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Thermal Indices of Groundnut (*Arachis hypogaea* L.) Cultivars under Rainfed Condition in Middle Gujarat

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AUTHORS CONTRIBUTION

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ABSTRACT

A field experiment was carried out to know the thermal indices of groundnut under rainfed condition in middle Gujarat at Agronomy Farm, Anand Agricultural University, Anand (Gujarat) during 2019 and 2020. Analysis of data showed that groundnut accumulated about 2143.5°C day and 1906°C day GDD, 27293°C days h and 26322°C days h PTU and 9466°C days h and 11648°C days h HTU for obtained better pod yield (2176 kg ha^{-1} and 1862 kg ha^{-1}) in first date of sowing as compared with second sowing (1976 kg ha^{-1} and 1592 kg ha^{-1}) and third sowing (1614 kg ha^{-1} and 1369 kg ha^{-1}) during 2019 and 2020, respectively. Among the varieties, GG 20 accumulated about 2254°C days and 1951°C days GDD, 27293°C days h and 26322°C days h PTU and 9466°C days h and 1164°C days h HTU required for getting higher pod yield (2043 kg ha^{-1} and 1701 kg ha^{-1}) in comparison with GJG 34 and TAG 37A. Also, results analysis showed that onset of monsoon recorded higher HUE (1.02 kg ha^{-1} °C day and 0.91 kg ha^{-1} °C day, respectively) that attributed to higher pod and biomass yield. In varieties, GG 20 recorded higher HUE (0.91 kg ha^{-1} °C and 0.87 kg ha^{-1} °C day) and higher pod and biomass yield. Hence, first date of sowing was significantly superior for pod and biomass yield due to better thermal responses, well distributed rainfall and available soil moisture.

Keywords : Thermal indices, Heat use efficiency, Rainfed groundnut and Yield

GROUNDNUT (*Arachis hypogaea* L.) is an impor-tant oilseed crop of tropical and subtropical regions of the world. In our country, it is one of the most important cash crop. The well-distributed rainfall at least 500 mm during crop growth period and abundance of bright sunshine hours with relatively warm temperature is ideal. Temperature in the range of 25ºC to 30ºC is optimum for plant development. Being a C3 crop, higher temperature may affect its productivity and to some extent its distribution (Weiss, 2000). In India, groundnut occupies an area of 5.5 m ha producing 9.6 mt with a productivity of 1750 kg ha^{-1} (Shwetha *et al.,* 2017). It is mainly grown in rainy season *i.e., kharif* season. Gujarat stands first rank in area & production and two-thirds of the global production occurs in rainfed regions of the semi-arid tropics where rainfall is generally erratic and insufficient, causing unpredictable drought stress, the most important constraint for groundnut production (Kumar *et al.,* 2020), occupies 1.95 m.ha. producing 3.39 m.ha. with a productivity of 1777 kg ha^{-1}. The occurrence of different phenological stages during crop growth period in relation to temperature can be estimated by using accumulated growing degree days or heat units (Murthy and Rao, 1986). Thermal time is an independent variable to describe plant growth and development of crop. It can be used as a tool for characterizing thermal responses in crops. Knowledge of accumulated GDD can provide an estimate of development stage as well as crop harvest date (Roy *et al*., 2005). Thermal indices such as growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) can be used very effectively for growth as well as yield of crops.

Therefore, the present investigation was carried out to assess the thermal indices of groundnut under rainfed condition in middle Gujarat.

Material and Methods

The field experiment was conducted during *kharif* 2019 and 2020 at Anand Agricultural University, Anand, Gujarat, India. Anand is located at the latitude of 22° 35' N and longitude of 72° 55' E with an altitude of 45.1 m above the mean sea level. The type of soil is sandy loam in texture with a field capacity of 15.4 to 15.8 per cent at 15, 30 and 45 cm depth. Bulk density was 1.52 g cm^{-3} to 1.55 g cm^{-3} in the depth of 15 to 45 cm layer at the experimental site. The treatments consists of three dates of sowing *viz;* first - onset of monsoon, second - 10 days after onset of monsoon and third - 20 days after onset of monsoon with three varieties GG 20, GJG 34 and TAG 37A. The experiment was replicated with four times in randomized block design with factorial concept. The crop was sown at a distance of 30 cm x 10 cm. Approximately 60 mm for heavy irrigation and 40 mm for light irrigation was given as a life saving irrigations. The meteorological data were collected from the Agrometeorological observatory which is adjacent to the experimental site. Entire package of practices was followed as per recommendation of AAU, Anand. The statistical analysis was carried out by using 'Analysis of variance techniques'. The significance was tested by 'F' value at 5 per cent level of significance. The value of critical difference for examining treatment means for their significance was done at 5 per cent level. The growing degree days were determined on the basis of base temperature 10 °C (Ghadekar 2011) for the groundnut crop. Thermal indices and Heat use efficiency were computed by using the weather data and crop growth data with the pertinent prescribed formula.

Growing Degree Days (GDD)

Growing degree days (GDD) is an arithmetic accumulation of daily mean temperature above the base temperature and calculated based on the following formula.

$$GDD\ (^{o}C) = \left[\frac{Tmax + Tmin}{2}\right] - T_{base}$$

Where,

Tmax : Daily maximum temperature (^{o}C) during a day

Tmin : Daily minimum temperature (^{o}C) during a day

T_{base} : Base temperature 10 ^{o}C

Heliothermal units (HTU)

The sum of the HTU for the duration of each phenophase were computed as mentioned below :

HTU (^{o}C day hr) = GDD x Actual Bright sunshine hours

Photothermal Unit (PTU)

Photothermal units (PTU) is the product of GDD and corresponding the maximum possible sunshine hours for that day calculated for Anand latitude.

PTU (^{o}C day hr) - GDD x N

Where, N = Maximum possible hours of sunshine

Heat use efficiency (HUE)

Heat use efficiency (HUE) was computed based on the following formula :

$$\text{Heat use efficiency (kg ha}^{-1}\ ^{o}\text{C)} = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Accumulated heat units (}^{o}\text{C day)}}$$

Results and Discussion

Thermal Indices

The thermal indices *viz.,* growing degree days (GDD), photothermal unit (PTU) and heliothermal unit (HTU), required for attainment of each crop growth stage of groundnut varieties are given in Table 1 to 3.

Growing Degree Days (GDD)

Result showed that the accumulated growing degree days of first sowing date was 2144 °C day and 1906 °C day, second sowing date was 2368 °C and 1894 °C day and third sowing date was 2264 °C day and 1906 °C day during 2019 and 2020, respectively (Table 1). The accumulated GDD from sowing to physiological maturity was highest (2368 ^{o}C days) in

TABLE 1

Phenophase wise accumulated growing degree day (°C days) of groundnut during 2019 and 2020

Crop growth stages	Emergence		Flowering		Initiation of pod filling		Peak LAI		Maturity		Harvesting	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Date of sowing												
Onset of monsoon	160	155	694	648	1435	1433	1607	1646	2125	1891	2145	1906
10 days after onset of monsoon	147	124	636	583	1448	1398	1636	1608	2351	1881	2368	1895
20 days after onset of monsoon	159	155	599	648	1182	1433	1596	1646	2245	1891	2264	1906
Varieties												
GG 20	151	140	637	637	1355	1424	1607	1634	2237	1937	2254	1951
GJG 34	164	140	655	637	1367	1431	1607	1634	2237	1937	254	1951
TG 37A	151	147	637	617	1343	1405	1607	1634	2237	1937	2254	1951

second sowing date to other dates of sowing. It may be noticed that duration of crop growth period or number of days taken to physiological maturity was higher in second sowing date in 2019. The accumulated GDD followed an increasing trend of GDD values from flower initiation to maturity. The highest accumulated GDD was observed in emergence, flowering and initiation of pod filling stage under first date of sowing followed by second and third date of sowing during both the years. Guled (2013) showed that the differences were significantly higher for first date of sowing (2193 °C days) being on par with second date of sowing (2187 °C days) dates of sowing as compared to rest of the sowing dates. Among the varieties, accumulation of GDD from sowing to physiological maturity were 2254 °C days and 1951 °C days during 2019 and 2020 respectively.

Photothermal Units (PTU)

Analysis of data revealed that photothermal units were 27293 °C days h, 29369 °C days h and 27533 °C days h during 2019 for first, second and third dates of sowing, respectively. However, it was 26322 °C days h, 24184 °C days h and 23659 °C days h during 2020 respectively. The highest accumulated PTU was observed in emergence, flowering and initiation of pod filling stage under first date of sowing followed by second and third date of sowing during 2019. Similar results were found by Kingra and Kaur 2011. In case of varieties, accumulation of PTU from sowing to harvesting were 28065 °C days h and 24721 °C days h in 2019 and 2020, respectively (Table 2).

Heliothermal Units (HTU)

The heliothermal units of first date of sowing (onset of monsoon) was 9466 °C days h and 11648 °C days h, 10 days after onset of monsoon (second date of sowing) was 11510 °C days h and 10806 °C days h and 20 days after onset of monsoon (third date of sowing) was 10565 °C days h and 11653 °C days h during 2019 and 2020, respectively (Table 3). The accumulated HTU from sowing to physiological maturity was highest (21653 °C days h) in 20 days after onset of monsoon sowing as compared to other

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TABLE 2

Phenophase wise accumulated photothermal units (°C days h) of groundnut during 2019 and 2020

Crop growth stages	Emergence		Flowering		Initiation of pod filling		Peak LAI		Maturity		Harvesting	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Date of sowings												
Onset of monsoon	2170	2003	9359	8903	18833	18772	20952	21479	27081	26142	27293	26322
10 days after onset of monsoon	1981	2094	8506	8641	18758	18565	21036	21174	29185	24016	29369	24184
20 days after onset of monsoon	2149	1674	7911	7694	15235	17896	19973	20344	27380	23508	27533	23659
Varieties												
GG 20	2045	1894	8514	8497	17609	18462	20654	20999	27882	24556	28065	24722
GJG 34	2210	1894	8745	8497	17758	18547	20654	20999	27882	24556	28065	24722
TG 37A	2045	1983	8516	8244	17459	18223	20654	20999	27882	24556	28065	24722

TABLE 3

Phenophase wise accumulated heliothermal units (°C days h) of groundnut during year 2019 and 2020

Crop growth stages	Emergence		Flowering		Initiation of pod filling		Peak LAI		Maturity		Harvesting	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Date of sowing												
Onset of monsoon	356	1027	3316	2643	5714	6397	5905	8312	9405	11556	9466	11684
10 days after onset of monsoon	1141	803	3037	1989	5686	6832	6491	8350	11357	10663	11510	10806
20 days after onset of monsoon	1225	244	1774	2130	3830	7220	5967	9166	10454	11571	10565	11653
Varieties												
GG 20	906	691	2690	2295	5085	6837	6121	8609	10406	11263	10513	11381
GJG 34	909	691	2747	2295	5097	6893	6121	8609	10406	11263	10513	11381
TG 37A	906	63	2690	2172	5049	6719	6121	8609	10406	11263	10513	11381

two dates of sowing. It showed that PTU was maximum under 2019 as compared to 2020. It was observed due to the higher temperature and more actual bright sunshine hours from sowing to harvesting *i.e.,* during growing period of crop. The HTU an increasing pattern from flower initiation to maturity.

In case of varieties, total HTU from sowing to harvesting were 10513 °C days h and 11381 °C days h during 2019 and 2020 respectively (Mote and Pandey, 2016).

Heat Use Efficiency (HUE) for Pod Yield and Biomass

HUE of pod yield decreased with decreasing the pod yield and biomass of groundnut crop during 2019 and 2020. Results showed onset of monsoon recorded higher HUE (1.06 kg ha^{-1} °C day and 0.91 kg ha^{-1} °C day) as compared to 10 days after onset of monsoon (0.82 kg ha^{-1} °C day and 0.84 kg ha^{-1} °C day) and 20 days after onset of monsoon (0.72 kg ha^{-1} °C day and 0.72 kg ha^{-1} °C day) which could be attributed to higher pod yield. The lowest HUE for pod yield in 20 days after onset of monsoon sowing might be due to the lowest pod yield. The results were in conformity with Meena *et. al.* (2015). In case of varieties, GG 20 recorded higher HUE (0.91 kg ha^{-1} °C and 0.87 kg ha^{-1} °C day) and higher pod yield followed by GJG 34 (0.85 kg ha^{-1} °C and 0.83 kg ha^{-1} °C day) and TAG 37A (0.79 kg ha^{-1} °C and 0.77 kg ha^{-1} °C day). The lowest HUE for pod yield in variety TAG 37A might be due to the lowest pod yield. These results are also enclosed agreement with the findings by Kingra and Kaur (2012). Meena *et. al.* (2015) also showed that higher heat unit efficiency was observed in HNG 10 variety compared with TG 37A variety (Table 4).

The HUE of biomass was found more in year 2019 as compared with 2020. Among the dates of sowing, onset of monsoon sowing recorded higher HUE (2.76 kg ha^{-1} °C day to 2.24 kg ha^{-1} °C day) compared to 10 days after onset of monsoon sowing (2.00 kg ha^{-1} °C day to 1.92 kg ha^{-1}°C day) and 20 days after onset of monsoon sowing (1.98 kg ha^{-1} °C day to 1.62 kg ha^{-1} °C day) which could be attributed to higher biomass. The lowest HUE and lowest biomass was found in 20 days after onset of monsoon sowing. similar results were found by Meena *et al.* (2015). Kingra and Kaur (2012) reported that late sown crop

TABLE 4

Heat use efficiency of pod yield and biomass of groundnut using the GDD, HTU and PTU

Treatments	Heat use efficiency (kg ha^{-1} °C-1 day)											
	Pod yield						Biomass					
	GDD		HTU		PTU		GDD		HTU		PTU	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Dates of sowing												
Onset of monsoon	1.02	0.91	0.23	0.18	0.08	0.08	2.76	2.24	0.62	0.39	0.22	0.17
10 days after onset of monsoon	0.82	0.84	0.17	0.18	0.07	0.08	2.00	1.92	0.41	0.34	0.16	0.15
20 days after onset of monsoon	0.72	0.72	0.15	0.16	0.06	0.08	1.98	1.62	0.42	0.26	0.16	0.13
Varieties												
GG 20	0.91	0.87	0.19	0.15	0.07	0.07	2.36	2.05	0.51	0.35	0.19	0.16
GJG 34	0.85	0.83	0.18	0.14	0.07	0.07	2.25	1.94	0.48	0.33	0.18	0.15
TG 37A	0.79	0.77	0.17	0.13	0.06	0.06	2.08	1.81	0.45	0.31	0.17	0.14

TABLE 5

Pod yield and biomass of groundnut during 2019 and 2020

Treatments	Pod yield (kg ha^{-1})		Biomass (kg ha^{-1})	
	2019	2020	2019	2020
Date of sowing				
Onset of monsoon	2176	1862	5909	4765
10 days after onset of monsoon	1937	1592	4739	4193
20 days after onset of monsoon	1614	1369	4463	3519
Variety				
GG 20	2043	1701	1872	5341
GJG 34	1915	1612	1763	5071
TG 37A	1769	1511	1640	4699
SEm ±	46.7	47.9	33.4	43.4
CD at 5%	135.3	138.7	95.1	125.6
CV %	8.5	10.3	9.3	3.0

(July) availed less growing degree-days and accumulated less dry matter than the earlier sown (June) crop, thus indicating a decrease in dry matter and heat use efficiency. Among the varieties, GG 20 (2.36 kg ha^{-1} °C day to 2.05 kg ha^{-1} °C day) recorded higher HUE followed by GJG 34 (2.25 kg ha^{-1} °C day to 1.94 kg ha^{-1} °C day) and TAG 37A (2.08 kg ha^{-1} °C day to 1.81 kg ha^{-1} °C day). The lowest HUE in TAG 37A might be due to the lowest biomass (Table 4).

From results, it could be concluded that the varieties and sowing dates had significant influence on pod and biomass yield of groundnut. GG 20 variety should be sown earlier at onset of monsoon particularly in middle Gujarat agro climatic zone could be considered as thermo tolerant.

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