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Relevance of thermal units in deciding sowing time and yield prediction of groundnut (*Arachis hypogaea* L.) under irrigated condition of western Rajasthan

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ABSTRACT

Experiment was conducted for two years from 1998 to 1999 on loamy sand soil at Agricultural Research Station, Beechwal, Bikaner (Western Rajasthan) to study the relevance of thermal units with respect to sowing time and pod yield prediction of irrigated groundnut (*Arachis hypogaea* L.). Pod yield and biomass production were the highest for the 15th March and 1st April sowing dates followed by a progressive decrease in later dates of sowing. The pod yield was positively correlated with heat use efficiency (HUE), heat unit (HU) and photothermal units (PTU) from flower initiation to maturity phenophase (R^2) ranged from 0.913 to 0.989.

Key Words: Groundnut, heat units, sowing time

The pod yield and oil content of groundnut (*Arachis hypogaea* L.) are influenced by several factors. The temperature prevailing during three weeks of pod development and maturity of kernels as well as rainfall distribution during the pod development stage particularly influence the oil content of groundnut (Smartt, 1976). High temperature favours accumulation of high oil content and pod yield (Sankara Reddi, 1988). The heat unit (GDD) concept was extensively employed to measure the temperature response in many crops, including groundnut (Young, 1979). A linear relationship between growth and development of plants with temperature was reported (Arnon, 1972). Because of its non-thermoperiodic and photoinsensitive nature and the linear nature of the relationship between growth and temperature, sowing time, groundnut phenology, yield prediction and optimum harvest time prediction can be assessed and quantified by the adoption of heat unit system (Mills, 1964).

Research work has been reported on various aspects of heat unit and photothermal units (PTU) in wheat, toria and other crops (Sastry and Chakravarty, 1982) and of groundnut (Mills, 1964 and Leong and Ong, 1983). Since, there is sufficient scope a study was conducted to examine heat indices in deciding best sowing time and optimize groundnut yield under irrigated high temperature condition of Rajasthan. Simple correlation and multiple regressions were developed for yield forecasting based on accumulated heat indices during 1998 and 1999.

MATERIALS AND METHODS

The study was conducted at Agricultural Research Station, Bikaner

Table 1: Mean weekly meteorological data recorded during crop growth period of 1998 and 1999

Met. stand. week	Maximum temperature		Minimum temperature		Relative humidity (%)				Rainfall (mm)		Wind speed (km h^{-1})	
					Morning		Evening					
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
15	34.3	40.3	18.6	22.6	61	49	19	17	0.0	0.0	6.8	7.5
16	41.1	40.8	25.2	22.5	45	31	18	16	0.0	0.0	7.0	5.3
17	40.0	43.2	25.0	24.3	63	27	31	8	16.0	0.0	15.2	4.8
18	41.3	45.1	26.2	29.5	45	42	21	14	0.0	0.0	7.4	6.7
19	38.0	43.2	21.1	28.1	54	48	22	18	1.6	4.5	6.7	9.3
20	45.5	43.7	28.2	29.1	43	48	13	19	0.0	0.0	5.5	7.6
21	46.4	37.3	32.1	25.7	43	69	15	48	0.0	54.9	8.1	7.7
22	44.9	40.3	30.7	26.6	50	60	20	33	2.2	4.8	9.7	10.4
23	42.6	39.0	27.8	28.1	53	60	38	34	9.1	0.0	9.9	7.8
24	37.1	42.3	25.6	29.0	63	58	37	26	14.4	9.2	8.2	8.0
25	42.9	41.8	30.7	29.4	46	60	28	30	0.0	0.0	8.2	7.9
26	43.1	39.6	31.6	28.5	54	70	29	37	0.0	0.0	8.5	12.7
27	37.2	40.0	28.0	30.4	82	58	54	39	95.5	0.0	8.9	9.2
28	36.5	40.6	28.2	28.4	80	73	53	43	46.2	4.6	7.7	10.3
29	36.9	37.7	29.0	27.4	77	74	47	57	0.0	45.6	10.3	7.4
30	34.2	38.5	28.8	28.6	73	69	44	45	0.0	0.0	10.1	9.5
31	41.1	32.3	29.9	26.3	62	80	39	61	0.0	26.4	9.5	7.5
32	39.3	38.0	28.6	28.4	73	77	29	47	2.8	0.0	8.5	8.5
33	39.0	37.4	28.2	27.2	74	75	42	42	7.4	0.0	8.7	8.8
34	39.6	37.6	28.2	26.9	73	70	45	38	5.0	0.0	7.4	9.9
35	37.8	30.0	27.0	27.5	75	71	41	44	0.0	0.0	8.2	7.5
36	39.4	38.8	28.2	27.4	68	71	38	42	0.0	7.6	5.9	6.1
37	38.2	40.1	26.7	27.4	77	68	49	30	0.0	0.0	9.1	6.1
38	36.9	37.8	25.4	26.7	91	66	63	32	17.3	0.0	9.2	7.7
39	35.3	34.0	25.2	26.4	85	66	45	28	12.1	0.0	4.9	6.1
40	37.9	36.8	26.6	23.5	75	77	39	28	0.0	0.0	6.5	5.3
41	38.0	38.5	23.1	23.0	65	58	25	19	0.0	0.0	5.7	4.4
42	29.0	37.7	19.1	19.9	82	45	57	21	111.0	0.0	5.5	4.2
43	33.5	37.2	19.4	18.9	71	47	31	17	0.0	0.0	2.7	4.0
44	32.3	37.2	19.4	18.5	71	45	41	19	0.0	0.0	3.0	3.1
45	29.5	33.3	15.8	17.0	75	45	39	18	0.0	0.0	3.6	4.6
46	30.1	33.2	14.2	15.8	65	56	25	26	0.0	0.0	2.8	3.6
47	29.0	31.1	11.9	11.5	58	60	24	30	0.0	0.0	2.3	2.3

(Rajasthan) during 1998 and 1999. Semi spreading groundnut variety MA 10 (Chitra) was grown in a randomized block design having nine treatments of sowing dates namely, 15 March and at subsequent fortnightly intervals till 15[th] July (Table 2) under irrigated condition on loamy sand soil in Indira Gandhi Canal Command area with four replications. Recommended dose of 20 kg N and 40 kg P_2O_5 ha^{-1} was applied through DAP and urea at sowing. The crop under wide range of sowing dates experienced comparatively low temperature and short sunshine hours in early dates, high temperature and long sunshine hours in middle dates with low relative humidity, normal temperature and long sunshine hours, with high relative humidity prevailing in later dates. Thus varying climatic conditions during the crop growing season could be ensured. The observations recorded (Table 1) at the Meteorological Observatory of Agricultural Research Station, Beechwal, Rajasthan Agricultural University, Bikaner (28° 01" N lat. and 73° 32" E long., 234 amsl) during the crop seasons were used for study. The crop was irrigated at 15 days interval. Biomass observations was taken at flower initiation and at physiological maturity phenophases and utilized to compute heat use efficiency (kg ha^{-1} day^{-1} ^{0}C).

Daily maximum and minimum temperature and day length were used to calculate accumulated heat indices (Wilsie 1962) from sowing to flower initiation and flower initiation to physiological maturity phases. A base temperature of 10°C was used as done for "PNUTGRO" model (McCloud *et al.*, 1980). The accumulated heat units were used to calculate heat use efficiency of the groundnut.

$$HUE = \frac{\text{Biomass yield}}{\text{Accumulated heat units}}$$

Flower initiation was identified as the date on which a few flowers appeared in the respective sowings. For simplicity the entire crop life was divided into two phases namely vegetative phase (sowing to flower initiation) and reproductive phase (flower initiation to maturity phase). The correlation coefficient and regression models between heat indices and pod yield were worked out at both the phases.

RESULTS AND DISCUSSION

Biomass and pod yield are the best measure of overall performance and response of the groundnut crop to environmental. Highest mean biomass was recorded under the 15[th] March sowing (Table 2) in both the stages considered, with a decline in biomass production under later sowings. The pod yield also showed higher values for the earlier sowing dates with a decreasing trend for later sowings. The seasonal variation in biomass and pod yield in some of sowing dates might be explained on the variability in weather variables (Table 1). Purushothaman *et al.* (1974) from their fortnightly sowing experiment also reported that mid March was the best time for sowing groundnut under the Parambikulam Aliyar Project taken up in Kerela (State). Thus, from pod yield and biomass production results, sowing on 15[th] March and 1[st] April are superior than other dates. Low yield in later sowings was observed due to shorter growing period for crop to reach maturity because of prevalence of low night temperature. Phenological development of the crop, seasonal differences in days taken are fairly consistent between 1998 and 1999

Table 2: Pod yield and biomass production of groundnut as influenced by sowing dates

Treatment (Sowing dates)	Biomass production from S to IF (kg ha^{-1})			Biomass production from IF to PM (kg ha^{-1})			Pod yield (kg ha^{-1})		
	1998	1999	Mean	1998	1999	Mean	1998	1999	Mean
15th March	1909	2014	1962	11623	13916	12632	4484	4432	4457
1st April	1881	1985	1933	10441	14105	12125	3382	4675	4128
15th April	1881	1968	1925	5994	10312	8177	2358	3930	3144
1st May	1853	1880	1867	5201	6630	5916	1954	2702	2328
15th May	1892	1898	1895	3840	4372	4107	1857	2072	1964
1st June	1920	1896	1908	3376	3334	3355	1752	1630	1691
15th June	1948	1902	1925	4671	3188	3930	2178	1610	1894
1st July	1943	1816	1889	2157	2254	2186	1300	1060	1180
15th July	1926	1814	1870	1257	1196	1226	977	527	752
CD(P=0.05)	89.5	102.3	90.8	815.1	640.2	801.9	619.2	327.4	461.1

S = Sowing, IF = Flower initiation, PM = Physiological maturity

Table 3: Influence of sowing dates on days taken to reach the crop at various phenological growth stages

Treatment (Sowing dates)	Days taken from S to IF		Days taken from IF to PM		Days taken from S to PM	
	1998	1999	1998	1999	1998	1999
15th March	38	36	182	172	220	208
1st April	40	40	169	164	209	204
15th April	43	41	162	158	205	199
1st May	44	43	146	142	190	185
15th May	40	37	138	138	178	175
1st June	37	35	128	125	165	160
15th June	34	32	118	116	152	148
1st July	32	29	107	105	139	134
15th July	30	28	95	92	125	120

S = Sowing, IF = Flower initiation, PM = Physiological maturity

Table 4 : Accumulated heat and photothermal unit of gronudnut under different sowing dates at various phenophases

Treatment (Sowing dates)	Accumulated heat unit (Day °C)						Accumulated photothermal unit (Day °C)					
	S to IF			IF to PM			S to IF			IF to PM		
	1998	1999	Mean	1998	1999	Mean	1998	1999	Mean	1998	1999	Mean
15th March	678	656	667	4252	4051	4152	8175	7913	8044	53771	51429	52600
1st April	863	899	881	3916	3802	3859	10704	11151	10928	49546	47982	48764
15th April	1100	996	1048	3557	3573	3565	14147	12776	13462	44622	44944	44783
1st May	1026	1061	1044	3279	3180	3230	13618	14092	13855	40626	39365	39996
15th May	970	902	936	3057	3044	3051	12897	11997	12447	37615	37422	37519
1st June	875	857	866	2713	2713	2713	11644	11397	11521	32956	32952	32954
15th June	834	800	817	2433	2462	2447	10997	10539	10768	29295	29644	29469
1st July	748	697	723	2126	2191	2159	9706	9054	9380	25265	26075	25670
15th July	724	622	673	1833	1918	1876	9168	7913	8541	21963	23006	22485

S = Sowing, IF = Flower initiation, PM = Physiological maturity

Table 5: Heat use efficiency of groundnut under different sowing dates during different phenophases

Treatment (Sowing dates)	Heat use efficiency (kg ha^{-1} day^{-1} °C)					
	From S to IF			From IF to PM		
	1998	1999	Mean	1998	1999	Mean
15th March	2.817	3.069	2.942	2.734	3.435	3.043
1st April	2.181	2.209	2.195	2.590	3.710	3.142
15th April	1.711	1.976	1.838	1.685	2.886	2.294
1st May	1.806	1.771	1.789	1.586	2.085	1.832
15th May	1.951	2.105	2.025	1.256	1.436	1.346
1st June	2.194	2.213	2.203	1.245	1.229	1.237
15th June	2.335	2.378	2.356	1.531	1.295	1.413
1st July	2.597	2.607	2.615	1.015	1.029	1.013
15th July	2.661	2.916	2.779	0.686	0.102	0.387
CD(P=0.05)	0.111	0.117	0.109	0.134	0.126	0.121

S = Sowing, IF = Flower initiation, PM = Physiological maturity

(Table 3).

The data in respect of mean value of heat unit/GDD and PTU from sowing to flower initiation and flower initiation to maturity phenophases for different sowing dates are given in Table 4. It may be inferred from the Table 4 that the cumulative HU and PTU values from sowing to flower initiation were initially low. These values got increased and thereafter decreasing trend was observed depending upon the temperature which prevailed during crop growing under different sowing dates. Further those data (Table 4) reveal that with shifting of sowing dates from 15th March to 15th July, a steady decrease in accumulated heat and photothermal unit for maturity phenophase was observed due to lowering of temperature on set with of south west monsoon for later sowing dates compared to early dates.

Data from Table 5 reveal that different sowing dates showed variable heat unit utilization. The thermal use efficiency of 3.043 and 3.143 kg ha^{-1} day °C was observed for early sowing dates namely 15th March and 1st April and this was followed by a decrease in heat use efficiency. This was due to low productivity and prevalence of high temperature during middle sowing dates.

The accumulated HU, PTU and HUE during IF to PM phase have a significant and positive correlation with pod yield. The observed and estimated pod yields with different models are shown in Fig 1. It shows that accumulated heat unit between 4151.4 - 3858.9, corresponded to maximum pod yield for 15th March sowing followed by 1st April. Pod yield is progressively increased with the increase in heat indices. The multiple regression models developed with HU, PTU and HUE during IF to PM explained the yield variation (Table 6).

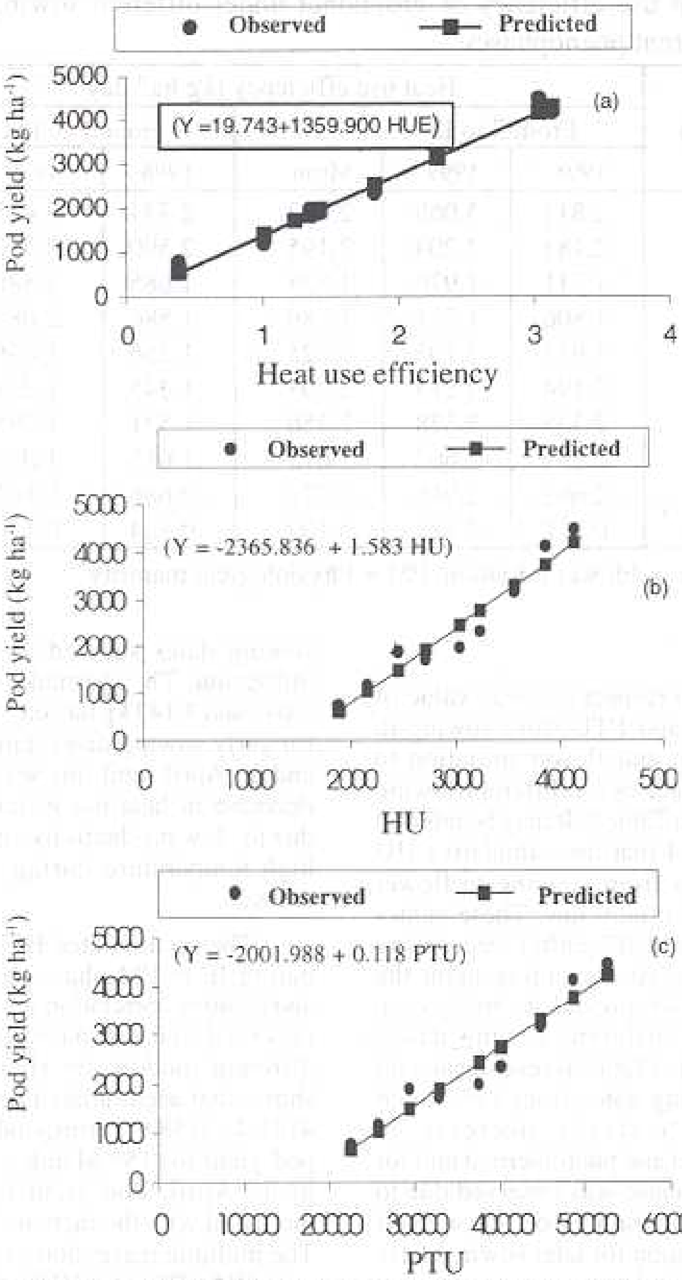

Fig. 1: Observed and predicted pod yield of groundnut in relation to (a) heat use efficiency (b) accoumulated heat units and (c) accumulated photothermal units during IF to PM phenophase

Table 6: The multiple regression model of pod yield of groundnut and HUE, HU and PTU during IF to PM (Mean of two years)

Regression equation	Coefficient of determination (R^2)
Y = -2117.080+0.00132 HUE + 4.5107 PTU Y = - 553.609 +1075.400 HUE+ 0.355 HU	0.985** 0.984**

HUE = Heat use efficiency, HU = Heat unit

Based on the above results it can be concluded that for western Rajasthan region based on thermal indices sowing of groundnut on 15th March and 1st April would be an economical viable no cost technology.

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