB, 2006). Cotton was grown as relay crop, after soybeans. Environmental conditions such as radiation, rainfall and maximum and minimum temperatures are showed on Figure 1.

Figure 1. Maximum and minimum temperatures, rainfall and global radiation in cotton crop from sowing to harvest. Primavera do Leste, MT. Brazil. 2014.



The experimental design was a 4x2 factorial allocated in a randomized block with 4 replications. Cotton cultivars included IMA5675B2RF (early), IMA5672B2RF (mid-early), IMA5822B2RF (mid-early) and TMG 82WS (late) under shaded and no shaded conditions.

Cotton was sowed in 28/01/14 at 0.90 m spacing between rows at a plant density of 9 plants m^{-1}. The fertilization was performed via basal application and it included 18 kg ha^{-1} of nitrogen and 86 kg ha^{-1} of phosphorus at sowing and the topdressing fertilization was performed with 90 kg ha^{-1} of nitrogen and potassium, divided in two applications at 35 and 60 days after emergence.

The plot had 4 rows with 5 m of length. At onset of flowering (66 days after emergence – F2/F3 stage – MARUR; RUANO, 2001) a black net with 50% of light reduction was displayed over the plant canopy for 2 weeks. The shade net was removed during pesticides applications and readily re-installed.

Plant growth regulators (PGR) were used when necessary, considering the early cultivar as a reference plant, to avoid excess of PGR and to allow plant re-growth after treatment removal. The active ingredient used was mepiquat chloride at a rate of 96 g ha^{-1} (8 g ha^{-1} at 68 DAE; 50 g ha^{-1} at 75 DAE and 37,5 g ha^{-1} at 93 DAE).

Despite of cotton cultivars being transgenic plants (Bollgard II and Widestrike), the cultivar of the commercial field was conventional (FM 910) and weeds, diseases and pests were controlled according to the management of the commercial field. Cotton was defoliated with thidiazurom + diurom at 0.4 L ha^{-1} at 175 DAE.

At harvest cotton was hand picked in 1 m of the two central rows and boll number, boll weight, node number, seed cotton yield, fiber yield and gin turnout were evaluated. Fiber properties were determined by High Instrumentals Volume (HVI) method for micronaire, length, strength and maturity. Treatment means were compared using Tukey test (α=0.05).

RESULTS AND DISCUSSION

The interaction between cultivar and shade was significant for the most of the evaluated traits, except for plant density, short fiber content (SFC) and maturity (Table 1).

Table 1. Probability of significance for each source of variation and interaction of evaluated traits.

Source of variation	Cultivar (C)	Shade (S)	C x S	CV%
Plant density	0.74	0.99	0.33	19.65
Node number	0.28	0.64	0.04	14.68
Boll number	0.001	0.01	0.01	15.98
Boll weight	0.001	0.54	0.001	5.45
Yield	0.001	0.001	0.001	14.23
Gin turnout	0.001	0.01	0.001	2.21
Micronaire	0.03	0.02	0.01	10.56
Strength	0.08	0.68	0.02	5.82
Length	0.36	0.31	0.03	3.53
SFC	0.45	0.81	0.24	16.95
Maturity	0.66	0.69	0.23	1.06

CV: coefficient of variation.

Treatments did not affect plant density (average 8.8 plants m^{-1}), SFC (average 8.7) and maturity (83.3) (Table 2).

Table 2. Plant density, short fiber content (SFC) and fiber maturity as affected by cultivar and shade.

	Plant density (m^{-1})	SFC (%)	Maturity
Cultivar			
TMG82WS	8.5	8.5	83.5
IMA5675B2RF	9.0	8.8	83.1
IMA5672B2RF	9.3	8.3	83.3
IMA5822B2RF	8.6	9.5	83.0
Shade			
No-Shaded	8.8	8.7	83.3
Shaded	8.8	8.8	83.1

There was interaction between cultivar and shade on node number and it was higher on cultivar TMG 82WS under shade as compared to IMA 5822B2RF. No differences among cultivars were observed under no shade treatment (Figure 2). The late cultivar TMG 82WS under shading issued two more nodes in the top of the plant, as a result of the compensation capacity of this cultivar. The behavior of the others cultivars was different and there was no difference between shading treatments early and mid-early cultivars IMA 5675B2RF, IMA 5672B2RF and IMA 5822B2RF. In fact, the compensation on the late cultivar only happens because a significant rain of 45 mm late in may, when the yield potential was not defined yet (Figure 1).

Yeates et al. (2013), showed that environmental stress such as cold temperatures contributed to the reduced yield from early first position flowers as a result of the reduced proportion of survivors flowers, but as temperature increases the flower issue increases and the recovery occurs in P3 and MP (monopodia and P4+) positions. The node number was not increased in the Yeates´s study, probably because their plant were grown in pots in a glasshouse experiment, and the plant growth in this situation can be restricted due to soil volume exploration. On the other hand, in the present research, node number was increased because soil humidity and air temperatures were not limiting to plant growth (Figure 1), and as a result the boll number was recovered in the cultivar TMG 82WS under shading. Boll number was higher on TMG 82WS for both shaded and no shaded treatments as compared to IMA 5822B2RF (Figure 3).

Despite no differences were observed among shade treatments within cotton cultivars, boll number was numerically similar on TMG 82WS and a small difference was observed in the others. Reports evaluating the effect of cotton cultivars responses to shading are scarce on literature. Results from Echer and Rosolem (2015b) showed in a three year/location experiment a small but insignificant decrease on boll number on shade at F1 stage (first flower) as compared to non shaded treatment in three different genotypes (FM 966LL, IMA 6001LL and FMT 701) and the average boll number reduction was 15%, similar to the reduction on cultivars IMA 5675B2RF, IMA 5672B2RF and IMA 5822B2RF in this experiment (Figure 3). The environmental condition such as rainfall (two experiments) and temperature window (one experiment) late in the season in the Echer´s study prevented full recovery.

Figure 2. Effects of cotton cultivar and shading on plant node number. Vertical bars show the standard error of the mean. A>B within shaded treatment (Tukey, 0.05). NS: no shaded, S: shaded.

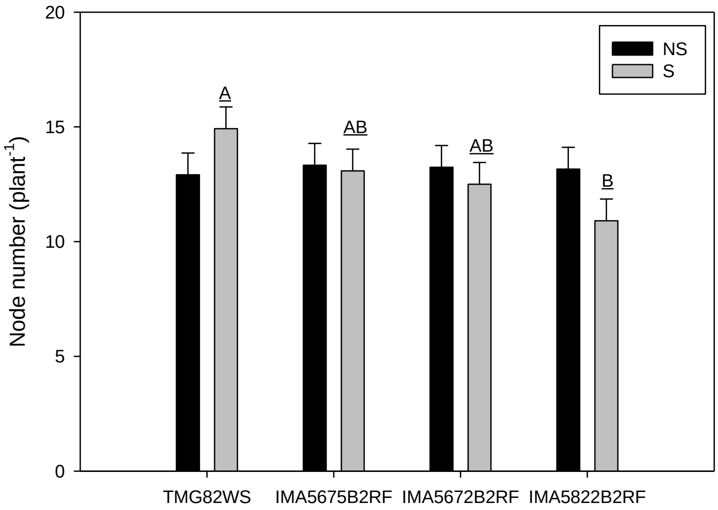
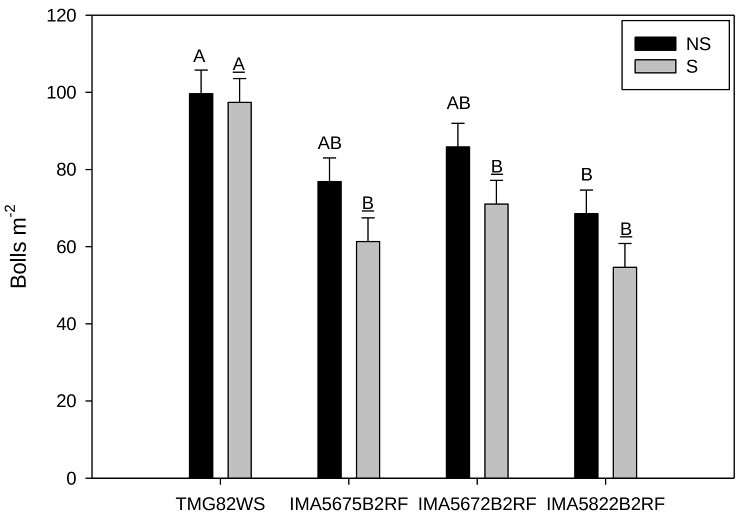
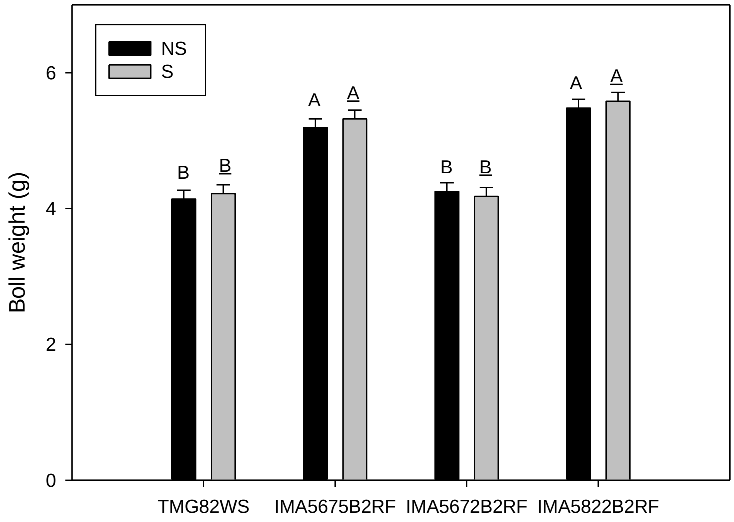


Figure 3. Boll number as affected by cotton cultivar and shading. Vertical bars show the standard error of the mean. A>B within shaded treatment and A>B within no shaded treatment (Tukey, 0.05).



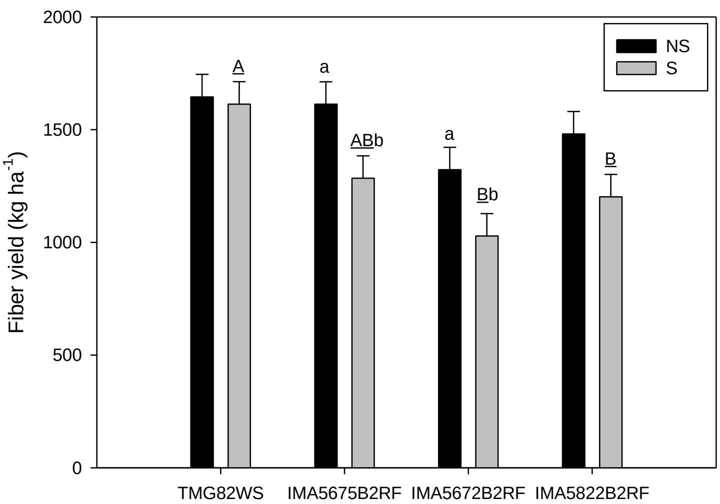
Boll weight was higher on cultivars IMA 5822B2RF and IMA 5675B2RF as compared to TMG 82WS and IMA 5672B2RF for both shaded and no shaded treatments (Figure 4) as a result of the lower number of bolls in those treatments (Figure 3). This finding corroborates to previous studies in cotton (ECHER; ROSOLEM, 2015; BRADOW; DAVIDONIS, 2010) due to an alteration on source-sink ratio and as a consequence of fruit shedding, the remaining bolls had an increase on carbohydrate availability and finally on boll weight. According to Pettigrew (2001) a plant only sets a number of bolls that it can supply with carbohydrates, and as a result of the lack of assimilates mainly during the two weeks after anthesis, there is a high probability of boll shed. Since the shade was imposed at onset of flowering stage in this research, a decreased on carbohydrates level could increase the ethylene/sugars ratio leading to shedding of flowers and young bolls.

Figure 4. Boll weight in cotton cultivar and shading treatments. Vertical bars show the standard error of the mean. A>B within shaded treatment and A>B within no shaded treatment (Tukey, 0.05). NS: no shaded. S: Shaded.



Shade significantly decreased fiber yield on cultivars IMA 5675B2RF and IMA 5672B2RF. Additionally, cotton fiber yield was greater on TMG 82WS under shading as compared to IMA 5672B2RF and IMA 5822B2RF (Figure 5). This performance can be attributed to the compensation that occurred on TMG 82WS (Figure 3). This compensation capacity of cotton was reported earlier in a late cultivar by Yeates et al. (2013) in a pot study with low temperatures during flowering. It was possible because plants were able to produce and retain more flowers before plant stress or due to the retention of late pollinated flowers as a result of an adequate environmental condition such as warm temperature and increased radiation. Similarly to the findings of this experiment, Echer and Rosolem (2015b) also reported a decrease in fiber yield due to shading at F1 stage in a early cultivar in an environment (Cfa - Köppen) with a short growing season (low temperature after cut-out), but in another environment (Aw - Köppen) (no temperature restriction) using a mid-late cultivar with adequate soil humidity the yield was similar to the control as a result of the compensation in boll weight.

Figure 5. Fiber yield of cotton cultivar under shading treatments. Vertical bars show the standard error of the mean. A>B within shaded treatment and a>b within cultivar. (Tukey, 0.05). NS: no shaded. S: Shaded.



Gin turnout was decreased by shading on cultivar IMA 5672B2RF (Figure 6). In addition, the gin turnout was lower on IMA 5672B2RF for both shaded and no shaded treatments, as compared to the other cultivars (Figure 6). Gin turnout is a characteristic genetically controlled, but as observed in this research, it can be affected by environment. Earlier studies reported an increase in gin turnout when shade was placed at boll development stage in a 4-day interval for a 16-day period compared to unshaded treatment (ZHAO; OOSTERHUIS, 2000). Other studies reported less effect of shade on fiber percentage (ECHER; ROSOLEM, 2015; CHEN et al., 2016) and those differences can be attributed to shading level, duration or stage of plants.

Micronaire was decreased by shade on cultivars IMA 5675B2RF (Figure 7). Additionally, the micronaire was lower on cultivar IMA 5822B2RF under no shade as compared to the others. Micronaire is a fiber trait related to the diameter of the fiber, and as the fiber is composed of more than 90% of cellulose, an organic compound derived from glucose, that in turn comes from photosynthesis (Pn), thus as a result of shading, there is a reduction in Pn (ZHAO; OOSTERHUIS, 1998; ECHER; ROSOLEM, 2015) and the reduction of carbohydrates results in a fiber with low micronaire (PETTIGREW, 2001; ZHAO; OOSTERHUIS, 2000; CHEN et al., 2017).

Figure 6. Effect of shade and cotton cultivar on gin turnout. Vertical bars show the standard error of the mean. A>B within shaded treatment and A>B within no shaded treatment and a>b within cultivar (Tukey, 0.05). NS: no shaded. S: Shaded.

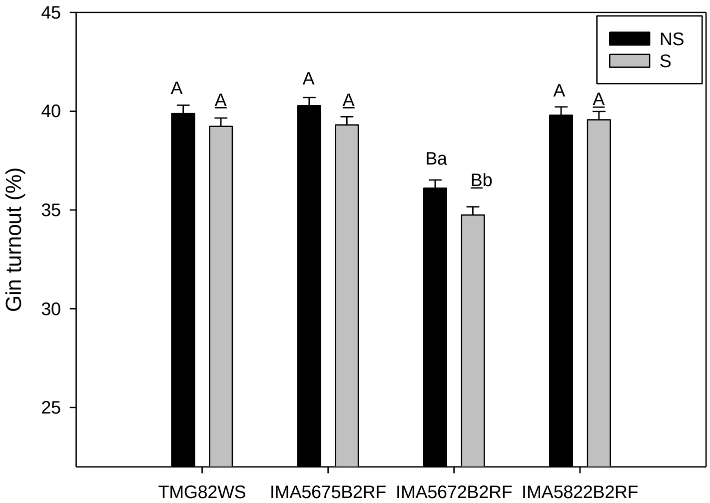
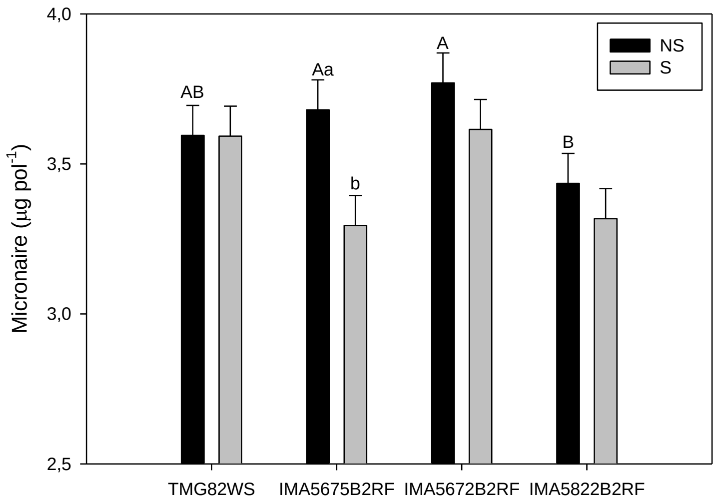
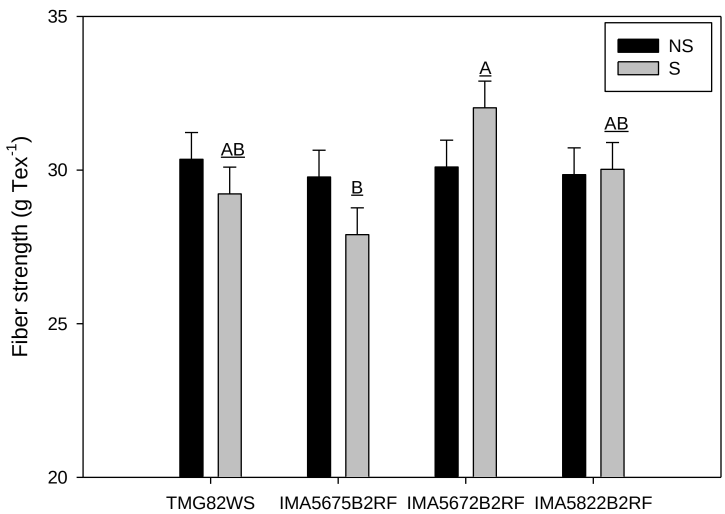


Figure 7. Micronaire of cotton cultivars under shade treatments. Vertical bars show the standard error of the mean. A>B within no shaded treatment and a>b within cultivar (Tukey, 0.05). NS: no shaded. S: Shaded.



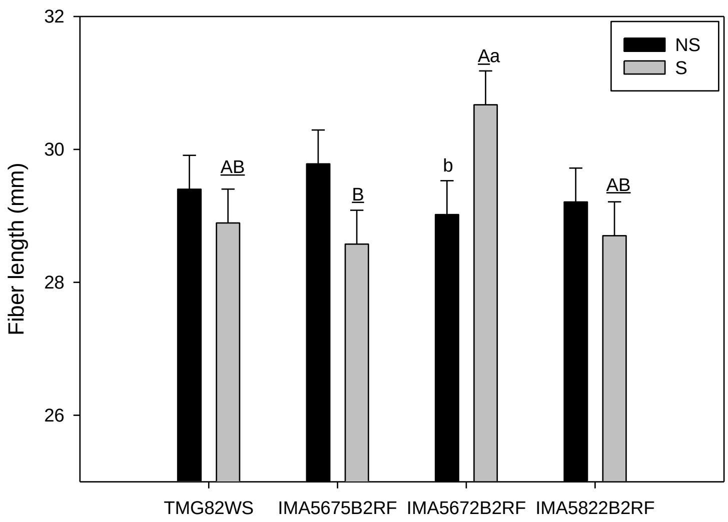
There was a cultivar effect on fiber strength under shading, and it was higher on IMA 5672B2RF as compared to IMA 5675B2RF (Figure 8). This behavior can be attributed to the lowest number of bolls and the lightest boll weight (Figures 3 and 4) in this cultivar. As the number of sink (bolls) was reduced, the remained bolls could be filled and the fiber strength was improved. Results from Echer and Rosolem (2015b) in a tropical environment showed a non-significant effect of shading (50% of light reduction for 8-10 days) over fiber strength in a three year/locations experiment. In other studies, Pettigrew (1995) noticed a decreased in fiber strength as a result of shading at 30% of light reduction for about 40 days. Additionally, Zhao and Oosterhuis (2000) showed a reduction in fiber strength as a result of shading at boll development stage when shading was alternated in 2 and 4 days of shading in a treatment period of 16 days. Both studies were developed in a temperate climate with a short growing season window. The inconsistent results from the present experiment and those from Echer and Rosolem (2015b), Pettigrew (1995) and Zhao and Oosterhuis (2000) can be attributed to the stage of shading occurrence, shading degree and duration as well as the recovery time after shading removal.

Figure 8. Effect of shade and cotton cultivar on fiber strength. Vertical bars show the standard error of the mean. A>B within shaded treatment (Tukey, 0.05). NS: no shaded. S: Shaded.



Fiber length was increased by shading on cultivar IMA 5672B2RF as compared to IMA 5675B2RF (Figure 9). Additionally, within IMA 5672B2RF, shading treatment increased fiber length. Early reports had showed inconsistent results of shade on fiber length. For example Echer and Rosolem (2015b), Pettigrew (2001) and Zhao and Oosterhuis (2000) reported a non-significant shading effect on length. On the other hand, Pettigrew (1995) and Eaton and Ergle (1954) noticed an increase in fiber length under shading, similarly to the finding of this experiment (Figure 9).

Figure 9. Responses of shading and cultivar on fiber length. Vertical bars show the standard error of the mean. A>B within shaded treatment and a>b within cultivar (Tukey, 0.05). NS: no shaded. S: Shaded.



CONCLUSIONS

The hypothesis of this research was that cultivars could tolerate/recovery distinctively to shading. It was concluded that in a season with no water or temperature limitation, the late cultivar could recovery the yield in the top of the plant. Shading decreases micronaire index, but the response depends on cultivar. Fiber length and strength was increased on cultivar IMA 5672B2RF under shading as a result of the low fruit retention and yield.

REFERENCES

BRADOW, J.; DAVIDONIS, G. Effects of environment on fiber quality. In: STEWART, J.; OOSTERHUIS, D.; HEITHOLT, J.; MAUNEY, J. (Eds.). Physiology of Cotton. Netherlands: Springer, 2010. p.229–245. https://doi.org/10.1007/978-90-481-3195-2_21

CHEN, B.; YANG, H.K.; MA, Y.N.; LIU, J.R.; LV, F.J.; CHEN, J.; MENG, Y.L.; WANG, Y.H.; ZHOU, Z.G. Effect of shading on yield, fiber quality and physiological characteristics of cotton subtending leaves on different fruiting positions. **Photosynthetica**, v.55, n.1, p.240-250, 2017. https://doi.org/10.1007/s11099-016-0209-7

EATON, F.M.; ERGLE, D.R. Effects of shade and partial defoliation on carbohydrate levels and the growth, fruiting, and fiber properties of cotton plants. **Plant Physiology***,* v.29. n.1 p. 39-49, 1954. https://doi.org/10.1104/pp.29.1.39

ECHER, F.R.; ROSOLEM, C.A. Cotton leaf gas exchange responses to irradiance and leaf aging. **Biologia Plantarum,** v.59, n.2, p.366-372, 2015a. https://doi.org/10.1007/s10535-015-0484-3

ECHER, F.R.; ROSOLEM, C.A. Cotton yield and fiber quality affected by row spacing and shading at different growth stages. **European Journal of Agronomy**, v.65, p.18-26, 2015b. https://doi.org/10.1016/j.eja.2015.01.001

IUSS WORKING GROUP WRB. **World Reference Base for Soil Resources**. Rome: FAO, 2006. 128 p. (World Soil Resources Reports; n. 103).

GUINN, G. Abscission of cotton floral buds and bolls as influenced by factors affecting photosynthesis and respiration. **Crop Science**, v. 4, n.2, p.291-293, 1974. https://doi.org/10.2135/cropsci1974.0011183X001400020036x

MARUR, C.J.; RUANO, O. A reference system for determination of developmental stages of upland cotton. **Revista de Oleaginosas e Fibrosas**, v.5, n.2, p.313-317, 2001.

PETTIGREW, W.T. Environmental effects on cotton fiber carbohydrate concentration and quality. **Crop Science**, v. 41, n. 4, p. 1108-1113, 2001. https://doi.org/10.2135/cropsci2001.4141108x

PETTIGREW, W. T. Source-to-sink manipulation effects on cotton fiber quality. **Agronomy journal.** v.87, n.5, p.947-952, 1995. https://doi.org/10.2134/agronj1995.00021962008700050029x

ZHAO, D.; OOSTERHUIS, D. M. Cotton responses to shade at different growth stages: growth, lint yield and fiber quality. **Experimental Agriculture**, v.36, n.1, p.27-39, 2000. https://doi.org/10.1017/S0014479700361014

ZHAO, D.; OOSTERHUIS, D. M. Cotton responses to shade at different growth stages: nonstructural carbohydrate composition. **Crop Science**, v.38, n.5, p.1196-1203. 1998. https://doi.org/10.2135/cropsci1998.0011183X003800050014x

YEATES, S.J. KAHL, M.F.; DOUGALL, A.J.; MÜLLER, W.J. The impact of variable, cold minimum temperatures on boll retention, boll growth, and yield recovery of cotton. **Journal of Cotton Science**, v. 17, n. 2 p. 89-101, 2013.

Recebido para publicação em 09/06/2017
Revisado em 13/09/2017
Aceito em 09/10/2017