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Vora VD
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Sanepara DP
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Chopada MC
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Vekariya PD
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Patel JT
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Rakholiya KD
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Sharma GR
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Sutaria GS
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Correspondence
Vora VD
Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia, Gujarat, India

Thermal requirement of *kharif* crops under rainfed condition in north Saurashtra of Gujarat

Vora VD, Sanepara DP, Chopada MC, Vekariya PD, Patel JT, Rakholiya KD, Sharma GR and Sutaria GS

Abstract
The experiment was conducted to determine thermal requirement of short (Sesame: Guj. Til-2, Black gram: T-9, Pearl millet: GHB-558) and long duration crops (Cotton: G Cot-Hy-8, Castor: GCH-6, Groundnut: GG-13) at the Dry Farming Research Station, Junagadh Agricultural University, Targhadia, (Dist: Rajkot, Gujarat, India) at north Saurashtra agro climatic zone – VI during *kharif* seasons of 2008-2010. The experiment was laid out in a sampling techniques and plot size was gross: 4.5m x 3.6m and net: 2.7m x 1.8m. The objectives of the experiment were to find out meteorologically suitable date of sowing, to calculate thermal requirement as well as heat use efficiency of the crops. The two years results revealed that the highest growing degree days (GDD), photo thermal units (PTU), heat use efficiency and yield for sesame, black gram, pearl millet and spreading groundnut were recorded during first date of sowing. For cotton and castor crops the two years results showed that the highest growing degree days (GDD), heliothermal units (HTU), photo thermal units (PTU), heat use efficiency and yield recorded under first date of sowing. It means first date sown crop utilized higher thermal / heat energy. Thus, delay in sowing resulted in declined yield in cases of both short and long duration *kharif* crops.

Keywords: Growing degree days, heat use efficiency, heliothermal units photo thermal units

Introduction
Thermal and photoperiodic conditions expressed by the crop during its life cycle play an important role in deciding the initiation and completion of different phenophases, growth and yield. The application of agro climatic indices provides a base for determining the effect of temperature and photoperiod on phenological behavior of the crop. Crop physiological process are dependent on integrated atmospheric parameters (Ko *et al*., 2010) [7], in which temperature is an important weather parameter that affects plant growth, development and yield. Winter crops are vulnerable to high temperature during reproductive stages and differential response of temperature change (rise) to various crops has been noticed under different production environments (Reddy *et al*., 2013; Moniruzzaman *et al.*, 2015) [18, 12].
The changing climate is one of the biggest threats to agriculture in the future. According to estimates, on an average 50% yield losses in agricultural crops are due to different abiotic stresses. The expected changes in the climate could strongly affect the crop production worldwide (Kajla *et al.*, 2015) [5]. As per estimates the global mean temperature is steadily rising which may result in significant decline in crop yields (Modarresi *et al*., 2010; Kumar and Kumar; 2014) [11, 8]. Heat unit requirement or growing degree day (GDD) has been used for characterizing the thermal response in different winter crops (Rajput *et al*., 1987) [16]. The quantification of heat use efficiency (HUE) is useful for the assessment of yield potential of a crop in different growing environments (Kingra and Kaur, 2011; Pal *et al*., 2013) [6, 15].
The aim of the present study was to find out the most favorable sowing date, thermal requirement and heat use efficiency of the *kharif* crops.

Materials and Methods
The experiment was conducted to determine thermal requirement of short (Sesame: Guj. Til-2, Black gram: T-9, Pearl millet: GHB-558) and long duration crops (Cotton: G Cot-Hy-8, Castor: GCH-6, Groundnut: GG-13) at the Dry Farming Research Station, Junagadh Agricultural University, Targhadia situated at north Saurashtra agroclimatic zone – VI at latitude of 22.17' N,longitude of 70.48' E and altitude 137.7 m above mean sea level. The experiment was conducted during the *kharif* seasons of 2008-2010. The design used was sampling techniques with three dates of sowing i.e. onset of monsoon, 15 days after onset of monsoon and 30 days after onset of monsoon in main plots and short and long duration crops in subplots. The plot size was kept as gross: 4.5m x 3.6m and net: 2.7m x 1.8m.

The growing degree days (GDD), heliothermal unit (HTU), photo thermal unit (PTU) and heat use efficiency (HUE) were calculated by using the given formula (Major *et al.* 1975, Ramkutty N. 2002,Sahu *et al.* 2007; Amrawat *et al.*, 2013 and Sondarva *et al.* 2014) [10, 17, 19, 1, 21] for different phenophases of long and short duration crops.
The methods of computation of the heat indices are as under.

(1) Growing Degree Days (GDD)
Growing Degree Days (GDD) (°C day) were calculated by simple accumulation of daily mean air temperature above a given threshold or base temperature.

$$GDD = \sum_{ds}^{dp} \left\{ \frac{(T_{max} + T_{min})}{2} - Tb \right\}$$

Where, ds = Dates of sowing
dp = Dates of different phenological stages
Tmax = Daily maximum temperature (ºC)
Tmin = Daily minimum temperature (ºC)
Tb = Base temperature (ºC)

(2) Photothermal Units (PTU):
They can be calculated by the formula as under:

$$PTU = GDD \times N$$

Where, N=Maximum possible sunshine hours. It varies with latitude and season.

(3) Heliothermal Units (HTU)
They can be calculated by the formula as under:

$$HTU = GDD \times n$$

Where, n=Actual duration of bright sunshine hours.

(4) Heat Use Efficiency (HUE)
The Heat use efficiency (HUE) indicates the efficiency of crop to utilize the available heat energy.

$$HUE = \frac{\textbf{Total seed yield (kg/ha)}}{\textbf{Accumulated GDD (degree day)}}$$

The base temperatures for different crops were taken as under.

Sr. No.	Crop	Base Temperature (ºC)
1	Sesame	8.0 (Langham, 2007)
2	Black gram	10.0 (Das and Shree, 2013)
3	Pearl millet	10.0 (Ong,1983)
4	Castor	10.0 (Severino and Auld, 2014)
5	Cotton	10.0 (Krzyzanowski and Delouche, 2011)
6	Groundnut	10.0 (Vara *et al.*, 2009)

Result and Discussions
The average results of yield, Growing Degree Days, Heliothermal Units, Photothermal Units and Heat Use Efficiency of different crop viz., short and long duration under different dates of sowing are given in table 2.1 to 2.3 and 3.1 to 3.3, respectively.

Sesame: In this crop five important phenophases were under study i.e. germination, branching, flowering, capsule formation and maturity. The average of two years results presented in table 2.1 revealed that the highest growing degree days (GDD), heliothermal units and photo thermal units (PTU) of 1862ºC day, 24554 ºC day hours and 22387 ºC day hours were recorded under first date of sowing. In general with advancement in sowing dates the thermal requirement of the crop was decreased. It means first date sown crop utilized higher thermal/heat energy. The highest heat use efficiency and yield 0.40 kg/ha /degree day and 747 kg/ha respectively were also observed under first sowing date. The similar result was also observed in soybean by Kumar *et al.* (2008) [8].

Black gram: The germination, branching, flowering, pod development and maturity are the important phenophases of the crop. The results presented in table 2.2 revealed that the highest growing degree days (GDD) and photo thermal units (PTU) of 1708 ºC day and 22387 ºC day hours were recorded under first date of sowing. In general as the date of sowing advanced the thermal requirement of the crop was decreased. It means first date sown crop utilized higher thermal / heat energy. The highest heat use efficiency and yield of 0.41 kg/ha /degree day and 667 kg/ha, respectively were also observed in the first date sown crop. The similar result was obtained by Gill *et al.* (2011) [4] in mungbean crop.

Pearl millet: The important phenophases under study were germination, tillering, flowering, grain formation and maturity. The phenophase wise GDD and other thermal indices are depicted in Table 1.1. The results presented in table 2.3 revealed that the highest growing degree days (GDD) and photo thermal units (PTU) of 1641 ºC day and 23461 ºC day hours were recorded during first date of sowing respectively. The highest heat use efficiency and yield 1.2 kg/ha /degree day and 1980 kg/ha, respectively were also observed in the first date (10/07/09) sown crop.

Cotton: In the crop five important phenophases were under study i.e. germination, branching, flowering, ball formation and maturity. The average of two years results presented in table 3.1 revealed that the highest growing degree days (GDD), heliothermal units (HTU) and photo thermal units (PTU) of, 3120 ˚C day, 18511 ˚C day hours and 38542 ˚C day hours were recorded under the first dates of sowing, respectively. The highest heat use efficiency and yield 0.17 kg/ha /degree day and 531 kg/ha, respectively were also observed under first date of sowing.

Castor: In castor five important phenophases were under study i.e. germination, branching, flowering, capsule formation and maturity. The average of two years results presented in table 3.2 revealed that the highest growing degree days (GDD), heliothermal units (HTU) and photo thermal units (PTU) of 3092 ˚C day, 18301 ˚C day hours and 38221 ˚C day hours were recorded under the first dates of sowing, respectively. The highest heat use efficiency and yield 0.51 kg/ha /degree day and 1597 kg/ha, respectively were also observed under first date of sowing.

Groundnut: The five important phenophases were under study i.e. germination, flowering initiation, full pegging, pod development and maturity. The average of two years results presented in table 3.3 revealed that the highest growing degree days (GDD) and photo thermal units (PTU) of 2325 ºC day and 29728 ˚C day hours were recorded under first dates of sowing, respectively. In general as the date of sowing advanced, the thermal requirement of the crop was decreased. It means first date sown crop utilized higher thermal / heat energy. The highest heat use efficiency and yield 0.29 kg/ha /degree day and 665 kg/ha, respectively were also observedunder first date of sowing. The similar finding was observed by Kingra and Kaur (2011) [6].

Table 1.1: Determination of thermal requirement for different *kharif* crops under rainfed condition

Sr. No.	Particular	Long duration crops								
		Cotton			Castor			Spreading groundnut		
		I*	II**	III***	I*	II**	III***	I*	II**	III***
	Yield (kg/ha)	531	357	96	1597	1350	467	665	443	36
	HUE	0.17	0.13	0.04	0.51	0.49	0.19	0.29	0.22	0.02
	Phenophase	**Growing Degree Days (GDD) (°C day)**								
1.	Germination	115	113	123	153	133	123	153	153	123
2.	Branching	808	715	679	876	768	639	700	647	463
3.	Flowering	1093	1009	749	1156	1051	821	443	422	326
4.	Capsule/pod formation	722	620	417	545	486	308	593	495	401
5.	Maturity	384	336	257	365	257	277	436	451	402
Total		3120	2792	2224	3092	2694	2167	2325	2066	1715

I*. Onset of monsoon II**. 15 days after onset of monsoon III***. 30 days after onset of monsoon

Table 2.1: Yield (kg/ha) and phenophasic thermal requirement of sesamum (G.Til-2) (Average of 2 years)

Sr. No.	Phenophase	1st date of sowing					2nd date of sowing					3rd date of sowing				
		Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)
1	Germination	747	105	182.5	1416	0.40	547	125	341	1676.5	0.34	158	118	367	1554	0.10
2	Branching		752	2035	10128			583	1912	7764			558	3235	7179	
3	Flowering		422	1562	5550			377	1650	4959.5			361	2484	4430	
4	Capsule Formation		370	2489	4837			312	2559	3872.5			311	2626	3722	
5	Maturity		212	1821	2621.5			221	1462	2808			172	1505	2017	
Total			1862	8089	24554			1619	7926	21080			1517	10215	18801	

Table 2.2: Yield (kg/ha) and phenophasic thermal requirement of black gram (T-9)

Sr. No.	Phenophase	1st date of sowing					2nd date of sowing					3rd date of sowing				
		Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)
1	Germination	667	76	264	1019	0.41	384	94	275	1254	0.24	94	87	333	1155	0.07
2	Branching		455	823	6119			421	1380	5644			355	1877	4568	
3	Flowering		347	1854	4644			318	1323	4116			247	1834	3003	
4	Pod development		525	3630	6772			544	3986	6902			414	3041	5091	
5	Maturity		306	2452	3833			258	1754	3180			254	2122	2982	
Total			1708	9023	22387			1635	8718	21096			1356	9206	16949	

Table 2.3: Yield (kg/ha) and phenophasic thermal requirement of pearl millet (GHB-558)

Sr. No.	Phenophase	1st date of sowing					2nd date of sowing					3rd date of sowing				
		Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)
1	Germination	1980	105.5	1191	1418	1.2	1709	132	1876	1779	1.18	539	124	1688	1634	0.38
2	Tillering		644	8582	8650			551	6690	7322			569	7798	7296	
3	Flowering		407	6116	5305			298	4136	3840			293	3903	3599	
4	Grain Formation		327.5	4849	4218			300	4532	3691			261	3426	3111	
5	Maturity		157.5	2722	1940			170	3072	2093			128	1759	1496	
Total			1641	23461	21531			1452	20308	18727			1375	18574	17136	

Table 3.1: Yield (kg/ha) and phenophasic thermal requirement of cotton (G.Cot Hybrid-8) (Average of 2 years)

Sr. No.	Phenophase	1st date of sowing					2nd date of sowing					3rd date of sowing				
		Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)
1	Germination	531	115	165	1541	0.17	357	113	309	1515.5	0.13	96	123	409	1615	0.04
2	Branching		808	2236	10810			715	2235	9443			679	4515	8647	
3	Flowering		1093	7162	13626			1008.5	7865.5	12374			749	5853	8965	
4	BallFormation		722	6274	8378			620	5302	7173			417	3502	4796	
5	Maturity		384	2676	4188			336	2257	3650.5			257	1741	2769	
Total			3120	18511	38542			2792	17967.5	34156			2224	16019	26792	

Table 3.2: Yield (kg/ha) and phenophasic thermal requirement of castor (GCH-6)

Sr. No.	Phenophase	1st date of sowing					2nd date of sowing					3rd date of sowing				
		Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)
1	Germination	1597	153	168	2066	0.51	1350	133	336	1780	0.49	467	123	409	1615	0.19
2	Branching		876	2511	11686			768	2624	10114			639	4125	8143	
3	Flowering		1156	8478	14242			1051	8549	12754			821	6731	9771	
4	Capsule Form.		545	4611	6288			486	3909	5597			308	2332	3528	
5	Maturity		362	2529	3939			257	1826	2774			277	2079	2991	
Total			3092	18301	38221			2694	17242	33017			2167	15275	26049	

Table 3.3: Yield (kg/ha) and phenophasic thermal requirement of groundnut (GG-13)

Sr. No.	Phenophase	1st date of sowing					2nd date of sowing					3rd date of sowing				
		Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)	Yield	GDD (°C day)	HTU (°C day hour)	PTU (°C day hour)	HUE (Kg/ha/°C day hour)
1	Germination	665	153	168	2066	0.29	443	153	386	2042	0.22	36	123	409	1615	0.02
2	FlowringIniti.		700	2106	9396			647	2176	8518			463	2827	5946	
3	Full pegging		443	1935	5728			422	3073	5374			326	2140	4002	
4	Pod devp.		593	4325	7382			495	3638	6045			401	3526	4748	
5	Maturity		436	3846	5156			451	3937	5267			402	3389	4660	
Total			2325	12378	29728			2066	13210	27240			1715	12291	20970	

Conclusion

Based on the results obtained from the field experiment, it was concluded that with delay in onset of monsoon, the GDD and HUE of sesame, black gram, pearl millet, spreading groundnut, cotton and castor crops were tended to decline. In all the crops, the highest thermal indices and heat use efficiencies were recorded in the first date of sowing.

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References

1. Amrawat T, Solanki NS, Sharma SK, Jajoria DK, Dotaniya ML. Phenology growth and yield of wheat in relation to agro meteorological indices under different sowing dates. Afr. J. Agric. 2013; 8:6366-6374.
2. Anil Kumar, Pandey V, Shekh AM, Manoj Kumar. Growth and Yield Response of Soybean (*Glycine max* L.) In Relation to Temperature, Photoperiod and Sunshine Duration at Anand, Gujarat, India. American-Eurasian Journal of Agronomy. 2008; 1(2):45-50.
3. Das M, Shree D. Temperature effect on morphobiochemical characters in some black gram (*Vigna mungo*) genotypes. ISRN Biotechnology, 2013.
4. Gill KK, Guriqbal Singh, Bains GS, Ritu. Prediction of Mungbean Phenology of Various Genotypes Under Varying Dates of Sowing Using Different Thermal Indices. Book: Challenges and Opportunities in Agrometeorology. 2011, 491-497.
5. Kajla M, Yadav VK, Chhokar RS, Sharma RK. Management practices to mitigate the impact of high temperature on wheat. J Wheat Res. 2015; 7:1-12.
6. Kingra PK, Kaur P. Agroclimatic indices for prediction of pod yield of groundnut (*Arachis hypogaea* L.) in Punjab. J Res. 2011; 48:1-4.
7. Ko J, Ahuja L, Kimball B, Anapalli S, Ma L, Green TR *et al*. Simulation of free air CO_2 enriched wheat growth and interactions with water, nitrogen, and temperature. Agricultural and Forest Meteorology. 2010; 150:1331-1346.
8. Kumar S, Kumar B. Thermal time requirement and heat use efficiency in wheat crop in Bihar. J Agrometeorol. 2014; 16:137-139.
9. Langham DR. Phenology of Sesame. J. Janick and A. Whipkey (eds.). ASHS Press, Alexandria, VA. pp. 144-182.Krzyzanowski, F.C., Delouche, J.C. (2011). Germination of cotton seed in relation to temperature. Revista Brasileira de Sementes. 2007; 33:543-548.
10. Major MJ, Johanson DR, Tanner JW, Anderson IC. Effect of day length and temperature on soybean development. Crop Sci. 1975; 15:174-179.
11. Modarresi M, Mohammdi V, Zali A, Mardi M. Response of wheat yield and yield related traits of high temperature. Cereal Res. Commun. 2010; 38:23-31.
12. Moniruzzaman M, Rahman MM, Hossain MM, Karim AJM, Khaliq QA. Effect of sowing dates and genotypes on the yield of coriander (*Coriandrum sativum* L.). Bangladesh J Agril. Res. 2015; 40:109-119.
13. Naveen Kalra N, Chakraborty D, Sharma A, Rai HK, Jolly M, Chander S *et al*. Effect of increasing temperature on yield of some winter crops in northwest India. Current Science. 2008; 94:82-88.
14. Ong CK. Response to temperature in a stand of Pearl Millet (*Pennisetum typhoides* S. & H.): 4. Extension of individual leaves. Journal of Experimental Botany 1983; 33:1731-1739.
15. Pal RK, Rao MNN, Murty NS. Agro-meteorological indices to predict plant stages and yield of wheat for Foot Hills of Western Himalayas. Int. J. Agric. Food Sci. Technol. 2013; 4:909-914.
16. Rajput RP, Desmukh MR, Paradker VK. Accumulated heat units and phenology relationship in wheat as influenced by planting dates under late sown conditions. J. Agron. Crop Sci. 1987; 159:345-349.
17. Ramkutty N. The global distribution of cultivable lands; current patterns and senility, 2002.
18. Reddy AA, Rao PP, Yadav OP, Singh IP, Ardeshna NJ, Kundu KK *et al*. Prospects for *kharif* (Rainy Season) and Summer Pearl Millet in Western India. Working Paper Series no. 36. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 2013, 24.
19. Sahu DD, Chopada MC, Patoliya BM. Determination of sowing time for chickpea varieties in south Saurashtra, India. J Agrometeorol. 2007; 9(1):68-73.
20. Severino LS, Auld DL. Study on the effect of air temperature on seed development and determination of the base temperature for seed growth in castor (*Ricinus communis* L.). Australian Journal of Crop Science 2014; 8:290-295.
21. Sondarva KN, Rank HD, Jayswal PS Summer sesame response to moisture and thermal regimes. Africal Journal of Agricultural Research. 2014; 9(27):2095-2103.
22. Vara PV, Kakani PVG, Upadhyaya HD. Growth and production of groundnut, in Soils, Plant Growth and Crop Production, [Ed. Willy H. Verheye], in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK, 2009.