E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 274-276
Received: 10-07-2025
Accepted: 13-08-2025

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Compute growing degree days by different methods for Parbhani location in *rabi* sorghum crop

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9d.3762

Abstract
The present study was conducted at the research farm of the Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, to examine the Effect of thermal regimes on rabi sorghum (*Sorghum bicolor*.L) varieties. The experiment followed a split-plot design with three replications. Three sowing dates were evaluated: D1 (42nd Standard Meteorological Week - SMW), D2 (43rd SMW), D3 (44th SMW). The study involved four sorghum varieties: V1 - Dagadi, V2 - Parbhani Moti, V3 - Parbhani Super Moti, and V4 - Parbhani Shakti. The crop was sown at a spacing of 45 × 15 cm, and the net plot size for each treatment was 4.5 × 2.1 m².

Findings revealed that early sowing (D1) resulted in a longer crop duration from sowing to maturity compared to later sowing dates. Among the varieties, Parbhani Moti took the maximum number of days to reach maturity, followed byParbhani Super Moti, Dagadi and Parbhani Shakti.

Accumulated thermal indices such as Growing Degree Days (GDD) were highest under the earliest sowing (D1), with a decreasing trend seen through D2 and D3. Among the varieties, Parbhani Moti recorded the highest values for GDD followed by, Parbhani Super Moti, Dagadi. Parbhani Shakti accumulated the least thermal units over the crop cycle.

Keywords: Nanourea, conventional urea, growth, LAI, yield and wheat

Introduction
Sorghum (*Sorghum bicolor* L.), often referred to as the king of millet'sis a key food and fodder crop belonging to the Gramineae family. Originally from Africa, it ranks as the fifth most important cereal globally, following wheat, rice, maize, and barley. Due to its strong adaptability to diverse environmental conditions, sorghum serves as a staple crop across the semi-arid tropics (SAT). Its ability to grow with minimal rainfall has earned it the nickname 'Camel of the Desert'.

The name 'Sorghum' originates from the Latin word sargo, meaning 'to rise above', reflecting its ability to grow taller than many other crops in the field. Due to its large grain size and extensive cultivation area, it is also commonly known as Jowar, durra, and giant millet. Jowar serves a dual purpose, offering nutritious grains for human consumption and providing moderate-quality fodder for livestock. In India, sorghum grains are widely used both as a staple food and as feed for animals. Nutritionally, sorghum contains about 10-12% protein, 3% fat, and around 70% carbohydrates. It is processed into various products such as syrups, alcohol, starch, dextrose, and other derivatives. Sorghum is cultivated during both the *Kharif* (June-October) and *Rabi* (September-March) seasons, with Maharashtra, Karnataka, Madhya Pradesh, Rajasthan, and Andhra Pradesh being the major producing states. It remains the most important food crop in the arid and semi-arid regions of India.

Sowing time plays a key role in influencing sorghum's growth phases. Studies have shown that the projected decline in sorghum yields under future climate change scenarios across different parts of India is mainly due to a shortened crop growth duration caused by rising temperatures (Boomiraj *et al*., 2012) [1].

Sorghum is primarily cultivated on red soils (Alfisols) and black soils (Vertisols), with an ideal plant population between 1.00 and 1.35 lakh per hectare. For germination, a minimum temperature of 8.0°C to 10.0°C is required, and the crop thrives best in temperatures ranging from 35.0°C to 40.0°C. The optimal temperature for sorghum growth falls between 24.0°C and 30.0°C. Its base temperature is around 10°C, below which growth and development are significantly hindered. Both high temperatures and drought conditions can lead to reduced yields (Ghadekar, 2005) [2].

Materials and Methods

Field experiment was conducted during Rabi season 2024 entitled "Effect of thermal regimes on *rabi* sorghum (*Sorghum bicolor*L.) Varieties" on the research farm of the Department of Agricultural Meteorology, located at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

GDD was computed by using following 8 methods.

1. Method 1 Standard degree day method

$$GDD = \sum[(\frac{Tx+Tn}{2}) - base]$$

Where Tx and Tn are the daily maximum and minimum temperature respectively.

2. Method 2 Maximum instead of mean method

$$GDD = \sum(Tx - Base)$$

3. Method 3 Reduced ceiling method

Ex. (2) Tx <Ceiling 31˚C

$$GDD = \sum((Tc - (Tx - Tc)) - Base)$$

Tx > Ceiling i.e. if maximum is greater than ceiling. Tc set maximum equal to the ceiling minus the difference between the maximum and ceiling.

4. Method 4 Owens and More (1974) method.

GDD = (((Tx Tn)/2 - (Tx-Ceiling)) - Base)

Tx > Ceiling

5. Method 5-8

Same as method 1 to 4 but multiply by day length (DL/12) Ex method 5 would 1 × DL/12

$$GDD = \sum \frac{DL}{12}(Tx + Tn)/2 - base)$$

Day length was the actual day length divided by 12.

Results AND Discussion

Late sowing of Rabi crops often exposes them to heat stress during their maturity stage. Sorghum, when sown late in the Rabi season, is particularly vulnerable to temperature variations, which can negatively impact its growth, developmental stages, yield, and yield-related traits.

Methods of Growing Degree Days (GDD)

To calculate Growing Degree Days (GDD), eight different methods outlined by Perry *et al*. (2001) [3] were employed. These methods were applied to four crop varieties sown on different dates. The initial four methods used varying weightings of daily maximum and minimum temperatures. The remaining four methods were modifications of the first four, incorporating day length by multiplying each equation with the actual day length divided by 12. The first method used the average of daily maximum and minimum temperatures above a base temperature of 10°C. In the second method, only the maximum temperature was considered. The third method introduced a ceiling temperature, capping the maximum temperature at 31°C.In method number 4 the difference between the maximum and ceiling temperature was also used along with mean temperature and base temperature for calculating GDD. Results from these computations are presented in Tables 1 to 1.2

On the basis of C.V. values of different 8 methods were examined it was found that method 1 (Standard Degree Day method) and method 5 (method 1 × DL/12) was recorded the least C.V. for all the varieties across the sowing dates. Hence for further analysis of GDD method 1 (Standard Degree Day method) and method 5 (method 1 × DL/12) found suitable for Parbhani location for Rabi sorghum crop. The highest Growing Degree Days (GDD) was observed in first date of sowing D1 followed by D2 and D3 respectively. Among the varieties highest GDD was reported Parbhani Moti followed by Parbhani Super Moti and Dagadi. Lowest total accumulate was in Parbhani Shakti. Therefor Parbhani Moti recorded highest GDD accumulation therefor clearly indicate tolerant to thermal stress.

Table 1: Growing Degree Days by different methods

GDD using different methods									
Varieties	Date of sowing	Method-1	Method-2	Method-3	Method-4	Method-5	Method-6	Method-7	Method-8
Dagadi	21-10-2024	2786	3871	1827	1415	2535	3522	1663	1288
	28-10-2024	2643	3663	1655	1290	2405	3333	1506	1174
	04-11-2024	2502	3459	1559	1174	2277	3148	1418	1069
	CV%	4	5	7	8	4	5	7	8
Parbhani Moti	21-10-2024	3034	4223	1980	1511	2761	3843	1802	1375
	28-10-2024	2858	3974	1812	1385	2600	3616	1649	1260
	04-11-2024	2715	3767	1713	1270	2470	3428	1559	1156
	CV%	5	5	6	7	5	5	6	7
Parbhani Super Moti	21-10-2024	2858	3974	1880	1447	2600	3616	1711	1316
	28-10-2024	2762	3836	1743	1342	2513	3491	1586	1221
	04-11-2024	2598	3594	1629	1216	2364	3271	1482	1107
	CV%	4	5	6	8	4	5	6	8
Parbhani Shakti	21-10-2024	2690	3733	1758	1374	2448	3397	1599	1250
	28-10-2024	2554	3529	1585	1250	2324	3211	1443	1137

	04-11-2024	2403	3324	1489	1133	2186	3025	1355	1031
	CV%	5	5	7	8	5	5	7	8

Table 2: Phenological stagewise accumulated Growing Degree Days (GDD) of sorghum crop by Method 1

Date of Sowing	Phenological stages							
	Emergence stage	**Seedling stage**	**Flag leaf stage**	**Flowering stage**	**Soft dough stage**	**Hard dough stage**	**Physiological maturity stage**	**Total GDD**
D1V1:21/10/2022	101.69	104.24	355.26	282.05	165.35	156.16	228.64	1393.39
D2V1:28/10/2022	95.32	131.95	298.25	277.69	126.13	165.21	230.73	1325.28
D3V1:04/11/2022	103.51	102.65	312.54	280.92	105.38	129.04	225.68	1259.71
MEAN	100.18	112.95	322.02	280.22	132.28	150.13	228.35	1326.13
D1V2:21/10/2022	115.30	89.04	407.54	301.03	188.01	207.84	218.45	1527.21
D2V2:28/10/2022	129.68	103.97	354.72	284.65	159.20	198.24	214.17	1444.63
D3V2:04/11/2022	101.69	117.85	284.10	353.22	139.37	162.71	217.44	1376.38
MEAN	115.55	103.62	348.79	312.96	162.19	189.60	216.69	1449.40
D1V3:21/10/2022	101.69	117.85	368.82	284.65	131.40	239.60	200.61	1444.63
D2V3:28/10/2022	129.68	103.97	312.81	310.40	130.27	203.93	203.11	1394.17
D3V3:04/11/2022	115.30	89.04	299.30	282.37	117.16	153.70	242.88	1299.75
MEAN	115.55	103.62	326.98	292.47	126.28	199.08	215.53	1379.51
D1V4:21/10/2022	87.95	116.39	342.11	274.68	114.57	178.04	242.56	1356.31
D2V4:28/10/2022	115.30	104.24	284.10	244.74	133.22	140.60	264.81	1287.01
D3V4:04/11/2022	101.69	102.65	271.23	238.60	127.31	136.82	225.32	1203.61
MEAN	101.65	107.76	299.15	252.68	125.03	151.82	244.23	1282.31

Table 3: Phenological stagewise accumulated Growing Degree Days (GDD) of sorghum crop by Method 5

Date of Sowing	Phenological stages							
	Emergence stage	**Seedling stage**	**Flag leaf stage**	**Flowering stage**	**Soft dough stage**	**Hard dough stage**	**Physiological maturity stage**	**Total GDD**
D1V1:21/10/2022	101.69	104.24	355.26	282.05	165.35	156.16	228.64	1393.39
D2V1:28/10/2022	95.32	131.95	298.25	277.69	126.13	165.21	230.73	1325.28
D3V1:04/11/2022	103.51	102.65	312.54	280.92	105.38	129.04	225.68	1259.71
MEAN	100.18	112.95	322.02	280.22	132.28	150.13	228.35	1326.13
D1V2:21/10/2022	115.30	89.04	407.54	301.03	188.01	207.84	218.45	1527.21
D2V2:28/10/2022	129.68	103.97	354.72	284.65	159.20	198.24	214.17	1444.63
D3V2:04/11/2022	101.69	117.85	284.10	353.22	139.37	162.71	217.44	1376.38
MEAN	115.55	103.62	348.79	312.96	162.19	189.60	216.69	1449.40
D1V3:21/10/2022	101.69	117.85	368.82	284.65	131.40	239.60	200.61	1444.63
D2V3:28/10/2022	129.68	103.97	312.81	310.40	130.27	203.93	203.11	1394.17
D3V3:04/11/2022	115.30	89.04	299.30	282.37	117.16	153.70	242.88	1299.75
MEAN	115.55	103.62	326.98	292.47	126.28	199.08	215.53	1379.51
D1V4:21/10/2022	87.95	116.39	342.11	274.68	114.57	178.04	242.56	1356.31
D2V4:28/10/2022	115.30	104.24	284.10	244.74	133.22	140.60	264.81	1287.01
D3V4:04/11/2022	101.69	102.65	271.23	238.60	127.31	136.82	225.32	1203.61
MEAN	101.65	107.76	299.15	252.68	125.03	151.82	244.23	1282.31

Conclusion

The study demonstrated that delayed sowing of Rabi sorghum led to reduced thermal accumulation (GDD) across all phenological stages, indicating increased vulnerability to thermal stress. Among the GDD calculation methods evaluated, Method 1 and Method 5 showed the highest consistency and were therefore used for further analysis. Across both methods, early sowing (42nd SMW) consistently resulted in higher GDD accumulation, supporting better growth and development. Parbhani Moti and Parbhani Super Moti recorded the highest GDD value.

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