Original Research Article

<https://doi.org/10.20546/ijcmas.2021.1002.278>

Assessment of Genotypic Variability for Morpho Physiological, Biochemical Parameters, Yield and Yield Attributing Characters under Drought Stress in Cotton

K. N. Pawar*, S. Md. Akbar and Hema C. Rao

Agricultural Research Station, Dharwad Farm, University of Agricultural Sciences,
Dharwad, Karnataka, India

*Corresponding author

ABSTRACT

The drought stress is a complex phenomenon affecting the physiology of cotton plant which in turn reduces crop growth, yield and yield components. The detrimental impact of drought on cotton crop can be minimized by developing drought tolerant cultivars. An experiment was conducted using seventeen *Gossypium hirsutum* genotypes grown in split plot design at Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India. The genotypes were evaluated for genotypic variability for growth phenomena, biophysical and biochemical parameters, yield and yield attributing characters under irrigated and water deficit conditions. In irrigated condition highest number of bolls per plant were recorded in the genotype DLSa17 (27.3bolls/ plant). The relative water content of leaves was significantly highest in the genotype DSC1651 (81.79%) under rainfed condition. The leaf area was significantly highest in Sahana (920.50cm²) in rainfed condition. The mean seed cotton yield per hectare was higher in irrigated (796 kg/ha) than in rainfed (755kg/ha) condition but the difference was non significant. The genotypes ARBC1651, DSC-1651 and PA810 were high yielding under both the conditions among all the genotypes and the mean yield was 1286, 1077 and 1211 kg/ha respectively and therefore are said to be drought tolerant genotypes. The leaf carbohydrate content was significantly highest in the genotype DSC1651 (131.6mg/g) under rainfed condition. The leaf proline content was significantly highest in DSC1651 (2.24 µmol/g) under rainfed condition. The leaf protein content was highest in CPD1652 (120mg/g) under rainfed condition. The protein content was varying across the sub plots. Mean protein content was found to be high in irrigated conditions (21%) compared to rainfed condition (17%). The high levels of mean protein content at both the conditions were observed to be 22% in PA810, ARBH1601 and CPD1652 followed by 21% in DSC1651 and ARBC1651.

Keywords

Cotton, Chlorophyll content, Relative water content, Proline, Carbohydrate, Yield

Article Info

Accepted:
20 January 2021
Available Online:
10 February 2021

Introduction

Cotton (*Gossypium hirsutum* L.) is the world's leading natural fiber crop, is grown in

arid and semi arid regions of the world. The sustainability and improvement of cotton yield are major challenges to meet the upcoming threats of increasing volume of

world's population, deterioration of aerable land, depletion of water resources and environmental stresses. However drought is one of the major yield limiting factors among these stresses (Boyer, 1982). The growth and yield of a crop plant is drastically affected directly or indirectly by altering metabolism, growth and development (Garg *et al.*, 2002). Well focused research work to understand drought tolerance mechanism was conducted on cereals, especially rice (Babu *et al.*, 2003; Tester and Bacic, 2005). However reports on drought tolerance of cotton crop are limited. The detrimental impact of drought on cotton crop can be minimized by developing drought tolerant cultivars.

The drought tolerance is a complex mechanism that is influenced by a wide range of physiological traits which have some relationship with productivity under water deficit conditions. It is known that quantity and quality of the fiber produced in cotton crop are directly related to water availability during the different phenological phases of development. Regardless of whether it is irrigated or not cotton is often exposed to drought, which adversely affects both yield and lint quality (Pettigrew, 2004). Genetically equivalent cotton plant populations when subjected to water deposits show reduction in yield of upto 50% when compared to those that have been irrigated, especially when the stress factor is imposed during the period between flowering and fructification (Araujo *et al.*, 2003).

Cotton has a C₃ carbon metabolism, however its photosynthetic potential is relatively high (Efrath *et al.*, 1990). Reduction of photosynthetic rate in cotton under water limited environment is documented. The reduction may be attributed to stomatal and non stomatal factors (Ennahli and Earl, 2005). A higher photosynthetic rate under drought is a decisive factor for higher cotton production

(Lopez *et al.*, 1995). There is a considerable diversity of growth parameters like plant height, number of leaves, specific leaf area, plant dry weight, leaf dry weight and productivity traits like number of bolls per plant, boll diameter, staple length, fiber length, ginning out percentage in relation to varying moisture deficit periods. Hence in this direction we studied the genotypic variability among the cotton cultivars for growth, biophysical and biochemical parameters, yield and yield attributing characters.

Materials and Methods

An experiment was conducted at Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka State, India. The experimental material consisted of 17 cotton genotypes which were under agronomic trials to evaluate for drought stress tolerance. Seeds of the cultivars were obtained from Agricultural Research Station, University of Agricultural Sciences, Dharwad and cotton research stations located at different ecological regions of India.

Experimental design

Seventeen cotton cultivars were evaluated under need based irrigated and rainfed regime in the field during 2019 – 20 at the research area of the Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India. Daily rainfall during each growing season was recorded. The experimental plot was laid out in Split plot design. Cotton seeds were delinted with sulphuric acid and soaked in water for 12 h before sowing. Sowing was completed in the first week of July. A commercial chemical fertilizer was applied at the rate of 100:50:50 kg/ha of N:P₂O₅:K₂O at the time of seed bed preparation. Appropriate control measures were adopted for insect pest and weed infestation and applied evenly to all the plots.

Assessment of physiological and biochemical attributes

The biophysical parameters like chlorophyll content, total dry matter production, relative water content of leaf, SPAD value and leaf area were assessed. The carbohydrates, protein and proline content of cotton genotypes were assessed along with drought stress. The total Carbohydrates in leaves was determined by Anthrone method (Sadasivam and Mannikkam, 2008). The protein content in leaves was estimated by following Lowry's method and the proline content was determined following the method given in the book Biochemical methods (Sadasivam and Mannikkam, 2008).

Results and Discussion

Growth and yield parameters

In the present study the morphological parameters like plant height and number of sympodia were significantly highest under irrigated conditions compared to rainfed. The genotype Sahana was measured significantly highest height (145.8 cm). The number of sympodia per plant was highest in the genotype Sahana with 19.6 per plant under irrigated conditions (Table 1). The relative water content of leaves was significantly highest in the genotype DSC1651 (81.79%) under rainfed condition. The SPAD value was highest in the genotype DSC1651 (37.5) under rainfed condition. The leaf area was significantly highest in Sahana (920.50cm²) in rainfed condition. The root to shoot ratio was highest in DB1602 (0.56) under irrigated condition. The chlorophyll content was significantly highest in DLSa 17 (6.92mg/g) under rainfed condition (Table 3 and 4). In areas under limited water supplies, irrigation water use efficiency (WUE), and grain yield can be improved by using different strategies, including adopting site-specific agronomic

practices, developing drought-tolerance genotypes. Deficit irrigation is another agronomic practice suggested for improving WUE under limited water supplies. It has been reported that the WUE of most cereal crops can be increased significantly by about 10–42% using deficit irrigation treatments when compared with full irrigation treatments (El Hendawy *et al.*, 2019).

The mean seed cotton yield per hectare was higher in irrigated (796 kg/ha) than in rainfed (755kg/ha) condition but the difference was non significant. The genotypes ARBC1651, DSC-1651 and PA810 were high yielding under both the conditions among all the genotypes and the mean yield was 1286, 1077 and 1211 kg/ha respectively. The genotypes GISV -298, DB-1601, DB-1602, ARBH-1601 and LAHB-1 showed least yield (< 600kg/ha). The genotypes viz., GISV-298, DB-1601, DB-1602, SCS-1061, CPD-1652, and PA-810 exhibited least percent yield reduction (-26, -5, -27, -21, -15, and – 28%) (Table 2). Cotton lint yield is generally reduced because of reduced boll production, primarily because of fewer flowers and also because of increased boll abortions when the stress is extreme and when it occurs during reproductive growth. Cotton has mechanisms that make it well adapted to semi-arid regions. An understanding of the response of cultivars to water deficits is also important to model cotton growth and estimate irrigation needs (Karademir *et al.*, 2011).

Biochemical parameters

The leaf carbohydrate content was significantly highest in the genotype DSC1651 (131.6mg/g) under rainfed condition indicates that its drought tolerant variety. The leaf protein content was highest in CPD1652 (120mg/g) under rainfed condition.

Table.1 Growth characters and chlorophyll content of cotton genotypes as influenced by water regimes

		Plant height (cm)			No. of sympodia/ plant			Chlorophyll content (mg/g fr. wt.)		
	Genotypes	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean
1	GISV298	82.10	84.60	83.35	11.30	10.60	10.95	3.00	3.87	3.43
2	DSC1651	76.50	84.50	80.5	12.60	11.40	12.00	3.81	3.90	3.86
3	ARBC1651	64.30	79.70	72	9.80	10.80	10.30	3.17	3.90	3.53
4	Suraj (LC/ZC)	62.90	78.30	70.6	10.50	11.30	10.90	3.75	5.72	4.74
5	DB1601	62.90	71.40	67.15	12.50	12.30	12.40	5.63	4.81	5.22
6	DB1602	60.20	68.50	64.35	22.40	12.50	17.45	4.40	6.22	5.31
7	Suvini(LC/ZC)	59.90	71.50	65.7	12.60	13.20	12.90	5.96	3.79	4.88
8	SCS1061	75.80	71.60	73.7	13.20	12.20	12.70	4.14	4.35	4.24
9	CPD1652	62.70	74.00	68.35	12.40	12.00	12.20	3.52	5.34	4.43
10	ARBH813	106.10	115.30	110.7	16.60	17.10	16.85	5.08	3.93	4.51
11	Sahana	126.10	145.80	135.95	18.80	19.60	19.20	5.28	4.14	4.71
12	DLSa17	122.50	135.10	128.8	17.60	18.20	17.90	6.92	4.51	5.72
13	JLA110	69.30	81.00	75.15	13.70	13.10	13.40	4.74	4.08	4.41
14	PA810	88.60	91.40	90	14.80	14.20	14.50	4.93	3.50	4.22
15	ARBH1601	81.20	100.40	90.8	14.60	14.40	14.50	5.78	5.36	5.57
16	LAHB-1	71.00	90.10	80.55	13.20	14.40	13.80	5.23	5.28	5.26
17	DCH 32 (LC/ZC)	90.10	105.10	97.6	15.20	14.90	15.05	5.06	4.43	4.75
	Mean	80.12	91.07		14.22	13.66		4.73	4.54	
		MP	Genotype(S)	Interaction	MP	Genotype(S)	Interaction	MP	Genotype (SP)	Interaction
	SEm	1.23	3.68	5.20	0.50	1.40	1.98	0.01	0.02	0.04
	CD (5%)	3.69	10.62	14.99	1.59	4.03	5.72	0.21	0.08	0.12

Table.2 Yield and yield-related parameters as influenced by soil moisture stress in cotton genotypes

S. No.	Genotypes	Boll Weight (g)			Seed Cotton Yield (kg/ha)			% Yield reduction
		Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean	
1	GISV298	3.70	3.50	3.60	627.78	496.83	562.30	-26.36
2	DSC1651	3.70	3.80	3.75	1076.19	1079.76	1077.98	0.33
3	ARBC1651	3.70	4.00	3.85	1088.89	1483.73	1286.31	26.61
4	Suraj (LC/ZC)	4.00	5.00	4.50	1137.70	1427.38	1282.54	20.29
5	DB1601	2.50	2.30	2.40	543.65	515.08	529.37	-5.55
6	DB1602	2.80	2.40	2.60	484.92	381.35	433.13	-27.16
7	Suvin(LC/ZC)	2.40	2.10	2.25	90.48	55.95	73.21	-61.70
8	SCS1061	4.10	4.00	4.05	715.08	589.29	652.18	-21.35
9	CPD1652	4.30	4.50	4.40	834.92	722.62	778.77	-15.54
10	ARBH813	4.60	4.90	4.75	684.92	712.70	698.81	3.90
11	Sahana (LC/ZC)	4.10	3.80	3.95	713.89	748.81	731.35	4.66
12	DLSa17 (LC/ZC)	3.70	3.80	3.75	1144.05	1323.02	1233.53	13.53
13	JLA110	4.20	4.20	4.20	969.05	1190.48	1079.76	18.60
14	PA810	3.90	3.90	3.90	1360.71	1062.30	1211.51	-28.09
15	ARBH1601	2.10	2.30	2.20	409.13	589.68	499.40	30.62
16	LAHB-1	2.10	2.30	2.20	312.30	777.38	544.84	59.83
17	DCH 32 (LC/ZC)	2.60	2.80	2.70	649.60	390.87	520.24	-66.19
	Mean	3.44	3.51		755.49	796.90		
		MP	Genotype(S)	Interaction	MP	Genotype(S)	Interaction	
	SEm	0.012	0.19	0.26	15.74	40.44	57.68	
	CD (5%)	0.22	0.55	0.76	47.22	116.52	166.17	

Table.3 Leaf relative water content (RWC), SPAD value and leaf area as influenced by soil moisture stress in cotton genotypes

		RWC (%)			SPAD value			Leaf area (cm ²)		
	Genotypes	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean
1	GISV298	78.80	83.03	82.41	31.55	38.75	35.15	219.25	282.05	250.65
2	DSC1651	81.79	83.31	84.05	37.50	37.65	37.57	167.46	260.50	213.98
3	ARBC1651	80.62	82.53	83.07	36.75	37.30	37.03	99.76	314.00	206.88
4	Suraj (LC/ZC)	79.00	84.67	81.83	34.30	36.95	35.63	80.70	454.75	267.73
5	DB1601	73.13	80.57	78.35	29.75	32.75	31.25	256.75	209.25	233.00
6	DB1602	72.73	81.75	78.74	28.70	30.25	29.48	211.00	268.25	239.63
7	Suvin(LC/ZC)	69.91	80.06	76.48	30.60	33.25	31.93	128.03	233.25	180.64
8	SCS1061	78.77	81.14	81.45	35.25	38.20	36.73	362.25	314.50	338.38
9	CPD1652	78.58	82.82	82.20	33.30	39.15	36.23	143.21	401.00	272.10
10	ARBH813	78.19	84.39	82.79	35.70	40.10	37.90	498.50	666.50	582.50
11	Sahana	76.70	82.09	80.89	34.25	38.55	36.40	920.50	884.00	902.25
12	DLSa17	76.66	78.24	78.95	35.35	36.45	35.90	340.50	726.50	533.50
13	JLA110	79.50	84.56	83.53	32.55	38.80	35.68	120.33	237.50	178.91
14	PA810	81.68	81.66	81.67	36.55	36.70	36.62	270.75	376.25	323.50
15	ARBH1601	73.36	77.42	76.89	34.55	42.75	38.65	158.75	173.25	166.00
16	LAHB-1	77.32	77.85	79.09	37.25	41.35	39.30	153.75	159.00	156.38
17	DCH 32 (LC/ZC)	77.21	78.63	79.42	35.75	41.70	38.73	165.75	281.25	223.50
	Mean	77.29	81.45		34.10	37.69		252.78	367.16	
		MP	Genotype(SP)	Interaction	MP	Genotype(SP)	Interaction	MP	Genotype(SP)	Interaction
	SEm	0.70	0.975	1.511	0.067	0.690	0.949	34.406	57.128	85.599
	CD (5%)	2.59	2.81	4.35	1.20	1.99	2.73	102.50	164.57	246.58

Table.4 Root, shoot length and root/shoot ratio as influenced by water stress tolerance genotypes

		Root length (cm)			Shoot length (cm)			Root/shoot ratio		
	Genotypes	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean
1	GISV298	20.50	34.75	27.63	82.50	90.25	86.38	0.25	0.38	0.32
2	DSC1651	26.50	29.50	28.00	75.25	81.25	78.25	0.36	0.36	0.36
3	ARBC1651	28.25	33.00	30.63	68.50	83.25	75.88	0.41	0.40	0.41
4	Suraj (LC/ZC)	25.50	35.25	30.38	59.00	83.00	71.00	0.43	0.42	0.43
5	DB1601	29.75	28.75	29.25	63.25	59.00	61.13	0.47	0.49	0.48
6	DB1602	28.25	36.50	32.38	62.50	65.75	64.13	0.47	0.56	0.51
7	Suvin(LC/ZC)	29.75	33.75	31.75	60.00	77.00	68.50	0.50	0.47	0.49
8	SCS1061	33.00	25.25	29.13	75.25	73.00	74.13	0.44	0.35	0.39
9	CPD1652	20.25	30.50	25.38	73.25	77.50	75.38	0.28	0.39	0.33
10	ARBH813	33.00	29.75	31.38	102.50	105.00	103.75	0.32	0.28	0.30
11	Sahana	31.50	40.00	35.75	124.00	140.50	132.25	0.27	0.29	0.28
12	DLSa17	29.50	40.50	35.00	131.75	118.75	125.25	0.26	0.34	0.30
13	JLA110	29.25	35.50	32.38	69.75	79.00	74.38	0.42	0.45	0.44
14	PA810	30.25	32.50	31.38	98.00	96.25	97.13	0.31	0.34	0.32
15	ARBH1601	35.00	28.25	31.63	99.00	95.00	97.00	0.40	0.29	0.34
16	LAHB-1	28.50	23.00	25.75	77.50	87.25	82.38	0.37	0.27	0.32
17	DCH 32 (LC/ZC)	23.50	34.25	28.88	85.50	107.25	96.38	0.28	0.33	0.30
	Mean	28.37	32.41		82.79	89.35		0.37	0.38	
		MP	Genotype(SP)	Interaction	MP	Genotype(SP)	Interaction	MP	Genotype(SP)	Interaction
	SEm	1.050	2.136	3.113	1.393	4.09	5.78	0.024	0.032	0.05
	CD (5%)	3.15	6.15	8.97	4.17	11.78	16.65	0.43	0.09	0.14

Table.5 Biochemical parameters as influenced by soil moisture stress in cotton genotypes

		Leaf carbohydrate (mg/g of tissue)			Leaf protein (mg/g of tissue)			Leaf proline ($\mu\text{mol.g}^{-1}$ of tissue)		
	Genotypes	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean	Rainfed	Irrigated	Mean
1	GISV298	98.47	66.40	82.43	100.57	83.14	91.86	1.61	0.32	0.97
2	DSC1651	131.60	76.33	103.96	78.57	76.86	77.71	2.24	0.44	1.34
3	ARBC1651	97.27	84.53	90.90	70.57	64.00	67.29	1.74	0.29	1.02
4	Suraj (LC/ZC)	67.00	46.20	56.60	97.71	79.43	88.57	1.72	0.58	1.15
5	DB1601	69.67	60.00	64.83	97.43	82.86	90.14	1.67	0.45	1.06
6	DB1602	56.73	83.20	69.97	102.57	91.14	96.86	2.13	0.38	1.25
7	Suvini(LC/ZC)	63.73	80.40	72.07	81.71	58.29	70.00	1.35	0.60	0.98
8	SCS1061	68.20	79.80	74.00	114.29	108.00	111.14	1.78	0.68	1.23
9	CPD1652	63.40	58.27	60.83	120.00	99.43	109.71	2.41	0.29	1.35
10	ARBH813	77.47	71.27	74.37	101.14	84.29	92.71	2.09	0.37	1.23
11	Sahana	83.60	70.07	76.83	80.00	69.14	74.57	1.74	0.46	1.10
12	DLSa17	76.27	99.47	87.87	98.29	92.57	95.43	1.74	0.42	1.08
13	JLA110	89.20	77.47	83.33	81.14	80.29	80.71	1.26	0.58	0.92
14	PA810	92.47	87.27	89.87	102.57	86.57	94.57	1.93	0.32	1.13
15	ARBH1601	77.20	69.33	73.27	108.29	87.14	97.71	1.50	0.67	1.08
16	LAHB-1	77.80	70.87	74.33	101.14	94.86	98.00	1.65	0.57	1.11
17	DCH 32 (LC/ZC)	111.93	89.67	100.80	111.14	105.71	108.43	2.85	0.74	1.80
	Mean	82.47	74.74		96.89	84.92		1.85	0.48	
		MP	Genotype(SP)	Interaction	MP	Genotype(SP)	Interaction	MP	Genotype(SP)	Interaction
	SEm	1.997	3.471	5.136	0.071	0.290	0.404	0.012	0.014	0.022
	CD (5%)	5.88	10.00	14.87	1.28	0.84	1.16	0.21	0.04	0.06

The leaf proline content was significantly highest in DSC1651 (2.24 $\mu\text{mol/g}$) under rainfed condition clearly indicates that it's a drought tolerant variety. The protein content was varying across the sub plots. Mean protein content was found to be high in irrigated conditions (21%) compared to rainfed condition (17%). The high levels of mean protein content at both the conditions was observed to be 22% in PA810, ARBH1601 and CPD1652 followed by 21% in DSC1651 and ARBC1651 (Table 5). The water stress significantly affected most morphological, physiological, and biochemical characteristics as well as budding success on the Apple rootstocks. Proline contents increased with the impact of stress (Bolat *et al.*, 2014).

In conclusion the genotypes ARBC1651, DSC-1651 and PA810 were high yielding under both the conditions among all the genotypes and the mean yield was 1286, 1077 and 1211 kg/ha respectively and they showed high mean yield and therefore are said to be drought tolerant genotypes. The above genotypes showed highest carbohydrate and proline content, which indirectly indicates that these genotypes showed all the desirable characters to overcome drought situations. These conclusions are supported by biochemical parameters, physiological characters and yield components. These lines can be used in breeding programmes for moisture stress tolerance as well as yield stability.

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How to cite this article:

Pawar, K. N., S. Md. Akbar and Hema C. Rao. 2021. Assessment of Genotypic Variability for Morpho Physiological, Biochemical Parameters, Yield and Yield Attributing Characters under Drought Stress in Cotton. *Int.J.Curr.Microbiol.App.Sci*. 10(02): 2347-2356.
doi: <https://doi.org/10.20546/ijcmas.2021.1002.278>