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Performance of cotton genotypes for water stress tolerance

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Abstract
Changing climate is influencing the onset withdrawal and distribution of monsoon rainfall cotton production in limited by biotic and abiotic stress factors. Among them drought or water deficit is a complex phenomenon effecting the physiology of cotton plant in turn reduces crop growth and yield. An experiment was conducted in two years during 2013-14 to 2014-15 using twenty *Gossypium hirsutum* genotypes grown in RBD design at cotton Research station Nanded to evaluated for genotypic variability for growth, physiological parameters and yield parameters under irrigated as will as in water deficit rainfed condition. The two years pooled analysis showed that among the 20 genotypes, the strain TSH-04-115 followed by RAH-806, BS-37, NH-615(LC) and BS-39 were recorded significantly highest seed cotton yield (kg/ha) associated with higher yield /plant (g), No. of bolls/plant and boll weight (g) in both protected and unprotected condition. The genotype ARBH-1352, GBHV-182, NDLH-1938 and SCS-1213 were recorded (9.0 to 15.5%) least reduction in yield, CSI, DSI (< 1.0), higher RWC(%), Proline content(%) and yield stability index in rainfed condition. Similarly, these genotypes shows earliness in terms of 50% flowering and 50% boll bursting and possesses high degree of indices for DMSI, LASI, PHSI, YSI, LAI, CSI, total chlorophyll, SLW and RWC with least (< 1.0) drought susceptibility index (S) and also least yield reduction under rainfed condition indicating better water stress tolerance capacity. These genotypes can be used as desirable genotypes for drought conditions.

Keywords: Cotton, growth, yield, water deficit, proline content

Introduction
Climate change is one of the most important global environmental challenges with implications for cotton production. Changing climate is influencing the onset, withdrawal and distribution of monsoon rain challenging their livelihoods. Cotton is the most preferred source of natural fibre and economically important for farmers globally. In India, cotton is an important cash crop and India has the longest cotton area in world. However, cotton production is limited by biotic and abiotic factors. Among them drought or water deficit is a major abiotic stress, which limits fiber development. Yield is severely affected when drought stress occurs during the reproductive phase (Selote and Chopra, 2004) [7]. More than 60 percent of cotton cultivated in India under rainfed, where water stress frequently occurs in any phase of crop development. Growth and yield of a crop plant is drastically affected directly or indirectly by altering metabolism, growth and development (Pettigrew, 2004) [5]. Drought tolerance is a complex mechanism that is influenced by wide range of physiological traits which havesome relationship with productivity under water deficit conditions. Cotton plant population when submitted to water deficit show reduction in yield up to 50% if compared to those that have been irrigated, especially when the stress factor is imposed during the period between lowering and boll development (Patil et.al., 2012) [6]. Reduction in relative water content and photosynthesis in cotton under water limited environment may be attributed to stomatal and non-stomatal factors (Flexas, *et al*., 2005 and Ennahli, et. al., 2005) [2]. A higher relative water content, chlorophyll content and chlorophyll stability Index under drought is a decisive for higher cotton production (Lopez, *et al*., 1995) [4]. The higher proline content under water stress condition is also important factor for higher seed cotton yield under drought condition.

There is a considerable variation in growth parameters plant height, plant dry weight, leaf area Index, specific leaf weight and productivity traits viz bolls / plant, boll weight and yield in relationto varying moisture deficit periods. The juvenile growth stages were more susceptible to water deficit (Seema Mohmood *et al* 2006) [8].

Therefore, development of drought resistant cotton cultivars has been a major cotton breeding objective. Hence present study was made on the genotypic variability among the cotton genotypes for growth, physiological parameters and yield characters focusing on identifying a suitable screening index for drought tolerance.

Materials and Methods

Twenty top performing genotypes of *G. bhirsutum* cotton were selected from across the country under All India coordinated cotton Improvement Project. The experiment was conducted at Cotton Research Station, Nanded. The experiment was sown in June during 2013-14 and 2014-15 with RBD design in three replication under rainfed (unprotected) as well as irrigated (Protected) condition. All cultural practices for cotton were followed.

The fully expanded leaf (fourth node from the top) was used for determination of all physiological parameters at 110 and 140 days after sowing. Seed cotton was picked from each plot at 180 days and recorded as yield and yield parameters. The stress indices and percent yield reduction was calculated by taking mean yield under irrigated and rainfed condition.

Results and Discussion

Twenty genotypes were evaluated for yield and yield components, physiological characters under rainfed and irrigated situation. The data on performance of different genotypes is presented in table 1 to 4.

Seed cotton yield (kg/ha)

Genotypes depicted significant differences for seed cotton yield which ranged in between 492 kg/ha (TCH 1777) to 1606 kg/ha (TSH 04-115) in unprotected and protected condition respectively. The Protected condition recorded highest mean of seed cotton yield (1220 kg/ha), whereas unprotected condition recorded lowest mean of seed cotton yield (749 kg/ha) with 33% yield reduction. The genotypes TSH-04-115 recorded significantly highest seed cotton yield (1606 kg/ha) followed by RAH-806 (1486 kg/ha) and BS-37 (1426 kg/ha) and BS-39 (1418 kg/ha) in protected condition, while genotype BS-37 (970 kg/ha), BS-39 (952 kg/ha),

NH-615 (940kg/ha), RABH-1353 (910 kg/ha) and TSH-04-115 (896 kg/ha), RAH-806 (894 kg/ha), GBHV-182 (886 kg/ha) and LRA-5166 (830 kg/ha) recorded significantly highest yield over other genotypes in unprotected condition. The genotypes ARBH-1352 (9%), GBHV-182 (12.1%), NDLH-1938 (13.9%), SCS-1213 (15.5%) and NH-615(28%) recorded lowest reduction in yield under unprotected condition. However, the highest percent yield reduction was recorded by AKH-09-05 (48.3%), GJH-516 (45.3%), TSH-04-115 (44.2%) and SCS-1062 (43.2%). Similar observations on cotton genotypic variability were recorded by Seema Mohamad *et al*. (2006) [8] and Patil B.C. *et al.* (2012) [6].

Yield stability index (YSI)

The highest YSI was observed in ARBH-1352(91.0), GBHV-1182(87.9), NDLH-1938(86.0) and SCS-1213(84.6). The lowest YSI was recorded by AKH -09-5(51.7), GJH-516(54.7), TSH—04-115(55.8) and SCS-1062 (56.8).

Drought susceptibility index(S)

The least susceptibility index (<1.0) was observed by ARBH-1352(0.27),GBHV-182(0.36),NDLH-1938(0.39),NH-615(0.43),SCS-1213(0.45),CCH-12-3(0.87),CNH-1110(0.90), BS-39(0.96)and BS -37 (0.97), whereas,the genotype AKH -09-5 recorded highest susceptibility index (1.45) followed by GJH-516(1.36),TSH-04-115(1.33)and SCS-1062(1.30).

Number of bolls/plant

The genotype TSH-04-115 (28.1) followed by NH-615(27.8), BS-37 (27.5) and BS-39 (24.6) recorded significantly highest no. of bolls/plant in protected condition. Whereas, the genotype TSH-04-115(14.8) followed by BS-37 (13.3), ARH-806 (14.2), GBHV-182 (13.1), NH-615 (12.9), BS-39(12.9), ARBH-1352 (12.9), GBHV-177 (12.0), PH-1060 (12.6), LRA-5166 (12.5) and NH-615 (12.4) recorded highest no. of bolls / plant in unprotected condition.

Boll weight (g)

The genotype, BS-39 (3.6 g) recorded significantly highest boll wt. (g) followed by BS-37 (3.4g), RAH-806 (3.3g), TSH-04-115 (3.3g), CNH-1110 (3.2g) and GBHV 182 (3.2g) in protected condition. Whereas the genotype viz. NH-615(3.1g), BS-39 (3.1 g), RAH-806 (2.9 g), SCS-1062 (2.4 g), GSHV-169 (2.8 g), NDLH-1943 (2.7 g) and GBHV-177 (2.7 g) recorded higher seed cotton yield in unprotected condition.

Physiological parameters

Specific leaf weight (SLW)

Among the genotype AKH-09-5 followed by NDLH-1938, RAH-806, GJH-516, GSHV-169 were recorded significantly highest specific leaf weight (SLW) in both protected and as well as unprotected condition at 110 and 140 DAS.

Leaf area index

In this experiment, the genotype TSH-04-115 recorded highest LAI followed by GBHV-182, CCH-12-3, PH-1060 ARBH-1352 and NDLH-1943, whereas, the strains *viz*. SCS-1213, GBHV-169, SCS-1062 GJH-516 and LRA-5166 (ZC) recorded lowest LAI in both protected and as well as in unprotected condition at 110 DAS and 140 DAS as compared to other genotypes.

Total chlorophyll content (mg/g)

Among the genotypes, NDLH-1943 recorded highest total chlorophyll content (3.25 mg/g) followed by RAH-806 (3.10 mg/g), NH-615 (3.1 mg/g), TSH-04-115(3.12 mg/g) and PH-1060 (3.12 mg/g) in protected condition, whereas the genotype PH-1060 (2.98 mg/g) BS-37 (2.40 mg/g), NH-615 (2.70 mg/g) LRA-5166(2.50mg/g) and NDLH-1943 (2.50 mg/g) were recorded highest total chlorophyll in unprotected condition at 110 DAS.

At 140 DAS, the genotype NDHL-1943 recorded highest chlorophyll (3.15 mg/g) followed by NH-615 (2.93 mg/g),LRA-5166, (2.77 mg/g) CNH-1110(2.99 mg/g) and BS-37 (2.75 mg/g) in protected condition, whereas PH-1060 recorded highest chlorophyll (2.60 mg/g) followed by LRA-5166 (2.60 mg/g), BS-37(2.03mg/g) and NH-615 (2.53 mg/g) in unprotected condition.

Chlorophyll stability index

The genotype NH-615 recorded lowest chlorophyll stability index followed by BS-37, NDLH-1938,SCS-1213,RAH-806 and CCH-12-3 in both protected and unprotected condition at 110 DAS and 140 DAS.

Relative water content (%)

The genotype NH-615 followed by TSH-04-115, SCH-1062, GBHV-182 and CNH-1110,RAH-806 and BS-37 were

recorded significantly highest relative water content (%) in both protected and unprotected condition at 110 DAS and 140 DAS as compared to all other genotypes.

In general, the values of relative water content (%) were higher at 110 DAS as compared to 140 DAS, whereas the values of RWC (%) were observed maximum in protected condition as compared to unprotected condition.

Proline content (%)

The genotype NH-615 followed by TSH-04-115, SCS-1213, GBHV-182, ARBH-1352 and NDLH-1938 were recorded significantly highest proline content (%) in both protected and unprotected condition at 140 DAS as compared to all other genotypes.

In general, the values of Proline content (%) were observed maximum in unprotected condition as compared to protected condition. It is also observed that the values of Prolinecontent (%) were correlated with RWC (%)

Table 1: Seed cotton yield (kg/ha) and yield contributing characters of cotton genotypes under protected and unprotected condition.

Sr. No.	Genotypes	Seed cotton yield kg / ha		Percent yield reduction	YSI	DSI (S)	No. of Bolls/Plant		Boll wt.(g)	
		Protected	Unprotected				Protected	Unprotected	Protected	Unprotected
1	TSH 04-115	1606	896	44.2	55.8	1.33	28.1	14.8	3.3	2.4
2	GBHV-182	1008	886	12.1	87.9	0.36	15.1	13.1	3.2	2.6
3	GBHV-177	1054	684	35.1	64.8	1.06	15.5	12.0	3.0	2.7
4	PH-1060	1093	736	32.7	67.3	1.0	15.2	12.6	2.8	2.5
5	CCH-12-3	738	523	29.3	70.8	0.87	16.5	10.4	2.9	2.6
6	GSHV-169	1123	772	31.3	68.7	0.093	17.5	12.6	3.1	2.8
7	TCH-1777	783	492	37.2	62.8	1.12	14.7	12.0	2.9	2.6
8	SCS-1213	678	574	15.5	84.6	0.45	15.8	11.8	3.0	2.4
9	SCS-1062	1394	792	43.2	56.8	1.30	19.4	12.0	2.8	2.8
10	AKH-09-5	1338	692	48.3	51.7	1.45	20.1	11.2	3.1	2.4
11	NDLH-1943	785	508	35.3	64.7	1.06	13.7	12.4	2.9	2.7
12	CNH-1110	974	677	30.5	79.5	0.90	15.3	10.5	3.2	2.4
13	ARBH-1352	1001	910	9.0	91.0	0.27	15.7	12.9	2.8	2.5
14	NDLH-1938	885	762	13.9	86.0	0.39	11.4	11.0	2.8	2.6
15	RAH-806	1486	894	39.8	60.2	1.21	24.6	14.2	3.3	2.9
16	BS-37	1426	970	32.0	68.0	0.97	26.5	13.3	3.4	2.3
17	BS-39	1418	952	32.2	67.8	0.96	27.6	12.9	3.6	3.1
18	GJH-516	1120	613	45.3	54.7	1.36	16.2	11.6	2.9	2.2
19	LRA-5166	1295	830	35.9	64.1	1.09	17.0	12.5	2.8	2.6
20	NH-615	1296	940	28.0	72.5	0.43	27.8	12.9	3.1	2.8
	G.M.	1220	749	33.1	68.8	0.90	17.1	12.1	2.88	2.62
	SE+	70.9	58.4	-	-	-	0.98	0.61	0.11	0.14
	CD @ 5%	195.8	161.5	-	-	-	2.7	1.85	0.36	0.40
	C.V. %	10.7	13.5	-	-	-	9.95	10.2	13.6	14.2

Table 2: Genotypic differences for specific leaf weight (SLW) and Leaf area index (LAI) in cotton genotypes under protected and unprotected condition

Sr. No.	Genotypes	SLW 110 DAS		SLW 140 DAS		LAI 110 DAS		LAI 140 DAS	
		Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
1	TSH 04-115	0.035	0.024	0.028	0.025	0.043	0.032	0.063	0.036
2	GBHV-182	0.030	0.026	0.027	0.023	0.041	0.036	0.050	0.048
3	GBHV-177	0.036	0.019	0.024	0.021	0.037	0.034	0.045	0.042
4	PH-1060	0.033	0.021	0.022	0.020	0.044	0.038	0.049	0.040
5	CCH-12-3	0.028	0.021	0.023	0.020	0.043	0.036	0.050	0.049
6	GSHV-169	0.033	0.030	0.032	0.030	0.035	0.034	0.057	0.036
7	TCH-1777	0.046	0.038	0.023	0.023	0.033	0.031	0.053	0.048
8	SCS-1213	0.037	0.030	0.024	0.023	0.032	0.030	0.040	0.032
9	SCS-1062	0.032	0.030	0.027	0.023	0.031	0.031	0.043	0.037
10	AKH-09-5	0.038	0.026	0.036	0.021	0.046	0.031	0.049	0.035
11	NDLH-1943	0.037	0.022	0.021	0.020	0.055	0.032	0.058	0.048
12	CNH-1110	0.031	0.028	0.028	0.025	0.044	0.028	0.051	0.043
13	ARBH-1352	0.028	0.024	0.022	0.020	0.042	0.038	0.049	0.043
14	NDLH-1938	0.032	0.031	0.032	0.023	0.054	0.031	0.051	0.041
15	RAH-806	0.046	0.032	0.028	0.028	0.045	0.031	0.049	0.043
16	BS-37	0.027	0.026	0.027	0.025	0.036	0.034	0.044	0.043
17	BS-39	0.037	0.021	0.025	0.023	0.033	0.039	0.048	0.040
18	GJH-516	0.042	0.035	0.039	0.022	0.033	0.027	0.036	0.029
19	LRA-5166	0.041	0.034	0.021	0.020	0.035	0.031	0.044	0.039
20	NH-615	0.028	0.025	0.026	0.023	0.044	0.029	0.051	0.044
	G.M.	0.031	0.025	0.029	0.036	0.036	0.034	0.046	0.040
	SE+	0.006	0.003	0.004	0.005	0.004	0.003	0.006	0.003
	CD @ 5%	0.18	0.11	0.13	0.15	0.012	0.012	0.18	0.012
	C.V. %	5.18	2.54	3.64	3.7	7.5	6.5	6.5	8.2

Table 3: Genotypic differences for Chlorophyll content and Chlorophyll Stability Index (CSI) in cotton genotypes under protected and unprotected condition.

Sr. No.	Genotypes	Chlorophyll content (mg/g) 110 DAS		Chlorophyll content (mg/g) 140 DAS		CSI 110 DAS		CSI 140 DAS	
		Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
1	TSH 04-115	3.12	2.40	2.71	2.10	0.032	0.022	0.029	0.027
2	GBHV-182	2.10	2.00	1.99	1.61	0.038	0.029	0.033	0.027
3	GBHV-177	2.30	2.01	2.52	1.98	0.080	0.068	0.075	0.068
4	PH-1060	3.12	2.98	2.93	2.60	0.055	0.040	0.048	0.037
5	CCH-12-3	2.88	2.40	2.59	2.35	0.039	0.028	0.032	0.025
6	GSHV-169	2.82	2.10	2.85	2.20	0.078	0.065	0.066	0.052
7	TCH-1777	2.20	1.80	2.42	1.69	0.090	0.068	0.088	0.078
8	SCS-1213	1.90	1.70	1.85	1.52	0.032	0.025	0.026	0.015
9	SCS-1062	3.04	2.40	2.90	1.96	0.071	0.060	0.090	0.085
10	AKH-09-5	2.08	1.33	1.91	1.20	0.090	0.083	0.110	0.098
11	NDLH-1943	3.25	2.50	3.15	2.46	0.115	0.101	0.080	0.077
12	CNH-1110	2.58	2.03	2.99	1.90	0.065	0.053	0.088	0.075
13	ARBH-1352	2.92	2.11	2.75	2.01	0.155	0.125	0.138	0.127
14	NDLH-1938	2.90	1.98	2.68	1.82	0.41	0.025	0.028	0.019
15	RAH-806	3.10	2.06	2.91	1.98	0.039	0.028	0.032	0.025
16	BS-37	2.98	2.41	2.75	2.03	0.037	0.020	0.030	0.022
17	BS-39	2.55	2.11	2.40	1.90	0.061	0.055	0.052	0.040
18	GJH-516	2.90	2.42	2.80	2.10	0.038	0.030	0.050	0.045
19	LRA-5166	2.96	2.48	2.77	2.60	0.040	0.038	0.045	0.035
20	NH-615	3.10	2.7	2.93	2.53	0.022	0.020	0.020	0.016
	G.M.	3.71	2.19	2.67	2.07	0.100	0.056	0.059	0.052
	SE+	0.09	0.07	0.060	0.037	0.004	0.005	0.006	0.003
	CD @ 5%	0.275	0.212	0.183	0.123	0.014	0.016	0.019	0.01
	C.V. %	10.4	12.6	11.2	9.42	7.12	5.7	10.5	13.4

Table 4: Genotypic differences for relative water content (RWC) and Proline content in cotton genotypes under protected and unprotected condition.

Sr. No.	Genotypes	RWC (%) 110 DAS		RWC (%) 140 DAS		Proline content (%) 140 DAS	
		Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
1	TSH 04-115	80.6	70.9	67.9	56.2	2.582	2.870
2	GBHV-182	77.5	70.3	68.6	53.4	2.440	2.735
3	GBHV-177	79.8	72.4	62.5	54.4	2.010	2.235
4	PH-1060	60.7	50.5	67.1	53.6	1.985	2.117
5	CCH-12-3	70.1	57.0	67.8	45.6	1.270	2.540
6	GSHV-169	72.6	67.1	57.7	54.4	2.180	2.310
7	TCH-1777	69.8	61.5	58.1	54.1	2.140	2.400
8	SCS-1213	73.7	64.5	70.0	53.9	2.430	2.750
9	SCS-1062	74.0	72.8	64.6	56.1	2.210	2.435
10	AKH-09-5	66.6	61.8	60.5	56.4	2.160	2.380
11	NDLH-1943	81.3	67.2	60.5	38.8	1.112	2.110
12	CNH-1110	75.2	62.5	67.1	55.8	2.240	2.370
13	ARBH-1352	70.5	56.4	65.3	51.5	2.300	2.512
14	NDLH-1938	75.2	57.6	61.2	51.1	2.500	2.810
15	RAH-806	75.0	67.5	69.9	55.6	2.210	2.340
16	BS-37	77.2	60.3	69.0	53.1	2.117	2.310
17	BS-39	80.1	62.5	62.2	50.3	2.230	2.480
18	GJH-516	77.2	60.3	69.7	52.2	1.765	2.070
19	LRA-5166	76.2	57.5	50.2	49.9	1.501	1.987
20	NH-615	75.8	60.2	59.7	57.3	2.510	2.560
	G.M.	72.7	63.0	63.6	52.6	2.094	2.416
	SE+	2.1	1.52	1.81	0.60	0.09	0.11
	CD @ 5%	6.2	4.22	5.0	1.7	0.28	0.30
	C.V. %	4.8	4.36	4.7	3.1	3.3	2.4

Conclusion

The cotton genotypes TSH-04-115, RAH-806 recorded more seed cotton yield in irrigated condition but high DSI (more than 1.2). These lines can be used in breeding programme for moisture stress tolerance as well as for yield stability. Where BS-37, BS-39, NH-615, GBHV-182 and ARBH-1352 recorded moderate yield with low DSI (less than 1.0). These are the genotypes suitable for stress condition. However the least yield was recorded by CCH-12-3, SCS-1213 CHH-1110 and NDLH-1938 and these showed low DSI (less than 1.0) but TCH-177 NDLH-1943, SCS-1062, AKH-09-5 and GJN-516 recorded low yield as well as highest DSI (more than 1.2) which are undesirable features for drought condition.

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