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Chickpea Phenology and Yield Related to Agrometeorological Indices Under Different Temperature Regimes

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Abstract: Agrometeorological variables have a major impact on crop development and yield, known as crop phenology. The phenology of chickpea under various thermal regimes was evaluated in a field experiment during the rabi season of 2019–2020 at Ishwardi, Pabna district of Bangladesh. Three chickpea cultivars (V1 = BARI Chola 5, V2 = BARI Chola 10, and V3 = BARI Chola 11) were planted under irrigation in four temperature regimes (D1 = November 5, D2 = November 20, D3 = December 5, and D4 = December 20). Early sowing on November 5 had a larger growing degree day (GDD), 2135.5 °C days from sowing to harvest, and later sowing on December 20 had a lower GDD (1743.4 °C days). From planting to harvest, V1 required a greater GDD (1971.5°C days) while V3 required a lower GDD (1805.8 °C days). Average heliothermal unit (HTU) varied from 11764.07 °C day hrs (D4) to 13879.4 °C day hrs (D1). Variety V1 required 13757.85°C day hrs HTU, while V2 and V3 required 13347.05°C day hrs and 11636.8 °C day hrs, respectively. The number of days needed from planting to harvest under D1, D2, D3, and D4 growing conditions were 136.3, 122.6, 118.6, and 107.4 days, respectively. Growth and yield were better for V1 and V2 under D1 settings, but they were lower under D3 conditions, while V3 was better under D2 conditions. BARI Chola 11 among the genotypes was harvested much more quickly and produced more effectively in late-sowing conditions. Physiological maturity and grain yield can be predicted with 92% and 99% accuracy, respectively, using cumulative GDD and HTU. Therefore, the study recommended that different thermal conditions and cultivars' reactions to heat utilization and economic yield have a substantial impact on chickpea cultivar yields.

Key words: Growing degree day; Heliothermal unit; Physiological maturity; Yield; Chickpea.

INTRODUCTION

People in developing nations, particularly Bangladesh, acquire a lot of protein from legumes. Pulses are an inexpensive source and have relatively higher protein content than grains, adding nutritional value to grain-dominant diets. Chickpea (*Cicer arietinum* L.) is planted in Bangladesh as a post-monsoon winter crop since it needs cool and dry weather conditions for maximum development. It is grown in area of 20591 acre with annual production is 8777 metric tons during the year of 2018 (BBS, 2020). Seasonal temperature is an important climatic component that may considerably impact agricultural output. According to Kalra et al. (2008) winter crops are especially sensitive to high temperatures during the reproductive stage and each crop reacts differently to temperature variations in various production conditions.

Most of the places in Bangladesh where chickpeas are produced are planted in November on heavy soils in a rice/jute-fallow-chickpea cycle. About 35-40% chickpea is cultivated in the aman rice-chickpea cropping pattern, where it is seeded in December (Rahman and Mallick, 1988) as a late-sown crop. Apart from these systems, chickpea is planted as a mixed crop with linseed, barley, and mustard and as an intercrop with sugarcane.

Chickpeas are a very healthy and inexpensive source of protein, the protein content of which varies between 15 and 30% depending on the variety and environmental conditions (Nleya et al., 2000). It also supply roughly 60-65% carbohydrates, 6% fat, and are a rich source of minerals and essential B vitamins. They may be cooked, eaten raw as fresh veggies, or roasted, peeled to generate dal, or turned into flour that can be used to make bread. It provides important vitamins such as riboflavin, niacin, thiamin, folic acid and carotene, a precursor of vitamin A. It could have good effects on numerous vital human ailments, including as type 2 diabetes, difficulties of the digestive system, and certain types of cancer. Overall, chickpeas are an essential pulse crop with a broad variety of potential nutritional and health benefits.

Planting date has been demonstrated to be one of the non-monetary elements that determines chickpea yield. The buildup and dispersion of structures throughout various development phases eventually influences food productivity. Premature maturity is induced by late planting and results to a large drop in yield. Chickpea yields are varied as they respond differently to environmental changes and temperature needs of particular genotypes in specific agroclimatic situations. Yield success is therefore determined by phenology and planting time. A specific number of agrometeorological metrics, including growing degree days (GDD), photothermal units (PTU), heliothermal units (HTU), and phenothermal index (PTI), have been utilized by numerous researchers to describe variations in phenological behavior and growth factors in and across the globe. The thermal indices (GDD, HTU, and HUE) for three chickpea cultivars were calculated under varied thermal regimes to investigate the impact of the thermal environment on growth and seed yield, and a yield prediction model was constructed.

MATERIALS AND METHODS

Experimental site

The study site was placed between 24.80° North latitude and 89.40° East longitudes, with an elevation of 18 m (59 ft)) above sea level. The location represents high Ganges flood plain soils under AEZ 11. The climate of the experimental site is subtropical, characterized by significant rainfall from May to October and limited rainfall in other months. In Ishwardi, the summer season is hot, oppressive, and mainly cloudy, while the dry season is warm and mostly clear. Over the course of the year, the temperature normally fluctuates from 11 to 35 °C and is rarely below 8 °C or above 39 °C. The average rainfall is highest in June (159.5 mm) and July (177.9 mm), and least in December (4.9 mm) and January (4.9 mm).

Treatment details, experimental design, and management

The experiment was laid out in a split plot design consisting of three varieties of chickpea, namely BARI Chola-5 (V1), BARI Chola-10 (V2), and BARI Chola-11 (V3), and four sowing dates: the 5th of November (D1), the 20th of November (D2), the 5th of December (D3), and the 20th of December (D4), respectively. They were replicated three times. The plot size was 4.8 square meters each. The chickpea crop was sowed in lines 30 cm apart. Each unit plot was equally fertilized with urea (45 kg ha^{-1}), TSP (80 kg ha^{-1}), MP (30 kg ha^{-1}), gypsum (60 kg ha^{-1}), and boron (7 kg ha^{-1}) All fertilizers were applied at the time of final land preparation and blended completely with the soil. After seeding, the seeds were covered with topsoil to conserve soil moisture.

Calculation of agrometeorological indices

Weather parameters *viz.*, maximum temperature (Tmax), minimum temperature (Tmin), Bright sunshine hours (BSS) were recorded at the agrometeorological observatory located near the experiment field. The agrometeorological indices *viz.*, growing degree days (GDD), heliothermal unit (HTU) was computed and heat use efficiency was calculated as reported by Jan et al. (2022) as follows-

Growing degree days (°C day) = (Tmax +Tmin)/2 - Tbase

Where, Tmax=Daily maximum temperature (°C) Tmin =Daily minimum temperature (°C), Tb =Base temperature (10 °C)

Accumulated HTU (°C day hr)= ∑ GDD × Bright sunshine hours

$$\text{Heat Use Efficiency (kg ha}^{-1}\text{°C day}^{-1}) = \frac{\text{Grain yield (kg/ha)}}{\text{Accumulated GDD (°C day)}}$$

Yield and yield components

Plants were sampled from each plot at 30 DAT, 60 DAT, and at harvest to record various morphological observations related to yield and yield components. Plant height was measured by using a measuring tape. After taking fresh weight, samples were kept in a dryer at 80 °C for 48 hours to take dry weight. At harvest, plant samples were taken to determine the yield components (primary branches, pod weight per plant, seed per pod, and 100-grain weight) and seed yield.

Statistical analysis

All the captured data were gathered and processed for statistical analysis. The Analysis of Variance (ANOVA) was done with the help of R statistics program version 3.5.3. The treatments' differences were assessed with the LSD value from the ANOVA table.

RESULTS AND DISCUSSION

Accumulated Growing degree days (GDD)

The average GDD values were between 1743.4 and 2135.5 degree days under varied treatment regimes. GDD values were 2135.5, 1813.7, 1970.5, and 1743.4 degree days for D1, D2, D3, and D4 conditions, respectively. GDDs of 1971.5, 1970.1, and 1805.8 were required for variations V1, V2, and V3 (Table 1). Heat units, or GDDs, have been proposed to describe the relationship between growth duration and temperature. Based on the station and field data, the growing degree days at different seasonal stages of chickpea crops at different planting dates were estimated and shown in Table 2. It can be noticed that GDD

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to reach the germination stage was higher in D4 and lower in D3. To reach the floral initiation stage, D4, the fourth growing habitat, required less GDD, whereas D1, the first growing environment, required the highest GDD. It signifies that the crop has begun to undergo temperature stress in the final stages of its growth cycle, and the time required to attain a given phenophase has begun to shorten. There is a third phase in chickpea, which is labeled "100% flowering," and that was attained quite early in the second and third growing conditions. More quantity of GDD was required to attain this phase in the first and last growing conditions. Further analysis showed that in all growing environments except D4, more GDD was necessary for V1 and less GDD was required for V2.

Physiological maturity from 100% flowering was obtained with very similar GDD in D2, D3, and D4, although higher GDD was required in the D1 thermal regime. The reasonable reason for this is that the third and fourth growth environments are subjected to thermal stress conditions, and physiological maturity will be achieved early in the crop that is sown last. V3 required a greater GDD to reach physiological maturity in the D1 condition, while V1 required a comparatively lower GDD to reach physiological maturity in all growth circumstances. GDD was reduced in the D2 condition and higher in the D4 condition to achieve physiological maturity to harvesting maturity. V1 required a greater GDD to attain harvesting maturity, but V2 required a comparatively lower GDD to reach physiological maturity in all growing circumstances. From sowing to harvest, early sowing, i.e., the first growth environment (D1), required a higher GDD, while later sowing required a lower GDD. In the case of varieties, V2 required a higher GDD while V3 required a lower GDD from seeding to harvest. Siddique et al. (1999) reported that temperature was the key factor affecting the phenology of Kabuli-type chickpea at various sowing dates and under varied moisture regimes. Nishad et al. (2018) observed that the number of growing degree days (GDD) for chickpea under irrigation environments varied from 4080, 3062 and 3086 under D1, D2 and D3 conditions, respectively. The total degree days under rainy conditions were 1139, 1246, and 1069, as observed from early to late sowing conditions. Pandy et al. (2010) revealed limited usage of temperature units during the delay of planting crop.

Accumulated Heliothermal Units (HTU)

It is common that the heat alone does not affect crop growth, but the sunshine affects the growth and development of crops as well. In light of this, the heliothermal unit (HTU) at various phenological phases was also worked out using both observatory and field data (Table 3). The average HTU values were between 11764.1 and 13879.4 °C day/hour under varied treatment regimes. HTU values were 13879.4, 13112.6, 12899.6, and 11764.1 °C day/hour under D1, D2, D3, and D4 settings, respectively. Variety V1, V2, and V3 needed daily average HTUs of 13757.8, 13347.1, and 11636.8 °C (Table 1). It can be noticed that HTU for germination was higher in D2 and lower in D4.

Higher HTU was required for D1 to achieve floral initiation stage, which subsequently decreased in delayed planting conditions. Except for V1 in D3 condition, 100% flowering phage initiation was achieved with lower HTU in D2 condition, while higher HTU was required in D4 condition. It has been established that to acquire physiological maturity, the highest HTU are necessary in the first growing environment, and these go on reducing with the delay in seeding. That is owing to the fact that the chickpea plant faced a thermal stress condition in the later portion of growth. Except for V1, the D2 condition was obtained at harvesting maturity with a minimum HTU, but a larger HTU was required in the D4 condition.

The total amount of heliothermal units (HTU) for chickpea in the irrigated environment ranged from 10466 in D1 to 10100 in D2, while in D3 the value of HTU was the highest (11376). In terms of non-irrigated environment, HTU values were 9164 under D1, 9334 under D2 and 8048 under D3 (Nishad et al., 2018). Pandey et al. (2010) showed that the need of heat units reduced for various phenological stages with a delay in planting. The initial planting date in cv. Jaya from emergence to physiological maturity revealed a much bigger value of total HTU than the second and third sowing dates (Mote et al., 2015).

The average number of days required for chickpea harvest differed between 107.4 and 136.3 days under different treatment regimes. D1, D2, D3, and D4 conditions required 136.3, 122.7, 118.7, and 107.4 °C days, respectively. Variety V1, V2, and V3 needed 124.2, 123.9, and 115.8 days to reach harvest, respectively (Table 1). From Table 4, it was determined that the initial growing condition required a higher number of days from sowing to harvest and that the number of days steadily dropped in the later growing condition. For flower initiation, V2 required a maximum of 58 days in D3 condition, while V3 required a minimum of 33.7 days in D1 condition. In the case of 100% blooming to maturity, V3 required a maximum of 73 days in D1 condition, while V1 required a minimum of 26.3 days in D4 condition. Variety V1 in D1 condition required a maximum of 138.7 days for harvest, while variety V3 in D4 condition required a lower 103.7 days. Agrawal et al. (2002) and (2010) noticed that days-to-maturity were the maximum in the early sown crop and that this continuously reduced with repeated sowing. Late planting was connected with a warm climate and longer day length, which lowered the reproductive time and hastened crop maturity, resulting in a decreased seed yield. Similar results were reported by Ahmed et al. (2011).

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Table 1: Accumulated growing degree days (GDD), Heliothermal Units (HTU) and Numbers of days for different chickpea varieties under different thermal regimes

Treatment	Avg. Total GDD	Avg. Total HTU	Avg. Total Days
Thermal regimes			
D1	2135.49 a	13879.37 a	136.33 a
D2	1813.73 b	13112.56 ab	122.66 abc
D3	1898.15 ab	12899.58 ab	118.66 bc
D4	1743.44 b	11764.07 b	107.44 c
Variety			
V1	1917.27 ab	13757.84 a	124.16 ab
V2	1970.08 ab	13347.04 ab	123.91 ab
V3	1805.75 b	11636.79 b	115.75 bc
Lsd(0.05)	90.45	1200.25	12.34

Table 2: Interaction effect of sowing time and cultivars on accumulated growing degree days (°C day) at different phenological stages of chickpea

	Phenological stages					
Treatments	**Sowing to Germination**	**Germination to Flower initiation**	**Flower initiation to100% Flowering**	**100% flowering to Physiological Maturity**	**Physiological maturity to Harvesting Maturity**	**Total**
D1V1	99.0	918.4	208.5	757.8	189.0	2172.7
D1V2	99.0	950.3	183.1	769.8	161.6	2163.8
D1V3	99.0	485.4	168.5	1146.5	170.7	2070.0
D2V1	100.4	839.8	91.8	570.2	129.0	1731.2
D2V2	100.4	842.4	44.5	859.6	72.7	1919.7
D2V3	100.4	706.3	110.4	761.9	111.3	1790.3
D3V1	80.6	787.1	108.7	531.9	194.3	1701.5
D3V2	80.6	795.9	84.6	595.9	160.2	1717.2
D3V3	80.6	708.6	93.3	658.7	150.5	1691.7
D4V1	132.0	610.1	192.2	533.7	311.7	1779.6
D4V2	132.0	596.9	230.0	601.3	219.4	1779.6
D4V3	132.0	491.7	151.6	669.0	226.8	1671.1
LSD	**34.12**	**216.50**	**101.22**	**263.31**	**100.39**	**321.77**
Level of significance	**NS**	**NS**	**NS**	**NS**	**NS**	**0.05**

[*D1=November 5, D2=November 20, D3= December 5 and D4 = December 20; V1 = BARI chola 5, V2 = BARI chola 10 and V3 = BARI chola 11*]

Heat Use Efficiency (HUE)

Under various treatment regimes, the average heat usage efficiency of chickpea was between 0.68 and 0.90 kg ha^{-1}°C^{-1} d^{-1}. D1, D2, D3, and D4 conditions had HUE values of 0.84, 0.90, 0.68, and 0.77 kg ha^{-1}°C^{-1} d^{-1}, respectively. D2 (20 November) had the highest heat use efficiency (1.11) and D3 had the lowest (0.52) (Fig. 1). The effectiveness was better in all varieties (except V3 in D1) under an early sowing date compared to a late sowing date. The HUE was 0.72, 0.79, and 0.88 kg ha^{-1}°C^{-1} d^{-1} for cultivars BARI Chola 5, BARI Chola 10, and BARI Chola 11, respectively. Results reveal that HUE differed greatly due to planting dates and types. Varieties V1 and V2 showed lower HUE at later sowing dates, whereas variety V3 had lower HUE at an earlier sowing date. The efficiency of conversion of thermal energy into dry matter varies upon genetic markers, sowing time, and crop variety (Rao et al., 1999). Gupta et al. (2013) performed an experiment with chickpeas and observed that the maximum heat consumption efficiency (dry matter) of 0.143 kg ha^{-1}°C^{-1} d^{-1} was attained during the blooming season. Although HUE rose with the development of crop age until pod setting and subsequently, it decreased up to physiological maturity.

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Table 3. Interaction effect of sowing time and cultivars on Accumulated helio thermal unit (°C day hrs) at different phenological stages of chickpea

	Phenological stages					
Treatments	**Sowing to Germination**	**Germination to Flower initiation**	**Flower initiation to100% Flowering**	**100% flowering to Physiological Maturity**	**Physiological maturity to Harvesting Maturity**	**Total**
D1V1	434.2	6243.7	1196.6	4947.5	1322.0	14144.0
D1V2	434.2	6348.5	1134.6	5052.7	1129.5	14099.5
D1V3	434.2	3740.5	678.7	7408.6	1132.6	13394.7
D2V1	707.7	5152.3	625.4	3825.1	3883.2	14193.7
D2V2	707.7	5175.2	324.3	6954.1	547.8	13709.2
D2V3	707.7	4331.5	704.3	4904.0	787.3	11434.8
D3V1	597.8	4544.4	1877.9	4790.1	2785.7	14595.8
D3V2	597.8	4606.3	461.8	5273.0	2542.8	13481.6
D3V3	597.8	4021.6	603.0	4324.9	1074.1	10621.3
D4V1	308.9	4123.4	1282.1	3440.7	2942.8	12097.9
D4V2	308.9	4014.7	1521.8	4039.6	2212.9	12097.9
D4V3	308.9	3238.7	1148.2	4280.2	2120.4	11096.4
LSD	**281.58**	**1323.41**	**740.729**	**1890.45**	**1407.33**	**1729.95**
Level of significance	**NS**	**NS**	**NS**	**NS**	**0.05**	**0.05**

[D1=November 5, D2=November 20, D3= December 5 and D4 = December 20; V*1 = BARI chola 5, V2 = BARI chola 10 and V3 = BARI chola 11*]

Table 4. Interaction impact of thermal regimes and cultivars on numbers of days needed at various phenological phases of chickpea varieties

	Phenological Stages					
Treatments	**Sowing to Germination**	**Germination to Flower initiation**	**Flower initiation to100% Flowering**	**100% flowering to Physiological Maturity**	**Physiological maturity to Harvesting Maturity**	**Total**
D1V1	5.0	52.7	22.3	47.3	11.3	138.7
D1V2	5.0	55.7	20.3	47.3	9.7	138.0
D1V3	5.0	33.7	10.0	73.0	10.7	132.3
D2V1	7.0	55.0	10.7	45.7	6.7	125.0
D2V2	7.0	55.3	5.3	52.3	4.3	124.3
D2V3	7.0	40.3	12.3	51.7	7.3	118.7
D3V1	6.0	57.0	9.3	36.0	15.3	123.7
D3V2	6.0	58.0	8.3	38.3	13.3	124.0
D3V3	6.0	48.0	10.7	34.7	9.0	108.3
D4V1	7.0	50.3	9.3	26.3	16.3	109.3
D4V2	7.0	49.0	11.3	31.0	11.0	109.3
D4V3	7.0	38.0	15.0	31.7	12.0	103.7
LSD	**1.53**	**7.11**	**8.59**	**21.55**	**5.68**	**19.43**
Level of significance	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

[D1=November 5, D2=November 20, D3= December 5 and D4 = December 20; *V1 = BARI chola 5, V2 = BARI chola 10 and V3 = BARI chola 11*]

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Growth, yield contributing characters and yield of chickpea

It was found that the highest plant height was seen in the D1 condition and the lowest plant height was found in the D4 condition (Table 5). Usually, greater plant heights were reported in early sowing conditions (D1 and D2) compared to later sowing conditions (D3 and D4) (D3 and D4). For variety 1, the highest plant height was recorded in condition D2 and the lowest plant height was observed in condition D4. V2 showed the highest plant height in D1 and the lowest plant height in D2. V3 has the maximum plant height in D2 condition and the lowest plant height in D3 condition.

Table 5 revealed that the number of primary branches in the D1 growing condition was unusually high (>20), whereas other growth conditions had similar numbers of primary branches (10). The pod weight per plant ranged from 27.0 to 60.03 g. The largest pod weight was reported in D1 condition and the lowest in D2 condition in the same variety (V2). V1 fared pretty similarly in all growing conditions except D4. V2 performed better in D1, somewhat in D3, and lower in D2 and D4 growth circumstances. V3 performed better at D2 and D4 circumstances. The average number of seeds per pod varied from 1.20 to 1.92. A higher number of seeds per pod was detected in later sowing conditions (D3 and D4) compared to early sowing settings. Variety V3 had a higher amount of seeds under D2 and D4 conditions. In the case of 100 seed weight, all kinds in all crop-growing environments had very similar weights of seeds, which varied from 17.33 to 18.33.

Prediction model

The regression model was created utilizing various agrometeorological variables in order to figure out the final multiple regression models for prediction of the existence of primary phenophases and grain output. It seems that 68% of the variance in physiological maturity may be represented by GDD and 59% by HTU, but the best prediction of physiological maturity was done using an assemblage of accumulated GDD and HTU, with an accuracy of 92% (Table 6). During D2 and D3 development circumstances, the best prediction of chickpea seed yield could be done utilizing combinations of GDD and HTU with an accuracy of 99%.

Gupta et al. (2013) conducted experiments with chickpea and found that the physiological maturity was done with an assemblage of accumulated GDD, PTU, and HTU with an accuracy of 98%, and the prediction of grain yield (kg ha-1) of chickpea under rainfed conditions could be done with combinations of GDD, PTU, and HTU with an accuracy of 95%. According to Srivastava et al. (2011) GDD accounted 75, 66, and 78% of the variance in biomass, seed yield, and oil content of Brassica, while HTU explained 73, 66, and 77% of the variation. The temperature based indicators may be utilized in a crop simulation model to quantify yield variation across agroecological zones.

Table 5. Yield contributing characters of chickpea varieties under different thermal regimes

Thermal regimes	Varieties	Plant height (cm)	Primary branches/plant (no)	Pods wt/ plant (g)	Seeds/ pod (no)	100 seed wt. (g)
	V1	47.4 (±4.5)	20.33 (±10.2)	45.06 (±26.3)	1.53 (±0.1)	17.52 (±5.1)
D1	V2	66.2(±3.2)	25.07(±8.6)	60.03(±18.0)	1.43(±0.2)	18.33(±6.4)
	V3	54.3 (±4.6)	19.40 (±5.2)	42.87(±14.6)	1.53 (±0.2)	18.33 (±5.7)
	V1	51.6 (±4.4)	9.4 (±2.6)	39.4 (±12.8)	1.46 (±0.2)	18.0 (±6.8)
D2	V2	41.8 (±5.8)	9.8 (±1.1)	27.0 (±15.2)	1.20 (±0.2)	17.33(±5.6)
	V3	59.3 (±4.5)	7.73 (±1.3)	54.54 (±3.5)	1.92 (±0.2)	18.33 (±5.7)
	V1	46.6 (±3.4)	7.87 (±1.6)	42.87 (±13.4)	1.87 (±0.2)	17.33 (±4.7)
D3	V2	52.2 (±4.5)	6.87 (±1.2)	43.60 (±18.9)	1.64 (±0.3)	17.33 (±6.0)
	V3	48.2 (±3.2)	7.73 (±1.3)	39.47 (±22.4)	1.53 (±0.3)	18.0 (±5.2)
	V1	40.4 (±4.3)	6.27 (±2.3)	24.60 (±11.8)	1.67 (±0.2)	18.33 (±5.6)
D4	V2	48.3 (±3.4)	6.33 (±1.8)	28.13 (±6.1)	1.73 (±0.2)	17.33 (±5.2)
	V3	80.8 (±4.2)	8.27 (±0.6)	46.87 (±22.8)	1.90 (±0.2)	18.33 (±5.4)

[*D1=November 5, D2=November 20, D3= December 5 and D4 = December 20*; *V1 = BARI chola 5, V2 = BARI chola 10 and V3 = BARI chola 11*]

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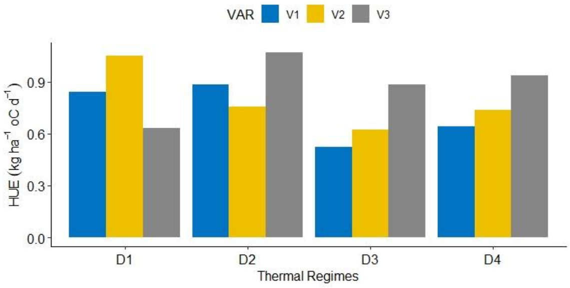
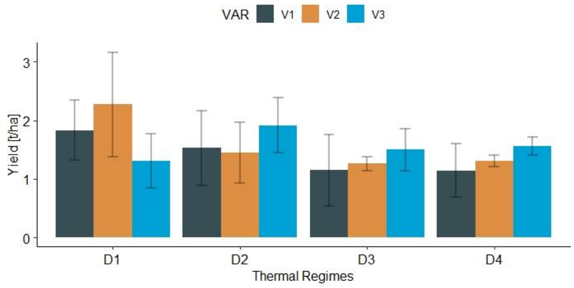
Table 6. Prediction model for physiological maturity stage (Y_1) and seed yield (Y_2) of chickpea crop based on agrometerological indices.

Equation		R^2	Adj R^2
Y_1 = 37.46 GDD +0.045		0.68	0.63
Y_1 = 97.82 HTU +0.005		0.59	0.54
Y_1 = 125.78+0.032ΣGDD – 0.005 ΣHTU		0.92	0.89
Regime	Equation	R^2	Adj R^2
D1	Y_2 = 0.82 -46.89ΣGDD +7.34ΣHTU	0.87	0.82
D2	Y_2 = 5208.45 -0.82 ΣGDD – 0.16 ΣHTU	0.99	0.96
D3	Y_2 = 2509.55 -0.27 ΣGDD – 0.05 ΣHTU	0.99	0.97
D4	Y_2 = 1.04+19.37 ΣGDD -2.75 ΣHTU	0.94	0.91



[D1=November 5, D2=November 20, D3= December 5 and D4 = December 20; V1 = BARI chola 5, V2 = BARI chola 10 and V3 = BARI chola 11]

Figure 1. Heat use efficiency of chickpea varieties under different thermal regimes [*Lsd (0.05) = 0.432*].



[D1=November 5, D2=November 20, D3= December 5 and D4 = December 20; V1 = BARI chola 5, V2 = BARI chola 10 and V3 = BARI chola 11]

Figure 2. Seed yield (t ha^{-1}) of chickpea varieties under different thermal regimes [*Lsd (0.05) = 0.893*].

CONCLUSION

Growing degree days (GDD) values are identified to be maximum in the first growing environment and go on decreasing with the second, third, and fourth growing environments, which is why the phenological stages are shorter with a delay in planting. Similarly, HTU values are shown to be highest in first-growth environments and decrease with rest-growth situations. Higher heat usage efficiency (0.90) was measured for D2 (20 November), and V3 showed higher HUE (0.88). Variety V1 and V2 performed better in D1 conditions while performing worse in D3 conditions; however, V3 performed better in D2 conditions. Among the genotypes, BARI Chola 11 took a much reduced number of days for harvest and also demonstrated greater yield under late sowing conditions, making it the most promising variety for late culture. The prediction model for the occurrence of physiological maturity and yield in chickpea was worked out. Accumulated GDD and HTU can forecast physiological maturity and seed yield with an accuracy of 92% and 99%, respectively.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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