Biological Forum – An International Journal 15(3): 583-588(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effect of Thermal Unit and Heat use Efficiency at various Phenophases of Chickpea (*Cicer arietinum* L.) Cultivars

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(Received: 20 January 2023; Revised: 15 February 2023; Accepted: 26 February 2023; Published: 22 March 2023)
(Published by Research Trend)

ABSTRACT: During the Rabi season of 2019–20, a field experiment was conducted on the sandy loam soil at the C.S.A. University of Agriculture and Technology in Kanpur, Uttar Pradesh, India. At various phenological stages, the diverse climatic conditions that are created by various sowing dates have a significant impact on accumulated thermal unit and heat use efficiency. Temperature stands out as one of the main contributors to the behaviour's fluctuations throughout time and space. The effects of temperature on chickpea cultivars (KWR-108, KPG-59 and KGD-1168) phenology and heat use efficiency grown was evaluated in a trial with a split plot design (SPD) with 4 replications, where sowing dates were November 10, November 20, and November 30 (year 2019). At various phenophases, there was a tremendous discrepancy in the cumulative growth degree days/heat unit; the heliothermal unit and photothermal unit were impacted by the variable sowing date/sowing temperature. higher heat unit/growing degree days. When chickpea cultivar KGD-1168 was sowed on November 10 (at a temperature of 22°C), followed by a crop on November 20 (at a temperature of 17°C), heliothermal and photothermal units were detected at all phenological phases, particularly given that they took the longest to mature. Heat use efficiency (HUE) enhanced inside the crop when it was sown on November 10 at a temperature of 22°C, followed by variety KGD-1168 on November 20 at a temperature of 17°C, and it decreased on November 30. This showed that the crop exposed a suboptimal thermal regime as a result of the delayed sowing (with sowing temperature 16°C).

Keywords: Chickpea, Growing Degree Days, Heliothermal Unit, November, Phenological Stages, Photothermal Unit and Temperature.

INTRODUCTION

After dry beans, chickpea (*Cicer arietinum* L.) is the second-largest legume crop globally. India leads the world in chickpea production, accounting for 68% of it, followed by Australia (60%), Turkey (47%), Burma (42%) and Ethiopia (35%). Gaur *et al.* (2012). Chickpea production covers a total area of 8.32 mha in India, with a productivity of 7.70 mt and an average yield of 925 kg ha^{-1} (Anonymous, 2014). From a nutritional standpoint, chickpea seeds include 20–30% unprocessed protein, 40–60% sugar, and 3–6% oil (Primi *et al*., 2019).

In terms of production and consumption of pulses, our nation comes in first. In India, the main pulses grown are chickpea, pigeonpea, lentil, urd bean, mung bean, pea, and moth bean. The most popular pulse crop in our country is chickpea (Agegnehu and Sinebo 2012). It provides a protein-rich diet to Indian vegetarians and adds important amino acids, vitamins, and minerals to the stable cereals found in their diets (Pingoliya *et al*., 2013). They have 22 to 24% protein, which is approximately twice as much as that in wheat and three times as much as that in rice (Shukla *et al.,* 2013), as well as 61.51% carbohydrate, 4.5% fat, and are generally free of antinutritional elements (Fotiadis *et al*., 2017).

Chickpea is grown in India as post monsoon winter season (*Rabi*) crop as it requires cool and dry weather for optimum growth. Both temperature and moisture supply during the growing period had a strong influence on chickpea (Prasad *et al.,* 2012). Start of flowering in chickpea is dependent on photothermal conditions (Ali *et al.,* 2018). The most important step in increasing chickpea production is to make sure that the crop's phenology is well-aligned with the resources and growth and development limits of the crop (Summerfield *et al.,* 1990). Grain yield is significantly sensitive to water stress during the pod setting to grain development periods irrespective of soil texture (Torkaman *et al*., 2018). Higher temperature about 30 – 35°C has a detrimental effect on growth of chickpea.

Early maturity due to delayed sowing results in a severe drop in production. Chickpea productivity in the eastern

Uttar Pradesh is quite poor, and it must be increased by resource and climate management (Neenu *et al.,* 2017). Unusual weather during a crop's reproductive time has a negative impact on the crop productivity. Temperature and a precise amount of heat are necessary for plant development as they progress from one stage of their life cycle to the next, such as from the seeding to the harvest stage (Tiwari and Meena 2016). The timing of biological activities is greatly influenced by temperature, which controls plant growth and development (Ul-Hassan *et al*., 2021).

Crop production can be predicted with the use of a quantitative understanding of how phenological development responds to environmental conditions. By shortening the crop's growing season, the crop is rushed into maturity under hot, dry conditions (over 300°C) (Richards *et al.,* 2020). The pheno-thermal index (PTI), heat usage efficiency (HUE), growing-degree days (GDD), and heliothermal units (HTU) are temperature-based indices that can be used to describe phonological behaviour and other growth factors such leaf area development, biomass output, and yield (Wang *et al*., 2006). The chickpea is the pulse that is most temperature sensitive. When the mean daily temperature is below 15°C, chickpea flowers are most likely to abort. Plant height can be impacted by late sowing, which could lower vegetative cover, decrease water use efficiency, and increase pest occurrence. Two significant elements that might impact chickpea development and output are sowing timing and cultivars (Devasirvatham *et al.,* 2012).

With the current state of climate change, weather conditions have a significant impact on crop productivity at the same time as a result of global warming. The temperature is rising during the day and dropping significantly at night. Chickpea is the pulse that is most sensitive to temperature (Kiran and Chimmad 2015).

MATERIAL AND METHODS

A. Geographical location of the test site

The experimental site of CSA University of Agriculture & Technology, Kanpur, Uttar Pradesh, India geographically. The. Experimental. site is situated at 26°29′ N latitude, 80°18′E longitude and at an altitude of 125.m above mean.sea level (MSL) in the Indo-gangetic plain. The. Site has sub-tropical. Climate and is frequently vulnerable to climatic extremes, *i.e*. cold winter and hot summer.

B. Climatic conditions

The temperature begins to elevate in February and continues to rise until June. The temperature in the month of May-June may go up to the 44 – 47°C. Throughout the summer, hot air blow from the southwest to the northeast. Different meteorological parameters such as rainfall (mm), maximum and minimum temperatures (°C), relative humidity recorded during the course of crop growth period have been depicted in Fig. 1.

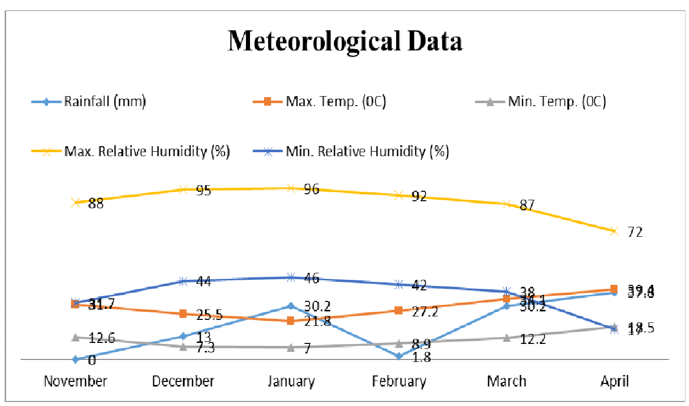

Fig. 1. Mean meteorological observation during crop season (2019 - 2020).

C. Design and Layout of the Experiment

Spilit plot design used for experiment with four replications. Three Sowing date/sowing temperature treatments *viz.* D_1- November 10/ 22°C, D_2- November 20/ 17°C and D_3- November 30/ 16°C were allocated in main plots; whereas sub- plots consisted three varieties *viz.* V_1- KWR-108 , V_2- KPG-59 and V_3- KGD-1168. A unit plot was 4.5 m × 5.0 m in size. The main irrigation channel is 1.5 m wide.

D. Days taken to different phenological stages

The total number of days taken from sowing to various phenophases of the chickpea crop was recorded, visually as to know the effect of various treatment on the phenophasic duration.

E. Accumulated growing degree day /Heat unit

The following formula was used to determine heat units at various phenological stages (Nuttonsoon, 1955):

$$\text{Heat unit} = \sum_{i=1}^{n} \text{GDD} \qquad (1)$$

Where i= 1, 2, 3…… n is the number of day

$$\text{and GDD} = \frac{\text{Tmax} + \text{Tmin}}{2} - \text{base temp.} \qquad (2)$$

Base temperature for chickpea - crops is 5°C

(i) Heliothermal unit (°days h). Heliothermal unit was measured at several phenological stages and estimated using the formula below (Hundal *et al.,* 2005).

$$\text{HTU} = \sum \text{GDD} \times \text{actual BSS (hrs)} \qquad (3)$$

(ii) **Photo thermal unit (°days h).** Photo thermal unit was estimated at different phonological stages were calculated by using following formula;

$$PTU = \sum_{i=1}^{n} GDD \times \text{day length (hrs)} \quad (4)$$

(iii) **Heat use efficiency (g m^{-2} degree days^{-1}).** Heat use efficiency (HUE) was calculated. According to the following formula:

$$HUE = \frac{\text{Total dry matter (gm}^{-2})}{\text{Acc. Heat unit } 0_{\text{days}}} \quad (5)$$

F. Statistical analysis

The data acquired throughout the experiments were statistically analysed using the Fisher and Yates, 1963 technique. For each parameter, the standard error of mean (SEM) was determined, and the critical difference (CD) at the 5% level of significance was calculated for comparison. Everywhere the 'F' test was found to be significant.

RESULTS AND DISCUSSION

A. Days taken to different phenological stages

Data on distinct phenological stages of chickpeas as affected by sowing date/temperature and variety are presented in (Table 1). Regardless of sowing date, the time it took from sowing to pod maturity ranged from 151.50 to 144.72 days. More days from vegetative to maturity were recorded when the crop was sown on November 10 with a sowing temperature of 22 degrees Celsius, followed by a crop sown on November 20 with a sowing temperature of 17 degrees Celsius. Sowing temperature Delay in sowing (November 30) reduced the vegetative phase by 8.22 days over November 10 sowing and 3.78 days over Nov 20 sowing. While from sowing to pod maturity duration was reduced by 6.78 days over November 10 and 4.34 days over November 20 sowing. Maximum days taken from sowing to maturity (151.50 days) were recorded under sowing temperature 22°C (occurred on November 10) followed by sowing temperature 17°C (exist on November 20). Delay in sowing recorded higher days taken to emergence.

Various varieties have a significant impact on all the phenological stages of chickpea. Higher days taken from sowing to pod maturity were obtained in KPG-59 (149.08 days) followed by KGD-1168 while lowest days at all phenophases were recorded in KWR-108. The current investigation's findings are likewise consistent with those of Ahmed *et al.* (2011); Singh *et al.* (2014); Ramteke *et al.* (2020).

B. Accumulated thermal unit (GDD)

Table 2 shows data on the accumulated thermal unit need of chickpea at various phenophases as affected by sowing dates/sowing temperature and variety. From sowing to maturity in, the maximum heat Unit (GDD) demand 2026.82°C days were recorded at sowing temperature 22°C (occurred on November 10), followed by 1915.18°C days at sowing temperature 17°C (occurred on November 20), and the minimum accumulated growing degree days from sowing to maturity was 1859.86°C days at sowing temperature 16^{0}C (occurred on November 30). Delays in sowing resulted in a minimal GDD requirement at all stages.

Table 1: Days taken to different Phenological stage of chickpea as affected by date of sowing/temperature and varieties.

Treatments	Phenophases				
	Emergence	Vegetative	50% flowering	Pod formation	Pod maturity
Date of sowing/ sowing temperature					
November 10/22°C	5	104.81	117.27	129.60	151.50
November 20/17°C	6	100.37	117.38	128.60	149.06
November 30/16°C	5.56	96.69	113.38	125.66	144.72
S.Em±	0.23	1.89	1.54	1.80	2.03
CD at 5%	0.70	5.80	4.73	5.53	6.23
Varieties					
KWR-108	6	99.50	115.62	128.41	147.63
KPG-59	5.3	103.17	116.64	129.10	149.08
KGD-1168	5.2	99.10	115.78	126.34	148.57
S.Em±	0.13	1.85	1.45	2.21	2.35
CD at 5%	0.55	8.01	6.28	9.53	10.16

Table 2: Accumulated thermal unit (GDD) at different phenophases of chickpea as affected by various treatments.

Treatments	Phenophases				
	Emergence	Vegetative	50% flowering	Pod formation	Pod maturity
Date of sowing/sowing temperature					
November 10/22°C	103.93	1221.13	1442.20	1667.97	2026.82
November 20/17°C	104.37	1170.62	1402.47	1609.28	1915.18
November 30/16°C	101.09	1112.70	1352.22	1505.91	1859.86
S.Em±	1.34	29.03	22.62	32.70	43.68
CD at 5%	4.14	89.10	69.42	100.36	134.05
Varieties					
KWR-108	103.46	1160.78	1398.44	1593.27	1928.87
KPG-59	103.51	1167.44	1400.11	1595.21	1941.53
KGD-1168	102.41	1176.23	1398.34	1592.67	1931.47
S.Em±	0.76	10.67	3.28	1.38	13.83
CD at 5%	3.26	46.09	14.17	5.95	59.77

At all phenophases, different varieties exhibited a significant influence on chickpea growing degree days. Regardless of variety, accumulated GDD ranged from 1928.870 days to 1931.470 days. KGD-1168 had the highest G.D.D/heat Unit required from sowing to maturity (1931.470 days), whereas KWR-108 had the lowest (1928.87°C days) from planting to maturity. These results also confirms the findings of Tripathi *et al.* (2009).

C. Heliothermal Unit (°days h)

With varied sowing dates, the heliothermal unit of maturity ranged from 15178.66 to 16324.000 days hours. A review of the data presented in the table reveals that the greatest heliothermal unit 16324.000 days hrs was recorded on November 10 with a sowing temperature of 22 degrees Celsius, followed by November 20 with a sowing temperature of 17 degrees Celsius. Its lowest value, however, was reported in delayed sowing. Namely, November 30 (15178.660 days hrs.) with a temperature of 16°C.

Variations had a significant impact on the heliothermal unit. From sowing to maturity, the heliothermal unit took between 15604.030 and 15612.030 days. KGD-1168 had the highest heliothermal unit throughout all phenophases, followed by KPG-59 and KWR-108 chickpea varieties. The findings of the current research are also consistent with the findings of the investigation of Sahu *et al.* (2007); Sharma and Sonakiya (2019).

Table 3: Heliothermal Unit (°days hrs) at different phenophases of chickpea as affected by various treatments.

Treatments	Phenophases				
	Emergence	Vegetative	50% flowering	Pod formation	Pod maturity
Date of sowing /sowing temperature					
November 10/22^{0}C	828.17	8476.33	10452.20	12969.12	16324.00
November 20/17^{0}C	773.59	7650.17	10034.89	12464.12	15315.16
November 30/16^{0}C	782.00	7265.47	9880.74	12104.06	15178.66
S.Em±	5.17	6.42	3.69	4.86	5.98
CD at 5%	17.55	19.26	14.87	14.59	17.94
Varieties					
KWR-108	776.62	7793.61	10119.51	12504.52	15604.03
KPG-59	830.42	7802.09	10121.48	12518.26	15601.78
KGD-1168	776.73	7796.27	10126.84	12514.52	15612.03
S.Em±	5.09	5.23	2.87	3.53	4.85
CD at 5%	15.30	15.69	8.95	10.60	14.55

D. Photothermal Unit (°days h)

Details on photothermal units as affected by sowing date/temperature and variety are presented in (Table 4). The photothermal unit ranged between 19437.52 and 21268.420 days hours from planting to maturity. A review of the data presented in the table reveals that the maximum photothermal unit (21268.420 days hrs.) was observed in the November 10 sowing with sowing temperature 22 C, followed by the November 20 sowing with sowing temperature 17°C. The lowest figure, 19437.520 days h, was obtained in delayed sowing, i.e. Nov 30 with sowing temperature 16°C.

Different varieties had marked variation in photothermal unit at all the stages. From planting to maturity, the photothermal unit ranged from 20956.24 to 20401.420 day h. Maximum photothermal unit at all phenophases was recorded in KWR-108 followed by KWR-1168 and then in KPG-59 variety of chickpea. The current investigation's findings are also consistent with the findings of Agrawal and Upadhyay (2009); Johal *et al.* (2018).

Table 4: Photothermal Unit (° days hrs.) at different phenophases of chickpea as affected by various treatments.

Treatments	Phenophases				
	Emergence	Vegetative	50% flowering	Pod formation	Pod maturity
Date of sowing /sowing temperature					
November 10/22^{0}C	1325.03	12842.53	15432.62	17043.16	21268.42
November 20/17^{0}C	1252.08	12226.73	14381.66	16423.06	21064.34
November 30/16^{0}C	1229.98	11136.82	13739.90	16846.49	19437.52
S.Em±	3.56	4.12	5.49	5.46	4.85
CD at 5%	10.68	12.36	16.48	16.39	14.56
Varieties					
KWR-108	1287.76	12327.16	14667.36	16314.51	20956.24
KPG-59	1243.90	11995.63	14703.67	16090.51	20412.62
KGD-1168	1275.43	11883.28	14383.14	16908.06	20401.42
S.Em±	3.22	3.85	4.56	4.59	4.71
CD at 5%	9.67	11.56	13.69	13.78	14.14

E. Heat use efficiency (gm^{-2} °days^{-1})

Table 5 presents data on heat use efficiency as it relates to sowing date/sowing temperatures and cultivars. Regardless of treatments, heat use efficiency increased satisfactorily until 90 DAS and then steadily fell till maturity. The highest heat use efficiency was observed when sowing was done on November 10 with a temperature of 22 degrees Celsius, followed by sowing on November 20, and the lowest heat use efficiency was recorded when sowing was done on November 30 with a temperature of 16 degrees Celsius.

Among the varieties, maximum heat use efficiency was recorded under KGD-1168 followed by KPG-59 while minimum heat use efficiency was recorded under KWR-108 variety of chickpea. These findings also support the findings of Singh *et al.* (2008); Mhaske *et al.* (2019); Guar *et al.* (2019).

Table 5: Heat use efficiency (gm^{-2} °days^{-1}) at different DAS of chickpea as affected by various treatments.

Treatments	DAS			
	30	60	90	At harvest
Date of sowing /sowing temperature				
November 10/22°C	0.27	0.40	0.50	0.38
November 20/17°C	0.26	0.40	0.50	0.37
November 30/16°C	0.25	0.39	0.49	0.36
S.Em±	0.011	0.012	0.013	0.011
CD at 5%	0.032	0.035	0.00	0.032
Varieties				
KWR-108	0.24	0.42	0.51	0.35
KPG-59	0.26	0.38	0.50	0.37
KGD-1168	0.27	0.40	0.49	0.38
S.Em±	0.01	0.01	0.02	0.00
CD at 5%	0.06	0.06	0.10	0.00

CONCLUSIONS

The present study concluded that sowing of chickpea variety KGD-1168 on November.10 are exhibited significantly highest accumulated GDD 1931.47°days. Heliothermal Unit 158612.03° days h and photothermal. Unit 20401.42° days h from various reproductive stages of chickpea under prevailing weather condition of central plain zone of Uttar Pradesh. Maximum heat use efficiency was recorded under KGD-1168 sown on November 10.

FUTURE SCOPE

In agriculture, temperature is the most influential element in crop productivity. Proper sowing time with temperature based on sowing date/sowing temperature method will be the greatest option for enhancing productivity in a stressed environment. It is critical for producers to select improved chickpea varieties in order to obtain high crop output.

Acknowledgement. I would like to express my heartfelt gratitude to my major guide, Dr. Naushad Khan, and the members of my advisory committee for providing me with proper guidance throughout the course of study. I would also like to express my gratitude to C.S.A. University of Agriculture and Technology for providing necessary resources throughout the entire research work.

Conflict of Interest. None.

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How to cite this article: Mandeep Kumar, Naushad Khan, Ravindra Sachan, Shravan Kumar Maurya and Durgesh Kumar Maurya (2023). Effect of Thermal Unit and Heat use Efficiency at various Phenophases of Chickpea (*Cicer arietinum* L.) Cultivars. *Biological Forum – An International Journal, 15*(3): 583-588.