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Heat units and heat unit efficiency influenced by environment effect on yield and dry matter of rabi sorghum

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Abstract
The present investigation entitled, "Physiological and biochemical alterations in *rabi* sorghum in response to climate change" was undertaken during *rabi* 2010-11 at All India Co-Ordinated Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.). The experiment was laid out in split plot design with three replications. Four sowing dates (D_1-18th August, D_2-18th September, D_3-18th October and D_4-18th November) were assigned to main plot and four varieties (V_1-Phule Anuradha, V_2-Phule Chitra, V_3-Phule Vasudha and V_4-Phule Revati) were assigned to sub plot treatment. Among the different sowing dates and varieties lowest heat units was recorded at D_4 sowing date and in variety Phule Anuradha, respectively. Highest heat unit efficiency for dry matter was recorded at D_4 sowing date and for grain yield was recorded at D_3 sowing date. Highest heat unit efficiency for dry matter and grain yield was recorded in Phule Revati variety than other varieties.

Keywords: Heat units, yield, rabi sorghum, climate change

Introduction
As a climate is so gradually changing to higher temperature and rabi sorghum is bound to grow the genotypes tolerant to climate change need to be developed identified through physiological screening. Therefore, to generate physiological information on these aspects for practical utility the current investigation entitled "Physiological and Biochemical alterations in rabi sorghum in response to climate change" was undertaken with the following objectives:
To estimate growing degree-days (GDD) and heat unit efficiency (HUE) under different sowing dates and to identify heat unit efficient varieties under climate change.

Material and methods
The experimental material consisted of four rabi sorghum genotypes and four sowing dates under irrigated conditions. The salient features of the genotypes used in this study are presented in table 1. The experiment was laid out in Split plot design with 4 main factor (sowing dates- 18th August, 18th September, 18th October and 18th November), 4 sub factor (varieties- Phule Anuradha, Phule Chitra, Phule Vasudha and Phule Revati-) and three replications. The data were subjected to statistical analysis as per the method suggested by, standard error (S.E.) of the means worked out for each factor. Wherever the results were significant, critical difference (C.D.) at 5 per cent level of significance was worked out.

Table 1: Salient features of sorghum genotypes

Sr. No.	Genotypes	Salient features
1.	Phule Anuradha	Early maturity (105-110days), Drought tolerance variety, Resistance to shoot fly and charcoal rot, recommended for shallow soil.
2.	Phule Chitra	Drought resistance variety, Resistance to shoot fly and charcoal rot, Recommended for medium soil
3.	Phule Vasudha	High grain and fodder yield Resistance to shoot fly and charcoal rot, Recommended for deep soil
4.	Phule Revati	High yielding, Irrigation responsive variety, Recommended for medium to deep soil

Experimental Site

Experiments were conducted at All India Co-ordinate Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dis-Ahmednagar during rabi season 2010-11. The soil was medium black and well drained.

Table 2: Weather data during the experimental period (August 2010-March 2011)

MetWk.	Months - Dates	Temperature (^{0}C)		Humidity (%)		Sunshine (hrs)	Photoperiod (hrs)
		Max	Min	Max	Min		
33	13Aug-19Aug	30.1	21.9	93	66.6	4.5	12.39
34	20Aug-26Aug	29.1	21.3	92	69.9	2.1	13.06
35	27Aug-2Sept	28.7	21.6	94	74.6	2.2	13.00
36	3Sept-9Sept	29.0	21.5	92	59.9	2.8	12.19
37	10Sept-16Sept	31.0	20.6	91	40.1	6.6	12.13
38	17Sept-23Sept	31.6	20.8	94	61.7	5.9	12.05
39	24Sept-30Sept	30.7	21.5	94	64.0	7.4	11.70
40	1Oct-7Oct	30.7	20.8	92	58.9	8.1	11.51
41	8Oct-14Oct	32.0	18.8	94	47.8	6.1	11.43
42	15Oct-21Oct	31.2	21.7	92	56.1	5.1	11.36
43	22Oct-28Oct	30.7	19.8	92	50.3	6.6	11.30
44	29Oct-4Nov	29.9	17.7	91	44.0	8.2	11.22
45	5Nov-11Nov	29.1	19.5	92	59.0	4.6	11.16
46	12Nov-18Nov	29.5	19.9	92	65.9	5.9	11.11
47	19Nov-25Nov	30.0	21.5	91	59.3	6.5	11.06
48	26Nov-2Dec	30.3	23.8	91	50.7	7.7	11.02
49	3Dec-9Dec	28.4	13.8	90	43.6	7.8	10.58
50	10Dec-16Dec	28.1	9.7	91	37.6	5.0	10.56
51	17Dec-23Dec	27.7	5.3	89	30.4	4.6	10.55
52	24Dec-31Dec	28.9	10.0	91	40.5	9.3	10.54
1	1Jan-7Jan	25.1	9.8	92	35.2	5.1	10.70
2	8Jan-14Jan	28.0	10.1	90	29.7	10.0	11.02
3	15Jan-21Jan	29.9	10.5	89	29.6	10.0	11.05
4	22Jan-28Jan	30.5	9.6	88	29.1	10.0	11.10
5	29Jan-4Feb	31.2	10.1	90	31.4	10.0	11.15
6	5Feb-11Feb	31.8	10.0	90	28.4	10.1	11.22
7	12Feb-18Feb	30.9	11.5	90	29.3	9.8	11.28
8	19Feb-25Feb	30.2	11.6	91	32.0	9.8	11.35
9	26Feb-4Mar	32.4	14.2	91	31.9	8.7	11.42
10	5Mar-11Mar	34.7	14.0	91	26.8	10.0	11.47
11	12Mar-18Mar	33.5	11.3	89	21.85	10.7	11.64
12	19Mar-25Mar	39.7	15.2	90	25.57	10.0	12.05

Heat unit requirement

The total heat units required were worked out by total summation of the degree days above the base temperature with the help of formula suggested by Iwata (1984). Base temperature was taken as 10° C (Klages, 1958) [3].

$$\text{Heat unit (Growing degree days)} = \sum_{I=1}^{n} \frac{(\text{Max. temp.} + \text{Min. temp.})}{2} - \text{Base temp.}$$

Heat unit efficiency

The heat unit efficiency (HUE) was calculated for dry matter production per plant at maturity and seed yield per plant as per the formula given by Rajput (1980) [4].

$$\text{Heat Unit Efficiency (Dry matter)} = \frac{\text{Dry matter production (g/plant)}}{\text{Growing degree days}}$$

$$\text{Heat Unit Efficiency (Seed yield)} = \frac{\text{Seed yield (g/plant)}}{\text{Growing degree days}}$$

Result and discussion

Heat unit's accumulation (Growing degree days)

The data relating to mean heat unit required recorded in all physiological growth stages are presented in Table 3. Temperature affects the growth of plant in numerous ways from germination of seed to maturity of the crop by influencing various physiological processes. When temperature drops to a certain level, the process of growth and development could be cease. The lowest heat units (442) recorded during D_4 sowing date from sowing to panicle initiation due to fast accumulation of heat units. Maximum heat units (509) accumulated during D_3 sowing date due to slow accumulation of heat units. The variety Phule Anuradha recorded lowest heat units (455) among the varieties due to quick accumulation of heat unit resulted into early panicle initiation (32.33 days). Due to slow accumulation of heat units (504) in the variety Phule Revati, panicle initiation was delayed (35.92 days).

The D_4 sowing date accumulated the lower heat unit (790) from sowing to 50 % flowering among other sowing dates. The variety Phule Anuradha accumulated lower heat unit (937) among the varieties due to quick accumulation of heat unit. This variety flowered earlier than rest of varieties. Due to slow accumulation of heat units (1101), 50 % flowering was delayed in variety Phule Revati.

The D_4 sowing date accumulated the lowest heat units (342) during the Gs_2 period i.e. panicle initiation to 50 % flowering due to fast accumulation of heat units. More heat units accumulated during D_1 sowing date due to slow accumulation of heat units (729).

For completion as GsIII stage (50 % flowering to physiological maturity), The D_2 sowing dates resulted in lowest heat units (344) accumulation due to this reason D_2 sowing date complete its GsIII phase in short day (114.58 days) than rest of sowing dates. The GsIII stage was delayed in D_3 sowing date (123.08 days) mainly due to slow accumulation of heat units (389). The variety Phule Anuradha accumulated the highest heat units (450) among the varieties due to slow accumulation of heat unit.

The D_2 sowing dates resulted in lowest heat unit (1267) accumulated from sowing to physiological maturity, due to quick accumulation of heat units it matured earlier (118.42 days). The variety Phule Anuradha matured earlier (110.92 days) due to fast accumulation of heat units from sowing to physiological maturity (1388). The maturity period was delayed in the variety Phule Revati (124.42 days) due to slow accumulation of heat units during the period from sowing to physiological maturity (1528). Similar results were reported Ghadekar *et al*. (1985) [2].

The variety V_4 accumulated significantly highest mean heat units from sowing to physiological maturity during D_1 sowing date (1800) while the variety V_1 recorded significantly lowest mean heat units required from sowing to physiological maturity during D_4 sowing date (1127). The significant variation in heat unit requirement for panicle initiation (GsI), panicle initiation to flowering (GsII), sowing to flowering, flowering to physiological maturity (GsIII) and sowing to physiological maturity mainly attributed to different genetic make up and physiological efficiency of the sorghum varieties.

Table 3: Mean heat unit accumulated during different growth stages of *rabi* sorghum varieties as influenced by environment and their interaction at critical growth stages

Sowing Dates / Varieties	D_1 18th Aug	D_2 18th Sep	D_3 18th Oct	D_4 18th Nov	Mean
Sowing to panicle initiation					
V_1	452	477	472	420	455
V_2	463	487	494	431	469
V_3	474	503	518	451	486
V_4	480	519	551	467	504
Mean	467	497	509	442	479
	D	V	D x V (Main)	D x V (Sub)	
SEm±	1.31	2.55	5.09	3.83	
CD 5%	3.960	7.448	14.897	11.253	
Panicle initiation 50% Flowering					
V_1	627	561	462	280	482
V_2	715	649	507	343	553
V_3	785	672	506	367	583
V_4	789	671	482	379	580
Mean	729	638	489	342	550
	D	V	D x V (Main)	D x V (Sub)	
SEm ±	5.67	4.35	8.70	8.37	
CD 5%	17.198	12.727	25.455	24.890	
50 % flowering to physiological maturity					
V_1	620	384	368	427	450
V_2	584	335	372	461	438
V_3	536	336	409	512	448
V_4	530	323	408	510	443
Mean	568	344	389	477	445
	D	V	D x V (Main)	D x V (Sub)	
SEm ±	7.17	1.85	3.69	7.63	
CD 5%	21.752	5.401	10.803	23.053	
Sowing to physiological maturity					
V_1	1699	1423	1302	1127	1388
V_2	1761	1456	1362	1235	1454
V_3	1795	1510	1433	1351	1522
V_4	1800	1513	1441	1356	1528
Mean	1764	1476	1385	1267	1473
	D	V	D x V (Main)	D x V (Sub)	
SEm ±	7.74	2.41	4.82	8.45	
CD 5%	23.469	7.056	14.112	25.500	

*V_1–Phule Anuradha, V_2–Phule Chitra, V_3–Phule Vasudha, V_4–Phule Revati

Mean heat unit efficiency for grain yield and dry matter

The data on mean heat unit efficiency recorded for grain yield and dry matter yield are presented in Table 5. The heat unit efficiency for grain yield and dry matter yield were recorded as 1.24 and 0.10, respectively. Crop productivity mainly depends upon the climatic requirement of the particular crop. Temperature and sunshine hours had been known to affect the growth and yield of sorghum. Crop productivity inhibited at temperature higher than optimum, heat unit efficiency could be used as a measure of crop efficiency for temperature utilization. The D_3 sowing date was most efficient in converting heat into grain yield (1.39kg/ha) owing to efficient utilization of solar radiation.

Table 4: Mean heat unit efficiency of rabi sorghum varieties for total dry matter per plant (gm) and seed yield (kg/ha)as influenced by environment

Treatment	Heat unit efficiency	
	Grain yield (kg/ha)	**Total dry matter(gm)**
A. Sowing dates		
D_1: 18 Aug.	1.00	0.08
D_2: 18 Sept	1.25	0.10
D_3: 18 Oct.	1.39	0.11
D_4: 18 Nov	1.31	0.12
SE ±	1.0 E-2	1.0 E-4
CD at 5%	3.0 E-2	3.0 E-4
B. Varieties		
V_1: Phule Anuradha	1.01	0.09
V_2: Phule Chitra	1.13	0.09
V_3: Phule Vasudha	1.39	0.11
V_4: Phule Revati	1.41	0.11
SE ±	2.0 E-2	1.0 E-4
CD at 5%	5.0 E-2	3.0 E-4
C. Interaction (A x B)		
SE ±	3.0 E-2	2.0 E-4
CD at 5%	N.S.	7.0 E-4.
General mean	1.24	0.10

The D_4 sowing date was most efficient in converting heat into total dry matter (0.12 kg/ha). It might be due to favourable temperature (Max temp 27.97^{0}C and Min. temp 10.10^{0}C) and sunshine hours (7.8) at 30-60 DAS which is the best temperature for the sorghum vegetative growth so give higher total dry matter. The variety Phule Revati was observed to be most efficient in converting the heat into total dry matter (0.11kg/ha) and grain yield(1.41kg/ha), respectively owing to efficient utilization of solar radiation and due to its conversion efficiency of dry matter to the seed yield. The results reported in these studies are in agreement with those of Badha (1999) [1] and Shinde *et al.* (2008) [5].

Conclusion

Among the different sowing dates and varieties lowest heat units was recorded at D_4 sowing date and in variety Phule Anuradha, respectively. Highest heat unit efficiency for dry matter was recorded at D_4 sowing date and for grain yield was recorded at D_3 sowing date than other sowing dates. Highest heat unit efficiency for dry matter and grain yield was recorded in Phule Revati variety than other varieties.

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