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Physiological Analysis of Rabi Sorghum Genotypes for Drought Tolerance

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Abstract:
Drought triggers a wide variety of plant responses, ranging from cellular metabolism to changes in growth rates and crop yields. Drought induced changes in morphological, physiological and biochemical changes in plants. This study was conducted with the object to study the physiological basis of drought tolerance in Rabi sorghum. A field experiment was conducted at Pulses Improvement Project, MPKV, Rahuri during the year 2013-2014 and 2014-2015. Eight genotypes and two released varieties were grown in a split plot design with three replications. Seeds were grown separately under three moisture regimes viz; moisture stress condition irrigation given at the time of sowing, terminal stress condition, irrigation given at the time of sowing and panicle initiation stage and non stress condition irrigation was given at proper stages of growth. Physiological traits, stomatal frequency (Abaxial/Adaxial), canopy temperature depression, SPAD index were recorded at 50% flowering and dough stage. From the investigation, it was clear that all the physiological traits and grain yield were reduced, whereas canopy temperature increased due to moisture stress than terminal and non stress. Genotypes RSV 1572. RSV 1458, RSV 1237 and Phule Anuradha performed better with respect to canopy temperature, canopy temperature depression, SPAD index values. Therefore, canopy temperature, canopy temperature depression, SPAD index values might be used as selection criteria for drought tolerance. These genotypes had optimum stomatal frequencies on both leaf surfaces. The genotypes RSV 1572, RSV 1458, RSV 1237 and Phule Anuradha could be used for developing new drought tolerant variety in the further breeding program.

Keywords: *Moisture stress, terminal stress, moisture regimes, drought tolerance, SPAD index, Abaxial, Adaxial, CTD.*

1. Introduction

Sorghum is the fifth most important cereal crop next only to rice, wheat, maize and barley. It is the staple food of poor and the most food insecure people, living mainly in the semi-arid and tropics (Ali *et al*. 2009, Bibi *et al.* 2010). There has been a drastic reduction in sorghum productivity mostly in the post rainy season crop. This was mainly due water scarcity. The low yield of sorghum affected by various biotic and abiotic stresses. Moisture stress is one of the important drought factor. Nearly 70% sorghum area, depends on rains and rains are not assured in most of the sorghum growing areas. Where it is grown under stored and receding soil moisture conditions with increasing temperature after flowering. These face the problem of drought. As such the crop productivity in these areas is low. Moisture stress causes depletion in soil and water deficit with a decrease of water potential in plant tissues. It restricts the expression of full genetic potential of the plant. Moisture stress is a major constraint limiting sorghum crop growth and reducing its productivity. Many researches on the soil water relationship in sorghum and other crops have indicated that growth and yield are directly controlled by plant water deficit. Plant adapts to stresses using different mechanisms involving changes in morphological and developmental pattern as well as physiological and biochemical processes (Bohnert *et al.* 1995). There are several physiological mechanisms with the help of this plants can survive under drought stress. Sorghum is drought tolerant crop have an ability to withstand under moisture stress condition. Considering these facts the present study was undertaken.

2. Material and Methods

Eight genotypes *viz;* RSV 1188 (V_1), RSV 1199 (V_2), RSV 1209 (V_3), RSV 1237 (V_4), RSV 1454 (V_5), RSV 1458 (V_6) and RSV 1572 (V_7), RSV 1620 (V_8) with two check varieties Phule Anuradha (V_9) and Phule Yashoda (V_{10}) were evaluated for physiological analysis under different moisture regimes at Pulses Improvement Project, MPKV, Rahuri during the year 2013-2014 and 2014-2015.
The moisture stress trials were conducted under rain out shelter. The experiment was laid out in split plot design with three replications. Under moisture stress condition, irrigation was given at the time of sowing. Under terminal stress condition irrigations were given at the time of sowing and the panicle initiation stage, while, under non stress condition irrigation given at the time of

sowing and at proper growth stages. All the agronomic and plant protection measures were followed as and when needed. Canopy temperature was measured by using hand held infrared thermometer (Model OS 530 HR, Omega Engineering Inc Stamford CT USA). During each measurement, the natural leaf orientation with respect to the sun was maintained to avoid shade effects. The canopy temperature depression (CTD) was calculated by subtracting the air temperature from canopy temperature. Leaf chlorophyll content (SPAD index) was estimated nondestructively, using a SPAD-502 chlorophyll meter (Minolta Corp., Ramsey, NJ, USA). The data points were recorded at five positions along the length of the leaf blade and then the data points were averaged as a single value. Care was taken to ensure that the SPAD meter sensor fully covered the leaf lamina and the interference from veins and midribs to be avoided.

3. Results and Discussion

3.1. Stomatal Frequenceies (Abaxial/Adaxial)

In plants gaseous diffusion depends essentially on the stomatal pore size and its distribution in the epidermis. Stomatal frequency could be considered as an important parameter for screening of drought tolerant genotypes. In the present study, higher stomatal frequency was found on the abaxial surface compared to the adaxial surface in all sorghum genotypes These results are in agreement with the findings of Sanjana Reddy *et al.* (2012) and Chetti *et al.* (1997). Similarly stomatal frequencies increased from 50% flowering to dough stage in all sorghum genotypes. Same result reported by Surwenshi *et al.* (2007). Mean stomatal frequency (Adaxial) was reduced by 17.83 and 26.36 per cent due to terminal and moisture stress respectively at 50% flowering, whereas, at dough stage it was reduced by 17.14 and 25.71 per cent respectively (Table 1). Mean stomatal frequency (Adaxial) was reduced by 17.83 and 26.36 per cent due to terminal and moisture stress respectively at 50% flowering, whereas, at dough stage it was reduced by 17.14 and 25.71 per cent respectively (Table 2). Bayo *et al.* (2006) reported that water deficit, especially severe water deficit (-0.96 Mpa) severely affected the growth and physiology of sorghum. They observed that there was reduction in stomatal density due to severe water deficit. In the present study stomatal frequencies significantly differed among the genotypes. Mean values indicated that RSV 1188 and Phule Yashoda recorded significantly maximum mean stomatal frequency on lower surface (156 mm^2) at 50% flowering. However, at this stage RSV 1620 was recorded lowest mean stomatal frequency (119 mm^2). Similar trend observed at dough stage. Among the genotypes, RSV 1188 under moisture stress (141 mm^2), Phule Yashoda and RSV 1188 under terminal stress (150 mm^2) and Phule Yashoda under non stress (180 mm^2) recorded maximum stomatal frequency on lower surface of leaf at 50% flowering. At dough stage, RSV 1188 under moisture stress (151 mm^2), Phule Yashoda under terminal stress (158 mm^2), Phule Yashoda and RSV 1188 under non stress (188 mm^2) recorded maximum stomatal frequency. Similar trend was observed in the results of stomatal frequency (Adaxial). Several researchers reported that lower stomata number under limited water supply helps in preventing water losses thus contributing towards drought tolerance. Thus the results are in agreement with the findings of Patil *et al.* 2013 and Nirmal *et al.* 2013. Hiremath and Parvatikar (1985) reported that the stomatal number per plant did not show direct relation with grain yield in rabi sorghum. In the present study high yielding varieties under moisture stress and terminal stress had stomatal frequencies in the range of (123 to 133 mm^2) on lower surface of leaf and (106 to 113 mm^2) on upper surface of leaf at 50% flowering. At dough stage, in the range of (132 to 142 mm^2) on lower surface of leaf and (108 to 117 mm^2) on upper surface of leaf. This indicated that these genotypes maintained water balance under limited moisture and able to with stand under water deficit condition.

3.2. Canopy Temperature and Canopy Temperature Depression

Lower canopy temperature in drought stressed crop plants indicates a relatively better capacity for taking up soil moisture and for maintaining a relatively better plant water status by various plant adaptive traits. The difference between air and canopy temperature is referred to as canopy temperature depression (CTD). In the present study mean canopy temperature was increased by 3.96 and 8.24 per cent over terminal and non stress respectively at 50% flowering, whereas, at dough stage it was increased by 3.91 and 10.34 per cent respectively (Table 3). Mean canopy temperature depression was decreased by 28.54 and 51.80 per cent due to terminal and moisture stress respectively at 50% flowering, whereas, at dough stage it was decreased by 34.87 and 65.64 per cent respectively (Table 4). Siddique *et al.* (2000) reported that drought stressed plant had higher canopy temperature than well watered plants this might be due to drought stress resulted from an increase in respiration and decrease in transpiration due to stomata closure. McMaster *et al.* (2008) reported that water deficit causes stomatal closure and lead to higher canopy temperature. When stomates closed due to water deficit canopy temperature rises above ambient temperature. In fact, drought tolerant genotypes that had lower canopy temperature will use more of the available water in the soil thus limiting the negative effect of water stress on grain yield.

Canopy temperature and canopy temperature depression differed significantly among the genotypes. Gupta and Sastry (1986) reported that canopy temperature of fully watered wheat genotypes ranged from 12.3^{o}C to 24.8^{o}C at 21.1^{o}C and 30.3^{o}C air temperature, respectively while canopy temperature minus ambient temperature difference was always negative and ranged from 4.3 to 7.0^{o}C. Mean values indicated that RSV 1572 had significantly lowest canopy temperature at both stages. Among the genotypes, RSV 1572 under moisture stress (29.02 ^{O}C) and terminal stress (27.95 ^{O}C), whereas, Phule Yashoda under non stress (27.12 ^{O}C) recorded lowest canopy temperature at 50% flowering. At dough stage, RSV 1572 under moisture stress (30.05 ^{O}C), RSV 1237 under terminal stress (29.12 ^{O}C) and Phule Yashoda under non stress (27.70 ^{O}C) recorded lowest canopy temperature. Ayeneh *et al.* (2002) reported that high CTD has been used as a selection criterion to improve tolerance to heat stress. Balota *et al.* (2007) reported the application of canopy temperature depression (CTD) to estimate crop yield and to rank genotypes for tolerance to drought. In the present study, RSV 1572 recorded significantly maximum mean canopy temperature depression (-4.25^{O}C) followed by RSV 1237 (-4.14^{O}C), RSV 1458 and Phule Anuradha (4.13^{O}C) and RSV 1620 (-3.82^{O}C) at 50% flowering. At dough stage, RSV 1572 recorded significantly maximum mean canopy temperature depression (-2.95 ^{O}C) followed by RSV 1572 (-2.91 ^{O}C) and Phule Anuradha (-2.83 ^{O}C). Among the genotypes, RSV 1572 under moisture stress (-3.55 ^{O}C) and terminal stress (-4.38C) whereas, Phule Yashoda under non stress (-5.35 ^{O}C) recorded maximum canopy temperature depression at 50% flowering. At dough stage, RSV 1572 under moisture stress (-1.90 ^{O}C), RSV 1237 under terminal stress (-3.12 ^{O}C) and RSV 1188 under non stress (-4.35 ^{O}C) recorded maximum canopy temperature depression. Anjum *et al*. (2011) reported that canopy temperature is an important characteristic that influence plant water relations under drought stress. Lower canopy temperature in drought stressed crop plants indicates a relatively better capacity for taking up soil moisture and for maintaining a relatively better plant water status by various plant adaptive traits. In the present study RSV 1572, RSV 1458, RSV 1237 had lowest canopy temperature and highest canopy temperature depression under moisture and terminal stress, this could be able to maintain better water relations under water deficit.

3.3. SPAD Index
SPAD index is a non-destructive measurement method used to determine leaf chlorophyll content. This index was used preferentially because there is a strong relationship between readings of portable chlorophyll meter and leaf chlorophyll content this has been demonstrated by several researcheres. (Silva *et al.* 2007, Markwell *et al.* 1995). In the present study, mean SPAD index was reduced by 8.14 and 14.13 per cent due to terminal and moisture stress respectively at 50% flowering, whereas, at dough stage it was reduced by 10.62 and 17.78 per cent respectively (Table 5). These results are in line with the findings of Hayatu and Mukhtar (2010) and Mostafa *et al.* (2011). SPAD index values were significantly differed among the genotypes. Mean values indicated that Phule Anuradha had significantly highest mean SPAD index (49.2 %) followed by RSV 1237 (47.4%) at 50% flowering. However, at this stage RSV 1209 and RSV 1454 was recorded lowest mean SPAD index (38.2%). At dough stage, Phule Anuradha had significantly highest mean SPAD index (45.5%). However, at this stage RSV 1454 was recorded lowest mean SPAD index (34.4%). Under all moisture regimes Phule Anuradha recorded maximum SPAD index at both stages. Phule Anuradha is drought tolerant variety in this experiment used as check variety. High chlorophyll content under water deficit could be considered as a reliable indicator of drought tolerance.

3.4. Grain Yield
Farooq *et al.* (2009) reported that grain yield is the result of the expression and association of several plant growth components. The deficiency of water leads to severe decline in yield traits of crop plants. In the present study mean grain yield (kg/ha) was reduced by 67.76 and 78.68 per cent due to terminal and moisture stress respectively (Tyable 6). Grain yield (kg/ha) differed significantly among the genotypes. RSV 1237 recorded significantly highest mean grain yield (1826 kg/ha). However, RSV 1454 was recorded lowest mean grain yield (874 kg/ha). Among the genotypes, RSV 1572 under moisture stress (1003 kg/ha) and terminal stress (1426 kg/ha), whereas, Phule Yashoda under non stress (3643 kg/ha) recorded maximum grain yield. In the present study RSV 1572 recorded higher yield under moisture stress and terminal stress while RSV 1458 found second best genotype Increase in grain yield might be attributed to the higher panicle length, panicle width, grain yield/plant higher 1000 grain weight maximum earhead exertion, etc. In general, it could be seen that for obtaining higher yield not any single yield contributing character is important but rather it is an integrated effect of all the yield contributing characters. Therefore, the number of researchers found a positive correlation between yield and various yield contributing characters Kulkarni *et al*, 1983; SanjanaReddy *et al.*2012 and Hiremath and Parvatikar 1985.

4. Conclusion
The present investigation has revealed important differences in the responses of the genotypes to the physiological parameters and grain yield under different moisture regimes. Physiological activities and grain yield reduced under moisture stress. However, RSV 1572, RSV 1458, RSV 1237 and Phule Anuradha performed well under moisture stress and terminal stress resulting to obtain a better grain yield and found drought tolerant.

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Annexure

At 50% flowering stage												
	2013-2014				2014-2015				Pooled Data			
Genotypes	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	146	155	170	157	136	145	181	154	141	150	176	156
V_2	118	128	145	130	119	135	163	139	119	132	154	135
V_3	121	134	138	131	132	139	151	141	127	137	145	136
V_4	114	123	148	128	114	130	170	138	114	127	159	133
V_5	127	131	138	132	127	144	158	143	127	138	148	138
V_6	98	114	141	118	102	121	161	128	100	118	151	123
V_7	117	122	152	130	113	124	177	138	115	123	165	134
V_8	105	110	124	113	107	120	149	125	106	115	137	119
V_9	108	118	159	128	108	127	172	136	108	123	166	132
V_{10}	144	150	172	155	134	149	187	157	139	150	180	156
Mean	120	129	149		119	133	167		120	131	158	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	1.526	1.771	3.068		1.538	1.921	3.328		1.876	2.263	3.920	
C.D. at 5%	5.991	5.022	8.698		6.038	5.448	9.436		6.118	6.343	10.99	
At dough stage												
	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	153	155	174	161	148	154	202	168	151	155	188	164
V_2	134	142	160	145	128	141	174	148	131	142	167	147
V_3	148	152	156	152	141	146	166	151	145	149	161	152
V_4	115	136	162	138	120	136	176	144	118	136	169	141
V_5	136	154	155	148	136	151	165	151	136	153	160	150
V_6	105	125	158	129	114	126	166	135	110	126	162	132
V_7	119	128	170	139	117	129	190	145	118	129	180	142
V_8	111	122	141	125	107	124	154	128	109	123	148	127
V_9	110	138	165	138	127	130	180	146	119	134	173	142
V_{10}	151	158	170	160	143	157	206	169	147	158	188	164
Mean	128	141	161		128	139	178		128	140	170	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.703	2.029	3.514		1.241	2.120	3.672		1.236	2.541	4402	
C.D. at 5%	2.760	5.753	9.964		4.875	6.012	10.41		4.030	7.125	12.34	

Table 1: Mean stomatal frequency (Abaxial) (mm^2) as influenced by moisture regimes, genotypes and their interactions in sorghum.

At 50% flowering stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	119	135	142	132	105	118	141	121	112	127	142	127
V_2	100	104	130	111	91	105	125	107	96	105	128	109
V_3	101	121	128	117	100	110	113	108	101	116	121	112
V_4	92	104	131	109	87	97	133	106	90	101	132	107
V_5	109	120	126	118	95	115	112	107	102	118	119	113
V_6	81	95	129	102	75	87	119	94	78	91	124	98
V_7	94	101	137	111	90	92	131	104	92	97	134	108
V_8	82	88	112	94	83	87	111	94	83	88	112	94
V_9	89	98	138	108	80	103	129	104	85	101	134	106
V_{10}	117	125	150	131	102	120	148	123	110	123	149	127
Mean	98	109	132		91	103	126		95	106	129	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.829	1.725	2.988		0.524	1.874	3.247		0.849	2.206	3.822	
C.D. at 5%	3.256	4.892	8.473		2.057	5.316	9.207		2.770	6.185	10.71	
At dough stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	129	138	158	142	118	126	151	132	124	132	155	137
V_2	106	114	139	120	101	118	140	120	104	116	140	120
V_3	119	127	137	128	108	120	131	120	114	124	134	124
V_4	102	113	140	118	94	113	141	116	98	113	141	117
V_5	118	128	135	127	105	121	130	119	112	125	133	123
V_6	87	102	138	109	87	100	135	107	87	101	137	108
V_7	104	110	148	121	93	105	138	112	99	108	143	116
V_8	94	106	118	106	85	95	127	102	90	101	123	104
V_9	91	110	142	114	98	109	135	114	95	110	139	114
V_{10}	120	140	159	140	112	129	153	131	116	135	156	136
Mean	107	119	141		100	114	138		104	116	140	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.416	2.120	3.672		1.578	2.592	4.889		1.414	2.900	5.022	
C.D. at 5%	1.635	6.012	10.41		6.197	7.348	12.73		4.610	8.129	NS	

Table 2: Mean stomatal frequency (Adaxial) (mm^2) as influenced by moisture regimes, genotypes and their interactions in sorghum.

At 50% flowering stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	29.47	29.00	27.43	28.63	30.73	28.80	27.17	28.90	30.10	28.90	27.30	28.77
V_2	30.17	29.07	27.57	28.93	31.07	29.67	27.57	29.43	30.62	29.37	27.57	29.18
V_3	30.47	29.23	27.80	29.17	31.17	29.73	28.03	29.64	30.82	29.48	27.92	29.41
V_4	29.33	28.70	27.27	28.43	29.17	28.23	27.57	28.32	29.25	28.47	27.42	28.38
V_5	31.00	29.23	28.03	29.42	31.70	29.80	28.13	29.88	31.35	29.52	28.08	29.65
V_6	29.13	28.10	27.63	28.29	29.10	28.30	27.93	28.44	29.12	28.20	27.78	28.37
V_7	29.07	27.80	27.63	28.17	28.97	28.10	27.87	28.31	29.02	27.95	27.75	28.24
V_8	29.43	28.73	28.07	28.74	29.60	28.67	28.07	28.78	29.52	28.70	28.07	28.76
V_9	29.27	28.70	27.57	28.51	29.03	28.27	27.70	28.33	29.15	28.48	27.63	28.42
V_{10}	29.93	28.93	27.17	28.68	30.97	29.00	27.07	29.01	30.45	28.97	27.12	28.84
Mean	29.73	28.75	27.62		30.15	28.86	27.71		29.94	28.80	27.66	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.089	0.206	0.357		0.021	0.090	0.156		0.079	0.195	0.338	
C.D. at 5%	0.351	0.585	NS		0.081	0.254	0.441		0.259	0.546	NS	
At dough stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	30.80	30.00	27.93	29.58	31.87	29.77	27.90	29.84	31.33	29.88	27.92	29.71
V_2	31.10	30.10	27.93	29.71	32.20	30.53	28.00	30.24	31.65	30.32	27.97	29.98
V_3	32.13	30.93	28.17	30.41	32.57	31.00	28.77	30.78	32.35	30.97	28.47	30.59
V_4	30.23	28.90	27.80	28.98	30.97	29.33	27.97	29.42	30.60	29.12	27.88	29.20
V_5	31.63	30.43	28.47	30.18	32.37	30.70	28.93	30.67	32.00	30.57	28.70	30.42
V_6	29.85	29.33	28.03	29.07	30.43	29.60	28.53	29.52	30.14	29.47	28.28	29.30
V_7	29.97	28.97	27.93	28.96	30.13	29.53	28.23	29.30	30.05	29.25	28.08	29.13
V_8	30.50	29.63	28.33	29.49	30.97	29.60	28.63	29.73	30.73	29.62	28.48	29.61
V_9	30.40	29.57	27.83	29.27	30.37	29.57	28.10	29.34	30.38	29.57	27.97	29.31
V_{10}	30.80	29.90	27.53	29.41	31.90	30.33	27.87	30.03	31.35	30.12	27.70	29.72
Mean	30.74	29.78	28.00		31.38	30.00	28.29		31.06	29.89	28.15	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.065	0.173	0.300		0.026	0.090	0.155		0.061	0.169	0.293	
C.D. at 5%	0.256	0.492	NS		0.105	0.254	0.440		0.199	0.474	NS	

Table 3: Mean canopy temperature (^0C) as influenced by moisture regimes, genotypes and their interactions in sorghum.

At 50% flowering stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	-2.77	-4.00	-5.00	-3.92	-1.93	-3.20	-5.03	-3.39	-2.35	-3.60	-5.02	-3.66
V_2	-2.60	-3.97	-5.03	-3.87	-1.63	-2.97	-4.83	-3.14	-2.12	-3.47	-4.93	-3.51
V_3	-2.47	-3.93	-4.90	-3.77	-1.43	-2.70	-4.63	-2.92	-1.95	-3.32	-4.77	-3.34
V_4	-3.60	-4.30	-5.13	-4.34	-3.03	-3.93	-4.87	-3.94	-3.32	-4.12	-5.00	-4.14
V_5	-1.57	-3.80	-4.60	-3.32	-1.00	-2.40	-4.27	-2.56	-1.28	-3.10	-4.43	-2.94
V_6	-3.67	-4.70	-4.90	-4.42	-3.03	-3.83	-4.67	-3.84	-3.35	-4.27	-4.78	-4.13
V_7	-3.87	-4.70	-4.93	-4.50	-3.23	-4.07	-4.70	-4.00	-3.55	-4.38	-4.82	-4.25
V_8	-3.33	-4.20	-4.70	-4.08	-2.63	-3.63	-4.43	-3.57	-2.98	-3.92	-4.57	-3.82
V_9	-3.60	-4.33	-5.03	-4.32	-3.13	-3.93	-4.73	-3.93	-3.37	-4.13	-4.88	-4.13
V_{10}	-2.70	-4.13	-5.60	-4.14	-1.73	-3.13	-5.10	-3.32	-2.22	-3.63	-5.35	-3.73
Mean	-3.02	-4.21	-4.98		-2.28	-3.38	-4.73		-2.65	-3.79	-4.86	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.039	0.074	0.128		0.012	0.089	0.155		0.035	0.101	0.174	
C.D. at 5%	0.152	0.210	0.363		0.046	0.254	0.441		0.114	0.282	0.489	
At dough stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	-0.77	-1.97	-4.37	-2.37	-1.03	-2.43	-4.33	-2.60	-0.90	-2.20	-4.35	-2.48
V_2	-0.67	-1.93	-4.07	-2.22	-0.23	-2.27	-4.20	-2.23	-0.45	-2.10	-4.13	-2.23
V_3	-0.40	-1.23	-3.80	-1.81	-0.13	-1.87	-3.47	-1.82	-0.27	-1.55	-3.63	-1.82
V_4	-1.10	-2.97	-4.17	-2.74	-1.97	-3.27	-4.23	-3.16	-1.53	-3.12	-4.20	-2.95
V_5	-0.43	-1.63	-3.07	-1.71	-0.17	-1.90	-3.23	-1.77	-0.30	-1.77	-3.15	-1.74
V_6	-1.27	-2.50	-3.77	-2.51	-2.13	-2.80	-3.63	-2.86	-1.70	-2.65	-3.70	-2.68
V_7	-1.20	-2.70	-3.93	-2.61	-2.60	-3.07	-3.97	-3.21	-1.90	-2.88	-3.95	-2.91
V_8	-0.87	-2.37	-3.50	-2.24	-1.87	-2.53	-3.50	-2.63	-1.37	-2.45	-3.50	-2.44
V_9	-0.97	-2.47	-4.10	-2.51	-2.40	-3.00	-4.07	-3.16	-1.68	-2.73	-4.08	-2.83
V_{10}	-0.73	-2.10	-4.20	-2.34	-0.90	-2.30	-4.40	-2.53	-0.82	-2.20	-4.30	-2.44
Mean	-0.84	-2.19	-3.90		-1.34	-2.54	-3.90		-1.09	-2.37	-3.90	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.014	0.061	0.106		0.028	0.085	0.147		0.027	0.091	0.157	
C.D. at 5%	0.054	0.173	0.301		0.110	0.241	0.417		0.088	0.254	0.441	

Table 4: Mean canopy temperature depression as influenced by moisture regimes, genotypes and their interactions in sorghum.

At 50% flowering stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	40.6	45.4	51.1	45.7	38.2	40.9	45.2	41.4	39.4	43.2	48.2	43.6
V_2	36.5	40.7	47.5	41.6	37.3	39.3	44.1	40.2	36.9	40.0	45.8	40.9
V_3	36.0	39.3	43.4	39.6	33.3	35.8	41.3	36.8	34.7	37.6	42.4	38.2
V_4	45.2	46.6	53.2	48.3	43.2	47.2	49.0	46.5	44.2	46.9	51.1	47.4
V_5	36.3	39.9	42.2	39.5	33.4	36.9	40.5	36.9	34.9	38.4	41.4	38.2
V_6	42.1	45.6	48.2	45.3	38.6	40.5	44.6	41.2	40.4	43.1	46.4	43.3
V_7	44.8	45.9	46.5	45.7	40.1	42.0	43.1	41.7	42.5	44.0	44.8	43.7
V_8	45.2	46.2	52.2	47.9	40.3	42.3	46.8	43.1	42.8	44.2	49.5	45.5
V_9	46.1	50.0	54.2	50.1	45.7	48.4	50.6	48.2	45.9	49.2	52.4	49.2
V_{10}	42.1	44.5	47.4	44.7	37.7	39.6	43.2	40.2	39.9	42.1	45.3	42.4
Mean	41.5	44.4	48.6		38.8	41.3	44.9		40.1	42.9	46.7	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.250	0.582	1.008		0.275	0.588	1.018		0.322	0.717	1.241	
C.D. at 5%	0.982	1.650	2.859		1.081	1.667	NS		1.050	2.009	NS	
At dough stage												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	34.4	38.4	45.5	39.4	33.2	36.5	43.6	37.8	33.8	37.5	44.6	38.6
V_2	33.7	35.9	43.0	37.5	32.4	34.0	42.6	36.3	33.1	35.0	42.8	36.9
V_3	32.8	34.3	39.7	35.6	30.0	33.0	38.7	33.9	31.4	33.7	39.2	34.8
V_4	39.9	44.4	48.4	44.2	37.5	42.4	46.3	42.1	38.7	43.4	47.4	43.2
V_5	33.1	35.0	37.6	35.2	31.0	33.0	36.5	33.5	32.1	34.0	37.1	34.4
V_6	36.6	40.3	43.7	40.2	36.0	39.6	43.3	39.6	36.3	40.0	43.5	39.9
V_7	37.8	40.7	41.7	40.1	39.3	41.0	42.0	40.8	38.6	40.9	41.9	40.4
V_8	37.9	42.5	46.3	42.2	35.0	39.0	44.4	39.5	36.5	40.8	45.4	40.9
V_9	40.2	46.8	49.5	45.5	42.6	45.5	48.4	45.5	41.4	46.2	49.0	45.5
V_{10}	35.3	37.3	42.6	38.4	32.3	35.3	42.2	36.6	33.8	36.3	42.4	37.5
Mean	36.2	39.6	43.8		34.9	37.9	42.8		35.6	38.7	43.3	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	0.097	0.375	0.649		0.115	0.367	0.636		0.130	0.454	0.787	
C.D. at 5%	0.380	1.062	1.840		0.452	1.041	1.804		0.424	1.274	2.206	

Table 5: Mean SPAD index as influenced by moisture regimes, genotypes and their interactions in sorghum.

Grain yield (kg/ha)												
Genotypes	2013-2014				2014-2015				Pooled Data			
	MS	TS	NS	Mean	MS	TS	NS	Mean	MS	TS	NS	Mean
V_1	490	737	3547	1591	407	774	3473	1551	449	756	3510	1571
V_2	304	504	3120	1309	272	491	2970	1244	288	498	3045	1277
V_3	207	352	2785	1115	170	373	2832	1125	189	363	2809	1120
V_4	802	1240	3398	1813	890	1340	3287	1839	846	1290	3343	1826
V_5	196	313	2235	915	165	302	2031	833	181	308	2133	874
V_6	933	1312	2496	1580	1037	1372	2517	1642	985	1342	2506	1611
V_7	944	1402	2561	1636	1062	1449	2450	1654	1003	1426	2506	1645
V_8	775	1162	2483	1473	807	1227	2241	1425	791	1194	2362	1449
V_9	901	1293	2669	1621	933	1357	2754	1681	917	1325	2711	1651
V_{10}	467	720	3733	1640	424	698	3553	1558	445	709	3643	1599
Mean	602	903	2903		617	939	2811		609	921	2857	
	M	**G**	**M x G**		**M**	**G**	**M x G**		**M**	**G**	**M x G**	
S.E.±	19.86	20.78	35.99		13.82	37.44	64.86		20.96	37.09	64.24	
C.D. at 5%	77.99	58.92	102.06		54.28	106.17	183.89		68.34	103.97	180.07	

Table 6: Mean grain yield (kg/ha.) as influenced by moisture regimes, genotypes and their interactions in sorghum.