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RESPOSTA DO ALGODOEIRO À SUPRESSÃO HÍDRICA EM DIFERENTES FASES FENOLÓGICAS NO SEMIÁRIDO BRASILEIRO

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1 RESUMO

O Semiárido do Nordeste brasileiro tem como característica climática a irregularidade temporal e espacial do seu regime de chuvas. Portanto, objetivou-se com o presente trabalho avaliar o efeito da supressão hídrica, aplicada em diferentes fases fenológicas, sobre os componentes de produção de cultivares de algodoeiro herbáceo. O trabalho foi realizado na cidade de Apodi-RN. O delineamento experimental adotado foi em blocos casualizados em parcelas subdivididas e com quatro repetições. Os tratamentos consistiram de quatro períodos de supressão hídrica nos seguintes estágios fenológicos: primeiros botões florais, início do florescimento, pico do florescimento e abertura dos capulhos, além do tratamento controle (sem supressão hídrica) e quatro cultivares de algodoeiro herbáceo: BRS 368 RF, BRS 336, BRS 432 B2RF e BRS 430 B2RF. A supressão hídrica durante as fases de início da abertura das flores e no pico do florescimento foram as mais prejudiciais e as cultivares BRS 432 B2RF e BRS 368RF apresentaram os melhores resultados. Nas condições desse estudo, a irrigação até 90 dias após a emergência foi suficiente para conseguir altas produtividades. Dessa forma, a decisão em irrigar o algodoeiro com ou sem supressão hídrica é válida, e dependerá dos custos da irrigação e do valor de mercado do produto.

Palavras-chave: manejo de irrigação, *Gossypium hirsutum* L. r. *latifolium* H., estresse hídrico, produtividade.

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COTTON RESPONSE TO WATER STRESS AT DIFFERENT PHENOLOGICAL STAGES IN THE BRAZILIAN SEMIARID

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2 ABSTRACT

The semiarid of Brazilian northeast has as its climatic characteristic the temporal and spatial irregularity of its rainfall regime. Thus, this work aimed to evaluate the effect of water suppression, applied at different phenological stages, in the production components of herbaceous cotton cultivars. The study was conducted in the city of Apodi-RN. The experimental design was randomized blocks in a split-plot design with four replications. The treatments consist of four periods od water suppression in the following phenological stages: the first square, first flower, peak bloom, and first open boll, besides the control treatment (without water suppression), and four herbaceous cotton cultivars: BRS 368 RF, BRS 336, BRS 432 B2RF and BRS 430 B2RF. Water suppression causes greater losses in cotton yield during the first flower and peak bloom phenological stages, because of the high water demand in these phases. The cultivars BRS 432 B2RF and BRS 368RF had higher yield components. Under this study conditions, irrigation up to 90 days after emergence was sufficient to achieve high yields. Therefore, the decision to irrigate cotton with or without water suppression is valid, and will depend on the costs of irrigation and the market value of the product.

Keywords: irrigation management, *Gossypium hirsutum L. r. latifolium H*, water stress, productivity.

3 INTRODUCTION

Cotton-producing areas in semiarid regions, characterized by inconsistent rainfall, experience periods of good water availability as well as long and frequent dry spells. Currently, short, dry spells have become more common due to climate change, causing considerable productivity losses even in the Cerrado region, Brazil's most important cotton-producing area.

Cotton is grown commercially for its fiber and seeds. Cotton fiber has a variety of industrial uses, including yarn, fabric, clothing, thread, cotton swabs, bandages, photographic film, and radiographic plates; cellulose production; and the preparation of absorbent cotton for nursing, in addition to the use of cottonseed oil, which is used in ruminant feed and in the production of fertilizer, refined oil, margarine, and biodiesel.

In the northeastern semiarid region, in addition to occasional dry years and a short rainy season, the region also faces another form of climatic adversity for agricultural use: periods with very little or no rainfall during the rainy season, known as dry spells (SILVA; RAO, 2002). Planning based on dry spells is highly important for agriculture, as it enables both dryland and irrigated agricultural production. Determining the best planting time to prevent dry spells from occurring during critical periods of crop development, as well as maximizing efficient water use in irrigated areas, is essential.

Zonta et al. (2017) reported that short periods of water deficit can occur not only because of climatic anomalies but also because of failures in the water pumping system, unexpected maintenance, or even the need for direct supply to other crops that are in critical stages of growth.

A rigorous evaluation of crop responses to changes in irrigation regimes is necessary, given that changes in and management of irrigation and water-saving methods have great potential to save water in arid and semiarid regions (OWEIS et al., 2011; UNLU et al., 2011).

Therefore, the objective of this study was to evaluate the effects of water suppression, which is applied in different phenological phases, on the production components of four herbaceous cotton cultivars.

4 MATERIAL AND METHODS

4.1 Study area

The experiment was conducted from June to November 2016 at the Experimental Station of the Agricultural Research Corporation of Rio Grande do Norte – EMPARN, which is located in the municipality of Apodi-RN (geographic coordinates 5° 37' 19" S, 37° 49' 06" W and an altitude of 132 m).

According to the Köppen classification (1936), the predominant climate in the region is BSh, that is, hot and dry semiarid, with a rainy period between February and May, with an average annual precipitation of 893 mm and an average annual evapotranspiration of 2190 mm, according to data from the National Institute of Meteorology - INMET (RAMOS; SANTOS; FORTES, 2009). The soil in the experimental area was classified as an Eutrophic Cambisol (SANTOS et al., 2013) with a clayey-sandy texture.

4.2 Cotton cultivation and agronomic data

Four upland cotton cultivars were tested (BRS 368 RF, BRS 336, BRS 432 B2RF, and BRS 430 B2RF). The BRS 368 RF cultivar has a short plant size, a medium to early cycle, and a fiber yield of 40%. The BRS336 cultivar has a medium plant size, a medium cycle, and a fiber yield of approximately 39%. In turn, BRS 430 B2RF has a medium plant size, a medium cycle, and a fiber yield of 40.5%. Finally, BRS 432 B2RF has a medium plant size, a fiber yield of approximately 41.5%, and a medium cycle (FERREIRA; SILVA, 2019).

The study was conducted under a no-tillage system without cotton thinning practices. A three-row mechanized seeder was used for planting. For weed, disease, and insect control, phytosanitary treatments were applied after the first symptoms appeared, which was consistent across all the treatments. The agronomic and irrigation data are presented in Table 1.

Table 1. Agronomic data and irrigation parameters during the cotton growth cycle .

Variables	
Planting date	06/07/2016
Spacing between plant rows	0.8 m
Planting density	8-12 plants m^{-1}
Planting fertilization	150 kg of MAP ha^{-1}
Topdressing	150 kg of $Urea^{-1}$
Last irrigation	10/28/2016 (105 DAE)
Harvest date	11/21/2016
Crop cycle period	127 days
Total precipitation during the growing cycle	0.0 mm

4.3 Treatments and experimental design

The experimental design adopted was a randomized block design in split plots with four replications. Each experimental plot consisted of six six-meter-long rows spaced 0.8 m between rows, with the useful area of the plot being the four central rows, each five meters long, totaling an average of 200 plants per plot.

The treatments consisted of four periods of water suppression at the following phenological stages: first flower bud, beginning of flowering, peak flowering and boll opening, in addition to the control treatment (without water suppression), as shown in Table 2.

Table 2. Period of water withdrawal in each treatment .

Treatment	Start of irrigation suppression	Water suppression period (day)	Duration of suppression (day)	Total irrigation depth (mm)	Difference to Control treatment (mm)
First flower buds (PB)	Appearance of the first flower bud in at least 10% of the plants	35 – 51	17	673	107
Beginning of flowering (IF)	Opening of the first flower in at least 10% of the plants	52 – 63	12	675	105
Peak flowering (PF)	Apple filling. At least 10% of the plants are highly fruited, with fully filled fruit.	64 – 80	17	632	148
Boll opening* (AC)	Boll opening in at least 10% of the plants	From 90 onward	16	718	62
Control (total ETc)	No irrigation suppression throughout the crop cycle			780	

* This treatment did not receive irrigation after the suppression period because it occurred shortly before irrigation was removed.

The plants were returned to normal irrigation after the suppression period. Water replacement through irrigation was based on crop evapotranspiration and application efficiency (Equation (1)).

$$L_{bruta} = \mathrm{ETc}/Ea \quad (01)$$

where:
Gross L – Gross irrigation depth, mm
ETc – Crop evapotranspiration, mm
Ea – Application efficiency, decimal

Crop evapotranspiration (ETc) was obtained via Equation 2:

$$\mathrm{ETc} = \mathrm{ET_0} \times \mathrm{Kc} \quad (02)$$

where:
ET $_0$ – Reference evapotranspiration based on the Penman–Monteith methodology (ALLEN et al., 1998)
Kc is the cotton crop coefficient, which is estimated daily on the basis of the number of days after emergence (BEZERRA et al., 2010).

$$\mathrm{Kc} = -0{,}00006.\mathrm{DAE}^2 + 0{,}011.\mathrm{DAE} + 0.5703 \quad (03)$$

where:
DAE – Days after emergence

The irrigation system used was a fixed sprinkler system, with a sprinkler spacing of 12 × 15 m, an application rate of 9 mm hr $^{-1}$, and an application efficiency of 65%. Irrigation was carried out every three and a half days, maintaining the available water content above 40% of the total available water. The amount of available water was monitored via a DIVINER 2000 probe.

4.4 Production components

The production components evaluated were the number of bolls per plant, seed yield, lint yield, and fiber percentage. The number of bolls per plant was obtained by counting all bolls harvested from plants in a five-meter row and dividing by the number of plants. The fiber percentage was measured by shredding a 100-g subsample taken from the harvested sample. To calculate the seed yield, the entire useful plot was harvested, and the values were extrapolated to yield in kg ha^{-1}. Finally, the average lint cotton yield was calculated on the basis of the ratio of seed cotton yield to fiber percentage.

4.5 Statistical analysis

The data obtained were subjected to analysis of variance via the F test, with the means of the factor treatments, both qualitative, compared via the Tukey test at 5% probability, via the Sisvar statistical program (FERREIRA, 2011).

5 RESULTS AND DISCUSSION

The analysis of variance and mean test for seed cotton yield, fiber percentage, cotton lint yield, and number of bolls for the BRS 432 B2RF, BRS 368 RF, BRS 430 B2RF, and BRS 336 cultivars under water suppression at different stages of the crop cycle are presented in Table 3. The cultivar versus water suppression interaction (C × S) was significant for the fiber percentage (DMS = 1.78), cotton lint yield, and number of bolls per plant. However, for the seed cotton yield variable, the C × S interaction was not significant.

Table 3. Analysis of variance and tests of means for the variables seed cotton productivity, fiber percentage and cotton lint yield as a function of cultivar and water suppression.

	Pr>Fc			
Anova	**PROD (kg ha $^{-1}$)**	**FIBERS (%)**	**FEATHER (kg ha $^{-1}$)**	**BOWLS (unit)**
Cultivars (C)	<0.05	<0.01	<0.01	<0.05
Suppressions (S)	<0.01	<0.01	<0.01	<0.01
CXS	0.6	<0.01	<0.05	<0.05
		Averages		
Water suppression				
PB	3914.1B	39.5B	1550.8B	11.69B
IF	1331.3D	39.7B	531.7B	6.19BC
PF	2523.4C	37.4C	961.7B	4.50C
B.C	5787.5A	42.4A	2470.9A	21.50A
Total ETc	6276.6A	42.5A	2680.6A	19.94A
Cultivars				
BRS 432 B2RF	4275.0A	43.5A	1880.2A	9.75B
BRS 368 RF	4011.3AB	42.3A	1726.9A	15.70A
BRS 430 B2RF	4088.8AB	39.2B	1663.4A	12.25AB
BRS 336	3491.3C	36.2C	1286.0B	13.35B

Means followed by the same capital letter in the column do not differ from each other at a 5% probability according to the Tukey test. **Pr>Fc values equal to or less than 0.05 indicate a significant difference at 5%; values less than 0.01 indicate significance at 1%; PROD = productivity; %FIBERS = percentage of fibers; PLUMA = productivity in lint; BOLLS = number of bolls.

Considering the fiber percentage, cotton lint yield and number of bolls per plant, significant differences were observed for the periods of water suppression and cultivar, with significant interactions between these factors.

The cultivars that presented the highest average seed cotton productivity were BRS 432 B2RF, BRS 430 B2RF and BRS 368 RF, which produced 4275.3, 4088.8 and 4011.3 kg ha^{-1}, respectively (Table 3). The three cultivars mentioned above presented values below the varietal standard, which is 4500.0 kg ha^{-1} for the cultivars BRS 432 B2RF and BRS 430 B2RF (SUASSUNA et al., 2018) and 4200.0 to 4500.0 kg ha $^{-1}$ for the cultivar BRS 336 (MORELLO et al., 2011). Even cultivar BRS336, which presented the lowest average productivity, 3491.3 kg ha^{-1} (Table 3), presented productivity close to the national average in the 2015/2016, 2016/2017 and 2017/2018 harvests, whose values are 3197.0, 3921.0 and 3707.0 kg ha $^{-1, \text{ respectively}}$ (COTTON, 2018).

The results of the treatment without water suppression differed from those of almost all the treatments with suppression in the phenological phases, with the best result for productivity (6276.6 kg ha^{-1}) (Table 3), but did not differ from the yield obtained for water suppression after boll opening (AC), which presented a productivity of 5787.5 6276.6 kg ha -1. The early flowering (IF) and peak flowering (PF) phases presented productivity values of 1331.3 kg ha^{-1} and 2523.4 kg ha^{-1}, respectively, representing decreases of 79.79 and 59.80%, respectively, in relation to the treatment without suppression. In the

IF phase, and mainly in the PF, in which boll filling also occurs, suppression caused greater reductions in cotton productivity and quality owing to the abortion of the youngest fruits of the plant to maintain the supply of carbohydrates for the older bolls (ECHER, 2014). Vasconcelos et al. (2018) noted that, of the environmental factors that can cause abscission in cotton, soil water deficiency is considered the main factor.

An important characteristic related to productivity is the fiber percentage (Table 4), as a higher percentage represents a higher lint yield. This characteristic was affected by water shortages.

Table 4. Average values of fiber percentage for the interaction between cultivar and water type.

Cultivate	Water suppression period					
	PB	IF	PF	B.C	Etc	Average
BRS 432 B2RF	41.8Aa	42.9Aa	43.4Aa	44.8Aa	44.9Aa	43.6
BRS 368 RF	42.2Aa	41.9Aab	39.9Aa	44.5Aa	43.6Aa	42.4
BRS 430 B2RF	40.1ABa	37.7BCbc	33.2Cb	41.4ABab	43.6Aa	39.2
BRS 336	34.9ABb	36.1Abc	33.2Bb	38.8Ab	38.0ABb	36.2
Average	39.7	39.7	37.4	42.4	42.5	

Averages followed by the same capital letters in the rows (periods of water suppression within cultivars) and the same lowercase letters in the columns (cultivars within suppression periods) do not differ from each other according to the Tukey test at 5% probability.

Overall, the highest results were obtained in the control treatment (ETc), followed by AC, PB, and IF. The lowest percentage value, only 37.4%, was obtained for PF, which represents a 12% reduction compared with that of the control treatment. The percentages of cotton fibers equal to or greater than the varietal standard were not significantly different between BRS 432 B2RF and BRS 368 RF, which was 41.5% for the cultivar BRS 432 B2RF (SUASSUNA et al., 2018) and 40.0% for the cultivar BRS 368 RF (BARROSO et al., 2017). This result is important, since cotton growers prefer cultivars with a fiber percentage above 40%, thus aiming to obtain greater added value, since the price of fiber is higher than that of cottonseed (CORDÃO SOBRINHO et al., 2015).

There was a significant difference between the treatments for the cultivars BRS 430 RF and BRS 336, with the water suppression applied in the PF being the moment of greatest decrease in the fiber percentage, with a value of 33.2% for both cultivars. The value of 33.2% for BRS 336 is considered low compared with its natural lint percentage, which, according to Morello et al. (2012), varies between 38.2% and 43.5%. These results differ from those reported by other authors, among which Wen et al. (2013), Cordão Sobrinho et al. (2015) and Almeida et al. (2017), who, when using the cultivars BRS Aroeira, BRS Araripe, BRS 286 and BRS 336, concluded that the fiber percentage of these cultivars was not affected by water deficit but rather by their hereditary characteristics. In turn, Echer (2014) also argues that there is genetic variability in attributes associated with tolerance to water deficit.

The interaction (C×S) was significant for the lint yield variable (Table 3), indicating a dependence between the factors studied in terms of their influence on this variable, interpreted by the unfolding of the interaction of these factors on it. Under these conditions, the tolerance of cotton plants to lint yield depends on the combined effects of the cultivar and water-suppressing factors.

All cultivars presented better cotton lint yields under AC suppression and the control treatment (ETc) (Table 5), with an emphasis on cultivar BRS 432 B2RF, which produced 2998.6 kg ha^{-1} (AC) and 2937.2 kg ha^{-1} (control treatment), not significantly different from cultivars BRS 368 RF and BRS 430 B2RF. Therefore, suppression after AC did not harm production. On the other hand, the worst cotton lint yield occurred under IF suppression, with cultivar BRS336 presenting a cotton lint yield of 441.0 kg ha^{-1}, which represents an 80% decrease in relation to the control treatment and is well below the national average, which was 1444 kg ha^{-1} in the 2017/2018 harvest (COTTON, 2018).

Table 5. Average values of cotton lint yield for the interaction between cultivar and water shortage.

Cultivate	Water suppression period					
	PB	**IF**	**PF**	**B.C**	**Etc**	**Average**
BRS 432 B2RF	1574.4Ba	460.9Ca	1430.1Ba	2998.6Aa	2937.2Aa	1880.2
BRS 368 RF	1555.8Ba	705.3Ca	896.5BCab	2735.0Aa	2741.9Aab	1726.9
BRS 430 B2RF	1764.1Ba	519.5Ca	714.0Cb	2463.0Aa	2856.3Aa	1663.4
BRS 336	1308.7 BCa	441.0Da	806.1CDab	1687.0ABb	2187.2Ab	1286.0
Average	1550.8	531.7	961.7	2470.9	2680.6	

Averages followed by the same capital letters in the rows (suppression periods within cultivars) and the same lowercase letters in the columns (cultivars within suppression periods) do not differ from each other according to the Tukey test at 5% probability.

For the number of bolls per plant, a significant effect was also observed for the C × S interaction (Table 6). An analysis of the cultivars within the water suppression regimes revealed that the cultivars presented a significant difference only during the application of the control treatment (ETc), with an emphasis on the cultivars BRS 368 RF, with 30.0 bolls per plant, and BRS 430 B2RF, with 22.8 bolls per plant. None of the other treatments resulted in a significantly different number of bolls between the cultivars.

Table 6. Average values of the number of bolls per plant for the interaction between cultivar and water suppression.

Cultivate	Water suppression period					
	PB	**IF**	**PF**	**B.C**	**Etc**	**Average**
BRS 432 B2RF	10.0ABa	6.3Ba	3.5Ba	18.0Aa	11.0ABc	9.8
BRS 368 RF	11.8Ba	5.0Ba	5.0Ba	26.8Aa	30.0Aa	15.7
BRS 430 B2RF	9.3BCa	7.5 BCa	4.5Ca	17.3ABa	22.8Aab	12.3
BRS 336	15.8ABa	6.0Ba	5.0Ba	24.0Aa	16.0ABbc	13.4
Average	11.7	6.2	4.5	21.5	20.0	

Averages followed by the same capital letters in the rows (suppression periods within cultivars) and the same lowercase letters in the columns (cultivars within suppression periods) do not differ from each other according to the Tukey test at 5% probability.

All cultivars presented the best results for AC and ETc (control) suppression (Table 6), with the maximum value obtained for cultivar BRS 368 RF (30.0 bolls per plant). On the other hand, water suppression in IF and PF resulted in the lowest values, with an emphasis on cultivar BRS 432 B2RF, which produced only 3.5 bolls per plant.

6 CONCLUSIONS

The occurrence of water suppression during the initial flower opening and peak flowering phases was the most detrimental to the production components of the cotton cultivars.

The BRS 432 B2RF and BRS 368RF cultivars are recommended for irrigation during periods of water suppression or dry spells.

Short periods of water suppression can be applied to cotton irrigation, preferably in the initial stages of growth and after the bolls have opened.

Under the conditions of this study, irrigation up to 90 days after emergence was sufficient to achieve high productivity.

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