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AGROCLIMATIC INDICES AND YIELD OF CHICKPEA UNDER DIFFERENT GROWING ENVIRONMENTS

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ABSTRACT

The field experiment was conducted during *rabi* 2019-20 and 2020-21 to study the effect of growing environment on agroclimatic indices and yield of chickpea. Chickpea was grown with four dates of sowing (25 October, 5 November, 15 November and 25 November) and two chickpea varieties (PBG 8 and PBG 7) replicated four times in a split plot design keeping dates of sowing in main plots and varieties in sub plots. Maximum calendar days (177 days) were taken by 25 October sown crop to attain the physiological maturity followed by 5 November (170 days), 15 November (166 days) and 25 November (159 days) sown crop. Chickpea variety PBG 7 took more number of days to attain maturity as compared to PBG 8. Maximum growing degree days were accumulated in 25 October (1259.6ºC day) sowing followed by 5 November (1158.3ºC day), 15 November (1086.2ºC day) and 25 November (1048.7ºC day) sowing. Among different dates of sowing, crop sown on 5 November showed superiority over other dates by producing more number of branches per plant and pods per plant. The 5 November sown crop recorded 13.1, 3.9 and 14.9% higher seed yield over 25 October, 15 November and 25 November sowing date. The chickpea variety PBG 8 produced significantly higher yield attributes (pods per plant and 100 seed weight) and 10.3% higher grain yield than PBG 7. Therefore, it can be concluded that 5-15 November sown chickpea variety PBG 8 could be a good practice or alternative to get higher productivity of chickpea.

Keywords: Agroclimatic indices, Chickpea, Dates of sowing, Grain yield, Varieties

Chickpea (*Cicer arietinum* L.) is a cool season legume grown mainly in arid and semi-arid regions, where its production is constrained by a range of environmental factors such as temperature, soil moisture availability and day length. Chickpea requires cool and dry weather conditions for optimum growth. In India, during 2019-20, it was grown on an area of 9.44 mha with annual production of 10.13 mt (Vikram, 2021). In Punjab, during 2019-20, it was grown on 1.5 thousand hectares with production of 1.8 thousand tonnes. The average yield was 12.19 q/ha (Anonymous, 2021). Crop is predominantly grown under rainfed conditions and is raised mainly on conserved soil moisture. Sowing time has been proved to be one of the most non-monetary inputs affecting the yield of chickpea. Suboptimal photo-thermal requirement during crop growing season is identified to have a profound effect on yield. Selection of sowing time is vital to exploit the environmental conditions during the growth of chickpea for maximum production. Higher temperature in the range of 30-35^{o}C is unfavourable for growth of chickpea. Solar radiation is the ultimate source of energy that withstands crop production and governs the distribution of photosynthates among different organs of plants. The dry matter accumulation and distribution during different growth stages ultimately affect the yield of crop. Delay in sowing shortens the maturity period resulting in drastic reduction in grain yield. The yield of chickpea fluctuates as it responds differently due to the variation in the environment and thermal requirements of a given genotype in a particular agro-climatic condition. Crop plants have a wide range of strategies to survive abiotic constraints (Shunmugam *et al.,* 2018). Early phenology is a common crop strategy of escaping late season stresses and facilitates adaptation to short season environments. At the genetic level, the genes controlling chickpea phenology and growth durations are largely characterized and are well known (Gaur *et al.,* 2019). In addition to genetic knowledge, management practices such as optimizing sowing dates for specific varieties can minimize the exposure to environmental stress factors during critical growth periods (Lake and Sadras, 2014). As such, using a range of sowing dates across diverse sites and years is a practical way of testing for adaptability in new regions, by corresponding performance of cultivars to the long-term average climatic conditions.

Temperature is another important factor affecting crop growth, linked both directly and indirectly to other indicators such as soil temperature, day length

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(photoperiod) and solar radiation. Influence of temperature on phenology and yield of crop plants can be studied under field conditions through accumulated heat units' system (Pandey *et al*. 2010). So, this degree days concept expresses the time in terms of temperature, as crops have basic requirement for temperature to complete specific phenophases. This concept assumes that there is a direct and linear relationship between growth and temperature and this is called thermal effect on the crop. The application of growing degree day has vastly improved the description and prediction of phenology as compared to other approaches, such as time of year or number of days. Temperature based agroclimatic indices such as growing degree day (GDD), heliothermal unit (HTU) and photothermal unit (PTU) are very beneficial for predicting the growth and yield of crops. GDD requirement indicates the thermal status for the onset of a particular phenophase in the crop. Requirement of cumulative GDD is regulated by the ambient temperature as well as change in physiological stage of crop (Nath *et al*., 1999). The climate change has harmful effects on crop production in terms of period of maturity and yield. From the last few years, the change in climate has been observed which may adversely affect the phenology and production efficiency of crops (Swaminathan and Kesavan, 2012). Although many dynamic crop simulation models have been used for assessing the phenology of the crop but the lacking point in the same is the requirement of large input data (Bemal *et al.,* 2009; Kumar *et al.,* 2009). However, this problem can be resolved by using simplified growth and yield prediction models, needing lesser input data. The temperature based agrometeorological indices provide a reliable prediction for crop development and yield. Knowledge of accumulated GDD may project growing stages of a crop as well as its approximate date of harvest (Roy *et al*., 2005). Keeping this in view, the present study was planned to examine the effect of growing environment on accumulation of heat units and productivity of chickpea.

MATERIALS AND METHODS

The experiment was carried out during *rabi* 2019-20 and 2020-21 at Punjab Agricultural University Regional Research Station, Gurdaspur (32°03′ N and 75°25′ E) situated in the north eastern region of Indian Punjab. The sowing of chickpea was done on four different dates viz., 25 October, 5 November, 15 November and 25 November with two *desi* chickpea varieties (PBG 8 and PBG 7) having four replications for each treatment. The number of days taken by crop for phenological stages like 50% flowering and maturity under different growing environments was observed. Agroclimatic indices viz. growing degree days, heliothermal units and photo thermal units were calculated by using following formulae:

Growing degree days (GDD)

GDD were calculated by simple arithmetic accumulation of daily mean temperature above the base temperature of 5°C for chickpea crop. The growing degree days for each phenophases were calculated as:

$$\text{Growing Degree Days} = \frac{T_{\max} + T_{\min}}{2} - T_b$$

$$\text{Accumulated Growing Degree Days} = \sum_{i=1}^{n} \frac{T_{\max} + T_{\min}}{2} - T_b$$

Where,

T_{max} =Daily maximum temperature (°C)

T_{min} =Daily minimum temperature (°C)

T_b =Base temperature (5°C)

Heliothermal units (HTU)

The HTU is the product of GDD and bright sunshine hours for that day. The HTU was determined by using the following formula:

Helio Thermal Units (°C days hr) = GDD x Bright Sunshine hours

Accumulated Heliothermal Units (°C days hr) =

$$\sum_{i=1}^{n} (\text{GDD x Bright Sunshine hours})$$

Photothermal units (PTU)

The PTU for a day represent the product of GDD and day length for that day. The PTU was determined by using the following formula:

Photothermal Units (°C days hr) = GDD x Day length

Accumulated Photothermal Units (°C days hr) =

$$\sum_{i=1}^{n} (\text{GDD x Day length})$$

The growth parameters like plant population, plant height and number of branches per plant and yield attributing characteristics viz. number of pods per plant, number of seeds per pod and 100-seed weight (g) were recorded during both years at the time of harvesting. The number of plants were counted from one meter row length from three randomly selected rows and average plant population was calculated. The height of five randomly selected plants was measured at maturity and mean height was calculated. The total number of branches (primary and fruiting) were counted from the five randomly selected plants in each plot at maturity stage and the average value was worked out. The total pods were counted from the five randomly selected plants from each plot and then mean was calculated to get data for the number of pods per plant. To record data on seeds per pod, twenty pods were selected randomly from five selected plants, threshed and then average was calculated. The weight of 100 grains was recorded from each plot and expressed in gram (g). Data on number of days to 50% flowering and maturity were recorded. After threshing, the data on grain yield was recorded from each plot and expressed as kg/ha. A relationship was developed between grain yield and accumulated heat units to know the interaction between heat units and grain yield.

RESULTS AND DISCUSSION

Agroclimatic Indices

The duration of particular growth stages of crop shows a direct relationship with temperature and this duration may be predicted through summation of mean daily air temperature, because the duration of each growth phase determines the accumulation and partitioning of dry matter in different organs as well as crop responses to external environmental factors. The temperature, soil moisture, relative humidity and bright sunshine hours are the important weather elements that influence the crop life cycle. The growing degree days in chickpea are beneficial in explaining the relationships between growth duration and temperature. Growing degree days can be the best index to predict the various phenophases. The GDD for different phenological stages i.e. 50% flowering and maturity during both seasons varied with different dates of sowing and varieties. The heat units accumulated by crop during 50% flowering and maturity under different treatments are presented in Table 1. Among different dates of sowing, the AGDD for chickpea crop at 50% flowering for 25 October sown crop were 1259.6°C day followed by 5 November (1158.3°C day), 15 November (1086.2ºC day) and 25 November (1048.7ºC day) sowing. The AGDD decreased with successive delay in sowing. The early sown crop had accumulated the maximum number of GDDs at both phenological stages as compared to late sown crop. The thermal units consumed by the crop reduce progressively in case of delayed sowing. Chand *et al.* (2010) also worked on effect of growing degree days on chickpea productivity and revealed that crop sown on 25 October utilized more accumulated growing degree days (1946°C day) than 5 November sown crop (1829.9°C day) during cropping period from sowing to physiological maturity. Chickpea variety PBG 7 accumulated more GDD (2042.8°C day) for maturity than PBG 8 (1947.2°C day) because PBG 7 variety took more number of days to attain maturity as compared to PBG 8. Singh *et al.* (2010) observed that genotypes are known to show differential response with respect to AGDD, HTU and PTU.

Among different dates of sowing, accumulated heliothermal units (AHTU) for chickpea crop at 50% flowering for 25 October sown crop was 6502.9°C day hrs followed by 5 November (6321°C day hrs), 15 November (6293.8ºC day hrs) and 25 November (6271.2ºC day hrs) sowing. This was due to early sown crop took more number of days to attain maturity. Kingra and Kaur (2012) revealed that earlier sown crop availed higher heliothermal units during all the seasons and with delay in sowing the accumulation of heliothermal units decreased. PBG 7 variety accumulated more number of HTU (13786.6°C day hrs) for maturity than PBG 8 (13304.8°C day hrs) because PBG 7 took more number of days to reach maturity and complete its reproductive phase as compared to PBG 8. For different dates of sowing the accumulated photothermal units (APTU) requirement for early sown crop (25 October) was the highest (2342.99°C day hrs) followed by 5 November (22937.6°C day hrs), 15 November (22756.5ºC day

Table 1. Influence of sowing date and varieties on agroclimatic indices in chickpea (pooled data of 2019-20 and 2020-21)

Treatment	50% flowering			Maturity		
	AGDD	AHTU	APTU	AGDD	AHTU	APTU
Date of sowing						
25 October	1259.6	6502.9	13158.3	2100.0	13802.2	23342.9
5 November	1158.3	6321.8	12126.5	2007.9	13738.7	22937.6
15 November	1086.2	6293.8	11478.6	1965.1	13662.3	22756.5
25 November	1048.7	6271.2	11206.5	1912.4	13479.8	22276.3
CD(p=0.05)	3.15	2.03	NS	1.21	1.48	0.08
Variety						
PBG 8	1122.9	6228.1	11816.8	1947.2	13304.8	22470.1
PBG 7	1153.5	6466.8	12168.1	2042.8	13786.6	23186.7
CD(p=0.05)	0.62	1.69	1.21	0.38	0.24	1.01

Table 2. Influence of sowing date and varieties on growth parameters, yield attributes and grain yield of chickpea (pooled data of 2019-20 and 2020-21)

Treatment	Emergence count / meter row length (number)	Plant height (cm)	Branches / plant (number)	Pods/ plant (number)	Seeds /pod (no.)	100 - seed weight (g)	Grain yield (kg/ha)
			Date of Sowing				
25 October	9.8	76.7	22.1	46.1	2.3	13.5	1772
5 November	9.8	74.9	24.8	50.5	2.2	13.2	2004
15 November	10.5	67.5	21.5	50.2	2.3	13.4	1928
25 November	9.3	61.0	17.4	44.8	2.1	13.3	1744
CD(p=0.05)	NS	6.44	2.00	NS	NS	NS	150
			Variety				
PBG 8	9.8	71.6	22.2	49.9	2.3	13.8	1954
PBG 7	9.8	68.4	20.7	46.3	2.2	12.8	1770
CD(p=0.05)	NS	1.98	1.18	2.17	NS	0.22	106
Interaction	NS	NS	NS	NS	NS	NS	NS

hrs) and 25 November (22276.3ºC day hrs) sowing. The variety PBG 7 accumulated more number of PTU (23186.7°C day hrs) for maturity than PBG 8 (22470.1°C day hrs).

Grain yield and yield attributing characteristics

A perusal of data on plant population of chickpea revealed that plant population did not differ significantly by sowing dates (Table 2). The plant height was significantly affected by sowing dates. The crop sown on 25 October (D_1) and 5 November (D_2) gained significantly more height as compared to crop sown on 15 November (D_3) and 25 November (D_4). In early sown crop, vegetative growth continued for longer period of time resulting in more plant height. The number of branches/plant varied significantly by different sowing dates. The crop sown on 5 November (D_2) produced significantly higher branches/plant than other sowing dates. The number of pods/plant showed no significant variation but numerically higher number of pods/plant was observed in D_2 and D_3 sowing dates. The sowing dates had no significant effect on number of seeds/pod and 100-seed weight. The crop sown on 5 November recorded the maximum grain yield, which was at par with 15 November sowing but significantly higher than 25 October and 25 November sowings. The crop sown on 5 November recorded 13.1, 3.9 and 14.9% higher grain yield over 25 October, 15 November and 25 November sowing dates. The higher grain yield of chickpea sown during 5 November was attributed to a lower maximum temperature coupled with higher relative humidity and higher value of yield components (number of branches/plant and pods/plant) as compared with other dates of sowing. Similarly, Saini and Faroda (1997) and Nagarajaiah *et al*. (2005) also reported higher grain yield of chickpea in the first week of November sown crop.

Chickpea varieties observed non-significant variation in population count (Table 2). Considerable varietal differences were observed in plant height. The plant height of variety PBG 8 was significantly higher than variety PBG 7. Variation among the varieties in respect to plant height appears due to genotypic variation. Kabir *et al*. (2009) also observed variation of plant height among the varieties. Variety PBG 8 recorded significantly higher number of branches/plant, pods/plant and 100-seed weight. No significant variation was observed with respect to seeds/pod in between these two varieties. The variety PBG 8 produced significantly higher grain yield (10.3%) than PBG 7. The higher values of yield attributes like pods/plant and 100-seed weight of PBG 8 contributed to its higher grain yield. Munirathnam *et al*. (2013) also reported yield variation in chickpea varieties.

Relationship between agroclimatic indices and grain yield

Different researchers worked on aspect of degree days and revealed that agroclimatic indices play an important role in grain yield of crop. Al-Karaki (2012) concluded that grain yield of crop is positively correlated with degree days. Similarly, Amrawat *et al*. (2013) observed that long growth duration provides an opportunity to the plant for accumulation of maximum biomass. The linear regression equation was developed between the agroclimatic indices and grain yield to find out the extent of variability in grain yield due to different indices. It was observed that the

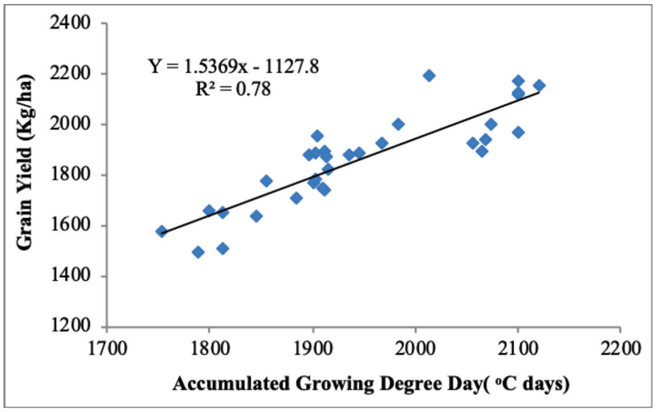

Fig.1. Relationship between accumulated growing degree days and grain yield of chickpea

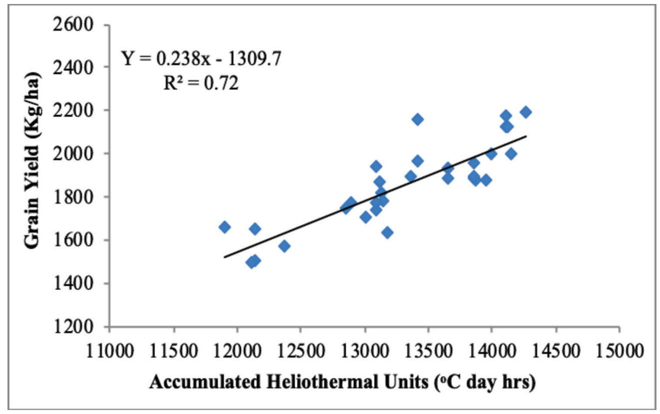

Fig. 2. Relationship between accumulated heliothermal units and grain yield of chickpea

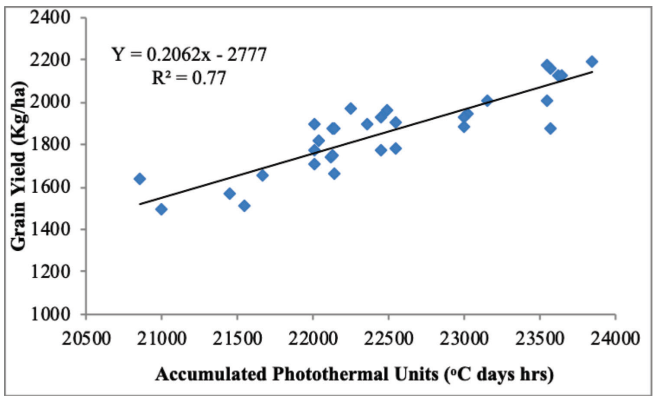

Fig. 3. Relationship between accumulated photothermal units and grain yield of chickpea

agroclimatic indices (GDD, HTU and PTU) were able to explain the variability in grain yield of chickpea by about 78, 72 and 77% respectively (Fig. 1, 2 & 3). Jain and Sandhu (2018) also developed relationships between different heat units and seed yield and revealed that the thermal indices (GDD, HTU and PTU) were able to explain the variability of seed yield by about 66, 61 and 63% respectively. Gupta *et al.* (2013) also revealed that the occurrence of 50% flowering in chickpea can be predicted well in advance using the accumulated HTU as compared to PTU and GDD with an accuracy of 82%. It showed that bright sunshine hours played a significant role in occurrence of flowering stage in chickpea. The physiological maturity was found to be more dependent on GDD and the prediction could be as high as 96%, with GDD as compared to PTU and HTU (93 and 72%), respectively.

The early sown chickpea crop took more days to mature and thus acquired more heat units throughout its growing period. But with delay in sowing, crop duration reduced which further decrease the accumulation of heat units viz., GDD, HTU and PTU values as the crop duration reduced. It can be concluded that the chickpea variety PBG 8 sown on 5-15 November performed better in terms of grain yield.

Authors' contribution

Conceptualization and designing of the research work (GS, HKV, CK); Execution of field/lab experiments and data collection (CK, HKV, GS); Analysis of data and Interpretation (CK, SKS); Preparation of manuscript (CK, SKS)

LITERATURE CITED

Al-Karaki G N 2012. Phenological development-yield relationships in durum wheat cultivars under late season high temperature stress in a semiarid environment. In: *Proc Int Scholar Res Net Agron, pp. 1-7.*

Amrawat T, Solanki N S, Sharma S K, Jajoria D K and Dotaniya M L 2013. Phenology growth and yield of wheat in relation to agrometeorological indices under different sowing dates. *African J Agric Res* **8**: 6366-74.

Anonymous 2021. *Package of Practices for Rabi crops.* Punjab Agricultural University, Ludhiana, pp.1-16.

Bemal S, Singh D and Singh S 2009. Assessing seasonal climatic variability impact on rice productivity in Haryana.

J Agrometeorol: **11** (Special Issue): 64-66.

Chand Mukesh, Singh Dhananjai, Roy Nishi, Kumar Vijay, Singh R B (2010) Effect of growing degree days on chickpea production in *Bundelkhand* region of Uttar Pradesh. *J Food Legumes* **23**(1): 41-43.

Gaur P M, Samineni S, Thudi M, Tripathi S, Sajja S B, Jayalakshmi V, Mannur D M, Vijayakumar A G, Ganga Rao N V P R and Ojiewo C 2019. Integrated breeding approaches for improving drought and heat adaptation in chickpea (*Cicer arietinum* L.). *Plant Breeding* **138**: 389-400.

Gupta V, Singh M, Jai K, Singh B N, Kumar A and Singh B 2013. Agrometerological indices for predicting growth and yield of chickpea for use in agromet advisory services. *J Agrometeorol* **15** (Special issue): 174-77.

Jain G and Sandhu S K 2018. Agroclimatic indices and yield of mustard under different thermal regimes. *J Agric Phys* **18**: 232-39.

Kabir A H M F, Bari M N, Karim M A, Karim K A, Qazi A and Ahmed J U 2009. Effect of sowing time and cultivars on the growth and yield of chickpea under rainfed condition. *Bangladesh J Agri Res* **34**: 335-42.

Kingra P K and Kaur P 2012. Effect of dates of sowing on thermal utilization and heat use efficiency of groundnut cultivars in central Punjab. *J Agri Phys* **12**: 54-62.

Kumar K, Singh S and Singh D 2009. Winter season's climatic variability and impact analysis on wheat productivity in western agroclimatic zone of Haryana. *J Agrometeorol* **11** (Spl Issue): 50-53.

Lake L and Sadras V O 2014. The critical period for yield determination in chickpea (*Cicer arietinum* L.). *Field Crops Res* **168**: 1–7.

Munirathnam P K, Kumar A, Neelima S and Padmalatha Y 2013. Influence of seed rates on chickpea varieties grown in scarce Rainfall Zone of Andhra Pradesh. *J Res ANGRAU* **41**: 88- 90.

Nagarajaiah K M, Palled Y B, Patil B N and Khot A B 2005. Response of chickpea varieties to seed rate and time of sowing under late sown conditions in Malaprabha Command Area. *Karnataka J Agric Sci* **18**: 609-12.

Nath R, Chakraborty P K and Chakraborty A 1999. Requirement of growing degree days, photothermal unit and heliothermal unit for different phenophase of sesame (*Sesamum indicum* L.) at different sowing dates. *Indian Agri* **4**: 127-34.

Pandey I B, Pandey R K, Dwivedi D K and Singh R S 2010. Phenology, heat unit requirement and yield of wheat (*Triticum aestivum*) varieties under crop growing environment. *Indian J Agric Sci* **80**: 136-40.

Roy S, Meena R L, Sharma K C, Kumar V, Chattopadhyay C, Khan S A and Chakravarthy N V K (2005). Thermal requirement of oilseed *Brassica* cultivars at different phenological stages under varying environmental conditions. *Indian J Agric Sci* **75**: 17-21.

Saini S S and Faroda A S 1997. Effect of sowing time, its pattern and seed rates on growth and yield of chickpea. *Indian J Agron* **42**: 64-68.

Shunmugam A S K, Kannan U, Jiang Y, Daba K A and Gorim L Y 2018. Physiology based approaches for breeding of next-generation food legumes. *Plants* **7**: 72.

Singh G, Sekhon H S, Ram H, Gill K K and Sharma P 2010. Effect of date of sowing on nodulation, growth, thermal requirement and grain yield of *kharif* mungbean genotypes. *J Food Leg* **23**: 132-34.

Swaminathan M S and Kesavan P C 2012. Agricultural research in era of climate change. *Agric Res* **1**: 3-11.

Vikram P K 2021. Status of chickpea (*Cicer arietinum*) cultivation in India – An overview. *Biotica Res Today* **3**:49-51.