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Thermal Indices and Phenological response of Sorghum (*Sorghum bicolor* L.) Genotypes for drought tolerance Under Varied Moisture Regimes

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Abstract: Twenty sorghum genotypes were grown in Rhizotron under two moisture regimes (stress and non stress) for characterization of morpho physiological, Thermal and yield attributing parameters for drought tolerance in Sorghum genotypes. The genotypes differed significantly with respect to various morpho- physiological, biochemical and thermal traits. days to 50 per cent flowering was recorded in genotype CSV29R followed bygenotype CRS70, PEC15, PEC30 and Phule suchitra. Days to physiological maturity was recorded higher in genotype CSV29R. Among the genotypes, significantly higher mean PTI was recorded in CRS73 and significantly higher mean PTI was recorded in CRS73. Further HUE was recorded higher inRSV1837. The investigation showed non stress condition had favorable agro-climatic conditions particularly temperature, day length and sunshine hours interms of required accumulation of GDD, PTI and HUE from 50% flowering to physiological maturity. The genotype RSV1837, RSV1984, SVD3165 and CRS70 which recorded higher grain yield and harvest index, also showed higher values in morpho-physiological and biochemical parameters. The genotype RSV1837, RSV1984, SVD3165 and CRS70 could be considered as drought tolerant sorghum genotypes. These could be promoted or used as promising donor parent in hybridization programme.

INTRODUCTION

Drought can reduce crop productivity which leading to lower income for farmers. Yield reduction can vary between 34 and 68 % depending on the developmental timing of the drought stress. Drought stress takes place when soil and atmospheric humidity is low and the ambient air temperature is high. This condition is the result of imbalance between the evapo-transpiration flux and water intake from the soil (Lipiec *et al.,* 2013). The *rabi* sorghum which is generally cultivated under stored and receding soil moisture with raising temperature at post-flowering stage. Hence, it experiences both the soil and atmospheric drought which is one of the major constraints responsible for destabilizing the *rabi* sorghum productivity. Sorghum genotypes which are adapted to arid and semi-arid environments showed higher resistance to drought than that of humid plants. The major reduction in the yield is due to the drought stress during developmental stages of the crop (Agboma *et al.,* 1997). Drought stress affects almost every stage of the plant growth mainly panicle initiation and anthesis development. (Sharma and Singh, 2003).

The *rabi* sorghum genotypes were grown on irrigated and rainfed condition under rhizotron. The soil moisture gradually decreased from sowing to till the harvest of the crop. This

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indicates that in drought stress condition the growth was grown under receding soil moisture. In the present investigation the genotypes for mean 50 % flowering varied from 71 to 78 days (Table 7). This could be accumulated for by the differential response of these genotypes to their requirement of photoperiod as the process of flowering is governed by photoperiod apart from the influence of other growing conditions like temperature, radiant energy, nutritional and soil moisture condition. The genotypes which took maximum duration from 50 % flowering to maturity produced higher grain yield in sorghum (Kadam *et al*., 2002).

Temperature-based agrometeorological indices of (GDD, HTU, PTU, and HYTU) are widely used for plant growth, phenological development, and harvest time estimation (Wurr *et al*., 2002 and Roy *et al*., 2005). These indices are based on the idea that the rate of phenological development is linearly related to temperature in the range between base temperature and optimal temperature (Monteith, 1981).

Drought stress in sorghum adversely affects the yield traits, such as, grain yield, number of grains per panicle, test weight, and harvest index. Overall, about 50% reduction in mean grain yield under post-flowering drought stress was noticed as compared with well-watered conditions (Vadez *et al*., 2011). Yield under drought can be explained by traits that are fully independent of the response of genotypes to the drought environment. Crop duration in sorghum plays a critical role and contributes to genotype environment interactions. Therefore, good understanding about plant responses to abiotic stresses might be helpful in the selection of more resistant crop varieties. (Allah Wasaya, 2018).

MATERIALS AND METHODS

Screening of *rabi* sorghum genotypes for drought tolerance associated with key root traits in rhizotron. Twenty sorghum genotypes were grown in Rhizotron under two moisture regimes (stress and non stress) for characterization of morpho physiological, Thermal and yield attributing parameters. The experiment was conducted out in a split plot design with three replications. Two moisture regimes as main plot and in combination with 20 sorghum genotypes as subplot were grown in the rhizotron structure for characterization of the morpho-physiological, key root traits and yield attributing characters. The experiment was taken in medium black soil. The seeds of twenty *rabi* sorghum genotypes were collected from the AICSRP sorghum, RARS Vijayapura and MARS Dharwad. The sowing was done on 10th October 2020. Line sowing was taken with healthy seeds. The plants were spaced 15 cm within a row and 45 cm between the rows. The recommended fertilizer dose 60:30:0 kg NPK was applied at the time of sowing. The first thinning was done at 15 days and retained two seedlings per hill. Anthesis (flowering) was noted when 50 % population of *Sorghum bicolour* accessions in each plot were flowered. And the number of days after sowing to the date on which the grains of the most of the plants in a plot shows the appearance of black spot on the hilum of seed will be taken as the indication of physiological maturity.

THERMAL INDICES

The knowledge on accumulation of heat units affords an estimate of various physiological stages and harvesting time (Ketring and Wheless, 1989). Under different temperature regime, the growing degree days (GDD) and heat use efficiency (HUE) of sorghum genotypes at different stages of crop growth varies significantly.

Growing Degree Days (GDD)

Growing degree days (GDD) were calculated at flower initiation, 50 % flowering and physiological maturity by taking the average of the daily maximum and minimum temperatures compared to a base temperature (usually 5 ^{0}C).

$$GDD = \sum \frac{T_{max} - T_{min}}{2} - Tb$$

Tb = Base temperature below which crop growth ceases

Phenothermal Index (PTI)

Phenothermal index (PTI) is the ratio of growing degree days to the number of days between two phenological stages (Masle, 1989) and is calculated as follows and expressed as.

$$Phenothermal\ index = \frac{GDD(day)}{Number\ of\ days\ taken\ between\ the\ two\ phenophases}$$

Heat Use Efficiency (HUE)

Heat use efficiency is useful for the assessment of yield potential of a treatment in different environment (Masle, 1989) and calculated as follows.

$$Heat\ use\ efficiency = \frac{Seed\ or\ biomass\ yield\,(kg\ ha^{-1})}{GDD(day)}$$

RESULTS AND DISCUSSION

Flowering time is an important consideration in sorghum breeding, as it affects adaptation and yield potential and the adaptation to a broad range of growing conditions, mainly in response to the photoperiod (Chantereau *et al*., 2001). Days to 50 per cent flowering deferred significantly with respective to irrigated and stressed condition, genotypes and their interactions. Among the irrigated and stressed conditions, irrigated condition recorded significantly higher mean days to 50 per cent flowering (75 days) followed by stressed condition (72 days). Significantly higher mean days to 50 per cent flowering was recorded in genotype CSV29R (78 days) followed by genotype CRS70, PEC15, PEC30 and Phule suchitra (75 days). Mean days to 50 per cent flowering was least recorded in genotype Lakamapur local, Kodmurki local and Bhagevadi local (71 days) followed by Basavanapada (72 days). The genotypes which took maximum duration from 50 % flowering to maturity produced higher grain yield in sorghum (Kadam *et al*., 2002 and (Bidinger *et al*., 1987). Similarly non stress condition recorded significantly higher mean days to physiological maturity (122 days). Significantly, least mean days to physiological maturity was observed in stressed condition (112 days). Among the genotypes, mean days to physiological maturity was recorded higher in genotype CSV29R (123 days) followed by genotype RSV1984, SVD1365 and PEC15 (120 days). Maturity date was earlier for stressed environment as a result of interaction effect which upshot early maturing genotypes to escape the moisture stress by utilizing the maximum stored water under post flowering drought (Kadam *et al.*, 2002). Similar findings were reported by El-Naim *et al*. (2012) and Yaqoob *et al*. (2015) in sorghum.

Temperature-based agrometeorological indices of (GDD, HTU, PTU, and HYTU) are widely used for plant growth, phenological development, and harvest time estimation (Wurr *et al*., 2002 and Roy *et al*., 2005). These indices are based on the idea that the rate of phenological development is linearly related to temperature in the range between base temperature and optimal temperature (Monteith, 1981). Significantly higher mean GDD was recorded in CSV29R (469) followed by the genotype CRS70 (414). Significantly least GDD was recorded in genotype Kodamurki local (383) followed by genotype Lakamapur local (385) at 50 % flowering. The data on phenothermal index (PTI) at 50 % flowering represents varied difference among stress levels. Significantly higher mean was recorded under stress condition (9.96) and significantly lower PTI was recorded under non stress condition (8.89) at 50 % flowering. Comparing stress and non stress conditions, stress condition recorded significantly higher mean PTI values (17.68) at maturity followed by non stress condition (16.78). Among the genotypes, significantly higher mean PTI was recorded in CRS73 (10.48) followed by the genotype PEC30 and Phule Suchitra (10.39). Significantly least PTI was recorded in genotype Kodamurki local (8.33) followed by genotype Bhagevadi local (8.59) at 50% flowering.

The data on Heat use efficiency (HUE) at 50 % flowering is represented in Table 11. Among the stress and non stress condition, significantly higher mean was recorded under non stress condition (0.151) and significantly lower HUE was recorded under stress condition (0.128) at 50 % flowering. The significantly higher mean HUE was recorded in RSV1837 (0.187) followed by the genotype SVD1365 (0.179). Significantly least HUE was recorded in genotype PVR947 (0.081) followed by genotype EP89 (0.094) at 50% flowering.

Drought stress in sorghum adversely affects the yield traits, such as, grain yield,

Table 1: Effect of drought stress on days to physiological traits and thermal indices in sorghum genotypes

	50% flowering		*Physiological maturity*	
Genotypes	*Stress*	*Non stress*	*Stress*	*Non stress*
RSV 1984	73	75	117	123
RSV1837	71	75	111	122
RSV1945	73	75	109	119
VJV111	72	74	115	123
VJV107	71	75	114	120
Lakamapur local	69	73	110	118
Kodmurki local	70	71	115	118
Bhagevadi local	70	72	113	119
SVD1365	72	76	114	125
CRS70	73	77	113	121
CRS73	73	75	107	120
Basavanapada	69	75	104	119
EP89	70	75	110	121
PVR947	72	76	109	126
PEC23	73	75	110	128
PEC15	73	76	114	125
PEC30	73	76	108	121
M 35-1(C)	72	76	113	122
CSV29R(C)	75	81	118	128
P. Suchitra(C)	73	76	108	121
Mean	72	75	112	122
	S.Em. ±	CD @5%	S.Em. ±	CD @5%
Moisture stress	0.02	0.12	0.06	0.36
Genotypes	1.36	3.84	2.17	6.11
Interaction	2.72	S	4.34	S

Table 2: Effect of drought stress on growing degree days at 50% flowering and physiological maturity in sorghum genotypes

Genotypes	*GDD at 50% flowering*		*GDD at maturity*	
	Stress	*Non stress*	*Stress*	*Non stress*
RSV 1984	399	414	744	794
RSV1837	386	414	692	784
RSV1945	399	414	678	762
VJV111	392	406	726	794
VJV107	386	414	717	769
Lakamapur local	372	399	685	753
Kodmurki local	379	386	726	753
Bhagevadi local	379	392	709	762
SVD1365	392	421	717	809
CRS70	399	429	709	776
CRS73	399	414	662	769
Basavanapada	372	414	637	762
EP89	379	414	685	776
PVR947	392	421	678	818
PEC23	399	414	685	837
PEC15	399	421	717	809
PEC30	399	421	670	776
M 35-1(C)	392	421	709	784
CSV29R(C)	414	523	752	837
P. Suchitra(C)	399	421	670	776
Mean	391	419	**698**	**785**
	S.Em. ±	CD @5%	S.Em. ±	CD @5%
Moisture stress	0.20	1.25	0.50	3.04
Genotypes	7.53	21.21	13.83	38.95
Interaction	15.06	S	27.66	S

Table 3: Effect of drought stress on phenothermal index at 50% flowering and physiological maturity in sorghum genotypes

	PTI @ 50% flowering		*PTI @ maturity*	
Genotypes	*Stress*	*Non stress*	*Stress*	*Non stress*
RSV 1984	9.07	8.64	16.92	16.54
RSV1837	9.66	8.82	17.32	16.69
RSV1945	11.09	9.42	18.84	17.32
VJV111	9.13	8.29	16.89	16.21
VJV107	8.99	9.21	16.69	17.10
Lakamapur local	9.09	8.87	16.71	16.73
Kodmurki local	8.44	8.22	16.14	16.02
Bhagevadi local	8.83	8.35	16.50	16.22
SVD1365	9.35	8.60	17.09	16.53
CRS70	9.98	9.77	17.73	17.64
CRS73	11.74	9.21	19.49	17.10
Basavanapada	10.65	9.42	18.21	17.32
EP89	9.49	9.01	17.13	16.87
PVR947	10.61	8.43	18.34	16.37
PEC23	10.79	7.82	18.52	15.80
PEC15	9.74	8.60	17.50	16.53
PEC30	11.41	9.36	19.17	17.24
M 35-1(C)	9.57	8.43	17.30	16.37
CSV29R(C)	10.11	11.14	17.50	17.81
P. Suchitra(C)	11.41	9.36	19.17	17.24
Mean	**9.96**	**8.89**	**17.68**	**16.78**
	S.Em. ±	CD @5%	S.Em. ±	CD @5%
Moisture stress	0.007	0.021	0.007	0.021
Genotypes	0.174	0.491	0.319	0.898
Interaction	0.349	S	0.638	S

Table 4: Effect of drought stress on grain yield, Harvest Index, HUE and number of grains per panicle in sorghum genotypes

	Harvest index (%)		*HUE at 50% flowering*		*No of grains per panicle*		*Grain yield (g plant^{-1})*	
Genotypes	*Stress*	*Non stress*	*Stress*	*Non stress*	*Stress*	*Non stress*	*Stress*	*Non stress*
RSV 1984	37.81	40.71	0.160	0.185	2342	2985	64.03	76.56
RSV1837	34.89	37.43	0.178	0.196	2416	3042	68.84	81.20
RSV1945	34.64	31.63	0.150	0.155	2288	2765	59.78	64.14
VJV111	27.12	29.73	0.099	0.146	1818	2635	38.86	59.22
VJV107	29.16	35.20	0.137	0.181	2117	2930	53.05	74.88
Lakamapur local	28.33	27.53	0.124	0.125	1973	2457	46.24	50.07
Kodmurki local	27.88	31.08	0.123	0.151	1989	2618	46.85	58.27
Bhagevadi local	27.68	28.48	0.136	0.150	2085	2649	51.57	58.82
SVD1365	34.92	36.03	0.167	0.191	2398	3015	65.51	80.63
CRS70	34.59	35.34	0.159	0.176	2310	2755	63.30	75.76
CRS73	23.94	26.24	0.097	0.118	1815	2468	38.81	49.04
Basavanapada	32.54	35.26	0.173	0.182	2368	2945	64.39	75.49
EP89	20.37	25.01	0.079	0.108	1608	2340	30.16	44.73
PVR947	15.75	22.13	0.065	0.096	1488	2253	25.49	40.64
PEC23	23.10	23.97	0.085	0.105	1700	2131	34.01	43.39
PEC15	28.99	30.96	0.128	0.143	2078	2659	51.20	60.46
PEC30	27.47	30.30	0.121	0.153	2034	2751	48.41	64.27
M 35-1(C)	28.61	30.61	0.134	0.151	2108	2721	52.70	63.46
CSV29R(C)	29.38	33.39	0.115	0.159	2004	3059	47.69	83.29
P. Suchitra(C)	30.71	30.12	0.120	0.141	2016	2677	47.98	59.60
Mean	28.90	31.06	0.128	0.151	**2048**	**2693**	**49.94**	**63.20**
	S.Em. ±	CD @5%	S.Em. ±	CD @5%	S.Em. ±	CD @5%	S.Em. ±	CD @5%
Moisture stress	0.01	0.04	0.0001	0.0006	3.34	20.3	0.07	0.42
Genotypes	0.59	1.65	0.002	0.007	45.3	127	1.12	3.14
Interaction	1.17	S	0.005	S	90.6	S	2.23	S

number of grains per panicle, test weight, and harvest index (Harris *et al*., 2007, Mutava *et al*., 2009, Vadez *et al.,* 2011 and Kapanigowda *et al*., 2013). The data pertaining to the grain weight per plant in sorghum genotypes is presented in table 4. Significantly higher mean grain weight per plant was recorded under irrigated condition (63.20 g) and under stressed condition recorded significantly lower mean grain weight per plant (49.94 g). The genotype RSV1837 (75.02 g) recorded significantly higher mean grain weight per plant followed by SVD1365 (73.07 g). Significantly, least grain weight per plant was recorded by the genotype PVR947 (33.07 g) followed by EP89 (37.45 g). The study revealed a large range of variation for grain yield under drought stress and under well-watered conditions. Overall, about 50% reduction in mean grain yield under post-flowering drought stress was noticed as compared with well-watered conditions (Vadez *et al*., 2011). Yield under drought can be explained by traits that are fully independent of the response of genotypes to the drought environment. Crop duration in sorghum plays a critical role and contributes to genotype environment interactions (Vadez *et al*., 2011 and Upadhyaya *et al*., 2014). Similarly, genotypes also varied significantly with respect to number of grains per panicle. The genotype RSV1837 (2729) recorded numerically higher mean number of grainsper plant which is followed by SVD1365 (2707). Post-flowering drought highly affected the yield of sorghum and similar findings were reported by Menezes *et al*. (2014), Khaton *et al*. (2016), Hamza *et al.* (2016) and Sory *et al*. (2017). Significantly, least grain number per panicle was recorded by the genotype PVR947 (1871) followed by PEC23 (1916). Likewise, the genotypes also varied significantly, the genotype RSV1984 recorded significantly higher mean harvest index (39.26%) followed by the genotype RSV1837 (36.16%). While, significantly least mean harvest index (18.94%) was accounted by the genotype PVR947. The proportion of total dry matter distributed to the grain (HI) was unaffected by different timings or magnitudes of grain-fill stress or seasonal stress. Genotype RSV1984 recorded significantly high harvest index (37.81%) followed by the genotypes SVD1365 (36.16%) and RSV1837 (34.89%). Differential stress on a cultivar had no effect on HI. It remained constant, although grain yield reductions depending on the stress treatment. While least harvest index was observed by the genotype PVR947 (15.7%). These data suggest that substantial amounts of stored stem reserves were mobilized to the grain. However, there appear to be a range of water deficits within which HI is unaffected. Passioura (1996) found that the HI of can be unaffected by drought stress if crop transpiration during the post-flowering stress above post-flowering period starts above 30% of the seasonal total.

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