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Study of physiological growth and drought tolerance in genotypes of Cotton (*Gossypium hirsutum* L.)

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Abstract
The study was conducted during *Kharif* season of 2016-17 and 2017-18 at AICRP on Cotton, B. M. College of Agriculture, Khandwa in a randomized block design with three replications in rainfed condition. Twenty cotton genotypes were sown at 60 cm row and plant spacing. The presence of ample variation among cotton genotypes for major yield attributing and drought tolerance traits was reflected from high estimates of phenotypic and genotypic coefficient of variation. The low magnitude of difference between genotypic coefficient of variation and phenotypic coefficient of variation suggested that traits RGR, CGR, NAR, RWC, transpiration rate, proline content, seed index, boll per plant, harvest index, boll weight (g), seed cotton yield (kg/ha), uniformity ratio and ginning *per cent* were more stable traits for environmental changes. the high heritability estimates and high mean of yield attributing traits *viz.*, boll /plant, boll weight (g), harvest index and seed cotton yield (kg/ha) and physiological growth and drought tolerance traits *viz.*, LAI, RGR, CGR, NAR, RWC, photosynthetic rate, transpiration rate, stomatal conductance, LWP and Proline content suggested that selection of parents through these traits may yield better genotypes for drought tolerance. The cotton genotypes JK-4, TCH-1199, TSH-327, AR-9108 and RS-2835 with high RWC, LWP, highest photosynthetic rate and low transpiration rate were found most suitable genotypes for use in further breeding programme for draught tolerant cotton varieties.

Keywords: Plant height, sympodia, monopodia, Dry matter production and seed cotton yield

Abbreviation: Leaf area index (LAI), Specific Leaf Area (SLA), Relative Growth Rate (RGR), Crop Growth Rate (CGR), Net Assimilation Rate (NAR), Leaf Area Duration (LAD), Relative water Content (RWC), Leaf water potential (LWP), (60-90), (90-120), (120-150), (150-180) Days after sowing (DAS).

1. Introduction

Cotton is a prominent fibre crop of the world. It has a great economicimportance asa domestic and export commodity. It has, in fact, been a decisive factor in the economic modernization and industrialization of the country. Cotton belongs to genus *Gossypium* of family Malvaceae. The genus *Gossypium* consists of 50 species (Poehlman and Sleper, 1995) [17] out of which only four species are cultivated, *viz G. hirsutum*,*G. barbadense*, *G. arboreum* and *G. herbaceum*. The species *G. hirsutum* and *G. barbadense* are tetraploid (2n=4x=52) while species *G. arboretum* and *G. herbaceum are* diploid (2n=2x = 26). Though all the four species producing spinnable lint but according to their production potential G. hirsutum gained more acreage in irrigated cotton areas while *G.arboreum* is limited up to rainfed areas in India.

China, India, USA, Pakistan, Argentina, Australia, Brazil, Mexico and Turkey are the major cotton producing countries and contributed approximately 85% of the world total cotton production. Economically and socially, it is one of the most important fibre crops in the world with the production of 117.8 million bales. India ranks first in area, second in production and fourth in productivity of cotton crop in the world. In India this crop occupies an area of 118.81lakh ha with a production of 352.0 lakh bales (170kg lint per bales) and productivity of 503 kg lint /ha. In India cotton grows mainly in seven states *viz*., Maharashtra, Gujrat, Karnataka, Andhra Pradesh, Madhya Pradesh, Hariyana and Rajasthan. Madhya Pradesh ranks first in respect to area 5.47 lakh hectares with production 17.0 (Lakh bales) and productivity 559 (kg/ha) as compared to other states (Anon, 2016) [2].

In Madhya Pradesh, Cotton is grown in Malva- Nimar region. The major districts having commercial cultivation of cotton in Malwa-Nimar region are Khandwa, Khargone, Dhar, Jhabua and Barwani. The area of cotton in Khandwa district is 6.03 lakhs hectares with production of 20 lakh bales and productivity of 578 kg lint/ ha.

The farmers of the Malwa and Nimar regions of Madhya Pradesh are facing the problems of abiotic stresses like scarcity of soil moisture, high temperature and drought in cotton cultivation. Drought is the most prevalent environmental stress affecting growth and development of crops via altered metabolism and gene expression (Leopold, 1990) [13].

Drought along with high temperature stress in cotton influences photosynthesis by decreasing quantum efficiency of the photosynthetic apparatus. Moisture stresses adversely affect plant growth, yield components and yield throughout the cotton growing states in India. The worldwide major limiting factors for food production are environmental stresses and it is very difficult to sort out the stress-free area to get their potential yield. Abiotic factors reduce the yield up to 71% (Boyer, 1982) [4].

2. Material and Methods

The field experiment was conducted during *Kharif* season of 2016-17 and 2017-18 at AICRP on Cotton, B. M. College of Agriculture, Khandwain a randomized block design with three replications in rainfed condition. Twenty cotton genotypes were sown at 60 cm row and plant spacing. Seeds were treated with mancozeb 2g + carbendazim @1g/ kg before sowing. Observations were recorded on five random plants for physiological growth and drought resistance parameters. The analysis of soil and plant samples was conducted inlab at P.M.B Gujrati Science College, Indore.

3. Result and Discussion

The estimate of phenotypic and genotypic coefficient of variation were high (> 20%) forDMP-60-90, LAI, RGR-60-90, CGR, NAR, Photosynthetic rate, Transpiration rate, Stomatal conductance, LWP, Proline content, Boll per plant, Boll weight (g), Harvest Index, Seed cotton yield (Kg/ha) and Uniformity ratio suggested the availability of abundant variations among the cotton genotypes in the present study that indicated the possibility of selection of better genotypes. The phenotypic and genotypic coefficient of variation were moderate (10-20%) for Plant height, Sympodia/plant, Monopodia/Plant, Nodes on main branch, DMP-90-120, DMP-120-150, DMP-150-180, RGR-90-120, WC-60-90, RWC-90-120, RWC-120-150, 2.5% bundle strength, Micronaire value, Ginning *per cent* and Seed index. The difference in magnitude of phenotypic coefficient of variation and genotypic coefficient of variation were low for the traits Sympodia/plant, Monopodia per plant, Nodes on main branch, LAI 60-90, LAI 90-120, LAI 120-150, LAI 150-180, RGR-90-120, RGR-120-150, CGR-60-90, NAR 90-120, NAR 120-150, RWC-60-90, RWC-90-120, RWC-120-150, Boll per plant, Harvest Index, Boll weight(g), Seed cotton yield (Kg/ha), Uniformity ratio, and Ginning *per cent* suggested that selection of genotypes for these traits should be useful in development of high yielding drought resistance variety.The genotypic coefficient of variation were higher than phenotypic coefficient of variation for the traits RGR-60-90, CGR-90-120, CGR-120-150, CGR-150-180, Transpiration rate, Proline content and Seed index indicating that these traits were less affected by the environment, hence for further improvement, selection of these traits should be practiced. The difference of the values of Phenotypic coefficients of variation and genotypic coefficients of variation were high for dry matter production, Photosynthetic rate, Stomatal conductance, LWP, 2.5% bundle strength and Micronaire value which reflect the high sensitivity of these traits for environmental change. Similar results were reported byRao and Reddy (2001) [18] and Kumar and Katageri (2017) [11] that the estimate of phenotypic coefficient of variation were higher than that of genotypic coefficient of variation for the traits monopodia per plant, sympodia per plant, boll weight and seed cotton yield indicating that these traits were highly influenced by the environmental conditions.

The high heritability coupled with high mean for yield attributing traits *viz* boll /plant, boll weight (g), Harvest Index and Seed cotton yield (kg/ha), hence selection based on these traits in further breeding programme may yield better genotypes. Fiber quality traits *viz* 2.5% bundle strength, uniformity ratio and ginning *per cent* were also showed high heritability for these traits suggesting that fiber quality may also be improve through selection for these traits. Reddy and Ratnakumari (2004) [19] also reported high heritability estimatesfor bolls plant-1and seed cotton yield plant -1.

The heritability estimates for all Physiological characters, physiological growth parameters and Drought tolerance parameters estimated in the present study *viz* Dry matter production, LAI, RGR, CGR, NAR, RWC, Photosynthetic rate, Transpiration rate, Stomatal conductance, LWP and proline content were high indicating the presence of desirable heritable content for transfer of draught resistance in the present genotypes of cotton. Reddy and Ratnakumari (2004) [19] also reported high heritability for dry matter production, proline content and SLA. Abbas *et al.* (2013) [1] found that high heritability was recorded for monopodial and sympodial branches, nods, number of bolls and plant height.

The Relative water content (RWC) is major determinant of drought tolerance in crop. The higher RWC was recorded in JK-4 (76.71%), TCH-1199 (75.31%) and TSH-327(73.26%) at 60-90 DAS but a gradual decrease in magnitude of RWC was observed up to 120-150 DAS. The genotype JK-4, TCH-1199 and TSH-327 were identified as promising genotypes for drought tolerance. Huyuan *et al.* (2013) [8] reported that the RWC is the most common parameter to assess the degree of water deficit. The leaf relative water content (RWC) is a measure of leaf water status and is a good indicator of drought tolerance in plants. It is closely related with plant water potential (Ober *et al*., 2005) [15]. Leaf RWC was significantly decreased by drought stress (Faizanullah *et al.*, 2012) [6]. All these studies were in support of the present findings. The maximum Leaf water potential was recorded in JK-4 followed by TCH-1199, AR-9108 and RS-2835, while minimum Leaf water potential was recorded in L-1384. Similar findings were reported by Koutu *et al*. (2005) [10] in cotton.

The highest photosynthetic rate (μ molm^{-2} Sec^{-1}) was recorded in the genotype JK-4 followed by the genotypes TCH- 1199, TSH-327 and AR-9108. Ojma *et al*. (1969) [16] found that crop yield depends upon both the rate and duration of photosynthesis and increased photosynthesis potential is considered to be a possible approach in improving yield. Kalpana *et al*. (2003) [9] suggested that photosynthetic rate was maximum at the flowering stage and declined at the pod development stage. Levi *et al*. (2009) [14] reported that photosynthetic rates have been used to identify the water deficit tolerant and sensitive genotypes of cotton.

The Transpiration rate was ranged from 7.81-16.21. The highest rate of transpiration was recorded by the genotype RHC-1202 which was at par with PH-1071, RB-610 and RB-

617 while the lowest rate of transpiration was recorded by the genotype TSH-327.Transpiration is one of the major gas exchange parameters associated with plant growth and productivity as stated by Taiz and Zeiger, 2002 [20]. Gupta *et al*. (2012) [7] reported that rate of transpiration decreased with the advancement of maturity. It might have occurred on account of the cumulative effect of decreased soil moisture content.

The Stomatal conductance was ranged between 166.16 to 291.83. The highest Stomatal conductance was recorded by the genotype CPD-1602 which was at par with the genotypes L-1060, GSHV-185, RB-610, RB-616 and RB-617. The lowest Stomatal conductance was noticed in the genotype AR-9108.According to kumar *et al*. (1998) [12] transpiration rate and stomatal conductance is in direct proportion to each other. Hence, for development of drought tolerance lines parents should have moderate transpiration rate and stomatal conductance. Anyia and Herzog (2003) [3] showed that drought caused a reduction in stomatal conductance. Burman *et al*. (2011) [5] observed that the stomatal conductance regulates movement of carbon dioxide and water vapor across whole leaf area which affects transpiration, water balance and photosynthesis.

Table 1: Genotypic Coefficients of Variation, Phenotypic Coefficients of Variation and Heritability of cotton genotypes during 2016-17 and 2017-18

Parameters	GCV		Pooled Mean	PCV		Pooled Mean	Heritability		Pooled Mean
	2016-17	2017-18		2016-17	2017-18		2016-17	2017-18	
Plant height(cm)	10.91	16.62	13.53	19.84	29.50	24.67	70.69	72.69	71.69
Sympodia/plant	12.84	13.38	13.11	13.85	16.13	14.99	85.99	98.78	92.38
Monopodia/Plant	12.87	14.61	13.74	13.74	14.89	14.31	90.74	93.02	91.88
Nodes on main branch	10.09	10.57	10.33	10.51	11.15	10.83	82.28	89.77	86.03
DMP-60-90	30.97	31.85	31.41	42.41	43.26	42.83	53.35	54.20	53.77
DMP-90-120	15.92	20.57	18.24	20.51	21.26	20.88	60.23	93.57	76.90
DMP-120-150	12.35	13.62	12.98	19.44	24.44	21.94	40.35	89.08	64.71
DMP-150-180	13.45	14.68	14.06	17.38	19.95	18.66	59.88	96.34	78.11
LAI (60-90)	43.09	49.27	46.18	43.12	50.47	46.73	90.87	95.31	93.09
LAI (90-120)	20.67	24.67	22.67	20.99	24.99	22.99	90.46	97.46	93.96
LAI (120-150)	30.07	35.06	32.56	30.16	35.16	32.66	90.47	99.47	94.97
LAI (150-180)	20.70	27.73	24.21	20.79	27.82	24.30	91.34	99.35	95.32
RGR-60-90	48.87	45.40	47.13	44.94	47.68	46.31	94.68	90.67	92.67
RGR-90-120	12.18	12.14	12.16	12.19	12.15	12.17	94.85	93.89	94.37
RGR-120-150	38.89	38.05	38.47	38.92	38.06	38.49	93.85	91.96	92.90
CGR-60-90	30.06	35.20	32.63	30.13	35.27	32.70	90.63	99.64	95.13
CGR-90-120	39.17	41.28	40.22	38.17	41.28	39.72	90.42	100.00	95.21
CGR-120-150	20.75	26.94	23.84	24.75	26.94	25.84	94.12	100.00	97.06
CGR-150-180	80.51	81.71	81.11	74.99	81.71	78.35	89.00	100.00	94.50
NAR (60-90)	34.83	38.39	36.38	32.83	38.39	35.61	90.99	99.78	95.52
NAR(90-120)	40.37	47.20	43.78	40.38	47.20	43.79	90.96	99.99	95.47
NAR (120-150)	20.46	26.58	23.52	20.47	26.60	23.53	90.93	99.85	95.39
RWC-60-90	7.77	9.23	8.43	7.85	9.34	8.52	90.92	97.57	94.24
RWC-90-120	4.47	8.37	6.24	4.79	8.64	6.71	86.78	93.79	90.28
RWC-120-150	8.92	14.38	11.65	9.09	14.58	11.83	90.34	97.23	93.78
Photosynthetic rate (μ molm^{-2} Sec^{-1})	33.93	36.98	35.38	35.45	39.02	37.40	80.90	89.79	85.34
Transpiration rate (m mol m^{-2} Sec^{-1})	30.65	39.94	35.29	33.71	34.06	33.88	80.67	82.55	81.61
Stomatal conductance (m mol m^{-2} Sec^{-1})	26.20	24.18	25.19	29.10	36.63	32.86	80.10	82.46	81.28
LWP(-MPa)	48.08	49.79	48.92	49.77	51.54	50.65	90.33	93.33	91.83
Proline content (%)	31.98	32.36	32.17	30.11	32.49	31.30	90.17	99.17	94.67
Boll/Plant	35.38	36.26	35.82	35.89	36.84	36.36	97.16	96.73	96.94
Boll weight(g)	24.39	26.06	25.22	25.00	26.72	25.96	90.15	95.15	92.65
Harvest Index (%)	30.96	31.70	31.33	31.56	32.64	32.10	90.24	98.49	94.36
Seed cotton yield (Kg/ha)	40.76	46.02	43.39	41.05	46.35	43.70	91.57	98.57	95.07
2.5% bundle strength	10.09	15.79	12.94	10.25	18.51	14.38	90.95	96.24	93.95
Micronaire value (10-6 g/inch)	15.87	16.76	16.31	28.22	33.23	30.72	31.62	52.04	41.83
Uniformity ratio (10 $^{-1}$ g inch $^{-1}$)	16.39	29.53	22.96	16.58	30.56	23.57	90.30	93.35	91.82
Ginning percent	14.46	24.11	19.23	14.53	24.58	19.55	90.00	98.61	94.30
Seed index(g)	18.79	19.83	19.31	20.22	23.32	21.77	80.29	86.48	83.38

Table 2: Pooled mean of Relative Water Content (%) at different growth stages and Leaf Water Potential at 100 DAS of cotton genotypes.

S. No.	Genotypes	Pooled Mean at different growth stages				Leaf Water potential		
		RWC 60-90 DAS	RWC 90-120 DAS	RWC 120-150 DAS	Average Pooled mean	2016-17	2017-18	Pooled mean
1	RS-2835	68.04	63.33	48.77	60.05	12.50	11.94	12.22
2	GSHV-185	69.70	64.77	53.07	62.51	13.00	12.44	12.72
3	GISV-310	68.38	62.44	54.32	61.71	16.10	15.55	15.83
4	CPD-1601	69.12	64.43	52.66	62.07	15.83	15.27	15.55
5	CPD-1602	67.38	66.36	54.66	62.80	16.33	15.77	16.05

6	ARBH-1601	65.38	65.03	53.98	61.46	15.50	14.95	15.23
7	TSH-324	64.37	65.80	53.44	61.20	23.10	22.54	22.82
8	TSH-327	73.26	69.69	61.82	68.25	18.27	17.71	17.99
9	L-1060	64.38	67.39	57.99	63.25	24.50	23.94	24.22
10	L-1384	69.70	62.69	50.87	61.09	25.50	24.94	25.22
11	L-799	67.38	66.36	57.33	63.69	21.50	20.94	21.22
12	PH-1071	68.71	65.51	54.58	62.93	14.50	13.94	14.22
13	AR-9108	71.04	68.86	57.32	65.74	10.78	10.22	10.50
14	RB-616	69.37	64.80	54.03	62.73	15.00	14.45	14.73
15	RB-617	68.38	64.73	51.98	61.70	16.50	15.94	16.22
16	RB-610	65.38	67.69	55.33	62.80	16.70	16.14	16.42
17	RHC-1202	68.11	64.99	53.17	62.09	15.50	14.94	15.22
18	RHC-1217	73.21	69.14	58.66	67.00	14.50	13.94	14.22
19	TCH-1199	75.31	69.97	60.13	68.47	9.32	8.76	9.04
20	JK-4	76.71	70.41	61.80	69.64	9.20	8.64	8.92
Se(M)±		0.477	0.65	0.56	0.562	1.21	1.20	1.20
CD @ 0.05%		1.36	1.88	1.60	1.613	3.50	3.44	3.44

Table 3: Physiological stress parameters of cotton genotypes during 2016-17 and 2017-18

S. No.	Genotypes	Photosynthetic rate		Pooled Mean	Transpiration		Pooled Mean	Stomatal conductance		Pooled Mean
		2016-17	2017-18		2016-17	2017-18		2016-17	2017-18	
1	RS-2835	15.11	13.85	14.48	10.61	10.23	10.42	246.74	237.05	241.89
2	GSHV-185	12.07	10.80	11.43	10.00	9.62	9.81	279.00	269.31	274.16
3	GISV-310	13.33	12.06	12.69	10.47	10.09	10.28	251.00	241.31	246.16
4	CPD-1601	14.35	13.08	13.72	10.25	9.87	10.06	216.67	206.99	211.83
5	CPD-1602	16.07	14.80	15.44	10.96	11.25	11.10	296.67	286.98	291.83
6	ARBH-1601	15.33	14.06	14.70	10.67	10.29	10.48	243.33	233.64	238.49
7	TSH-324	12.00	10.73	11.37	11.04	10.66	10.85	227.33	217.64	222.49
8	TSH-327	18.00	16.73	17.36	8.00	7.62	7.81	255.33	245.64	250.49
9	L-1060	9.00	7.91	8.46	12.00	11.62	11.81	317.00	241.35	279.18
10	L-1384	11.20	9.94	10.57	12.30	11.92	12.11	246.33	236.64	241.49
11	L-799	10.20	8.93	9.57	12.00	11.62	11.81	229.33	219.64	224.49
12	PH-1071	14.07	12.80	13.43	14.43	14.05	14.24	236.33	226.64	231.49
13	AR-9108	17.40	16.13	16.77	8.77	8.39	8.58	171.00	161.31	166.16
14	RB-616	16.00	14.74	15.37	12.00	11.62	11.81	264.00	254.31	259.16
15	RB-617	12.99	11.72	12.36	12.78	12.40	12.59	256.67	246.98	251.82
16	RB-610	10.82	9.55	10.19	14.04	13.66	13.85	266.00	256.32	261.16
17	RHC-1202	16.40	15.13	15.77	16.40	16.02	16.21	227.00	217.31	222.15
18	RHC-1217	14.73	13.46	14.09	9.97	9.92	9.95	185.00	177.98	181.49
19	TCH-1199	18.44	17.17	17.81	11.63	11.25	11.44	181.33	171.64	176.49
20	JK-4	19.10	17.83	18.47	8.14	8.09	8.12	195.00	187.06	191.03
Se(M)±		0.941	0.940	0.94	0.91	0.90	0.906	17.49	14.60	14.31
CD @ 0.05%		2.700	2.690	2.69	2.62	2.56	2.59	50.1	41.82	40.98

4. Conclusions

The study revealed that sufficient genotypic and phenotypic variation was present among the genotypes of cotton under study. The traits which are less effected with the environmental changes were RGR, CGR, NAR, RWC, Transpiration rate, Proline content, Seed index, Boll/Plant, Harvest Index, Boll weight(g), Seed cotton yield (Kg/ha), Uniformity ratio and Ginning percent. The estimates of heritability suggested that selection through boll /plant, boll weight (g), Harvest Index and Seed cotton yield (kg/ha), LAI, RGR, CGR, NAR, RWC, Photosynthetic rate, Transpiration rate, Stomatal conductance, LWP and proline content may helpful in selection of parent for further breeding programme for drought tolerant variety.On the basis of RWC, LWP, highest photosynthetic rate and low transpiration rate genotypes JK-4, TCH-1199, TSH-327 AR-9108 and RS-2835 with inherent capacity of transfer of draught tolerance, high number of bolls, Boll weight and high Seed Cotton Yield.

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