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Heat unit requirements, heat use efficiency of chickpea types under different thermal environment and irrigation

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Abstract
A field experiment was conducted to study the thermal requirement of chickpea types under different thermal environment and irrigation during *rabi* seasons of 2017-18 and 2018-19 at Research Farm, Department of Physics and Agrometeorology Jawaharlal Neharu Krishi Vishwa vidayalaya, Jabalpur (Madhya Pradesh). The experiment was laid out in split split-plot design with three replications consisted of three sowing environment *viz*., November 15th, December 1st and December 15th, three chickpea types *viz*., JG 14 (*Deshi*), JGG 1 (*Gulabi*) and JGK 1 (Kabuli) with three irrigation levels (No irrigation, Irrigation at 50% branching and two irrigation each at 50% branching and pod development) as main plot, sub-plot and sub sub-plot treatments, respectively. Results revealed that duration to attain different phenophases and thermal unit during sowing to maturity decreased with successive delay in sowing form November. December 1st sowing produced significantly higher total dry matter accumulation, higher seed yield and biological yield as compared to November 15th and December 15th. Among chickpea types, *Deshi* cultivar JG 14 exhibited significantly higher total dry matter accumulation, HUE, higher seed yield and biological yield followed by JGG 1 and JGK1.

Keywords: Chickpea types, GDD, PTU, HTU, heat use efficiency, phenology

Introduction
Chickpea is grown in India during *rabi* season and it requires cool and dry weather for optimum growth. The crop is predominantly grown under rainfed condition and is raised mainly on conserved soil moisture. Optimum sowing temperature and selection of improved cultivars play a remarkable role in exploiting the yield potential of the crop under particular agro climatic conditions. Sowing dates and irrigation has been proved to affecting the yield of chickpea. Sharma (1994) [12] found that one irrigation either at branching or flowering stage as well as two irrigations at both these stages in addition to pre-sowing irrigation gave significantly higher grain and straw yields then only pre- sowing irrigation under clay loam soil. Sub optimal thermal requirement during crop growing season are known to have profound effect on productivity Agrawal *et al*., 2010. Hence the optimum sowing time and irrigation is important to exploit the environmental conditions during the growth of chickpea for maximum production. Delay in sowing causes early maturity resulting drastic reduction in yield Jain *et al*., 2018, Rathod and Chimmad, 2016 [11, 5, 1].
The Growing degree days (GDD), Photo thermal unit (PTU), Helio-thermal unit(HTU) and Heat Use Efficiency (HUE) varied with different stages of crop growth under different dates of sowing. Gan *et al.*, 2006 [4] reported that higher temperature during vegetative stage promotes fast branching. Utilization of heat in terms of dry matter accumulation is also an important aspect. Efficiency of conversion of heat energy into dry matter depends upon genetic factors, sowing time and type of crop. Changes in seasonal temperature affect the grain yield mainly through changes in phenological development processes Silawat *et al*., 2015 [11]. Present study was an attempt to understand phenology, GDD, PTU, HTU, HUE biological and seed yield under varying sowing dates and irrigation levels in chickpea types.

Materials and Methods
The field experiment was conducted at Research Farm, Department of Physics and Agrometeorology, J.N.K.V.V., Jabalpur (23° 09’ N latitude, 79° 59’ E longitude at an altitude of 411 m above mean sea level), Madhya Pradesh, India during two consecutive *rabi* seasons

of 2017-18 and 2018-19. The soil of the experimental site was sandy clay loam with pH 7.5, EC 1.48 ds/m and organic carbon 0.68%. The total annual rainfall is 1350 mm in Jabalpur. The rainfall during the crop season was 19.4 and 51.8 mm, which was received in 3 and 5 rainy days during 2017-18 and 2018-19.The experiment was laid out in split split-plot design with three replications consisted three sowing dates *viz*., November 15th, December 1st and December 15th, three chickpea types *viz*., JG 14 (*Deshi*), JGG 1 (*Gulabi*) and JGK 1 (Kabuli) with three irrigation levels (No irrigation, Irrigation at 50% branching and two irrigation each at 50% branching and pod development) as main plot, sub-plot treatments and sub sub-plot, respectively. The crop was grown with all recommended package of practices of the region and application of irrigation was followed as per the treatments. Weather data were collected from the Agro-meteorological Observatory, Department of Physics and Agro-meteorology, College of Agriculture Engineering, JNKVV, Jabalpur. Agro-meteorological indices were computed for different phenophases by adopting procedure laid out by different workers as follows:

Growing degree day (GDD)

Growing degree day was calculated by following formula and the heat unit or GDD concept was proposed to explain the relationship between growths occurred during the specific temperature. It was calculated as per the formula suggested by Nattonson (1955):

$$\text{Growing Degree Day } (^{O}\text{C day}) = \left(\frac{Tmax+Tmin}{2}\right) - Tb$$

Where, Tmax- is the maximum temperature;
Tmin- is the minimum temperature;
Tb –base temperature at which there is no growth.

Helio thermal Units (HTU)

The helio-thermal unit for a given day represents the product of GDD and the actual hours of bright sunshine for that day. The sum of HTU for the duration of each phenophase was determined by using the formula (Rajput, 1980)

$$\text{Accumulated HTU } (^{o}\text{C day}) = (\text{GDD x D})$$

Where, D= bright sunshine hours.

Photo thermal unit (PTU)

The photo-thermal unit for a day represents the product of GDD and the possible sunshine hours calculated for Jabalpur, M.P. latitude (23.17). It was calculated by the given formula of day and night length that controls the period of vegetative growth for the photosensitive Chickpea types. It was calculated as per formula suggested by Wilsie (1962).

$$\text{Accumulated PTU } (^{O}\text{C day}) = \sum (\text{GDD x length of night or day}).$$

Heat use efficiency (HUE)

The heat use efficiency is the amount of above ground dry matter produced per degree day suggested by Haider *et al*., (2003) and it was calculated by using the formula:

Heat Use Efficiency (g/m^2/^{0}C day)

$$= \frac{\textbf{Dry matter yield (g/m)/Grain yield}}{\textbf{Accumulated growing degree days(0C day)}}$$

Results and Discussion

Heat units during crop growth period

Effect on phenology

The different phenological stages as influenced by various sowing dates and irrigation levels of chickpea types are given in Table1.The days taken to attain different phenological stages and total duration were differed significantly by changing the date of sowing and irrigation levels in all type of chickpea type. The crop duration to attain physiological maturity ranges from 101 to 114 and 100 to 113 during 2017-18 and 2018-19 crop season for different sowing dates respectively. The crop sown on 15th November taken highest number of days (114 and 113) to attain different growth stages i.e. from start of flowering to physiological maturity followed by 1st December and 15th December sown crop during both the crop season. This variation may be due to varied climatic conditions. Among the different irrigation levels two irrigation take maximum days (114 and 113) to attain the physiological maturity stages both the crop season respectively, whereas lowest number of days taken under no irrigation. The *Gulabi* chickpea type required maximum days (110 and 109) to attain physiological maturity during both the crop season. This variation may be due to genetic makeup of the crop condition. Significant changes in duration of different phenophases indicated the sensitivity to photo thermal conditions. Subsequent late plantings were exposed to warmer thermal regimes and longer day lengths which are known to be inductive conditions for chickpea and therefore, shortened the total duration and hastened crop maturity and resultant to lower seed yield Agrawal *et al*., 2010.

Growing degree days (GDD)

GDD varied remarkly due to sowing dates, irrigation levels and chickpea types (Table 1). The chickpea crop sown on 1st December was accumulated maximum GDD (1537 and 1527) at physiological maturity as compared to 15th November and 15th December during both the crop season. In between the chickpea types the *Gulabi* (JGG 1) recorded highest GDD (1667 and 1624) at both the year as compared to the *Deshi* (JG 14) and Kabuli (JGK 1) at physiological maturity stage. The maximum GDD (1528 and 1539) were found with two irrigation level at physiological maturity stage during both the years. The value was lowest in 15th December sown crop; this clearly described the effect of temperature on chickpea crop. Lower consumption of heat units under delayed sowing was also reported by Tyagi, 2014.

Helio-thermal units (HTU)

The accumulated HTU required attaining different phenological stages of chickpea types are presented in Table 1. The results indicated that highest value of HTU (12541 and 12036) was recorded at maturity when chickpea was sown on 1st December during both the crop season, while lowest value of heat unit (11373 and 10674) was observed in delayed sowing on 15th Decembe. In between the chickpea types the *Gulabi* (JGG 1) recorded highest HTU (13442 and 12299) at both the year as compared to the *Deshi* (JG 14) and Kabuli (JGK 1). The maximum HTU (12300 and 15595) were found with two irrigation level at physiological maturity stage during both the years. HTU for different phenological phases decreased with delay in sowing and increases with increasing the irrigation levels long duration chickpea type take higher HTU during different phenological stages. (Silawat and Agrawal, 2012 and Agrawal, *et al*., 2002) [10, 11].

Table 1: Accumulated GDD, HTU and PTU of Chickpea types at different phenological stages as influenced by sowing dates and irrigation levels

Treatments	50 % Flowering				50% Pod formation				Physiological maturity			
	Days	GDD	HTU	PTU	Days	GDD	HTU	PTU	Days	GDD	HTU	PTU
Sowing Dates 2017-18												
E_1 - 15th Nov.	55	655	4925	6901	76	932	7314	9956	114	1497	12155	16636
E_2 - 1st Dec.	56	681	5150	7172	77	918	7678	9748	112	1537	12541	17157
E_3 - 15th Dec.	49	645	4630	6843	66	900	6578	9766	101	1448	11373	15709
Irrigation levels												
I_0 - No irrigation	52	642	4737	6746	73	858	6670	9171	98	1464	11782	16144
I_1 - One irrigation	54	666	4955	7068	78	922	7243	9886	109	1490	11988	16444
I_2 – Two irrigation	57	673	5013	7102	81	969	7658	10413	114	1528	12300	16914
Chickpea types												
V_1 - *Deshi* JG 14	45	609	4446	6425	71	853	6634	9105	106	1363	10946	14940
V_2 - *Gulabi* JGG 1	61	753	5727	7997	77	1062	8469	11462	110	1667	13442	18564
V_3 - Kabuli JGK 1	57	619	4533	6494	64	835	6467	8903	102	1452	11682	15999
Sowing Dates 2018-19												
E_1 - 15th Nov.	54	605	4234	6369	76	884	5948	9311	113	1500	11134	16530
E_2 - 1st Dec.	56	702	4533	7020	78	909	6127	9415	112	1527	12036	17236
E_3 - 15th Dec.	50	593	3903	6324	67	835	6111	9063	100	1483	10674	15927
Irrigation levels												
I_0 - No irrigation	51	620	4128	6421	72	818	5586	8607	97	1466	10947	16103
I_1 - One irrigation	55	635	4239	6591	77	882	6106	9321	108	1506	11302	16591
I_2 – Two irrigation	57	645	4304	6701	80	929	6494	9862	113	1539	15595	16999
Chickpea types												
V_1 - *Deshi* JG 14	46	604	4010	6248	70	817	5588	8600	107	1445	10783	15851
V_2 - *Gulabi* JGG 1	62	711	4767	7420	76	1009	7136	10763	109	1624	12299	18016
V_3 - Kabuli JGK 1	58	585	3894	6045	65	802	5462	8426	102	1442	10763	15826

Table 2: Yield and heat use efficiency (HUE) of Chickpea types as influenced by sowing dates and irrigation Levels

Treatments	Yield (Kg/ha)				HUE (Kg/ ha/^{0}C days)			
	Seed yield		Biological yield		Seed yield basis		Biological yield basis	
Sowing Dates	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
E_1 - 15th Nov.	1732.36	2203.29	4212.24	4691.68	1.16	1.48	2.85	3.18
E_2 - 1st Dec.	1921.56	2258.59	4582.98	4920.43	1.25	1.49	2.99	3.20
E_3 - 15th Dec.	1518.85	1715.12	4201.22	4698.45	1.05	1.16	2.71	3.14
CD (P = 0.05)	35.49	28.75	50.43	38.49				
Irrigation levels								
I_0 - No irrigation	1557.16	1963.40	4011.45	4676.23	1.05	1.34	2.74	3.16
I_1 - One irrigation	1702.99	2056.62	4331.20	4750.84	1.15	1.37	2.96	3.18
I_2 – Two irrigation	1912.63	2156.99	4653.80	4883.49	1.25	1.40	3.05	3.20
CD (P = 0.05)	42.29	31.77	65.13	47.63				
Chickpea types								
V_1 - Deshi JG 14	1794.58	2123.88	4400.87	4870.52	1.30	1.46	3.10	3.37
V_2 - Gulabi JGG 1	1708.74	1968.44	4355.48	4719.67	1.01	1.21	2.61	2.90
V_3 - Kabuli JGK 1	1669.46	2084.69	4240.09	4720.38	1.14	1.44	3.03	3.26
CD (P = 0.05)	29.11	25.11	30.57	26.37				

Photo thermal units (PTU)

The variation in PTU in different treatments at various phenological phases of chickpea types are presented in Table 1.The chickpea types was sown on 1st December with two irrigation levels attained maximum PTU (17157,17236 and 16914,16999) at maturity during both the years respectively as compare to other treatments. The PTU was found lowest (15709 and 15927) under late sown crop i.e. 15th December. In between the chickpea types the Gulabi (JGG 1) recorded highest HTU (18564 and 18016) at both the year as compared to the Deshi (JG 14) and Kabuli (JGK 1). (Agrawal *et al*., 2002, Amrawat *et al*., 2013 and Silawat *et al*., 2015) [11, 121, 11].

Heat use efficiency (HUE)

HUE was calculated by GDD accumulated to produce unit amount of seed yield (Table 2). The maximum HUE for seed yield was 1.25 and 1.49 Kg / ha / ^{0}C days sand for biological yield was 2.99 and 3.20 Kg / ha / ^{0}C days under 1st December during both the years respectively as compare to other sowing dates. The highest HUE for seed yield was 1.25 and 1.40 Kg / ha / ^{0}C days and for biological yield was 3.05 and 3.20 Kg / ha / ^{0}C days under two irrigation levels during both the years respectively over the rest of the irrigation treatments. The HUE for seed yield was 1.30 and 1.46 Kg / ha / ^{0}C days and for biological yield was 3.10 and 3.37 Kg / ha / ^{0}C days found maximum in Deshi chickpea type (JG 14) during both the years respectively as compare to other chickpea types (Table 2). HUE was recorded significantly superior on Deshi chickpea type (JG 14) with two irrigation level sown on 1st December over rest of the treatment. The highest HUE on 1st December sown crop could be ascribed by proportionate increasing dry matter per each heat unit absorbed. The lowest HTU in delayed in sowing can be expected due to accumulation of comparable GDD to that of early sowing at later crop growth stages. This might be due to higher temperature remained during reproductive phase causing detrimental effect on dry matter accumulation and seed yield. Similar results in chickpea were also observed by Agrawal *et al*., 1999, Mrudala *et al*., 2012 and Pandey, 2013.

Grain yield and biological yield

The seed and biological yield of Deshi chickpea type (JG 14) were significantly superior on 1st December (1794.58, 4400.87 and 2123.88, 4870.52 Kg ha^{-1}) at both the crop season respectively than the rest of the treatments. The two irrigation levels were found significantly superior for seed and biological yield (1912.63, 4653.80 and 2156.99, 4883.49 Kg ha^{-1}) at both the crop season respectively over the one and no irrigation levels (Table 2). The higher seed yield of 1st December sowing may be due to higher GDD, HTU and PTU as compared to other sowings. The detrimental effect of temperature at later stage of crop development in early and delayed sowing had an adverse effect on seed yield. Early sown crop produced more dry matter and also resulted in higher seed yield as they availed more GDD which shortening of the duration of various growth phases might be the probable reason in the late sown crop for the reduction in the total biomass (Rathod and Chimmad, 2016, Silawat *et al*., 2015 and Tyagi, 2014) [5, 10, 7].

Conclusion

The present study concluded that sowing of Deshi chickpea type on December 1st with two irrigation level at 50% branching and pod development exhibited significantly higher growth and yield due to optimal thermal requirements for various plant processes at different growth stages. The heat unit requirements of chickpea types decreased with delay in sowing beyond December 1st.

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