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Climatic Impact on Phenology, Growing Degree Days and Seed Yield in Chickpea Cultivars

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Abstract The present study was carried out with four chickpea genotypes sown under three dates of sowing (41^{th}, 45^{th} and 49^{th} SMW). The results indicated that, days to flower initiation, 50% flowering, pod initiation and physiological maturity was significantly higher under 45^{th} standard week (43, 48, 51 and 77 days, respectively). Among the genotypes, BGD-128 recorded significantly higher phenological days (42, 46, 50 and 81 days, respectively) compared to other genotypes. Further, the Growing Degree Days for, days to flower initiation, 50% flowering, pod initiation and physiological maturity was higher under 45^{th} standard week (599, 666, 721 and 1049 days, respectively). Under delayed sowing plant growth phase was drastically affected minimum of 70 days for physiological maturity under 49^{th} standard week (14.79 g plant^{-1}). The yield and its associated characters were significantly higher in 45^{th} standard week. Higher seed yield per plant was recorded in genotype JG-11 (15.27g plant^{-1}) followed by BGD-128 (14.22 g plant^{-1}). This indicated that, genotype JG-11 had a stable yield even under late sown condition and can be further used for the breeding program.

Keywords Phenology, Flowering, Standard week, Growing Degree Days, Seed yield.

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Introduction

Chickpea (*Cicer arietinum* L.) ranks second among the world's food legumes in terms of area, and is a particularly important crop in South Asia, with large areas in India. Chickpea is grown in India during post-monsoon and winter season as it requires cool and dry weather conditions for optimum growth. Crop is predominantly grown under rain fed conditions and is raised mainly on conserved soil moisture. Sowing dates/sowing temperature 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 are known to have profound effect on productivity. Selection of sowing time is important to exploit the environmental conditions during the growth of chickpea for maximum production. Higher temperature about 30-35^{0}C has a detrimental effect on growth of chickpea. There is vast gap in existing and potential yield. The most important factors affecting chickpea productivity are temperature and photoperiod. Temperature based Growing Degree Days and Heat Use Efficiency is quite useful in predicting growth and yield of chickpea [1]. 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. Considerable work has been done on the Growing Degree Days and photothermal responses of chickpeas to access behavior of plant to heat units and change in plant architecture [2]. Keeping this in view, an investigation was undertaken to study the response of different dates of sowing in relation to

Table 1. Effect of temperature regimes on phenological characters and Growing Degree Days (GDD) at different stages of chickpea genotype.

Treatments	Days to flower initiation	Days to 50% flowering	Days to pod initiation	Days to physiological maturity	GDD at flower initiation	GDD at 50% flowering	GDD at pod initiation	GDD at physiological maturity
Dates of sowing (D)								
41th Standard week (D_1)	36	41	43	81	575	599	663	1182
45th Standard week (D_2)	43	48	51	77	599	666	721	1049
49th Standard week (D_3)	38	42	45	70	503	549	589	959
SEm±	0.46	0.42	0.52	0.44	6.73	10.91	7.26	6.55
LSD @ 5%	1.36	1.25	1.53	1.31	19.74	32.01	21.30	19.22
Genotypes (G)								
Annigeri-1 (G_1)	39	43	46	75	561	573	656	1050
JG-11 (G_2)	39	44	46	79	563	623	659	1103
JG-14 (G_3)	36	40	43	70	513	568	611	972
BGD-128 (G_4)	42	46	50	81	599	655	704	1128
SEm ±	0.53	0.49	0.60	0.51	7.77	12.60	8.388	7.56
LSD @ 5%	1.57	1.45	1.77	1.51	22.79	36.96	24.60	22.19

different chickpea cultivars with an objective to understand the reproductive efficiency in relation to utilization of heats units and grain productivity in four chickpea cultivars.

Materials and Methods

Four chickpea genotypes were obtained for field evaluation under high temperature with three dates of sowing. A randomized complete block design with three replications was used for field experiments during year 2015-16 at University of Agricultural Sciences, Dharwad, on a vertisol soil situated at 15^0 12´ N latitude and 76^0 34´ E longitude with an altitude of 678 meters above the mean sea level (MSL). The three dates of sowing was undertaken to create a different temperature regimes (9th October 2015 followed by 1st November and 30th November) to create a difference in temperature regime. The sowing dates represents the standard weeks 41th, 45th and 49th standard week. The crop was raised with a spacing of 30 × 10 cm, fertilized with 50:20:0 $N:P_2O_5:K_2O$. The T_{max} and T_{min} along with rainfall and humidity was recorded from the meteorological station UAS, Dharwad. The observation regarding phenology was recorded at respective growth stages and Growing Degree Days (GDD) was calculated using mentioned formula.

Growing Degree Days at different phenological stages were calculated by summation of daily mean temperature above base (T_b=10^0C) temperature for a corresponding period from sowing and expressed in ^{0}C days.

$$GDD = \Sigma \frac{(T_{max} + T_{min})}{2} - T_{base}$$

Results and Discussion

Effect of temperature on phenology

Heat unit concept has been applied to correlate phenological development in crops to predict sowing and maturity dates. The Growing Degree Days (GDD) and Heat Use Efficiency (HUE) varied with different stages of crop growth under different dates of sowing. Higher temperature during vegetative stage promotes fast branching [3]. Efficiency is quite useful in predicting growth and yield of chickpea. 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. The results indicated a significant difference with respective dates of sowing and geno-

Table 2. Effect of temperature regimes on yield and yield attributes at different stages of chickpea genotype.

Treatments	Seed number plant^{-1}	Seed yield plant^{-1}	Husk plant^{-1}	Unfilled pods plant^{-1}	Total dry matter plot^{-1}	Total dry matter plant^{-1}
Dates of sowing (D)						
41th Standard week (D_1)	54.02	13.35	5.290	6.08	1751	26.07
45th Standard week (D_2)	61.00	14.79	3.542	6.42	2088	25.86
49th Standard week (D_3)	66.06	13.83	3.764	5.98	1256	25.15
SEm ±	0.91	0.300	0.169	0.316	89.45	0.253
LSD @ 5%	2.67	0.880	0.497	NS	262.35	0.743
Genotypes (G)						
Annigeri-1 (G_1)	68.39	13.22	3.462	6.67	1481	20.35
JG-11 (G_2)	59.53	13.25	4.438	5.70	1580	23.13
JG-14 (G_3)	64.45	15.27	4.571	6.00	1824	24.97
BGD-128 (G_4)	49.06	14.22	3.923	6.27	1907	34.32
SEm ±	1.05	0.34	0.19	0.36	103.29	0.29
LSD @ 5%	3.09	1.01	0.57	NS	302.94	0.85

types. The increase in temperature significantly reduces time to onset flowering and had a greater impact on total crop duration of chickpea cultivation (Tables 1 and 2). Considering the standard weeks D_2 temperature regime (45th standard week) recorded higher days to flower initiation (43 days) and days to 50% flowering (50 days) followed by D_3 temperature regime (49th standard week) which recorded 38 and 42 days for flower initiation and 50% flowering. Among the selected genotypes BGD-128 recorded significantly higher days for days to flower initiation, 50% flowering pod initiation and physiological maturity (40, 46, 50 and 81 respectively) followed by genotype JG-11 (39, 44, 46 and 79 days respectively). Early flowering was observed in JG-14 (36 days). However, genotype Annigeri-1 and JG-11 were found on par with each other (39 and 39 days respectively).

Effect of temperature on Growing Degree Days (GDD)

Thus, it may inferred that the GDD requirement differ from sowing dates and also from genotype to genotype. The shifting of sowing dates corresponds to fluctuations in temperature causing either lengthening or shortening of the growth periods. Further, it was also found that in general a progressive delay in sowing causes a decrease in GDD requirement of constituent phenophases as well as for the crop duration as seen in D_3 temperature regime [4]. Days to pod initiation was observed early in case of D_1 temperature regime 41th standard week (43 days), while delayed pod initiation was recorded in D_2 temperature regime (51 days). It is due to the unexpected rainfall at early vegetative phase under D_2 temperature regime, which helped to maintain canopy greenness and lengthen the pod initiation phase. Among the dates of sowing D_3 temperature regime recorded significantly lower days (70) for physiological maturity compared to D_2 temperature regime and D_1 temperature regime (77 and 81 days). Similar observations were recorded [5] which stated that delayed sowing causes hastening of flowering and maturity, which resulted in reduction in productivity of chickpea as compared to normal sown condition and mean of total heat requirement up to maturity of low yielding genotypes was relatively lower followed by medium and high yielding cultivar. Days required to vegetative stage was recorded minimum (36 days) and maximum (43) under D_1 temperature regime and D_2 temperature regime respectively when crops are sown in 41th and 45th standard weeks (Table 1). D_2 temperature regime recorded significantly higher GDD (599, 666, and 720) for flower initiation, 50% flowering and pod initiation compared to D_1 and D_3 temperature regime [6]. However, for physiological maturity (1182) heat units were recorded under D_1 temperature regime. Least GDD (growing degree days) was observed under D_3 temperature regime (959) for physiological maturity (Table 1). Among the genotypes, BGD-128 recorded significantly higher GDD (599, 655, 704 and 1128) for flower initiation 50% flowering pod initiation and physiological maturity respectively. Genotype JG-14 recorded least GDD (611) for physiological maturity.

Effect of temperature on yield and yield attributes

The yield and yield attributes varied with dates of sowing and among the genotypes (Table 2). The number of seeds plant^{-1} was significantly higher under D_1 temperature regime (66.06) followed by D_2 temperature regime (61.00). However, the seed weight was recorded maximum under D_2 temperature regime (14.79). Simulations showed that, longer life cycle cultivars gave lower yields at a number of sites (Hisar, Indore Kabete and Ukirigure) under baseline or further elimate because the longer cycle exposed the crops to warmer temperatures later in the season along with the soil water depletion during the critical grain set and grain filling stage [7]. Among the genotypes Annigeri-1 recorded significantly maximum seed number (68.39 g plant^{-1}) compared to other genotypes. However, the seed weight was low compared to JG-14 which recorded (15.57 g plant^{-1}). Least seed number was recorded in genotype BGD-128 (49.06 g plant^{-1}). The unfilled pod plant^{-1} was found non-significant both under dates of sowing and genotypes. Further, the total dry matter was recorded significantly higher under D_2 temperature regime (2088) followed by D_1 temperature regime (1751) and D_3 temperature regime (1256). Increased number of branches were recorded in Annigeri-1 but the reduced seed size resulted in decreased yield. Among the genotypes, BGD-128 recorded significantly high biomass (1907 plant^{-1}`)followed by JG-14 (1874 g plot^{-1}) and JG-11 (1580 g plot^{-1}). These results earlier reported that delayed in sowing acts as an advantage for early flowering and shortening the crop life cycle in heat stress environments which influences the biomass production [8]. However, in sensitive genotypes, reproductive failures (flower abortion, poor pollen germination and increased pollen sterility) can cause poor grain yield [9]. The total dry matter per plant under D_2 and D_3 temperature regime were found on par with each other (25.86 and 25.15 g plant^{-1}). The biomass accumulation among the genotypes was significantly higher in genotype BGD-128 (34.32 g plant^{-1}) followed by JG-14 (24.97 g plant^{-1}). Although, BGD- 128 is a bold seeded, the number of pods produced and comparatively less compared to JG-14 and conversion of flower to pod ratio might be one of the factors that is responsible for decreased yields. A short period (10 day) of high temperatures (≥ 35^{0}C) during early flowering and pod development of chickpea are known to cause significant reduction in pod number, seed set and grain yield [10, 11]. Pre-anthesis and post-anthesis development and pollination processes are highly sensitive to higher temperature [12, 13]. The male (pollen, anthers) and female (stigma-style, ovary) organs in chickpea are most sensitive to temperature stress.

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