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Research Article

Evaluation of early maturing advanced breeding lines of rabi sorghum for drought tolerance

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Abstract

Sorghum (*Sorghum bicolor* (L.) Moench) is a C_4 grass plant, originated from the tropics and generally from more heat and drought tolerant regions. In present study the experiments were conducted in a split plot design with three replications during post-rainy season 2020-21 at Centre on Rabi Sorghum (ICAR-Indian Institute of Millets Research) Solapur under three levels of water regimes (three environments) along with four checks *viz.,*PhuleSuchitra, CSV-26, PhuleAnuradha& M35-1. Drought tolerant and susceptible genotypes were categorized on the basis of Stress Susceptible Index (SSI), Weighted Geometric Mean index (WGMI) and regression line. Growth Stage -I correlation coefficient between maturity, plant height and panicle length [0.46] was positive and significant which indicates that as plant height and maturity increases, panicle length also increases. Growth Stage – II correlation coefficient between panicle length and peduncle length [0.62**] was positive and significant,which shows higher the peduncle length, higher will be the panicle length and it is directly related to higher stover yield. Under all environments it was observed that, higher the peduncle length, earlier will be the flowering. Under GS-1, GS-II and Well Wateredenvironment Correlation between days to 50% flowering, maturity of the plant were [0.44**], [0.56**] and [0.57**] respectively showed positive and significant relationship under all environments. This is the common trait found in all environments. In water stress conditions Phulesuchitra (20.07) and DTE-14 (21.14) varieties gave high grain yield as compared to other early varieties. In physiological experiment,stomatas were observed in stem leaf and flag leaf which showed that flag leaf played important role in photosynthesis and supply of more energy to the plant for growth and development. The results are first of its kind observed under this study.**

Keywords: Drought stress, WGMI, growth stages, physiological traits, stomata

1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is a C_4type plant belonging to the family Poaceae. It is one of the important dry-land crops of semi-arid tropics and fifth most important cereal crop worldwide after rice, wheat, maize and barley (Kholova*et al.,* 2013). In India, post-rainy season (planting time following a rainy season) sorghum is very crucial for food and fodder security in the drought prone areas and the crop is mostly grown in the states of Maharashtra, Karnataka, Andhra Pradesh and Telangana where occurrence of drought is very common. It is cultivated for dual purpose i.e. grain and fodder in both rainy and post-rainy seasons. Grain and fodder of post-rainy harvest fetches more prices because of good quality grain and fodder. World over sorghum

is cultivated in nearly 42.10 million ha with an annual production of 59.30 million tons (FAOSTAT, 2018). Among sorghum producing countries, India ranks first in terms of area but fourth to the USA, and for total production (FAOSTAT, 2018). India produces 4.80 million tons of sorghum from 4.96 million ha of land (FAOSTAT, 2018).It is important to consider that though the area under sorghum cultivation is declining from year to year, the production levels have not declined drastically owing to adoption of improved cultivars. Maharashtra is the largest producer of sorghum in India and occupies almost 35% of the total cultivated area and 41.5% of the total production of sorghum in the country. Karnataka and Madhya Pradesh are second and third largest producers of sorghum in the country respectively. These three states together contribute around 62% in the total production. Andhra Pradesh, Rajasthan, and Tamil Nadu are the other major sorghum producing states in India.

In Sorghum, the grain yield is affected by various abiotic factors, among them; drought is one of the primary cause for low yield. Even though past achievements in the field of rabi sorghum improvement are remarkable, much needs to be done as average yields of rabi sorghum in Maharashtra is low. In post-rainy season sorghum, fodder quality may suffer due to senescence as the crop is grown on residual moisture and often experiences severe terminal drought stress. Developing plant type for water limited conditions could be advantageous and is the major challenge for sorghum improvement programme. Stay-green or delayed senescence is an important trait associated with drought tolerance (Rosenow 1977). It is indicated by maintenance of green stems and upper leaves when water is limiting during grain filling. Sorghum genotypes with the stay-green trait continue to fill their grains normally even under limited water or moisture stress conditions (Rosenow and Clark 1981, Borrell et al. 2000).Drought tolerance in rabi sorghum, is considered to be the product expression of many morphological, physiological and biochemical traits, therefore it is necessary to understand the traits conferring drought tolerance in rabi sorghum. Exploration of drought escape mechanism by developing early maturing genotypes could be the one strategy to develop drought tolerant varieties (Patroti et al., 2021).Delaying the onset of leaf senescence and reducing its rate offer an effective strategy for increasing grain production, fodder quality and grain crop residues, particularly under water limited conditions. Several strategies have been deployed to evaluate and isolate drought tolerant material as a part of national breeding programme at CRS (IIMR, RS) Solapur. In the present study an effort was made to evaluate 21early maturing advanced breeding lines possessing stay-green traitfor drought tolerance.

2. Materials and Methods

The field experiment consisted of 21 early maturing advanced breeding lines of post rainy season sorghum along with four checks was conducted in a split plot designwith three replications during rabi2020-21at Centre on Rabi sorghum (ICAR-Indian Institute of Millets Research) Solapur (Latitude: 17°40 N, Longitude: 75°54 E, Altitude: 473m above sea level) located in Maharashtra, India. The main plots consisted of three levels of moisture regimes (three environments) namely i) drought stress environment at GS1 stage (vegetative phase 20-35 days after sowing) without irrigation after, ii) drought stress environment at GS2 Stage (pre-anthesis 40-55 days after sowing) without irrigation after and iii) well watered (non-stress) environment, where irrigation was given as per need of the crop. The subplots consisted of 25 genotypes including four check varieties (PhuleSuchitra, CSV-26, PhuleAnuradha and M 35-1). These check varieties were usually used in the yield evaluation trials of All-India Co-ordinated Research Project on Sorghum as drought tolerant and high yielding genotypes. Each genotype was sown in three rows of 3m length, with a spacing of 45cm between rows and 15cm between plants. Soil moisture content was determined gravimetrically during the post-rainy season 2020-21. Data were collected according to the Standard Key Descriptor Lists for Characterizations for sorghum (IIMR and ICRISAT 1984). Data were recorded for grain yield (q/ha),measured as the overall weight of the grains obtained from panicles in a given plot size after threshing (g)stover yield (q/ha), days to 50 per cent flowering (days), measured as days at which 50% of the plants in a plot exhibits anthesis, peduncle length (cm), measured as distance between top most internode to the bottom of the panicle and panicle emergence (per cent), measured as distance between flag leaf to the bottom of the panicle. Stay green score (0-9) and number of stomata's on upper and lower surface of the flag leaf and other leaves. All the recommended cultural practices were adopted during the crop growth period to raise better experiment.

Calculation of SSI, WGMI and Statistical Analyses

WGMI was calculated by the formula as given below.

$$\text{Weighted Geometric Mean Index } \mathbf{(WGMI) = Antilog} \ \frac{\sum W \log X}{\sum W}$$

W=weight and X = variable

$$\text{W for drought stress at GS1 stage} = \frac{\text{Experimental mean yield under well watered moisture regime}}{\text{Experimental mean yield under water stress at GS1 stage}}$$

$$\text{W for drought stress at GS2 stage} = \frac{\text{Experimental mean yield under well watered moisture regime}}{\text{Experimental mean yield under water stress at GS2 stage}}$$

$$\text{W for well watered} = \frac{\text{Experimental mean yield under well watered moisture regime}}{\text{Experimental mean yield under well watered moisture regime}} = 1$$

Logic behind use of WGMI was when large weights have to be given to small items and small weights to large items, under such circumstances WGMI is most suitable (Gupta 1989). Calculated weights were common to all genotypes in respective environments in order to make experimental yield approximately in equal proportion in all genotypes. Genotypes having higher WGMI than summation of mean WGMI and standard deviation of WGMI were categorized as tolerant, only higher than mean WGMI were categorized as moderately tolerant and lower than mean WGMI were categorized as susceptible. Same criteria were applied to categorize genotypes for wide adaptability (suitable under all environments) and moderate adaptability. In case of SSI genotypes having value less than or equal to one were categorized as tolerant and higher than one as susceptible. WGMI were calculated using Microsoft Excel programme. Data in split plot design was analysed as per method given by Panse and Sukhatme 1976 using Web Agri. Stat Package (WASP) developed by ICAR-Central Coastal Agricultural Research Institute, Goa.

3. Results

3.1 Soil moisture content

Crop was irrigated after sowing for uniform germination to maintain optimum plant population. The data on soil moisture content indicated that under GS1 environment moisture content at 15 cm soil depth varied from 30.77 to 14.36 per cent and at 30 cm soil depth varied from 32.92 to 16.11 per cent. Under GS2 environment at 15 cm soil depth moisture content varied from 34.78 to 19.01 per cent, and at 30 cm soil depth varied from, 30.4to 23.9 per cent. Under Well Watered environment at 15 cm depth varied from 33.55 to 32.52 per cent, whereas at 30 cm depth varied from 32.96 to 35.44 per cent. Soil moisture data indicated that crop grown under GS1 environment suffered more due to water stress till maturity from 30 days after sowing (DAS) than GS2 environment, whereas crop grown under GS2 environment suffered due to water stress after 45 Days After Sowing. Crop grown under WW environment did not suffer from water stress and maintained soil moisture content almost at field capacity throughout crop growing season in comparison with GS1 and GS2 environments (Table 2).

3.2 Grain and stover yield performance under GS1, GS2 and WW environments

Analysis of variance indicated that both the variances due to genotypes and environments during post-rainy season 2020-21 were highly significant ($P<0.01$) for grain and stover yield (Tables 3, 5). Drought stress consistently lowered the yield of genotypes under GS1, GS2 than WW environment. Mean grain yield during post-rainy season were 19.16, 30.01and 36.99q ha^{-1} (Table 4) and mean stover yield were 42.15, 53.08 and 72.86q ha^{-1}under GS1, GS2 and WW environments respectively (Table 6). The grain yield varied from 28.80 q ha^{-1} in genotype DTE 1 to 52.675 q ha^{-1} in genotype DTL 6 under GS1 environment, 29.63q ha^{-1} in genotype DTE 4 to 28.42 q ha^{-1} in genotype CRS 92 under GS2 environment, 14.37 q ha^{-1} in genotype DTE 10 to 71.60 q ha^{-1} in genotype DTE 14 under WW environment (Table 6).

Table 1: Pedigree of breeding material

Sr. No.	Pedigree	Genotypes
1	BP 53 X 185 A X fodder. F5(122-123)	DTE 1
2	BP 53 X 185 A X S. sorghum TY -2 R -2 (19)	DTE 2

3	BP-53 X 185 A X S. sorghum TY-2 R-3(19)	DTE 3
4	BP-53 X 185 A X S. sorghum TY-1 R -2 (1)	DTE 4
5	BP-53 X 185 AX S. sorghum TY-2 R-2 (16)	DTE 5
6	BP-53 X 185 AX S.sorghum TY-1 R-3 (11)	DTE 6
7	BP-53 X 185 AX S.sorghum TY-2 R-3(8)	DTE 7
8	CRS-97	CRS 97
9	CRS-98	CRS 98
10	BP 53 X S.sorhum TY-1 R-2 (12)	DTE 8
11	BP-53X 185AX S.sorghum TY-2 R-2(3)	DTE 9
12	BP-53X 185AX S.sorghum TY-2 R-1(12)	DTE 10
13	P.Anuradha X 185A X S.sorghum TY-2 R-2(20)	DTE 11
14	BP-53 X 185A X S.sorghum TY-1 R-1 (7)	DTE 12
15	SolapurDagadi X P. Anuradha X P.Anuradha X BP-53	DTE 13
16	P.Anuradha X RPRT-53 TY-5 R-1 (19)	DTE 14
17	P.Anuradha X 185A X S.sorghum TY-2 R-1(2)	DTE 15
18	P.Anuradha X 185 A X S.sorghum TY-5 R-3(7)	DTE 16
19	P.Anuradha X 185A X S.sorghum TY-2 R-1(5)	DTE 17
20	M 35 l X E-228	DTE 18
21	CRS.102	CRS 102
22	PhuleSuchitra	P.suchitra
23	CSV-26	CSV-26
24	Phule .Anuradha	P.Anuradha
25	M 35-1	M 35-1

Table 2: Soil moisture content (%) under GS1, GS2 and WW environments

Time of Irrigation	Soil Depth	GS1 Stage	GS2 Stage	Well Watered
Sowing	15 cm	30.77	34.78	33.55
	30 cm	32.92	30.4	32.96
45 DAS	15 cm	32.93	34.99	33.31
	30 cm	32.39	33.58	35.64
60 DAS	15 cm	20.57	34.9	32.32
	30 cm	23.6	31.91	32.59
80 DAS	15 cm	14.36	19.01	32.52
	30 cm	16.11	23.9	35.44

Table 3: Analysis of variance for grain yield q/ha

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Replications	2	5.281	2.640	-	-
Environments	2	12104.020	6052.010	57.630	0.001
Error (a)	4	420.062	105.016	-	-
Genotypes	24	2080.307	86.679	2.727	0.000

Environments x genotypes	48	1928.910	40.186	1.264	0.147
Error (b)	144	4577.351	31.787	-	-
Total	224	-	-	-	-

Coefficient of Variation (a) = 35.683; Coefficient of Variation (b) = 19.632

Table 4: Grain yield (q/ha) and weighted geometric mean index under GS1, GS2 and All Environments (AE)

Sr. No.	Genotypes	GS1	GS 2	WW	WGMI GS 1	WGMI GS2	WGMI AE
1	DTE 1	18.362	28.091	31.341	22.04	29.50	23.68
2	DTE 2	13.194	26.148	39.358	19.16	31.41	21.00
3	DTE 3	19.243	32.708	49.21	26.51	39.28	28.21
4	DTE 4	20.634	32.872	33.119	24.25	32.98	26.53
5	DTE 5	22.206	32.93	43.169	27.86	37.18	29.27
6	DTE 6	25.852	33.268	44.79	31.19	38.01	31.79
7	DTE 7	20.444	32.395	35.737	24.74	33.85	26.79
8	CRS 97	20.502	30.321	39.572	25.66	34.17	26.96
9	CRS 98	23.086	29.975	38.461	27.48	33.52	28.19
10	DTE 8	16.979	34.831	45.49	23.77	39.26	26.61
11	DTE 9	18.749	29.169	34.913	23.18	31.62	24.81
12	DTE 10	17.909	30.288	36.963	22.93	33.12	24.90
13	DTE 11	17.827	30.946	37.49	22.98	33.73	25.09
14	DTE 12	18.296	30.197	38.37	23.56	33.62	25.35
15	DTE 13	16.642	40.272	38.222	22.10	39.34	26.39
16	DTE 14	21.136	24.979	31.819	24.30	27.84	24.50
17	DTE 15	21.473	28.337	35.44	25.48	31.33	26.29
18	DTE 16	19.325	35.177	39.226	24.61	36.94	27.35
19	DTE 17	15.967	25.094	34.823	20.84	29.07	22.01
20	DTE 18	16	24.815	33.301	20.55	28.31	21.73
21	CRS 102	17.712	27.58	45.465	24.43	34.51	25.32
22	PhuleSuchitra	20.066	29.037	31.391	23.38	30.07	24.92
23	CSV-26	15.399	23.103	25.482	18.29	24.14	19.60
24	PhuleAnuradha	16.387	30.057	31.531	20.49	30.71	22.95
25	M 35-1	25.588	27.687	29.942	27.00	28.68	27.20
	Mean	19.16	30.01	36.99	23.87	32.89	25.50
	weights	1.93	1.23	1.00			
	SD				2.89	3.96	2.71
		CD 5%	CD 1%				
	Environments	4.645	7.705				
	Genotypes	5.209	6.846				
	Environments x Genotypes	9.023	11.858				

Table 5: Analysis of variance for stover yield (q/ha)

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Replications	2	262.269	131.135	-	-
Environments	2	34735.791	17367.896	761.367	0.000
Error (a)	4	91.246	22.811	-	-
genotypes	24	15180.570	632.524	4.900	0.000
Environments x genotypes	48	14997.872	312.456	2.421	0.000
Error (b)	144	18586.667	129.074	-	-
Total	224	-	-	-	-

Coefficient of Variation (a) = 8.557; Coefficient of Variation (b) = 20.355

Table 6: Stover yield (q/ha) under GS1, GS2 and WW environments WGMI for GS1, GS2 and All Environments (AE)

S. No	Genotypes	GS1	GS2	WW	WGMI GS1	WGMI GS2	WGMI AE
1	DTE 1	28.81	55.14	94.65	44.54	69.26	47.83
2	DTE 2	42.80	40.33	69.14	51.02	50.63	47.16
3	DTE 3	37.04	64.20	70.78	46.95	66.90	52.13
4	DTE 4	42.80	35.39	95.47	57.42	53.80	48.85
5	DTE 5	38.68	56.79	53.50	43.56	55.38	47.60
6	DTE 6	52.68	52.68	67.49	57.68	58.48	55.96
7	DTE 7	51.03	61.73	91.36	63.16	72.83	62.68
8	CRS 97	35.39	39.51	62.55	43.60	47.96	42.19
9	CRS 98	44.44	53.50	86.42	56.70	65.50	55.61
10	DTE 8	43.62	61.73	79.01	54.23	68.50	56.62
11	DTE 9	51.03	36.21	51.85	51.33	42.14	45.68
12	DTE 10	34.57	29.63	52.68	40.33	37.77	36.39
13	DTE 11	47.74	54.32	60.91	52.19	57.01	52.89
14	DTE 12	45.27	50.21	60.08	50.21	54.16	50.21
15	DTE 13	41.98	67.49	90.54	55.63	76.40	59.34
16	DTE 14	46.09	71.61	83.95	57.41	76.58	61.81
17	DTE 15	41.30	51.85	78.19	52.17	61.66	52.07
18	DTE 16	35.39	63.37	90.95	50.01	73.81	54.13
19	DTE 17	37.00	37.86	45.00	39.75	40.72	39.11
20	DTE 18	37.86	56.79	66.67	46.58	60.76	49.77
21	CRS 102	42.80	57.82	80.66	53.98	66.54	55.23
22	PhuleSuchitra	48.56	65.84	83.13	59.13	72.65	61.29
23	CSV-26	41.15	54.32	61.73	47.74	57.33	49.85
24	PhuleAnuradha	45.27	57.61	66.67	52.16	61.27	53.92
25	M 35-1	40.47	51.03	78.19	51.51	61.10	51.35
	Mean	42.15	53.08	72.86	51.16	60.36	51.59
	Weigths	1.73	1.37	1.00	4.10		

SD			5.98	10.94	6.60
-	CD 5%	CD 1%			
Environments	2.165	3.591			
Genotypes	10.497	13.796			
Environments x Genotypes	18.182	23.896			

Table 7: Analysis of variance for stomata on lower flag leaf

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Replications	2	430.602	215.301	-	-
Environments	2	501.482	250.741	3.425	0.136
Error (a)	4	292.844	73.211	-	-
genotypes	24	608.307	25.346	1.267	0.197
Environments x genotypes	48	1315.073	27.397	1.370	0.080
Error (b)	144	2880.720	20.005	-	-
Total	224	-	-	-	-

Coefficient of Variation (a) = 32.001; Coefficient of Variation (b) = 16.728

Table 8: Analysis of variance for stomata on upper flag leaf

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Replications	2	134.462	67.231	-	-
Environments	2	557.802	278.901	11.968	0.021
Error (a)	4	93.218	23.304	-	-
genotypes	24	234.527	9.772	1.470	0.087
Environments x genotypes	48	441.087	9.189	1.383	0.074
Error (b)	144	956.987	6.646	-	-
Total	224	-	-	-	-

Coefficient of Variation (a) = 28.682; Coefficient of Variation (b) = 15.316

Table 9: Analysis of variance for stomata on lower stem leaf

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Replications	2	123.696	61.848	-	-
Environments	2	1658.176	829.088	12.346	0.019
Error (a)	4	268.618	67.154	-	-
genotypes	24	1266.562	52.773	1.282	0.186
Environments x genotypes	48	1522.158	31.712	0.771	0.850
Error (b)	144	5925.520	41.149	-	-
Total	224	-	-	-	-

Coefficient of Variation (a) = 35.417; Coefficient of Variation (b) = 27.724

Table 10: Analysis of variance of stomata on upper stem leaf

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Replications	2	76.949	38.474	-	-
Environments	2	506.836	253.418	11.003	0.024
Error (a)	4	92.124	23.031	-	-
genotypes	24	269.149	11.215	1.146	0.303
Environments x genotypes	48	369.164	7.691	0.786	0.831
Error (b)	144	1409.427	9.788	-	-
Total	224	-	-	-	-

Coefficient of Variation (a) = 31.777; Coefficient of Variation (b) = 20.716

Table 11: Stomata number in lower flag leaf, upper flag leaf, lower leaf and upper leaf under 40 X microscopic field.

Env.	Lower Flag leaf	Upper Flag leaf	Lower leaf	Upper leaf
GS1	26.58	16.47	24.22	15.40
GS2	24.99	15.11	19.41	13.13
WW	28.64	18.91	25.79	16.77
Mean	26.74	16.83	23.14	15.10
Total	43.57		38.24	

Analysis of variance showed that no significant differences were observed for genotypes and environments condition for stomata on lower flag leaf, upper flag leaf, lower stem leaf and upper stem leaf respectively (Table 7 to 10). Mean stomata (26.74, 16.83, 23.14, 15.10)were on lower flag leaf, upper flag leaf, lower stem leaf and upper stem leaf respectively (Table 11). The results showed that lower surface of leaf have greater number of stomata than upper surface of flag leaf as well as stem leaves. T test showed flag leaf stomata (43.57) were significantly higher than stem leaf stomata (38.24), this showed that flag leaf played an important role in photosynthesis and supply of more energy to plant for growth and development. This kind of first report observed under this study (Table 11).

Table 12. Correlation among the traits in GS 1

	GY	SY	DF	DM	PH @45 DAS	PH @ Maturity	PE	PL	Ped L	100 SW	LS
GY	1.00										
SY	0.25	1.00									
DF	0.30	-0.05	1.00								
DM	0.00	0.10	0.15	1.00							
PH @ 45 DAS	-0.32	-0.23	-0.57**	0.03	1.00						
PH @ Maturity	0.13	-0.12	0.44**	0.28	-0.07	1.00					
PE	-0.02	-0.14	-0.48**	0.07	0.39*	-0.24	1.00				
PL	-0.13	-0.07	0.00	0.20	-0.12	0.46**	0.00	1.00			

Ped L	-0.13	-0.19	-0.48**	-0.10	0.18	0.11	0.01	0.25	1.00		
100 SW	-0.07	0.05	-0.38*	-0.41	0.31	-0.30	-0.02	-0.38*	0.24	1.00	
LS	-0.23	-0.12	-0.65**	-0.29	0.64	-0.26	0.50	-0.11	0.28	0.38*	1

Significant at 5 per cent levels ** Significant at 1 per cent levels

Table 13. Correlation among the traits in GS 2

	GY	**SY**	**DF**	**DM**	**PH @45 DAS**	**PH @ Maturity**	**PE**	**PL**	**Ped L**	**100 SW**	**LS**
GY	1.00										
SY	0.23	1.00									
DF	-0.22	0.58**	1.00								
DM	0.34	0.59**	0.36*	1.00							
PH @45 DAS	0.37*	-0.41*	-0.83**	-0.14	1.00						
PH @ Maturity	-0.13	0.43**	0.56**	0.34	-0.41*	1.00					
PE	0.00	0.13	-0.02	0.34	-0.04	-0.26	1.00				
PL	-0.24	-0.06	-0.04	-0.01	-0.19	0.28	0.07	1.00			
Ped L	-0.27	-0.39*	-0.15	-0.24	-0.15	0.27	0.01	0.62**	1.00		
100 SW	0.49*	-0.34	-0.52**	-0.12	0.37*	-0.32	0.16	-0.10	0.20	1.00	
LS	-0.16	-0.48	-0.53**	-0.44**	0.47**	-0.34	0.02	0.27	0.03	0.08	1

Significant at 5 per cent levels ** Significant at 1 per cent levels

Table 14. Correlation among the traits under well watered condition

	GY	**SY**	**DF**	**DM**	**PH @45 DAS**	**PH @ Maturity**	**PE**	**PL**	**Ped L**	**100 SW**	**LS**
GY	1.00										
SY	-0.05	1.00									
DF	-0.39	0.59	1.00								
DM	0.14	0.54	0.32	1.00							
PH @45 DAS	0.57	-0.33	-0.74**	-0.26	1.00						
PH @ Maturity	-0.22	0.35	0.57**	0.14	-0.17	1.00					
PE	0.18	-0.21	-0.11	0.27	0.15	0.20	1.00				
PL	-0.31	-0.26	0.05	-0.07	0.07	0.48**	0.39*	1.00			
Ped L	0.16	-0.23	-0.30	-0.15	0.27	0.17	0.00	0.27	1.00		
100 SW	0.20	-0.02	-0.45**	-0.14	0.23	-0.45	-0.45	-0.35*	0.01	1.00	
LS	-0.17	0.33	0.34	-0.02	-0.04	0.19	0.01	-0.03	-0.51**	-0.25	1.00

Significant at 5 per cent levels ** Significant at 1 per cent levels

4. Discussion

Drought tolerant genotypes for grain and stover yield based on WGMI during post rainy season 2020-21

Mostly SSI has been used for selection of drought tolerant genotypes in different crop plants (Bonea and Urechean 2011; Kamrani*et al.* 2018). Though WGMI is well known, but it has been first time used as an indicator in plant breeding experiments to identify and select drought tolerant genotypes and has been reported by Samdur*et al.*(2017) and Samdur*et al.* (2020). These were the only reports available in the proposed area and hence, genotypes identified on the basis of WGMI as per classification given by Samdur*et al.* (2020) were discussed. On the basis of WGMI for grain yield under GS1 environment, four genotypes *viz.* DTE 14, DTE6, PhuleSuchitra and DTE, were found to be tolerant, 9 genotypes were found to be moderately tolerant *viz.,* DTE 9, M35-1, PhuleAnuradha, DTE 15, DTE 11, CRS 102, DTE 8, DTE 13 CRS 98, and DTE and remaining 13 genotypes were found to be susceptible. Under GS2 environment 5 genotypes (PhuleSuchitra, DTE 7, DTE 16, DTE 13, and DTE 14)were found to be tolerant and 9genotypes viz., DTE 18, M35-1, PhuleAnuradha, DTE 15, CRS 98, CRS 102, DTE 3, DTE 8, and DTE 1were found to be moderately tolerant. Under AE, four genotypes (DTE 13, PhuleSuchitra DTE 14 and DTE 7) were found to be wide adaptable, and eight genotypes (DTE 15, DTE 3, PhuleAnuradha, DTE 16, CRS 102, CRS 98, DTE 6, and DTE 8) were found to be moderately widely adaptable.

On the basis of WGMI for stover yield under GS1 environment 4 genotypes *viz.,* DTE 14, DTE 6, PhuleSuchitra, and DTE 7 were found to be tolerant and 10 genotypes *viz.,* DTE 9, M35-1, PhuleAnuradha, DTE 15, DTE 11, CRS 102, DTE 8, DTE 13, CRS 98, and DTE 14 were found to be moderately tolerant. Under GS2 environment 5 genotypes *viz.,*PhuleSuchitra, DTE 7, DTE 16, DTE 13, and DTE 14 were found to be tolerant, and eight genotypes DTE 18, M35-1, PhuleAnuradha, DTE 15, CRS 98, CRS 102, DTE 8,and DTE 1,were found to be moderately tolerant. Under AE 3 genotypes PhuleSuchitra, DTE 14, and DTE 7, were found to be widely adaptable and 10 genotypes DTE 15, DTE 3, DTE 11, PhuleSuchitra, DTE 16, CRS 102, CRS 98, DTE 6, DTE 8 and DTE 13were found to be moderately widely adaptable.

Conclusion

Post rainy season sorghum mostly value as dual purpose crop, where both grain and stover is important as for as its consumption is concern. On the basis of evaluation at different water regimes and new index WGMI, PhuleSuchitra, DTE 14, and DTE 7, were found to be widely adaptable and ten genotypes *viz.,*DTE 15, DTE 3, DTE 11, PhuleSuchitra, DTE 16, CRS 102, CRS 98, DTE 6, DTE 8 and DTE 13were found to be moderately widely adaptable.On the basis of WGMI for grain yield under GS1 environment four genotypes *viz.* DTE 14, DTE6, PhuleSuchitra and DTE were found to be tolerant, nine genotypes were found to be moderately tolerant *viz.,* DTE 9, M35-1, PhuleAnuradha, DTE 15, DTE 11, CRS 102, DTE 8, DTE 13 CRS 98, and DTE and remaining 13 genotypes were found to be susceptible. Under GS2 environment five genotypes (PhuleSuchitra, DTE 7, DTE 16, DTE 13, and DTE 14)were found to be tolerant and nine genotypes *viz.,* DTE 18, M35-1, PhuleAnuradha, DTE 15, CRS 98, CRS 102, DTE 3, DTE 8, and DTE 1were found to be moderately tolerant. Under AE, 4 genotypes (DTE 13, PhuleSuchitra DTE 14 and DTE 7) were found to be wide adaptable, and eight genotypes (DTE 15, DTE 3, PhuleAnuradha, DTE 16, CRS 102, CRS 98, DTE 6, and DTE 8) were found to be moderately widely adaptable. On the basis of WGMI for stover yield under GS1 environment 4 genotypes *viz.,* DTE 14, DTE 6, PhuleSuchitra, and DTE 7 were found to be tolerant and 10 genotypes *viz.,* DTE 9, M35-1, PhuleAnuradha, DTE 15, DTE 11, CRS 102, DTE 8, DTE 13, CRS 98, and DTE 14 were found to be moderately tolerant. Under GS2 environment five genotypes *viz.,*PhuleSuchitra, DTE 7, DTE 16, DTE 13, and DTE 14 were found to be tolerant, and eight genotypes *viz.,*DTE 18, M35-1, PhuleAnuradha, DTE 15, CRS 98, CRS 102, DTE 8, and DTE 1, were found to be moderately tolerant. Under AE three genotypes *viz.,*PhuleSuchitra, DTE 14, and DTE 7, were found to be widely adaptable and 10 genotypes *viz.,*DTE 15, DTE 3, DTE 11, PhuleSuchitra, DTE 16, CRS 102, CRS 98, DTE 6, DTE 8 and DTE 13were found to be moderately widely adaptable.Under GS-1, GS-II and Well Watered environment Correlation between days to 50% flowering, maturity of the plant were [0.44**], [0.56**] and [0.57**] respectively showed positive and significant relationship under all environments. This is the common trait found in all environments. In water stress conditions Phulesuchitra (20.07) and DTE-14 (21.14) varieties gave high grain yield as compared to other early varieties

Mean stomata (26.74, 16.83, 23.14, 15.10)were on lower flag leaf, upper flag leaf, lower stem leaf and upper stem leaf respectively (Table 11). The results showed that lower surface of leaf have more number of stomata than upper surface of leaf for flag leaf as well as stem leaves. T test showed Flag leaf stomata 43.57 were significantly higher than stem leaf stomata 38.24, this showed that flag leaf played important role in photosynthesis and supply of more energy to plant for growth and development. This is likely the first of such observation recorded under this study.

Author contributions

Conceptualization of experimentation (PP & PM); Designing of the experiments (PP, MS & MJ); Experimental materials (PP, RM & TV); Execution of field experiments and data collection (PP & MS); Analysis of data and interpretation (PM & MJ); Preparation of the manuscript (all authors).

Conflict of interest

The authors declare no conflict of interest.

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