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Evaluation of physiological traits associated with abiotic stress tolerance in *Gossypium hirsutum* L. genotypes under rainfed conditions in black cotton soils

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Abstract : A field experiment was laid out in a strip plot design with 2 irrigation levels as main treatments(need based irrigation and rainfed conditions) and 20 cotton entries *viz;* CPD 231, NH 635, GBHv 164, ARBH 813, GISV 218,BS 30, H1452, CPD 168, F2228, GJHv 358, HBB 101, BS 279, ARBH 2004, GSHv 97/612, Sahana, LRA 5166, MR 786, AKH0205, RCR 102 and H1353 as sub treatments to know the relative tolerance of the entries under moisture stress conditions in black cotton soils under natural conditions. Relative water content (RWC), specific leaf weight (SLW), chlorophyll stability index (CSI), SPAD chlorophyll meter reading (SCMR), leaf temperature, photosynthetic rate, seed cotton yield and per cent reduction in photosynthetic rate, dry matter production and seed cotton yield under rainfed conditions in comparison with irrigated conditions were examined and found significant variation among the entries tested. Significantly higher seed cotton yield was recorded in F 2228 (3909 kg/ha) followed by NH 635 (3061 kg/ha), H 1452 (2972 kg/ha), CPD231 (2954 kg/ha), MR 786 (2761kg/ha), GISV 218 (2721 kg/ha) and the higher yield was associated with higher boll number and weight. The entries *viz.,* H 1252, F2228, NH 635 GBHv 164, GISV 218 and ARBH 813 have shown good performance under rainfed conditions with their inbuilt tolerance to drought. Higher chlorophyll stability index was recorded in AKH0205, GBHv 164, ARBH 813, MR 786 and LRA 5166. Higher photosynthetic rate was recorded in MR 786 followed by LRA 5166, ARBH 813, RCR 102, F 2228 and H 1353. The entry F 2228 recorded significantly higher RWC followed by RCR 102, CPD 168 and GJHv 358. The experimental results indicated that the entries having higher productivity under rainfed conditions were associated with more than one drought tolerance parameters *viz.,* RWC, SLW and CSI in addition to less reduction in photosynthetic rate and dry matter production.

Key words : Cotton, CSI, drought, RWC, SCMR, SLW

Cotton plays an important role in Indian agriculture, industrial development, employment generation and in improving national economy. In Andhra Pradesh, cotton is one of the most important commercial crops. Climate change affects the rainfed areas of Andhra Pradesh badly. Deficient rains causes reduction in cotton yield. High temperatures also hasten the development especially during the boll filling period, thus resulting in smaller bolls, lower yields and poor lint quality. Due to these reasons, the ability of plants to tolerate drought conditions is crucial for agricultural production worldwide. A drought tolerant variety improves the cotton yield and thus a boon to farming community. Drought tolerant cotton genotypes showed moderate plant height, lower leaf area (Janagoudar *et al.,* 2004). Ninganur *et al.,* (2004) reported that less reduction in plant height, plant spread and leaf area by drought tolerant genotypes. Singh *et al.,* (2004) observed that the high yielding genotypes showed a higher total leaf area even under rainfed conditions. Cotton genotypes showed early squaring, flowering, boll opening and maturity under rainfed conditions (Patil *et al.,* 2004). Ratnakumari and Subbaramamma (2006) studied the genetic evaluation of *Gossypium hirsutum* genotypes for yield, drought parameters and fibre quality. Among the genotypes evaluated Gshv 97/612 had highest mean performance for sympodia/plant.

MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, during *kharif* season in black cotton soils under rainfed conditions. The soil of the experimental area was clay loam in texture, slightly alkaline with pH 7.8, low in organic carbon content (0.38%), low in available nitrogen (188 kg/ha), medium in available phosphorus (28 kg/ha) and high in available potassium (735 kg/ha). The total rainfall during the period under study was 920 mm in 52 rainy days. The experiment was laid out in strip plot design with 2 irrigation levels as main treatments *viz.*, rainfed (I_0) and need based irrigation conditions (I) and 22 cotton entries as sub treatments in 2 replications to screen the entries for drought tolerance in black cotton soils. The entries taken for the study were CPD 231, NH 635, GBHv 164, ARBH 813, GISV 218, BS 30, H1452, CPD 168, F 2228, GJHv 358, HBB 101, BS 279, ARBH 2004, GSHv 97/612, Sahana, LRA 5166, MR 786, AKH 0205, RCR 102 and H 1353. Each genotype was grown in 4 rows of 6m length with a spacing of 105 cm between rows and 60 cm in between plants. Fertilizers were applied as per the schedule. Five plants at random were selected in each plot and sympodia/plant, bolls/plant, boll weight and seed cotton yield/plant was recorded. Third and forth fully opened leaves were collected for estimating relative water content (RWC), chlorophyll stability index (CSI), specific leaf area SLA) and specific leaf weight (SLW). Leaf chlophyll content was also estimated. The mean data of 5 plants were also subjected to statistical analysis by adopting the standard procedures.

RESULTS AND DISCUSSION

Growth parameters : During the study no significant variation was noticed in plant height at 90 DAS and 120 DAS among the varieties, irrigation levels and also due to interaction of varieties with irrigation levels. The total dry matter production significantly differed among

Table 1. Drought tolerance evaluation of cotton with irrigated and rainfed conditions for physiological parameters at 90 DAS

Entry	SPAD chlorophyll (Meter reading)		Leaf temperature (^{0}C)		Photosynthetic rate (µ mole CO2 m^{-2}/sec)		Relative water content	
	I	I_0	I	I_0	I	I_0	I	I_0
CPD 231	48.48	50.49	30.45	30.73	13.05	07.85	58.4	61.4
NH 635	41.40	46.21	26.48	28.10	20.30	15.60	58.9	61.0
GBHv 164	43.45	42.96	27.88	29.70	22.73	08.32	55.9	55.6
ARBH 813	42.33	42.63	27.23	29.46	26.97	23.03	65.8	58.8
GISV 218	43.88	44.08	28.43	27.63	25.87	14.67	69.5	66.1
BS 30	45.70	46.48	28.76	28.17	14.40	13.43	64.1	60.5
H1452	44.59	44.66	27.53	28.30	33.33	16.03	72.3	53.4
CPD 168	44.39	44.10	27.70	28.36	15.57	13.27	77.4	65.4
F2228	46.03	43.15	26.86	27.95	27.60	18.17	79.1	69.8
GJHv 358	43.26	47.21	27.55	28.78	26.43	15.37	75.9	66.8
HBB 101	45.89	47.65	27.25	28.10	15.94	12.07	63.8	60.0
BS 279	43.45	43.86	28.15	29.17	12.43	14.57	66.8	69.7
ARBH 2004	45.18	44.14	28.05	28.68	30.13	12.80	66.5	66.7
GSHv 97/612	42.63	48.39	27.35	28.25	49.13	12.63	68.8	68.0
Sahana	43.86	47.23	28.70	27.78	44.93	16.50	67.6	62.2
LRA 5166	47.06	45.71	28.03	28.00	45.87	23.93	70.2	64.6
MR 786	49.95	47.63	27.03	26.55	21.63	24.43	53.3	64.9
AKH0205	46.90	45.57	30.72	29.73	13.23	16.77	62.5	65.3
RCR 102	41.39	41.58	28.60	27.65	44.17	20.13	74.8	68.6
H1353	41.40	41.50	28.60	29.55	39.13	18.13	68.4	62.1

I- With irrigation I_0 - Without irrigation

the entries, irrigation levels and also due to interaction of entries and irrigation levels. The total dry matter production was significantly high in BS 279 (441g/plant) followed by H 1452 (426g/plant), LRA 5166 (395g/plant) and MR 786 (390g/plant). The total dry matter production was significantly high under need based conditions (350g/plant) as compared to rainfed conditions (346g/plant). The results are in accordance with the findings of Ghongane *et al.,* (2009) reported that the plant height, monopodial branches/plant, sympodial branches/plant and total dry matter (g/plant) significantly reduced under no irrigation condition in *Bt* cotton as compared to 0.8 IW/CPE irrigation level. Significantly higher harvest index was noticed in F 2228 (0.42) followed by GShv 358 (0.38) and H 1353 (0.35). Under need based irrigation, the harvest index was significantly high (0.30) compared to rainfed conditions (0.27).

Physiological and biochemical parameters: Significant variation was noticed in recording drought tolerance parameters *viz.,* relative water content (RWC), specific leaf weight (SLW), chlorophyll stability index (CSI), SPAD chlorophyll meter reading (SCMR), leaf temperature, photosynthetic rate among the entries tested. SPAD chlorophyll meter reading is an indication of the light transmittance characteristics of the leaf which is dependent on the leaf chlorophyll content (Richardson *et al.,* 2002). SPAD meter is a simple diagnostic tool to measure the chlorophyll content of plant leaves. The chlorophyll content (SPAD reading) varied among the genotypes and the water regimes imposed (watered and stressed), although it was not significantly different between the sensitive and tolerant genotypes when subjected to the water deficit. Regardless of the water regime, the genotype CNPA 7H presented with chlorophyll values greater than those of the other genotypes, indicating greater leaf chlorophyll content (Brito *et al.,* 2011). The SLW was significantly high in F 2228 (8.8 mg/ cm^2) followed by ARBH 813, NH 635 (7.7 mg/ cm^2), H 1353(6.8 mg/ cm^2), AKH 0205 and GSHv 97/612 (6.7 mg/ cm^2) and GJHv 358(6.5 mg/ cm^2). The SLW was also significantly high under rainfed conditions (6.5 mg/cm^2) as compared to need based irrigated conditions (6.1 mg/ cm^2). No significant variation was noticed in recording RWC at 90DAS, but significant variation was noticed due to irrigation levels. At 120 DAS, significant variation was noticed in RWC among the entries and irrigation levels. The entry F 2228 recorded significantly higher RWC (74%) followed by RCR 102 (71.4%), CPD 168 (71.2%) and GJHv 358 (70.7%). Higher RWC is in correlation with boll weight and then yield. Significantly higher RWC was recorded under need based irrigated conditions (66.6%) as compared to rainfed conditions (63.3%) (Table 2). The chlorophyll stability index ranged from 72.10 to 88.17 under need based irrigated conditions and from 61.08 to 83.27 under rainfed conditions (Table 3). Higher chlorophyll stability index was recorded in AKH 0205, GBHv 164, ARBH 813, MR 786 and LRA 5166 under rainfed conditions and these entries performed well under drought conditions The photosynthetic rate of the entries ranged from 12.43 to 49.13 µ mole CO_2 m^{-2}/ sec under need based irrigated conditions , whereas under rainfed conditions, it ranged from 8.32 to 24.43 µ mole CO_2 m^{-2}/sec^{-}. Under rainfed conditions, higher photosynthetic rate was recorded in MR 786 (24.43 µ mole CO_2 m^{-2}/sec) followed by LRA 5166 (23.93), ARBH 813 (23.03 µ mole CO_2 m^{-2}/ sec), RCR 102 (20.13 µ mole CO_2 m^{-2}/sec), F2228 (18.17 µ mole CO_2 m^{-2}/sec) and H 1353 (18.13 µ mole CO_2 m^{-2}/sec). The SPAD chlorophyll meter reading ranged from 41.4 to 49.9 under need based irrigated conditions, whereas it ranged from 41.5 to 51.5 under rainfed conditions. Under rainfed conditions, higher SPAD values were recorded in CPD 231, GSHv 97/612, MR 786, GJHv 358, HBB 101 and Sahana. The leaf temperature ranged from 27 to 30.7 both under need based irrigated conditions and rainfed conditions. The leaf temperature was comparatively less in NH 635,

Table 2. Drought tolerance evaluation of cotton with irrigated and rainfed conditions for growth and yield parameters

Treatments		90 Days after sowing					120 Days after sowing			Boll weight (g)	Bolls/ plant	SCY/ plant
		Plant height (cm)	Sympodia/ plant	SLA	SLW	RWC	Sympodia/ plant	Plant height (cm)	Monopodia/ plant			
	Varieties(V)											
	CPD 231	78	12.6	169	5.7	72.7	22.4	103	1.62	3.17	24.7	2954
	NH 635	81	12.0	133	7.7	81.8	29.7	112	0.95	3.04	45.0	3061
	GBHv 164	67	12.8	135	7.2	77.4	19.8	84	0.30	3.48	34.3	2547
	ARBH 813	76	12.9	131	7.7	74.5	21.2	105	1.12	3.15	32.8	2296
	GISV 218	80	11.5	98	4.6	79.0	20.7	103	1.89	3.04	38.3	2721
	BS 30	72	11.6	152	6.2	71.9	21.3	102	1.38	3.67	39.4	2205
	H1452	78	12.6	164	5.8	71.9	22.0	116	1.32	3.34	34.8	2972
	CPD 168	80	12.1	208	4.7	62.5	18.7	110	0.81	3.43	28.7	3019
	F2228	81	11.9	108	8.8	67.6	19.3	122	1.13	4.01	45.5	3909
	GJHv 358	85	12.3	150	6.5	71.1	20.4	108	2.07	3.26	30.4	2610
	HBB 101	84	11.7	171	5.8	79.3	18.2	108	0.47	3.73	26.4	2624
	BS 279	74	11.1	176	5.3	75.6	17.5	100	1.39	3.66	31.1	2417
	ARBH 2004	85	12.9	165	6.3	74.3	20.5	117	0.99	3.48	32.5	2573
	GSHv 97/612	73	10.9	144	6.7	75.4	18.7	95	1.32	3.03	32.3	2418
	Sahana	79	11.8	125	4.6	80.2	20.4	113	1.66	3.60	26.3	2602
	LRA 5166	77	11.5	116	8.3	80.7	20.22	106	1.47	3.33	33.1	2245
	MR 786	81	11.5	180	5.4	81.2	18.2	124	1.05	3.38	42.4	2761
	AKH0205	79	11.8	145	6.7	57.2	18.4	107	0.97	2.97	27.4	2136
	RCR 102	73	10.9	236	5.1	72.0	21.6	114	1.15	2.98	12.4	2138
	H1353	87	12.7	135	6.8	46.2	11.0	105	0.7	3.82	34.6	2079
	SEm+	4.1	0.59	26.9	1.16	6.35	1.94	7.45	0.08	0.15	4.75	235
	P=0.05	NS	NS	NS	NS	NS	5.73	NS	NS	0.46	14.0	650
	Irrigarion(I)											
	I	77.5	12.24	152	6.5	73.2	19.7	107.4	1.25	3.34	35.8	2686
	I_0	79.4	11.69	150	6.1	72.1	20.3	107.9	1.12	3.41	29.4	2543
	SEm+	2.99	0.09	2.15	0.067	0.232	1.57	0.356	0.45	0.05	2.9	70.60
	P=0.05	NS	0.26	NS	0.2	0.685	NS	NS	NS	NS	NS	195.67
(V X I)	SEm+	3.69	0.66	2.57	0.17	0.998	3.86	7.49	0.53	0.305	4.0	223.30
	P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	11.8	NS
	CV (%)	6.66	7.78	2.39	3.85	1.94	27.2	9.84	62.9	12.7	17.34	14.09

Table 3. Drought tolerance evaluation of cotton for biochemical parameters at 90 DAS

Entry	Chlorophyll a			Chlorophyll b			Chlorophyll a/b			Total Chlorophyll			Chlorophyll stability index		
	I	I_0	**Mean**	I	I_0	**Mean**	I_0	I	**Mean**	I	I_0	**Mean**	I	I_0	**Mean**
CPD 231	0.577	0.574	**0.575**	0.832	0.782	**0.807**	0.693	0.733	**0.713**	1.408	1.356	**1.382**	88.17	76.87	**82.52**
NH 635	0.583	0.545	**0.564**	0.831	0.691	**0.761**	0.702	0.792	**0.747**	1.415	1.236	**1.325**	88.10	74.17	**81.14**
GBHv 164	0.562	0.529	**0.545**	0.756	0.714	**0.735**	0.743	0.741	**0.742**	1.319	1.243	**1.281**	87.32	83.27	**85.29**
ARBH -813	0.581	0.535	**0.558**	0.874	0.682	**0.778**	0.666	0.785	**0.726**	1.438	1.217	**1.328**	84.22	80.40	**82.31**
GISV 218	0.577	0.559	**0.568**	0.852	0.739	**0.796**	0.681	0.757	**0.719**	1.413	1.298	**1.356**	88.15	79.37	**83.76**
BS 30	0.562	0.547	**0.554**	0.771	0.715	**0.743**	0.729	0.765	**0.747**	1.333	1.262	**1.298**	81.28	70.67	**75.98**
H1452	0.593	0.547	**0.570**	0.832	0.678	**0.755**	0.713	0.808	**0.761**	1.425	1.224	**1.325**	74.90	69.52	**72.21**
CPD 168	0.571	0.541	**0.556**	0.784	0.628	**0.706**	0.730	0.861	**0.746**	1.353	1.170	**1.262**	75.90	68.25	**72.08**
F2228	0.566	0.531	**0.548**	0.847	0.733	**0.790**	0.470	0.725	**0.598**	1.413	1.264	**1.339**	73.28	63.58	**68.43**
GJHv 358	0.563	0.531	**0.547**	0.810	0.706	**0.758**	0.695	0.753	**0.724**	1.373	1.238	**1.306**	78.52	71.03	**74.78**
HBB 101	0.563	0.532	**0.548**	0.829	0.673	**0.751**	0.721	0.810	**0.765**	1.427	1.249	**1.338**	72.30	61.08	**66.69**
BS 279	0.598	0.576	**0.587**	0.842	0.700	**0.771**	0.684	0.750	**0.717**	1.418	1.266	**1.342**	76.37	62.52	**69.45**
ARBH 2004	0.576	0.553	**0.565**	0.841	0.662	**0.751**	0.684	0.777	**0.731**	1.417	1.185	**1.301**	83.17	73.50	**78.33**
GSHv 97/612	0.574	0.545	**0.560**	0.830	0.809	**0.820**	0.709	0.698	**0.704**	1.435	1.324	**1.380**	73.58	64.80	**69.19**
Sahana	0.589	0.562	**0.575**	0.812	0.751	**0.782**	0.719	0.735	**0.727**	1.396	1.314	**1.355**	78.59	71.13	**74.86**
LRA 5166	0.579	0.579	**0.579**	0.724	0.693	**0.709**	0.801	0.813	**0.807**	1.303	1.273	**1.288**	80.53	77.93	**79.23**
MR 786	0.569	0.541	**0.555**	0.765	0.689	**0.727**	0.752	0.757	**0.755**	1.334	1.230	**1.282**	82.52	78.43	**80.48**
AKH0205	0.581	0.552	**0.566**	0.788	0.773	**0.781**	0.729	0.722	**0.725**	1.369	1.325	**1.347**	88.10	84.58	**86.34**
RCR 102	0.554	0.542	**0.548**	0.798	0.743	**0.771**	0.681	0.729	**0.705**	1.352	1.285	**1.319**	86.52	73.87	**80.19**
H1353	0.559	0.548	**0.554**	0.773	0.716	**0.744**	0.725	0.741	**0.733**	1.332	1.264	**1.298**	82.51	75.82	**71.16**
Mean	0.574	0.548		0.810	0.714		0.701	0.763		1.384	1.261		81.20	73.04	
	SEm+	P=0.05	**CV (%)**	SEm+	P=0.05	**CV (%)**	SEm+	P=0.05	**CV (%)**	SEm+	P=0.05	**CV (%)**	SEm+	P=0.05	**CV (%)**
Main	0.013	NS	**3.88**	0.130	0.037	**3.03**	0.032	0.089	**7.63**	0.017	0.047	**2.24**	0.26	0.72	**0.58**
Sub	0.003	0.008	**2.69**	0.004	0.012	**3.08**	0.009	0.024	**6.57**	0.004	0.012	**1.79**	0.11	0.29	**0.76**
Interaction	0.009	NS	**2.70**	0.140	0.038	**3.10**	0.028	0.077	**6.60**	0.014	0.038	**1.80**	0.34	0.94	**0.80**

I- With irrigation I_0 - Without irrigation

MR 786, RCR 102, Sahana, ARBH 813 and GJHv 97/612 (Table 1).

C. Yield and yield attributing characters: Significant variation was noticed among the different entries in recording bolls/plant, boll weight, seed index, lint index, and harvest index and seed cotton yield/plant. Significantly higher seed cotton yield was recorded in F 2228 (3909 kg/ha), followed by NH 635 (3061 kg/ha), MR 786(2761kg/ha) and the higher yield in these entries were associated with higher boll number and boll weight.

From the experimental results, it is inferred that the entries *viz*., H 1252, F 2228, NH 635, GBHv 164, GISV 218 and ARBH 813 have shown good performance under rainfed conditions with their inbuilt tolerance to drought having higher drought tolerance parameters in addition to yield attributing characters under low moisture conditions.

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