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## Phenological studies using phytometeorological indices for Rabi sorghum under scarcity zone of Maharashtra

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### Abstract

The field data (2020-21 and 2021-22) of DFRS farm, Solapur, Maharashtra, India comprising four sowing windows in *Rabi* season i.e. S<sub>1</sub> - 36 MW (03-09 Sept.), S<sub>2</sub> - 38 MW (17-23 Sept.), S<sub>3</sub> - 40 MW (01 - 07 Oct.) and S<sub>4</sub> - 42 MW (15-21) and varieties (Maldandi, Mauli and Yashoda) The higher mean GDD, HTU and PTU was observed under treatment S<sub>3</sub>V<sub>1</sub> (40 MW) i.e. ((3248 and 3397) both the season. Similarly lowest GDD recorded in S<sub>4</sub>V<sub>1</sub> (Oct.15-21) (2339 and 2921) followed by rest of the treatments. Whereas, the highest GDD, HTU and PTU recorded in variety Maldandi i.e. (2735 and 3136), (18925 and 19075) and (31178 and 357449) degree days in 40 MW during 2020-21 and 2021-22 from sowing to physiological maturity and minimum was accumulated in case of Yashoda i.e. (2530 and 3019), (18334 and 18705) and (28839 and 34416) during 2020-21 and 2021-22, respectively.

**Keywords:** Phenological studies, phytometeorological indices, Rabi sorghum

### 1. Introduction

In India, Sorghum is cultivated over 4.10 million ha with an annual production of 4.17 million tonnes of grain with a productivity of 1018 kg ha<sup>-1</sup> whereas, under Maharashtra 2.17 million ha area, 1.81 million tonnes and 833 kg ha<sup>-1</sup>. (Anonymous, 2018) [1].

*Rabi* sorghum is grown from October to February. The best time of sowing for *rabi* sorghum is 15<sup>th</sup> October to reduce incidence of shoot fly, while irrigated sorghum can be sown up to the end of October. Early sown *Rabi* sorghum is prone to heavy shoot fly incidence.

Sowing time has an impact on sorghum growth stages. Number of days between sowing and flowering decreases as planting was delayed due to slower emergence and less rapid accumulation of heat units. Planting date affects not only the time from sowing to flowering but time from flowering to physiological maturity of grain sorghum.

### 2. Materials and Method

#### 2.1. Location of the Experimental Site

The field experiment was conducted at Mulegaon Agricultural Farm, Zonal Agricultural Research Station, Solapur during *rabi* season 2020-21 and 2021-22. The geographical location of the site (Solapur) was 17° 41'N, latitude; 75° 56'E, longitude and 483.6 m above mean sea level (MSL). The soil is medium black calcareous having depth of about 90 cm. The average annual rainfall of Solapur is 545 mm.

#### 2.2 Experimental Details

The field data (2020-21 and 2021-22) of DFRS farm, Solapur, Maharashtra, India comprising four sowing windows in *Rabi* season i.e. S<sub>1</sub> - 36 MW (03-09 Sept.), S<sub>2</sub> - 38 MW (17-23 Sept.), S<sub>3</sub> - 40 MW (01 - 07 Oct.) and S<sub>4</sub> - 42 MW (15-21) and varieties (Maldandi, Mauli and Yashoda) through the field experiment laid out split plot design were used for present studies. The experiment was conducted in a split-plot design with four replications and twelve treatment combinations were formed considering different varieties (3) and sowing windows (4) with recommended spacing 45 cm x 20 cm during *Rabi*, 2020-21 and 2021-22.

### 3. Results and discussion

#### 3.1 Growing Degree Day (GDD)

Bright sunshine hours, maximum and minimum temperatures during the growth period were recorded from meteorological observatory and GDD were calculated from them. Graphically it

was presented in Table 1 (a and b)

The cumulative growing degree days (GDD) varied from sowing to physiological maturity at different sorghum varieties responded differently in terms of accumulated GDD. The number of days and growing degree days accumulated were significantly decreased with each delay in sowing during both the year of experimentation. The number of days required to attain different phenological stages and growing degree days were higher in S<sub>3</sub>V<sub>1</sub> (Oct.01<sup>st</sup> -07<sup>th</sup>) treatment sown crop (3248 and 3397) both the season. Similarly lowest GDD recorded in S<sub>4</sub>V<sub>1</sub> (Oct.15-21) (2339 and 2921) followed by rest of the treatments.

This is due to longer duration required by S<sub>3</sub> sown crop and M-35-1 variety. Further, it was also noticed that the 40 MW sown crop received maximum amount of rainfall due to which soil moisture available was more, however late sown crop suffers the moisture stress situation resulted in less duration

required for maturity.

The higher mean GDD was observed under variety Maldandi (M-35-1) i.e. (2735 and 3136) degree days in 40 MW during 2020-21 and 2021-22 in Table 1 (a and b) respectively from sowing to physiological maturity and followed by lower GDD was noticed in case of Mauli (2644 and 3104 C days) and Yashoda (2530 and 3019 °C days) degree days during sowing to physiological maturity. In general, the GDD values decreased when the sowing was delayed. This might be due to early maturity of crops under delayed sown condition because of higher temperature. With delayed date of sowing, accumulated GDD reduced significantly in sorghum. This was due to increase in the temperature during delayed plantings which leads to early maturity of the crop. The similar results were reported by Poornima *et al.* (2008)<sup>[3]</sup> and Baviskar *et al.* (2017)<sup>[2]</sup>.

**Table 1 (a):** Cumulative Growing Degree Day (GDD) at different phenological stages of *Rabi* Sorghum crop under different treatments during 2020-21

Treatments	GDD (2020)							
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>
S1V1	184	148	407	582	243	252	323	451
Cumulative	184	332	739	1321	1564	1816	2139	2590
S1V2	123	124	454	640	198	302	238	429
Cumulative	123	247	701	1341	1539	1841	2079	2508
S1V3	184	125	381	532	221	229	300	428
Cumulative	184	310	691	1223	1444	1673	1972	2400
S2V1	176	175	415	614	335	271	346	431
Cumulative	176	351	766	1379	1715	1986	2332	2763
S2V2	160	147	418	695	283	368	307	375
Cumulative	160	307	725	1420	1703	2071	2378	2752
S2V3	176	147	388	587	311	295	323	406
Cumulative	176	323	711	1298	1609	1904	2226	2632
S3V1	188	172	502	791	332	439	375	448
Cumulative	188	360	862	1653	1985	2425	2800	3248
S3V2	205	204	442	638	382	295	371	480
Cumulative	205	408	850	1488	1870	2165	2536	3015
S3V3	160	147	447	719	308	391	329	399
Cumulative	160	307	753	1473	1781	2171	2501	2899
S4V1	123	124	427	592	177	278	214	404
Cumulative	123	247	674	1266	1443	1721	1935	2339
S4V2	184	125	356	504	221	229	277	403
Cumulative	184	310	666	1170	1391	1620	1897	2300
S4V3	97	98	400	567	177	255	214	379
Cumulative	97	195	596	1162	1339	1595	1808	2187

**Table 1 (b):** Cumulative Growing Degree Day (GDD) at different phenological stages of *Rabi* Sorghum crop under different treatments during 2021-22

Treatments	GDD (2021)							
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>
S1V1	91	98	446	700	191	719	451	357
Cumulative	91	189	634	1334	1525	2243	2694	3051
S1V2	197	211	444	666	401	318	395	395
Cumulative	197	407	852	1518	1919	2237	2632	3027
S1V3	170	153	473	747	321	438	323	386
Cumulative	170	324	797	1543	1864	2302	2625	3011
S2V1	170	127	391	576	250	505	749	406
Cumulative	170	297	688	1263	1514	2019	2768	3174
S2V2	92	98	473	726	191	718	448	377
Cumulative	92	190	663	1389	1580	2298	2746	3123
S2V3	143	126	363	549	248	486	752	387
Cumulative	143	269	632	1181	1429	1915	2667	3054
S3V1	170	153	417	625	274	544	808	406
Cumulative	170	324	741	1366	1640	2183	2991	3397

S3V2	117	98	500	777	215	774	507	398
Cumulative	117	215	715	1492	1707	2481	2987	3385
S3V3	170	181	501	798	346	463	347	410
Cumulative	170	351	852	1650	1996	2459	2806	3215
S4V1	170	211	417	641	375	318	395	395
Cumulative	170	381	798	1439	1813	2131	2526	2921
S4V2	143	153	446	720	321	413	323	363
Cumulative	143	297	742	1462	1783	2196	2519	2882
S4V3	170	183	389	615	375	295	374	395
Cumulative	170	353	742	1358	1732	2027	2400	2795

### 3.2 Helio Thermal Unit (HTU)

The data regarding mean helio thermal units is presented in Table 2 (a and b). The mean helio thermal units were higher in treatment S<sub>3</sub>V<sub>1</sub> (40MW) sown crop (20204 and 20561 °C

days) during both the season. Similarly lowest HTU recorded in S<sub>4</sub>V<sub>1</sub> (42 MW) (17988 and 17810 °C days) followed by rest of the treatments.

**Table 2 (a):** Cumulative Heliothermal unit (HTU) at different phenological stages of *Rabi Sorghum* crop under different treatments during 2020-21

Treatments	Heliothermal unit (HTU) at different phenological stages (2020)							
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>
S1V1	746	789	1929	4674	2122	2434	2623	3097
Cumulative	746	1536	3465	8139	10261	12695	15318	18415
S1V2	1472	318	2146	3852	2547	2578	2577	2727
Cumulative	1472	1790	3936	7788	10335	12913	15489	18216
S1V3	1279	497	2138	4874	1355	1997	2622	3397
Cumulative	1279	1776	3914	8787	10142	12139	14762	18159
S2V1	1472	318	2327	4088	2782	2707	2691	2708
Cumulative	1472	1790	4117	8205	10987	13694	16385	19093
S2V2	699	733	3978	4765	1621	2316	1267	3363
Cumulative	699	1432	5410	10175	11796	14112	15379	18742
S2V3	1279	489	2340	5245	1314	2165	2470	3202
Cumulative	1279	1768	4108	9353	10667	12832	15302	18504
S3V1	1608	337	2794	4206	2513	2657	2855	3234
Cumulative	1608	1944	4739	8945	11458	14115	16970	20204
S3V2	931	1092	2174	5169	2567	2580	2650	3030
Cumulative	931	2024	4198	9367	11934	14514	17164	20194
S3V3	746	938	2052	4928	2325	2370	3028	3420
Cumulative	746	1684	3736	8664	10989	13359	16387	19807
S4V1	699	733	3724	4619	1427	2358	1061	3368
Cumulative	699	1432	5155	9775	11201	13559	14620	17988
S4V2	1279	497	1904	4610	1355	1967	2426	3170
Cumulative	1279	1776	3680	8290	9645	11611	14037	17207
S4V3	577	579	3501	4396	1427	2175	1061	3148
Cumulative	577	1157	4658	9054	10481	12656	13717	16865

**Table 2 (b):** Cumulative Heliothermal unit (HTU) at different phenological stages of *Rabi Sorghum* crop under different treatments during 2021-22

Treatments	Heliothermal unit (HTU) at different phenological stages (2021)							
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>
S1V1	344	554	2832	5958	1496	3132	2177	2211
Cumulative	344	898	3731	9688	11184	14316	16493	18704
S1V2	693	1545	2484	5089	2444	1563	1800	2926
Cumulative	693	2238	4722	9811	12255	13819	15619	18545
S1V3	480	1027	2617	5615	1684	2044	2148	2565
Cumulative	480	1507	4123	9738	11422	13466	15614	18179
S2V1	693	932	2143	4618	1809	3174	3650	2207
Cumulative	693	1625	3768	8386	10195	13369	17019	19225
S2V2	786	1545	2685	5284	2562	1563	1800	2966
Cumulative	786	2331	5016	10300	12861	14424	16225	19190
S2V3	693	1027	2848	5802	1684	2228	2148	2746
Cumulative	693	1720	4568	10371	12054	14282	16430	19176
S3V1	693	1269	3013	6231	1808	2308	2326	2914
Cumulative	693	1962	4975	11205	13013	15321	17648	20561
S3V2	693	1027	2329	5095	2035	3281	3672	2272
Cumulative	693	1720	4049	9145	11179	14461	18132	20405
S3V3	349	554	3020	6257	1715	3399	2214	2408

Cumulative	349	903	3923	10179	11894	15294	17508	19915
S4V1	693	1406	2253	4984	2444	1495	1621	2913
Cumulative	693	2099	4353	9336	11780	13276	14896	17810
S4V2	480	786	1943	4362	1806	2911	3431	2056
Cumulative	480	1266	3208	7570	9376	12287	15718	17773
S4V3	152	554	2631	5787	1496	2924	1973	2033
Cumulative	152	706	3337	9124	10620	13544	15517	17551

Among the varieties it is higher in M-35-1 than Vasudha and Yashoda. This was due to more duration required by S<sub>3</sub> sown crop and M-35-1 variety. Since all sowing took identical days for sowing to physiological maturity, the differences in the requirement of helio thermal units due to variation in temperature or sunshine hours.

Helio Thermal unit (HTU) for different varieties varied considerably at maturity period in Table 2 (a and b). The higher mean HTU (18925 and 19075 °C days) was observed under variety Maldandi (V<sub>1</sub>) and Mauli (18590 and 18978 °C days) while variety Yashoda accumulated the lower HTU values (18334 and 18705 °C days) during 2020-21 and 2021-22, respectively. Further, it was also noticed that the early sown crop experienced maximum amount of rainfall due to which soil moisture available was more and duration was also more. However late sown crop suffered moisture stress situation resulting in less duration required for maturity.

With delayed sowing window, accumulated HTU reduced significantly in sorghum. This was due to increase in the temperature during delayed plantings which accelerated the growth of the crop. The similar results were reported by

Poornima *et al.* (2008) [3] and Baviskar *et al.* (2017) [2].

### 3.3 Photo Thermal Unit (PTU)

Different sorghum varieties responded differently in terms of accumulated PTU at the time of maturity it is presented in Table 3 (a and b).

Photo thermal unit (PTU) for different genotypes varied considerably from sowing to physiological maturity. In treatment S<sub>3</sub>V<sub>1</sub> (40MW) sown crop (37024 and 38725 °C days) highest during both the season. Similarly lowest PTU recorded in S<sub>4</sub>V<sub>1</sub> (42 MW) (26666 and 33303 °C days) followed by rest of the treatments. Higher mean photothermal units (PTU) observed in Maldandi (31178 and 35749 °C days) followed by Mauli (30139 and 35389 °C days) and Yashoda (28839 and 34416 °C days) during 2020-21 and 2021-22, respectively.

With delayed sowing window, accumulated PTU reduced significantly in sorghum. This was due to increase in the temperature during delayed plantings which accelerated the growth of the crop. The similar results were reported by Poornima *et al.* (2008) [3] and Baviskar *et al.* (2017) [2].

**Table 3 (a):** Cumulative Photothermal unit (PTU) at different phenological stages of *Rabi* Sorghum crop under different treatments during 2020-21

Treatments	Photothermal unit (PTU) at different phenological stages (2020)							
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>
S1V1	2100	1689	4640	6634	2771	2869	3680	5144
Cumulative	2100	3789	8429	15063	17835	20704	24384	29528
S1V2	1407	1411	5172	7298	2257	3441	2711	4891
Cumulative	1407	2819	7991	15289	17546	20987	23698	28588
S1V3	2100	1430	4347	6060	2523	2607	3414	4878
Cumulative	2100	3530	7877	13937	16460	19068	22482	27360
S2V1	2005	1993	4732	6994	3822	3093	3942	4912
Cumulative	2005	3997	8730	15723	19545	22639	26581	31493
S2V2	1825	1673	4767	7925	3226	4191	3497	4273
Cumulative	1825	3498	8265	16190	19416	23607	27104	31376
S2V3	2005	1677	4428	6692	3541	3359	3677	4631
Cumulative	2005	3682	8109	14801	18342	21701	25378	30009
S3V1	2142	1960	5726	9015	3789	5010	4279	5104
Cumulative	2142	4102	9828	18843	22632	27642	31921	37024
S3V2	2333	2320	5034	7275	4358	3359	4227	5468
Cumulative	2333	4653	9687	16963	21321	24680	28906	34374
S3V3	1825	1673	5090	8201	3509	4455	3752	4545
Cumulative	1825	3498	8588	16789	20298	24753	28506	33050
S4V1	1407	1411	4870	6744	2017	3174	2436	4606
Cumulative	1407	2819	7689	14433	16450	19624	22060	26666
S4V2	2100	1430	4057	5748	2523	2607	3160	4591
Cumulative	2100	3530	7587	13335	15859	18466	21625	26217
S4V3	1111	1114	4563	6463	2017	2912	2436	4320
Cumulative	1111	2225	6789	13251	15269	18180	20616	24936

**Table 3 (b):** Cumulative Photothermal unit (PTU) at different phenological stages of *Rabi Sorghum* crop under different treatments during 2021-22

Treatments	Photothermal unit (PTU) at different phenological stages (2021)							
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>
S1V1	1036	1116	5079	7981	2172	8191	5139	4066
Cumulative	1036	2152	7231	15212	17384	25575	30714	34780
S1V2	2240	2404	5067	7595	4567	3625	4502	4505
Cumulative	2240	4644	9711	17306	21874	25499	30001	34506
S1V3	1940	1748	5396	8511	3654	4996	3684	4402
Cumulative	1940	3688	9084	17595	21248	26245	29928	34331
S2V1	1940	1448	4452	6562	2852	5762	8541	4630
Cumulative	1940	3388	7840	14403	17254	23017	31557	36188
S2V2	1053	1116	5392	8279	2172	8186	5110	4298
Cumulative	1053	2169	7560	15840	18012	26198	31308	35606
S2V3	1632	1436	4139	6257	2831	5540	8569	4407
Cumulative	1632	3068	7208	13465	16296	21836	30405	34812
S3V1	1940	1748	4758	7123	3123	6197	9206	4630
Cumulative	1940	3688	8446	15569	18692	24889	34095	38725
S3V2	1335	1116	5697	8861	2447	8822	5775	4537
Cumulative	1335	2451	8148	17009	19456	28278	34053	38590
S3V3	1940	2062	5709	9095	3948	5279	3951	4671
Cumulative	1940	4003	9711	18806	22754	28033	31983	36654
S4V1	1940	2404	4754	7303	4269	3625	4502	4505
Cumulative	1940	4345	9099	16402	20672	24297	28799	33303
S4V2	1632	1748	5081	8206	3654	4711	3684	4136
Cumulative	1632	3380	8461	16667	20321	25032	28716	32852
S4V3	1940	2082	4439	7014	4269	3358	4260	4505
Cumulative	1940	4022	8462	15476	19745	23103	27363	31868

#### 4. Conclusions

Growing degree days were higher in S<sub>3</sub>V<sub>1</sub> (Oct.01<sup>st</sup> -07<sup>th</sup>) treatment sown crop (3248 and 3397 °C days) both the season and higher GDD, HTU and PTU was observed under variety Maldandi i.e. (2735 and 3136 °C days), (18925 and 19075 °C days) and (31178 and 35749 °C days) degree days while minimum GDD, HTU and PTU was accumulated in variety Yashoda i.e. (2530 and 3019 °C days), (18334 and 18705 °C days) and (28839 and 34416 °C days ) during 2020-21 and 2021-22 in 40 MW during 2020-21 and 2021-22 from sowing to physiological maturity, respectively.

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