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The Value of the Stay-green Traits with Grain Yield of Post Flowering Drought Tolerance in *Rabi* Sorghum

D. Dev Kumar[1*], V. Padma[2], H. S. Talwar[3] and Farzana Jabeen[4]

[1]Dept. of Crop Physiology, College of Agriculture, Rajendranagar, Hyderabad, Telanagana State (500 030), India
[2]Dept. of Crop Physiology, Administative Block, Lamform, Guntur, Andhra Pradesh (522 034), India
[3]Dept. of Plant Physiology, Indian Institute of Millet Research, Rajendranagar, Hyderabad, Telanagana State (500 030), India
[4]Dept. of Genetics and Plant Breeding, College of Agriculture, Rajendranaga, Hyderabad, Telanagana State (500 030), India

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Corresponding Author

D. Dev Kumar

e-mail: ddevkumar45@gmail.com

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Conflict of interests: The authors have declared that no conflict of interest exists.

Abstract

An experiment was conducted during *rabi* 2012-13 at research farm of Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad, Telengana State, India. The experiment was laid out in a split plot design, replicated thrice, with 10 Sorghum genotypes as main treatment Well-watered (WW) and Water-stress (WS) conditions) to examine the potential of Sorghum genotypes to adapt to the post flowering drought. 10 genotypes are sub-treatments CRS 4, CRS 19, CRS 20, PEC 17, CSV 18, M 35-1, Phule chitra, Phule moulee, EP 57 and CRS 1). Among the four stages viz., 10, 20, 30 and 40 days after flowering (DAF), the GLAR (stay green trait) at 10 DAF had a positive and higher significant correlation with grain yield (r=0.66). So, GLAR at 10 DAF is most appropriate stage to screen for post flowering drought tolerance. Among the yield components, number of grains per panicle, grain weight panicle^{-1} and harvest index (HI) are significantly and positively correlated with grain yield and therefore it can be ascribed that the genotypes, which partitioned more assimilates into economic parts and in which grain filling is high, recorded more grain yield. The overall yield reduction due to moisture stress during the post flowering drought was 10% and it ranged between 8-12% among the genotypes. This indicates that the genotypes used in the present study are relatively drought tolerant. The genotypes CSV 18 and Phule moulee registered least yield reduction (8%) in grain yield due to post flowering drought followed by PEC 17 and M 35-1 which registered 9% yield reduction. However, the overall grain yield of PEC 17 and M 35-1 was more than CSV 18 and Phule moulee even under moisture stress conditions.

Keywords: Leaf area, green leaf area retention, grain yield, *rabi* sorghum

1. Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is ranks fifth in the major grain crops in production, area harvested, and yield worldwide (Anonymous, 2017) and more than 300 million people use it as a staple food, particularly in developing semiarid tropical areas. Sorghum is the sixth most planted crop in the world, and it is one of the most important cereals used as a staple food for those primarily living in arid and semiarid areas (Zhao et al., 2019). It is consumed mostly in northern China, India, and southern Russia, where about 85% of the crops are consumed directly as human food. Sorghum has greater drought tolerance, soil toxicities, and temperature variation than other cereals and requires minimal fertilizers

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for cultivation, thus playing a critical role for food security in some semiarid areas of Asia, Africa, and Latin America (Kumar et al., 2017).

Drought is an extended abnormal dry period that occurs in a region consistently receiving a below-average rainfall. Globally, agriculture is the biggest consumer of water. The growth, development, and reproduction of plants require sufficient water. Drought is a complex environmental stress and major constraint to crop productivity (Mishra and Singh 2010). The early vegetative stage and reproductive stages (pre flowering and post flowering) of sorghum are vulnerable to the effects of water deficit (Kebede et al., 2001). Stay-green Sorghum genotypes maintain photosynthetically active leaf area better than genotypes that do not posses this trait under limited soil moisture during grain filling stage. Identify the key adaptive traits associated with post flowering drought in *rabi* season. (Borrell et al., 2000).

The aim of this research is to study the *rabi* sorghum, water-stress is one of the major factors limiting the crop growth and ultimately the production under rainfed farming. Certain species of sorghum have a versatile characteristic of withstanding the drought condition and thus having a genetic potential to defend the stress condition. In the present investigation, some of the existing and recently released cultivars of sorghum are taken to test their water-stress tolerance. These cultivars are presently used extensively in the commercial production in Indian farmers.

2. Materials and Methods

2.1. Location and experimental site

This investigation was conducted during winter (*rabi*) season, 2012-2013 at the research farm of Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad, Telengana state, India located at Latitude 17°19′ N, Longitude 78°28′ E and at an altitude of 542 m above the Mean Sea Level. The experiment was laid out in a split plot design, replicated thrice, with 10 Sorghum genotypes as main treatment (well-watered and water-stress conditions) and with 10 genotypes are sub treatments CRS 4, CRS 19, CRS 20, PEC 17, CSV 18, M 35-1, Phule chitra, Phule moulee, EP 57 and CRS 1).

2.2. Weather during the crop growth period

To characterize the weather conditions during the crop growing season, the meteorological parameters were recorded from a B – class meteorological observatory located at nearby experimental site.

During the Sorghum crop growth period (01-10-2012 to 12-2-2013) the mean weekly maximum temperature ranged from 27.5 to 32.6°C with an average of 30°C. The mean weekly minimum temperature ranged from 11.0 to 21.9°C with an average of 16.1°C. Relative humidity forenoon and afternoon during the crop growing period fluctuated between 67–94% and 27–69%, respectively. The mean weekly bright sunshine hours per day varied from 3.0 to 9.9 hours with an average of 8.0 hour**.** Likewise the mean weekly wind velocity ranged from 1.2 to 4.8 km h^{-1} with an average of 3.0 km h^{-1}.

The mean pan evaporation from USWB Class A pan evaporimeter during the cropping period ranged from 2.6 to 4.5 mm d^{-1} with an average of 4.0 mm d^{-1}. The total rainfall received during the cropping period was only 5.0 mm. Thus it is evident that the moisture was insufficient for active plant growth and that there was no interference of rain during the post flowering drought period and that there is a need for the irrigation water application.

2.3. Soil characteristics of the experimental site

The soil type of the experimental site is a vertisol with pH of 7.94, available nitrogen of 290 kg ha^{-1}, available phosphorus of 28 kg P_2O_5 ha^{-1}, available potassium of 624 kg ha^{-1}, organic carbon of 0.62% and organic matter content was low.

2.4. Data to be recorded

Average number of leaves having more than 50% green was calculated at the stage of flowering. Stay green type plants were scored during stress conditions on 0 - 9 scale. Where 0 = fully green top six leaves, 9 = fully senescent top six leaves, This observation was recorded at 10, 20, 30, 40 Days After Flowering. Average number of grains per panicle, grain weight per panicle taken at the time after harvesting. All the panicles form the net plot (3×1.2 m^2) area in all treatments were harvested (Kg ha^{-1}). Harvest index was calculated by using the formula given by Donald (1962).

2. 5. Statistical analysis

2.5.1. Analysis of variance

The data for different characters were statistically analyzed using split plot design (Panse and Sukhatme, 1967). Wherever the treatment differences were found significant, (‘F’ test) critical difference was worked out at 5% probability level and the values furnished. The treatment differences that were not significant were denoted by “NS”.

Significance of correlation coefficients were tested by comparing correlation coefficients with the table values (Fisher and Yates, 1965) at (n-2) degrees of freedom at 5%. Where “n” denotes the number of treatments used in the calculation.

3. Results and Discussion

3.1. No. of leaves plant^{-1}

The interaction between the treatments and genotypes was significant and among the genotypes presented in table 2PEC 17 recorded the highest number of leaves in both well-watered (13) and water-stress (12) conditions. The genotype V_1 (Phule Yashoda) was recorded significantly highest mean number of leaves plant^{-1} (3.95) and mean leaf area plant^{-1} (14.82), while significantly lowest was observed in V_5 (Phule Anuradha). These results are in agreement with the finding of (Zhang et al., 2004), Abdalla and El- Khoshiban, (2007).

Effects of water-stress on growth/ morphological parameters such as leaf area, number of leaves and girth (diameter) have been documented by (Zhang et al., 2004); Abdalla and El-Khoshiban, (2007).

3.2. Green leaf area retention (GLAR)

The interaction between genotypes and stress treatments was significant and among the genotypes PEC 17 recorded at 10 DAF recorded highest green leaf area retention in well-watered (1883) and water-stress (1521) conditions presented in Table 1. The lowest green leaf area retention in well-watered (1337) and water-stress (1121) conditions was observed in the genotype CRS 1. Similar results were observed at 20, 30 and 40 DAF. These results are in conformity to the reduction in leaf area would limit the development of plant transpiration surface and keeps sink demand well balanced with plant assimilatory capacity (Bayoumi et al., 2008). Similarly, genotype V_1 (Phule Yashoda) recorded significantly highest mean leaf area index (2.20). Earlier studies also indicated similar observations with particular reference to sorghum grown under water-stress condition (Sonawane et al. (2008).

Table 1: GLAR at 10 DAF, 20DAF, 30 DAF and 40 DAF and NL of Sorghum genotypes under well-watered and water-stress conditions

Genotypes	GLAR-10 DAF			GLAR-20 DAF			GLAR-30 DAF			GLAR-40 DAF			No. of leaves plant^{-1}		
	WW	WS	Mean	WW	WS	Mean	WW	WS	Mean	WW	WS	Mean	WW	WS	Mean
CRS 4	1601	1240	1421	1051	1024	1038	928	850	889	684	474	579	11	9	10
CRS 19	1505	1477	1491	1348	1342	1345	1289	1113	1201	797	718	758	11	11	11
CRS 20	1734	1284	1509	1462	1180	1321	1145	985	1065	797	742	770	10	9	10
PEC 17	1883	1521	1702	1477	1365	1421	1338	1086	1212	1040	825	932	13	12	13
CSV 18	1752	1463	1608	1417	1123	1270	1235	788	1012	843	628	735	11	10	11
M35-1	1841	1502	1671	1473	1113	1293	1272	807	1039	933	502	718	12	9	10
Phule Chitra	1563	1374	1469	1185	1328	1257	1303	916	1110	919	672	795	11	10	11
Phule Moulee	1457	1318	1388	1135	1023	1079	973	676	824	767	498	632	10	9	10
EP 57	1606	1451	1529	1317	1310	1314	928	946	937	701	623	662	11	10	10
CRS 1	1337	1121	1229	1005	1001	1003	850	654	752	537	384	460	10	9	9
Mean	1628	1375	1501	1287	1181	1234	1126	882	1004	802	607	704	11	10	10
CD (p=0.05)															
Genotypes (G)	154.64			124.31			131.23			121.46			1.03		
Treatments (T)	5.93			39.07			36.91			1.00			0.84		
G X T	18.74			23.57			16.74			3.17			1.48		
CV	22.54			6.74			7.15			6.69			7.22		

3.3. Yield and yield attributes

3.3.1. Grain weight panicle^{-1} (g)

The interaction between genotypes and treatments was significant and among the genotypes depicted in Table 2. PEC 17 recorded highest grain weight per panicle in water-stress (59 g) and well-watered (62 g) conditions. The lowest grain weight per panicle in water-stress (35 g) and well-watered (38 g) conditions was observed in the genotype CRS1.

3.3.2. Number of grains panicle^{-1}

The interaction between genotypes and water-stress treatments was also significant and among the genotypes PEC 17 recorded highest number of grain per panicle in water-stress (1145) and well-watered (1256) conditions. The lowest number of grain per panicle in water-stress (937) and well-watered (993) conditions were observed in the genotype CRS1 depicted in Table 2. Number of grains per panicle has a positive correlation with grain yield in Sorghum (Kadam et al*.,* 2002 and Awari et al*.,* 2003). A close observation of the data indicated that in drought susceptible genotypes, the grain number per panicle was more affected and the effect of stress appeared to be direct one on this parameter. These finding are in agreement with the results of Nouri et al. (2004). Pawar et al. (2005) reported that the number of grains per panicle greatly contributed to the total grain yield.

3.3.3 Grain yield (kg ha^{-1})

The interaction between genotypes and water-stress treatments was also significant and among the genotypes PEC 17 recorded highest grain yield in water-stress (1082 kg ha^{-1}) and well-watered (1192 kg ha^{-1}) conditions. The lowest grain yield in water-stress (772 kg ha^{-1}) and well-watered (875 kg

Table 2: Grain weight panicle^{-1}, no of grains panicle^{-1}, grain yield and harvest index of Sorghum genotypes under well-watered and water-stress conditions

Genotypes	Grain weight panicle^{-1} (g)			No. of grains panicle^{-1}			Grain yield (kg ha^{-1})			Harvest index (%)		
	WW	WS	Mean	WW	WS	Mean	WW	WS	Mean	WW	WS	Mean
CRS 4	45	37	41	1167	1081	1124	1045	951	998	25	24	25
CRS 19	59	57	58	1208	1121	1165	761	667	714	26	24	25
CRS 20	50	48	49	1194	1065	1130	1005	912	959	29	27	28
PEC 17	62	59	61	1256	1145	1201	1192	1082	1137	37	35	36
CSV 18	58	56	57	1139	1010	1075	1128	1035	1082	30	28	29
M35-1	44	43	44	1048	1018	1033	1190	1078	1134	35	33	34
Phule Chitra	47	44	46	1051	1033	1042	960	845	903	31	29	30
Phule Moulee	52	50	51	1025	952	989	999	919	959	28	26	27
EP 57	47	45	46	1041	1016	1029	915	827	871	25	23	24
CRS 1	38	35	37	993	937	965	875	772	824	24	22	23
Mean	50	47	49	1112	1038	1075	1007	909	958	29	27	28
CD (p=0.05)												
Genotypes (G)		15.34			92.50			115.63			2.15	
Treatments (T)		5.93			39.07			36.91			1.00	
G X T		18.74			23.57			16.74			3.17	
CV		22.54			6.74			7.15			6.69	

ha^{-1}) conditions was observed in the genotype CRS1 depicted in Table 2. The positive correlation between number of leaves and grain yield of sorghum correlation study also indicated that LAI had significant positive association with grain yield (Pawar and Jadhav, 1996).

3.3.4. Harvest index

The interaction between genotypes and treatments indicate significant difference. Among the genotypes PEC 17 recorded highest harvest index in water-stress (35%) and well-watered (37%) conditions. The lowest harvest index in water-stress (22%) and well-watered (24%) conditions was observed in the genotype CRS1 depicted in Table 2. Harvest index is the most important factor in determining the grain yield, which indicates the partitioning ability of total dry matter to the developing grains (Channaoppagoudar et al., 2008). The genotypes 296 B and ICSV 75 with lower HI (10.4-10.5%) resulted in poor yields of 66.1 and 77.3 g m^{-2}, respectively (Chimmad and Kamatar, 2003).

4. Conclusion

The decrease in grain yield was 10% due to post flowering moisture stress. This indicate that the genotype used are relative drought tolerance. Based on the above, it is inferred that the genotypes PEC 17, M35-1 and CSV 18 are more efficient because of improved morpho-phenological, biophysical and chemical characters. The genotype PEC 17 can withstand drought situation and yield better because of physiological manipulations.

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