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Cotton fiber quality affected by water availability and silicon application

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Abstract
The quality of cotton fiber is a fundamental criterion for determining the commercial value of the product, being influenced by the conditions of cultivation. The study aimed to evaluate irrigated and non-irrigated cultivation systems and the management of silicon fertilization on cotton fiber characteristics. The experiment was carried out in the field in Selvíria-MS, in the 2017/2018 agricultural crop. It was adopted a randomized block design, in a 2x6 factorial scheme, with two cultivation conditions (irrigated and rainfed) and six doses of Si (0, 50, 100, 150, 200 and 400 g ha^{-1}), with four replications. Seeds of the genotype TMG 11 WS were used. Irrigation was carried out with sprinklers spaced at 6x6 m. The application of Si via leaf was carried out at 50 and 70 days after emergence. From the cotton fiber, the characteristics of length, micronaire, strength, uniformity, elongation, reflectance, yellowing, degree of leaves, impurity and impurity particles were analyzed. The data submitted to analysis of variance by the F test, the means compared for the cultivation condition, and regression analysis for the amount of Si. The cotton fiber in irrigated cultivation showed improvement in the characteristics resistance, reflectance and yellowing. The application of Si via leaf reduced the leaf grade in the cotton fibers.
Keywords: Beneficial element; *Gossypium hirsutum*; irrigation.

Qualidade da fibra de algodão afetada pela disponibilidade de água e aplicação de silício

Resumo
A qualidade da fibra do algodão é critério fundamental para determinação do valor comercial do produto, sendo influenciado pelas condições de cultivo. O estudo teve como objetivo avaliar sistemas de cultivo irrigado e não irrigado e o manejo da adubação de silício sobre características da fibra do algodão. O experimento foi desenvolvido a campo no município de Selvíria-MS, na safra 2017/2018. Foi adotado delineamento em blocos ao acaso, em esquema fatorial 2x6, sendo duas condições de cultivo (irrigado e sequeiro) e seis doses de Si (0, 50, 100, 150, 200 e 400 g ha^{-1}), com quatro repetições. Foi utilizado sementes do genótipo TMG 11 WS. A irrigação foi realizada com aspersores espaçados em 6x6 m. A aplicação de Si via foliar foi realizado aos 50 e 70 dias após a emergência. A partir da fibra do algodão, foram analisadas as características de comprimento, micronaire, resistência, uniformidade, alongamento, reflectância, amarelecimento, graus de folhas, impureza e partículas de impureza. Os dados submetidos a análise de variância pelo teste F, as médias comparadas para a condição de cultivo, e análise de regressão para quantidade de Si. A fibra de algodão em cultivo irrigado apresentou melhoria nas características de resistência, reflectância e amarelamento. A aplicação de Si via foliar reduziu o grau de folhas nas fibras de algodão.
Palavras-chave: Elemento benéfico; *Gossypium hirsutum*; irrigação.

Introduction

The cotton crop (*Gossypium hirsut*um L.) has great economic importance worldwide. Brazil stands out among producers for its current production and the potential for expansion in area and yield (SEVERINO *et al.*, 2019). This visibility is related to the researchers conducted to analyze the productive viability in different regions, cultivars and in the selection of genetic materials (ALMEIDA *et al.*, 2017; BONIFÁCIO *et al.*, 2015; LIMA *et al.*, 2018). Brazilian product presents a trend towards the international market (CAVALCANTE; TANNÚS, 2020).

The management of the crop expresses direct effects on yield and on the final quality of the product, which is mainly destined for the textile industry (SEVERINO *et al.*, 2019). The adoption of practices that combine the production increase and increase the efficiency of resource use is fundamental for the production system. Water management is among techniques with a direct impact on cotton yield and quality (LIMA *et al.*, 2018; ZONTA *et al.*, 2015).

The presence of water deficit in critical periods for crop can affect the production components, with a decrease in yield varying according to the deficit level, edaphoclimatic and genetic conditions (LIMA *et al.*, 2018; ALMEIDA *et al.*, 2017; ZONTA *et al.*, 2015; COUTINHO *et al.*, 2015). In this sense, crop irrigation can be fundamental for productive success and economic return, mainly due to insufficient rainfall exclusion for the plant's demand (SANTOS *et al.*, 2018).

In addition to water management, the use of beneficial elements can mitigate adverse effects during cultivation (MALAVOLTA, 2006). Silicon is not considered an essential element, but a beneficial element that can favor the development of plants under unfavorable conditions, improve phytosanitary aspects and crop yield (ALCANTRA *et al.*, 2019; FERRAZ *et al.*, 2017; GAMA *et al.*, 2016; WENNECK *et al.*, 2021). Productive characteristics reflect on the quality of the product, and consequently on the commercialization value (MORAIS *et al.*, 2021), the adoption of techniques and management that maintain or improve the commercial quality of the product under unfavorable growing conditions has the possibility of increasing productive efficiency and yield.

The aim of the study was to analyze the technological quality of cotton fibers, grown under different conditions of water availability, silicon applications and the interaction of factors.

Material and Methods

The study was developed in the experimental area of the Faculty of Engineering of Ilha Solteira-UNESP, located at latitude 20º 22'S, longitude 51º 22' and altitude of 335 m, in Selvíria-MS, in the 2017/2018 agricultural crop. The average annual precipitation is 1370 mm, and the average annual temperature is 23.5°C (FEIS/UNESP, 2021). Table 1 refers to monthly precipitation and temperature data.

Table 1. Climatic data from December 2017 to May 2018 in the experimental area, Selvíria-MS.

Period of the year	Accumulated precipitation (mm)	Average temperature (°C)
December/2017	263.2	25.3
January/2018	258.4	25.5
February/2018	96.9	25.0
March/2018	52.3	27.6
April/2018	87.0	25.2
May/2018	8.3	24.8

Source: FEIS/UNESP, 2021

The experiment was carried out in randomized blocks, in a 2x6 factorial scheme, with two growing conditions (irrigated and not irrigated) and six doses of Si (0, 50, 100, 150, 200 and 400 g ha^{-1}), with four replications per treatment. To define application doses (treatments), it was considered according to responses to different cultivars obtained by Ferraz (2012).The experimental plots consisted of eight rows (4 m long) spaced 0.9 m apart, with the four central rows being considered as the useful area.

The soil is classified as LATOSSOLO VERMELHO Distrófico, correlated with Oxisoils (SANTOS *et al.*, 2018) the soil has a very clayey texture (67% of clay) and the chemical characteristics in the depth of 0.2 m were: pH ($CaCl_2$): 4.7; potassium: 0.25 $cmol_c$ dm^{-3}; calcium:

1.3 $cmol_c$ dm^{-3}; magnesium: 1.1 $cmol_c$ dm^{-3}; aluminum: 0.2 $cmol_c$ dm^{-3}; hydrogen: 4.0 $cmol_c$ dm^{-3}; cation exchange capacity: 6.85 $cmol_c$ dm^{-3}; base saturation: 39%; phosphorus (resin): 11 mg dm^{-3}; and organic matter: 26 g dm^{-3}. To increase saturation to 70%, dolomitic lime (30% CaO and 18% MgO) was applied the amount of 1.4 t ha^{-1}.

Seeds of the TMG 11 WS genotype had used. In sowing was used 350 kg ha^{-1} of formulated mineral fertilizer N-P-K (04-30-10), and 130 kg ha^{-1} of N were divided at 30 and 40 days after emergence, using urea as source.

In irrigated cultivation, a fixed sprinkler system was used, spacing 6 x 6 m between them, with application intensity of 3.3 mm h^{-1}. The volume of water applied was calculated using a class A tank, in order to obtain the reference evapotranspiration and using the crop coefficients, according to Allen *et al.* (1998). Irrigation had carried out until 120 days after emergence, when the crop had 70% of the bolls open.

Silicon applications had carried out using calcium silicate, foliar applications with a constant pressure costal spray, using model XR11002 nozzles with 2 L of volume and a pressure of 3.0 bar. The amount was divided into two applications, 50 and 70 days after plant emergence.

At 136 after emergence, bolls' harvest was carried out manually in the central plants (useful area). The material was sent to the fiber technology laboratory of the Sul Mato Grossense Association of Cotton Producers (AMPASUL), in Chapadão do Sul. Samples containing 20 bolls (from the middle third of the plant), from each experimental unit, were analyzed with the HVI equipment from Zellweger Uster/ Spinlab 900 series, the characteristics determined were, fiber length, length uniformity, maturation index, reliability index, spin consistency index, short fiber index, strength, reflectance, and degree of yellowing being determined.

Data were subjected to analysis of variance by the F test, and regression analysis for the amount of silicon.

Results and discussion

During the experiment period, the monthly rainfall accumulated in the initial months was greater than 250 mm (Table 1), and irrigation in the area was not often required, considering the demand for the crop and availability in the period (OLIVEIRA *et al.*, 2013). Although in the subsequent months the accumulated rainfall reduced, values above 50 mm had observed, supplying a large proportion of the crop demand, which varies between 450 and 700 mm during the cycle (CARVALHO *et al.*, 2013). In cotton crop, the maximum crop coefficient (Kc) is obtained close to 60 days after sowing, and during the cycle it varies from 0.39 to 1.16 (OLIVEIRA *et al.*, 2013).

Periods with water deficit is critical mainly in the reproductive phases, such as the development of buds, flowers and bolls (LIMA *et al.*, 2018), however it has the potential to reduce the number of bolls per plant in different phenological phases (ALMEIDA *et al.*, 2017).

Alterations related to resistance, reflectance and yellowing of the cotton fiber were significant only for the growing conditions (irrigated and not irrigated), while the leaf grade was significant for the application of Si (Table 2).

Table 2. Summary of analysis of variance.

Cotton's characteristic	Growing conditions (C)	Silicon (Si)	C*Si	CV (%)	Average
Fiber length	0.13^{ns}	0.66^{ns}	0.16^{ns}	2.30	27.61
Micronaire	0.06^{ns}	0.95^{ns}	0.41^{ns}	3.70	543.39
Resistance	0.05*	0.83^{ns}	0.96^{ns}	4.70	30.38
Uniformity	0.12^{ns}	0.67^{ns}	0.93^{ns}	1.14	82.24
Fiber elongation	0.11^{ns}	0.76^{ns}	0.68^{ns}	2.86	55.54
Reflectance	0.01**	0.27^{ns}	0.26^{ns}	1.24	81.64
Yellowing	0.01**	0.17^{ns}	0.84^{ns}	5.40	6.84
Leaf grade	0.13^{ns}	0.04*	0.54^{ns}	59.71	1.58
Impurity	0.19^{ns}	0.06^{ns}	0.57^{ns}	74.13	17.00
Impurity particles	0.59^{ns}	0.25^{ns}	0.89^{ns}	46.14	8.21

ns, * and **: not significant, 5% significant and 1% significant by the F Test, respectively.

Irrigation should be adopted in order to suppress demand in periods of deficit in order to allow the crop to perform maximum productive potential and commercial quality (SANTOS *et al.*, 2018), and the increase in soil moisture benefits the development of morphological and yield components (OLIVEIRA *et al.,* 2012).

Adequate water conditions are also fundamental for efficient fertilizer management, such as nitrogen application (BORIN *et al.*, 2017). Growing irrigated cotton under the study conditions increased fiber strength and reflectance (Table 3).

Table 3. Influence of water availability on cotton fiber characteristics.

Cotton's characteristic	Irrigated	Not irrigated	MSD[(1)]
Fiber length (mm)	27.73 a	27.48 a	32.89
Micronaire	549.12 a	537.67 a	11.82
Resistance (gf text^{-1})	30.80 a	29.96 b	8.39
Uniformity (%)	82.45 a	82.02 a	5.51
Fiber elongation (%)	55.17 a	55.92 a	0.93
Reflectance (%)	82.38 a	80.90 b	5.95
Yellowing (+b)	6.70 b	6.99 a	2.17
Leaf grade	1.79 a	1.37 a	0.55
Impurity (%)	15.00 a	19.00 a	0.07
Impurity particles	7.92 a	8.50 a	2.22

*Different letters in the same line differ from each other. [(1)]MSD-minimum significant difference.

Short periods of drought are enough to limit carbohydrate translocation to cotton fruits, negatively affecting micronaire characteristics and fiber strength (ECHER *et al.*, 2018), justifying lower resistance in non-irrigated conditions.

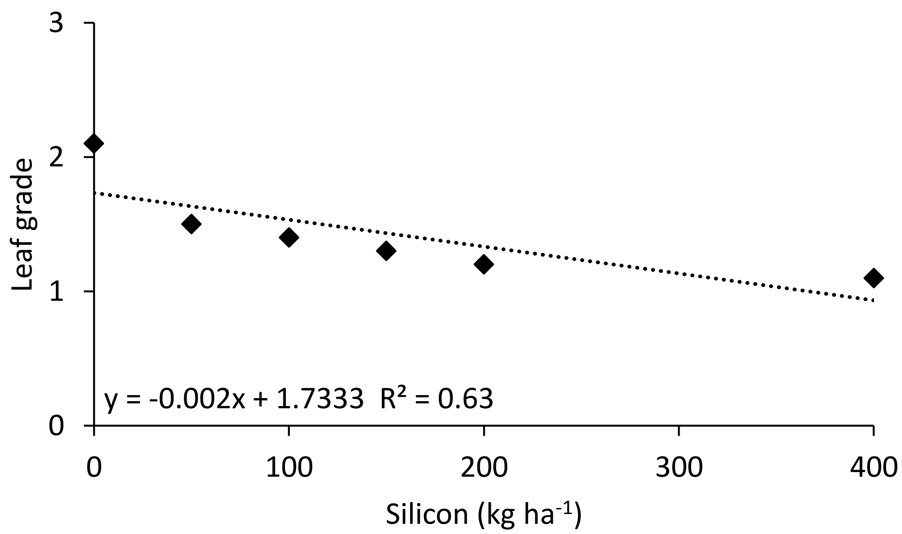
In the irrigated condition, the reflectance was higher and the yellowing was lower (Table 3), which is a positive point considering that the values can vary with a decrease in quality due to storage (LIMA *et al.*, 2009), and directly influencing the commercial value of the product.

Fiber quality characteristics are affected by environmental conditions such as temperature, light and shading, but the impact of each factor on final quality is variable by genetic conditions (ECHER *et al.*, 2018; BONIFÁCIO *et al.*, 2015). The fibers obtained in the study showed high quality for use in the textile industry, mainly because of their excellent fiber length (>25 mm) and uniformity (>47%) (SANTANA; WANDERLEY, 1995).

Regarding the application of Si, studies demonstrate the benefits of using it in cotton cultivation, with significant results in the seed growth rate, in the case of seed (FERRAZ *et al.*, 2017), and in fiber quality characteristics such as reflectance, short fiber index, micronaire and yellowing (GAMA *et al.*, 2016). It also can be adopt as a pest management strategy (ALCANTRA *et al.*, 2019), in addition to improve morphological development and yield under water deficit conditions (WENNECK *et al.*, 2021).

In the study, the application of Si was significant ($p<0.05$) only for the variable leaf grade (Table 2), which is an analysis parameter for the presence of impurities in the fiber. Under experimental conditions, Si reduced the leaf grade (Figure 1), increasing the commercial quality of the product.

Figure 1. Influence of Silicon foliar applications on leaf grade in cotton fibers.



Silicon has benefits on yield and quality in several crops, especially in unfavorable physical and chemical conditions, but the impact varies with the content of the element in the soil, plant species, source and form of application (MALAVOLTA, 2006). Foliar applications, in general, are more efficient due to lower cost and rapid absorption, however fertilization efficiency can be affected by environmental factors (GONÇALVES *et al.*, 2017).

However, genetic characteristics associated with response to Si application must be considered. Ferraz (2012) when analyzing the foliar silicon application (dose up to 200 g ha^{-1}) in different cotton cultivars obtained different results among the analyzed cultivars. Although studies with Si application in the material used (TMG 11 WS) are limited, the inexistence of significant effects for doses used can indicate that the cultivar isn't responsive to silicate fertilization.

Technological quality increments in cotton fiber have the potential to improve the commercial characteristics of the product, justifying the adoption of water management practices and silicate fertilization, however, an economic analysis is necessary to determine the cost/benefit ratio of the increment caused.

Conclusions

Under the growing conditions of this study, the cotton crop is more responsive to the water deficit condition than to silicon doses.

Cotton fiber in irrigated cultivation show improvement in resistance, reflectance and yellowing characteristics.

The application of Si reduce the leaf grade in the cotton fibers.

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