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Studies on morpho-phenological traits and heat unit accumulation in chickpea genotypes under different temperature regimes

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Abstract
Field experiment was carried out in factorial randomized block design to evaluate chickpea (*Cicer arietinum* L.) genotypes for high temperature tolerance. High temperature was imposed by delaying sowing dates *i.e.*, normal sown (D_1 temperature regimes at 41st SMW) and delayed sowing (D_2 and D_3 temperature regimes at 43rd and 46th SMW). Under late sown condition, high temperature was experienced by crop starting from flowering stage to crop maturity (during this period maximum temperature ranged from 25 to 40 ºC ranged from 25 to 40 ºC). Chickpea genotypes were evaluated for various morpho-phenological and heat unit's accumulation under different dates of sowing. A significant genotypic variability was recorded in plant height, number of branches, phenological stages and thermal indices *viz*., growing degree days (GDD), phenol-thermal index (PTI) and heat use efficiency (HUE). In general, delayed sown condition significantly reduces all the morphological parameter and reduced phenological stages which varies the thermal indices. The genotypes performed better in D_2 temperature regime with respect to morpho-phenological traits which showed higher plant height, number of primary branches and number of secondary branches which also took more number of days and accumulates optimum heat units for days to flowering, days to fifty per cent flowering, days to pod initiation and days to maturity and also showed decreasing trend in phenol-thermal index (PTI) with higher heat use efficiency (HUE) and yield was recorded in D_2 temperature regime. Hence, by considering all these parameters that all chickpea genotypes sown during 43rd SMW showed better performance by delaying 15 days than the normal date of sowing and also the genotypes JG-14, J-11 and Anigeri-1 showed lessr yield reduction in delayed sown condition than Jaki-9218 and KAK-2.

Keywords: chickpea, phenology, growing degree days, phenol-thermal index and heat use efficiency

Introduction

Chickpea (*Cicer arietinum* L.) is an important legume crop grown in many parts of the world. It is third most important food legume crop occupying first rank in area as well as production among the pulses grown in the country. India is the major chickpea producing country, while chickpea is basically grown in the dried region of India. The major chickpea producing states of India are Madhya Pradesh (39%), followed by Maharashtra (14%), Rajasthan (14%), Andhra Pradesh (10%), Uttar Pradesh (7%), Karnataka (6%) and other remaining states of India contributes 10 per cent. It is the most dominant pulse having a share of around 40 per cent in the total production followed by Tur/Arhar at 15 - 20 per cent and Urad/Black Matpe and Moong at around 8-10 per cent each (Anonymous, 2016) [2].

Chickpea is a cool season legume and high temperature during the reproductive period can limit grain yield. High temperature (>30 ◦C) regulates floral initiation and grain yield in chickpea. Chickpea is generally produced in warm environments (Devasirvatham *et al*., 2012a) [8] in rotation with cereals. However, there is potential to increase the area of chickpea rotation in future, especially in the warmer areas of India, Australia and Myanmar (Gentry, 2011 and Than *et al*., 2007) [9, 23]. Furthermore, heat stress is expected to increase due to predicted climate change further impacting chickpea production and productivity in current production areas.

Chickpea is well adopted to temperature range of 30/15 ºC (day maximum and night minimum) for crop growth and pod filling (Basu *et al*., 2009) [6]. Length of crop maturity depends on available heat units and moisture. The timing and duration of flowering has an important role in determining crop duration and grain yield at high temperature. The crop is forced into maturity under hot and dry condition (>30ºC) by reducing the crop duration (Summerfield *et al*., 1984) [22] so, the productivity of chickpea is related to its phenology, which is influenced by temperature.

Hence, the study was carried out in order to evaluate chickpea genotypes to heat stress and determine the best heat stress measures for increase and improvement of yield in stress and non-stress condition. Also, this study was undertaken to assess the selection criteria for identifying heat stress tolerance in chickpea genotypes, so that suitable varieties can be recommended for cultivation.

Materials and Methods

Field experiment was carried out in Main Agricultural Research Station (Mars), UAS, Dharwad, in rabi during 2016-17 and 2017-18. Experiment was laid out in two factorial design while, factor one was temperature regimes and factor two was genotypes. The Five genotypes *viz.*, Annigeri-1, JG-11, JG-14, Jaki-9218 and KAK-2 were sowed in combination with three different dates of sowing (D_1: 41st Standard Meteorological Week, D_2: 43rd Standard Meteorological Week and D_3: 46th Standard Meteorological Week) were chosen for the present field experiment. The data collected from the experiment was subjected to statistical analysis as described by Gomez and Gomez (1984) [10].

Observations recorded

Morphological characters: The observations on plant height and the number of primary and secondary branches were recorded as per the standard procedure in five tagged plants in the plot. Phenological parameter viz., days to flower initiation, days to fifty per cent flowering, days to pod initiation and days to maturity were recorded randomly in the plot and was expressed in days.

Thermal indices: The growing degree days (GDD), phenol-thermal index (PTI) and heat use efficiency (HUE) were calculated by using phenological data and weather data are as follows.

Growing degree days: Growing degree days at different phenological stages were calculated by Monteith (1984) [14] formula and expressed in degree celcius (° C, T_{base}: 10 °C).

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

Pheno-Thermal Index: Pheno-thermal index (PTI) was calculated by using Major *et al*. (1975) [13] formula.

$$\text{Pheno-thermal index} = \frac{\text{GDD (day)}}{\text{Number of days taken between the two phenophases}}$$

Heat Use Efficiency: Heat use efficiency (HUE) was given by Rajput, (1980) [18] and calculated as follows.

$$\text{Heat Use Efficiency} = \frac{\text{Seed or biomass yield (kg ha}^{-1}\text{)}}{\text{GDD (day)}}$$

Results and Discussion

Morphological parameters like plant height, number of primary and secondary branches, phenology and physiological maturity significantly differed due to different dates of sowing, genotypes and their interactions. Plant height is an important morphological character controlled genetically but the environmental factors also influence these characters. Variation in the plant height and branches was observed because of the effect of temperature regime. Bahl *et al*. (1984 [4]) and Sharma *et al*. (1988) [20] reported that the delay in sowing of chickpea genotypes from October last week to November last week decreases their plant height and number of primary and secondary branches significantly because of their earliness and quick growth. Significantly higher plant height (Table 1) was recorded in D_2 temperature regime (32.77 cm) which was followed by D_3 (31.43 cm) and D1 (30.82 cm) temperature regimes. The genotypes KAK-2 (33.84 cm) recorded highest plant height which was on par with JG-14 (33.18 cm) and followed byJaki-9218 (31.20 cm), JG-11 (31.14 cm) whereas, lowest was recorded in Annigeri-1 (29.02 cm) this genotypic variation in the plant height exists during the normal sown and late sown conditions, and it was significantly affected by high temperature (Neeraj *et al*., 2012) [15].

Significantly higher primary and secondary branches (Table 1) were recorded in D_2 (5.10 and 7.89) then D_3 (4.51 and 6.84) and D1 (4.48 and 7.89). The genotype Annigeri-1 (5.02 and 9.01) recorded significantly higher primary branches and secondary branches which was on par with Jaki-9218 (4.97 and 9.49) and JG-11 (4.89 and 8.82) and was followed by KAK-2 (4.39 and 4.97) and JG-14 (4.23 and 5.40). The genotype Annigeri-1 under D_2 temperature regime (5.87) recorded higher primary branches which was on par with JG-11 under D_2 (5.82), Jaki-9218 under D_3 (5.13) which was followed by Jaki-9218 under D_1 (4.89), Jaki-9218 under D_2 (4.88), Annieri-1 under D_1 (4.49), JG-11 under D_1 (4.47) temperature regimes and lowest was recorded in JG-14 under D_1 (3.88), KAK-2 under D3 (4.17) JG-14 under and D_3 (4.20) temperature regimes.

Phenological parameters

Phenological parameters (Table 2) like days to flower initiation, days to fifty per cent flowering, days to pod initiation and days to maturity are differed significantly with respect to temperature regimes genotypes and their interactions. Flowering initiation is sensitive to temperature change and can be delayed by prolonged low temperature or high temperature exposure. Cold temperature is known to delay flowering, while high temperature can induce early flower initiation (Zinn *et al*., 2010 and Balasubramanian *et al*., 2006) [25, 5]. Results are confirmed with field experiment that the D_2 temperature regime (37.6, 43.4, 50.6 and 91.1 days) took significantly more number of days for days to flower initiation, fifty per cent flowering, days to pod initiation and days to maturity this was mainly attributed to the optimum GDD (489.7, 554.0, 636.8 and 1109.0, respectively) which was on par with D_1 (36.9, 41.3, 49.2 and 90.4 days) temperature regime with highest GDD (492.9, 543.6, 641.2 and 1120.0, respectively) these were significantly differed with D_3 (33.9, 39.1, 46.5 and 82.5 days) temperature regime calculated lowest GDD (425.4, 485.3, 564.9 and 995.9, respectively). The genotype Jaki-9218 (38.8, 43.9, 51.3 and 92.0 days) took more number of days for all the phonological stages with higher GDD (501.2, 562.3, 646.9 and 1130.5) than Annigeri-1 (37.7, 42.6, 51.3 and 89.6 days), JG-11 (37.5, 42.7, 50.5 and 88.4 days), JG-14 (34.1, 39.4, 45.0 and 84.2 days) and KAK-2 (32.0, 36.5, 44.4 and 85.0 days). Results are in conformity that cold temperature is known to phonological stages, while high temperature can induce early flower initiation. Temperature plays a major in altering pheno-phases *i.e*., took longer days in cool regimes than in the delayed sowing in chickpea genotypes (Kiran, 2014 and Clarke, 2001) [11, 7]. Similarly same trend was followed for GDD values with respect to dates of sowing and genotypes indicating that higher GDD values for more number of days and heat units decrease for different phenological stages with delay in sowing (Paul and Sarker, 2000) [16]. Early reproductive phase attributed exposes to high temperature stress during pod development that affects the remobilization of photosynthates to grain and prevent the seeds from filling to their full potential size which limits yield (Wang *et al*., 2006) [24].

Pheno-thermal index (PTI) can be used to express developmental characters as it integrates pheno-logical behaviour with the thermal regime. Pragyan *et al*. (2009) [2] reported that phenothermal index value decreased till booting stage and there after gradually increased towards maturity. Generally in chickpea the PTI (Table 4) value decreased gradually towards maturity. Data pertaining Pheno-thermal index for days to flower initiation, fifty per cent flowering, pod initiation and days to maturity showed significant differences with respect to different temperature regimes but the genotypes and interactions did not differed significantly. D_1 (13.49, 13.38, 13.25, and 12.45, respectively) calculated as higher PTI for days to flower initiation, fifty per cent flowering, Days to pod initiation and days to maturity, which was on par with D2 (13.04, 12.78, 12.60 and 12.17, respectively) and followed by D_3 (12.54, 12.41, 12.14 and 12.07, respectively). Number of days to attain the phenophases and their duration were remarkably altered by change in the date of sowing (Kiran, 2014) [11]. Significantly higher heat use efficiency for yield was recorded in D_2 (2.21) which was followed by D_3 (2.02) and D_1 (1.71). Similar findings have been reported by Shahu *et al.* (2007) [19] and Agrawal and Upadhyay (2009) [1] and Kiran (2014) [11].

It is concluded that the genotypes Jaki-9281 recorded more number of branches, longer duration to days to maturity accumulates higher growing degree days and phenol-thermal index recorded higher mean yield (Table 4) but the per cent increase in yield was less by delayed sowing in Jaki-9218. But in JG-11, JG-14, Annigeri-1 and KAK-2 showed increase in percentage of chickpea yield compared to normal date of sowing.

Table 1: Effect of temperature regimes on Plant height (cm), primary branches (No's) and secondary branches (No's) of chickpea genotypes at harvest

Treatments	Plant height	Primary branches	Secondary branches
Dates of sowing			
D_1 (40th SMW)	30.82^{b}	4.48^{b}	7.89^{a}
D_2 (43rd SMW)	32.77^{a}	5.10^{a}	7.89^{a}
D_3 (46th SMW)	31.43^{ab}	4.51^{b}	6.84^{b}
S.Em.$\pm$	0.58	0.10	0.24
L.S.D. at 0.05	1.68	0.29	0.69
Genotypes			
G_1-Annigeri-1	29.02^{c}	5.02^{a}	9.01^{a}
G_2-JG-11	31.14^{bc}	4.89^{a}	8.82^{a}
G_3-JG-14	33.18^{ab}	4.23^{b}	5.40^{b}
G_4-JAKI-9218	31.20^{bc}	4.97^{a}	9.49^{a}
G_5-KAK-2	33.84^{a}	4.39^{b}	4.97^{b}
S.Em.$\pm$	0.75	0.13	0.31
L.S.D. at 0.05	1.87	0.32	0.77
Interactions			
D_1G_1	27.20^{d}	4.49^{b-d}	8.19^{bc}
D_1G_2	30.22^{b-d}	4.47^{b-d}	9.57^{ab}
D_1G_3	32.03^{a-c}	3.88^{d}	4.58^{de}
D_1G_4	30.70^{b-d}	4.89^{bc}	11.03^{a}
D_1G_5	33.97^{ab}	4.69^{bc}	6.06^{d}
D_2G_1	30.57^{b-d}	5.87^{a}	9.73^{ab}
D_2G_2	32.19^{a-c}	5.82^{a}	9.17^{bc}
D_2G_3	34.08^{ab}	4.61^{b-d}	7.61^{c}
D_2G_4	31.71^{a-c}	4.88^{bc}	8.26^{bc}
D_2G_5	35.31^{a}	4.30^{cd}	4.68^{de}
D_3G_1	29.30^{cd}	4.70^{bc}	9.11^{bc}
D_3G_2	31.02^{a-d}	4.37^{cd}	7.73^{c}
D_3G_3	33.43^{a-c}	4.20^{cd}	3.99^{e}
D_3G_4	31.19^{a-d}	5.13^{b}	9.19^{bc}
D_3G_5	32.23^{a-c}	4.17^{cd}	4.17^{e}
S.Em.$\pm$	1.29	0.22	0.53
L.S.D. at 0.05	3.75	0.65	1.54

Note: DMRT-Values in the column followed by the same letter do not differ significantly

Table 2: Effect of temperature regimes on days to flower initiation (DFI, days), days to fifty per cent flowering (DFF, days), days to pod initiation (DPI, days) and days to maturity (DM, days) phenological traits of chickpea genotypes

Treatments	Days to flower initiation	Days to fifty per cent flowering	Days to pod initiation	Days to maturity
	Days			
Dates of sowing				
D_1 (40th SMW)	36.9^{ab}	41.3^{ab}	49.2^{a}	90.4^{a}
D_2 (43rd SMW)	37.6^{a}	43.4^{a}	50.6^{a}	91.1^{a}
D_3 (46th SMW)	33.9^{b}	39.1^{b}	46.5^{b}	82.5^{b}

S.Em.±	0.7	0.8	0.7	1.0
L.S.D. at 0.05	2.0	2.3	2.1	2.9
Genotypes				
G_1-Annigeri-1	37.7^{a}	42.6^{a}	51.3^{a}	89.6^{a}
G_2-JG-11	37.5^{a}	42.7^{a}	50.5^{a}	88.4^{ab}
G_3-JG-14	34.1^{b}	39.4^{b}	45.0^{b}	84.2^{c}
G_4-JAKI-9218	38.8^{a}	43.9^{a}	51.3^{a}	92.0^{a}
G_5-KAK-2	32.0^{b}	36.5^{b}	44.4^{b}	85.0^{bc}
S.Em.±	0.9	1.0	0.9	1.3
L.S.D. at 0.05	2.3	2.5	2.3	3.3
Interactions				
D_1G_1	39.1^{ab}	43.1^{a-d}	51.9^{a}	91.0^{a-c}
D_1G_2	36.6^{a-c}	41.1^{a-f}	50.7^{ab}	91.8^{a-c}
D_1G_3	34.3^{b-d}	38.7^{c-g}	43.6^{de}	87.2^{b-d}
D_1G_4	39.6^{a}	43.2^{a-d}	51.1^{a}	93.4^{ab}
D_1G_5	33.1^{cd}	37.1^{e-g}	44.5^{c-e}	86.5^{b-d}
D_2G_1	38.9^{ab}	44.4^{a-c}	53.4^{a}	92.7^{a-c}
D_2G_2	39.8^{a}	45.8^{ab}	52.4^{a}	92.7^{a-c}
D_2G_3	36.9^{a-c}	42.7^{a-e}	48.0^{a-e}	86.3^{b-d}
D_2G_4	40.0^{a}	46.5^{a}	53.4^{a}	95.8^{a}
D_2G_5	32.3^{cd}	37.5^{d-g}	45.5^{b-e}	87.8^{b-d}
D_3G_1	34.9^{a-d}	40.3^{b-g}	48.5^{a-d}	85.1^{c-e}
D_3G_2	35.9^{a-d}	41.3^{a-f}	48.4^{a-e}	80.7^{de}
D_3G_3	31.3^{d}	36.8^{fg}	43.3^{de}	79.0^{e}
D_3G_4	36.7^{a-c}	42.1^{a-f}	49.3^{a-c}	87.0^{b-d}
D_3G_5	30.8^{d}	35.0^{g}	43.1^{e}	80.7^{de}
S.Em.±	1.6	1.7	1.6	2.3
L.S.D. at 0.05	4.5	5.0	4.7	6.5

Note: DMRT-Values in the column followed by the same letter do not differ significantly

Table 3: Effect of temperature regimes on growing degree days (GDD, ºC) for phenological stages of chickpea genotypes

Treatments	**Growing degree days for**			
	DFI	**DFF**	**DPI**	**DM**
Dates of sowing				
D_1 (40th SMW)	492.9^{a}	543.6^{a}	641.2^{a}	1120.0^{a}
D_2 (43rd SMW)	489.7^{a}	554.0^{a}	636.8^{a}	1109.0^{a}
D_3 (46th SMW)	425.4^{b}	485.3^{b}	564.9^{b}	995.9^{b}
S.Em.±	8.2	12.5	14.6	17.8
L.S.D. at 0.05	23.8	36.2	42.3	51.4
Genotypes				
G_1-Annigeri-1	491.1^{a}	546.1^{ab}	647.5^{a}	1095.6^{ab}
G_2-JG-11	487.7^{a}	546.9^{ab}	639.4^{a}	1084.0^{ab}
G_3-JG-14	448.3^{b}	508.3^{bc}	571.9^{b}	1027.3^{b}
G_4-JAKI-9218	501.2^{a}	562.3^{a}	646.9^{a}	1130.5^{a}
G_5-KAK-2	418.2^{b}	474.8^{c}	565.8^{b}	1037.5^{b}
S.Em.±	10.6	16.1	18.9	22.9
L.S.D. at 0.05	30.7	46.7	54.6	66.4
Interactions				
D_1G_1	528.3^{a}	571.4^{ab}	688.3^{a}	1133.0^{ab}
D_1G_2	493.9^{a-c}	552.9^{a-c}	675.4^{a}	1144.5^{ab}
D_1G_3	467.9^{a-d}	517.0^{a-d}	577.4^{ab}	1083.4^{a-c}
D_1G_4	528.3^{a}	577.4^{ab}	675.4^{a}	1162.1^{ab}
D_1G_5	446.1^{c-e}	499.4^{a-d}	589.8^{ab}	1077.3^{a-d}
D_2G_1	506.8^{ab}	568.1^{ab}	669.1^{a}	1125.6^{ab}
D_2G_2	519.6^{a}	578.2^{ab}	658.5^{a}	1132.7^{ab}
D_2G_3	479.7^{a-d}	547.5^{a-c}	608.9^{ab}	1049.0^{a-d}
D_2G_4	519.6^{a}	589.8^{a}	669.1^{a}	1171.4^{a}
D_2G_5	422.8^{d-f}	486.7^{b-d}	578.2^{ab}	1066.3^{a-d}
D_3G_1	438.2^{c-f}	498.8^{a-d}	585.1^{ab}	1028.4^{b-d}
D_3G_2	449.6^{b-e}	509.6^{a-d}	584.4^{ab}	974.7^{cd}
D_3G_3	397.5^{ef}	460.5^{cd}	529.4^{b}	949.6^{d}
D_3G_4	455.8^{b-e}	519.7^{a-d}	596.2^{ab}	1057.9^{a-d}
D_3G_5	385.8^{f}	438.2^{d}	529.4^{b}	968.9^{cd}
S.Em.±	18.3	27.9	32.7	39.7
L.S.D. at 0.05	53.2	81.0	94.6	115.0

Note: DFI: Days to flower initiation, DFF: Days to fifty per cent flowering, DPI: days to pod initiation, Dm: days to maturity DMRT-Values in the column followed by the same letter do not differ significantly

Table 2: Effect of temperature regimes on phenol-thermal index (PTI) for different phenological stages and heat use efficiency (HUE kg ha^{-1} °C) of chickpea genotypes

Treatments	Pheno-thermal index for				HUE for yield	Yield (kg ha^{-1})
	DFI	DFF	DPI	DM		
Dates of sowing						
D_1 (40th SMW)	13.49^a	13.38^a	13.25^a	12.45^a	1.71^c	1932^a
D_2 (43rd SMW)	13.04^a	12.78^a	12.60^a	12.17^a	2.21^a	2463^b
D_3 (46th SMW)	12.54^b	12.41^b	12.14^b	12.07^b	2.02^b	2015^b
S.Em.±	0.26	0.24	0.22	0.16	0.03	30
L.S.D. at 0.05	0.76	0.70	0.65	0.45	0.09	88
Genotypes						
G_1-Annigeri-1	13.02	12.81	12.61	12.23	2.03^{ab}	2218^b
G_2-JG-11	13.02	12.80	12.65	12.25	2.00^{ab}	2179^b
G_3-JG-14	13.12	12.89	12.72	12.20	1.94^{bc}	1992^c
G_4-JAKI-9218	12.91	12.79	12.61	12.27	2.10^a	2384^a
G_5-KAK-2	13.04	13.00	12.74	12.20	1.84^c	1911^c
S.Em.±	0.34	0.31	0.29	0.20	0.04	39
L.S.D. at 0.05	NS	NS	NS	NS	0.12	98
Interactions						
D_1G_1	13.49	13.27	13.26	12.45	1.71^{fg}	1945^{ef}
D_1G_2	13.49	13.45	13.31	12.47	1.58^g	1835^{ef}
D_1G_3	13.64	13.36	13.24	12.43	1.64^g	1795^f
D_1G_4	13.34	13.35	13.21	12.44	1.99^{c-e}	2335^{bc}
D_1G_5	13.47	13.47	13.24	12.45	1.61^g	1748^f
D_2G_1	13.03	12.79	12.52	12.14	2.22^{a-c}	2506^{ab}
D_2G_2	13.05	12.62	12.56	12.21	2.36^a	2676^a
D_2G_3	13.00	12.82	12.68	12.15	2.21^{a-c}	2316^{bc}
D_2G_4	12.99	12.68	12.54	12.23	2.25^{ab}	2647^a
D_2G_5	13.11	13.00	12.69	12.14	2.03^{b-e}	2172^{cd}
D_3G_1	12.54	12.38	12.05	12.09	2.15^{a-d}	2203^{cd}
D_3G_2	12.51	12.34	12.07	12.08	2.08^{b-e}	2025de
D_3G_3	12.72	12.50	12.22	12.02	1.96^{de}	1864^{ef}
D_3G_4	12.40	12.33	12.08	12.15	2.06^{b-e}	2171^{cd}
D_3G_5	12.55	12.54	12.28	12.01	1.87^{ef}	1813^{ef}
S.Em.±	0.58	0.54	0.50	0.35	0.07	68
L.S.D. at 0.05	NS	NS	NS	NS	0.20	196

Note: DFI: Days to flower initiation, DFF: Days to fifty per cent flowering, DPI: days to pod initiation, Dm: days to maturity
DMRT-Values in the column followed by the same letter do not differ significantly

References

1. Agarwal KK, Upadhyay AP. Thermal indices for suitable sowing time of chickpea in Jabalpur region of Madhya Pradesh. J Agrometeorol. 2009; 11(1):89-91.
2. Anonymous. India 2015-16 chana production likely down at 59 Lakh Tonnes, Commoditiescontrol, Mumbai, India, 2016.
3. Anonymous. Pulses in India: retrospect and prospects. Directorate of Pulses Development. 2016; 1(2).
4. Bahl PN, Singh KP, Dawit Singh, Singh D. Evaluation of tall chickpea genotypes for normal and late sowings. Indian J Agric. Sci. 1984; 54(2):110-113.
5. Balasubramanian S, Sureshkumar S, Lempe J, Weigel D. Potent induction of Arabidopsis Thaliana flowering by elevated growth temperature. *PLOS*. Genetics, 2006; 2:980-989.
6. Basu PS, Ali M, Chaturvedi SK. Terminal heat stress adversely affects chickpea productivity in northern India – strategies to improve thermotolerance in the crop under climate change. ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture, 23-25 February, New Delhi, India. 2009, 189-193.
7. Clarke H. Improving tolerance to low temperature in chickpea. Paper presented at the 4th European Conference on Grain Legumes, Cracow, Poland, 2001.
8. Devasirvatham V, Gaur PM, Mallikarjuna N, Tokachichu RN, Trethowan RM, Tan DKY. Effect of high temperature on the reproductive development of chickpea genotypes under controlled environments. Functional Plant Biology. 2012a; 39:1009-1018.
9. Gentry J. Chickpea Overview, 2011. Available at: www.daff.qld.gov.au
10. Gomez AK, Gomez AA. Statistical Procedures for Agricultural Research. 2nd Edition, A Wiley Inheritance Publication, New York, 1984, 187-241.
11. Kiran BA. Effect of temperature regimes on productivity of chcikepa genotypes. *M.Sc. (Agri.) thesis*, University Of Agricultural Sciences, Dharwad, 2014.
12. Krishnamurthy L, Gaur PM, Basu PS, Chaturvedi SK, Tripathi S, Vadez V *et al*. Large genetic variation for heat tolerance in the reference collection of chickpea (*Cicer arietinum* L.) germplasm. Plant Genetic Resources, 2011; 9:59-69.
13. Major DJ, Johanson DR, Tanner JW, Anderson IC. Effect of day length and temperature on soybean development, Crop Sci. 1975; 15:174-179.
14. Monteith JC. Consistenc y and convenience in the choice of units for agricultural. Sci. Exptl. Agric. 1984; 20:115-117.
15. Neeraj K, Nandwal AS, Yadav R, Bhasker P, Kuma rS, Devi S *et al*. Assessment of chickpea genotypes for high temperature tolerance. Indian J Plant Physiol. 2012; 17(3-4):225-232.

16. Paul NK, Sarker DK. Accumulated heat units and phenology relationships in wheat as influenced by sowing dates. Bangladesh J Bot. 2000; 29(1):49-54.
17. Pragyan K, Wadood A, Singh RS, Ramesh K. Responcse of wheat crop to different thermal regimes under the agro climatic conditions of Jharkhand. J Agrometeorol. 2009; 11(1):85-88.
18. Rajput RP. Response of soybean crop to climatic and soil environments. *Ph.D. thesis*, IARI, New Delhi, India, 1980.
19. Sahu DD, Chopda MC, Patoliya BM. Determination of sowing time for chickpea varieties in South Saurashtra, India. J Agrometeorol. 2007; 9(1):68-73.
20. Sharma ML, Chauhan YS, Bharadwaj GS, Sharma RK. Relative performance of chickpea varieties to sowing dates. Indian J Agron. 1988; 33(4):452.
21. Srivastav N, Dheer Singh, Alok Shukla SK, Guru Munna Singh, Rana DS. Effect of high temperature stress at post anthesis stage on photo system II, senescence, yield and yield attributes of wheat genotypes. Indian J Plant Physiol. 2012; 17(2):158-165.
22. Summerfield RJ, Hadley P, Roberts EH, Minchin FR, Rawsthrone S. Sensitivity of chickpea (*Cicer arietinum* L.) to hot temperatures during the reproductive period. Exp. Agr. 1984; 20:77-93.
23. Than AM, Maw JB, Aung T, Gaur PM, Gowda CLL. Development and adoption of improved chickpea varieties in Myanmar. SAT e J. 2007; 5:1-3.
24. Wang J, Gan YT, Clarke F, Mc Donald CL. Response of chickpea yield to high temperature stress during reproductive development. Crop Sci. 2006; 46(5):2171-2178.
25. Zinn KK, Tunc-ozdemir M, Harper JF. Temperature stress and plant sexual reproduction: uncovering the weakest links. J Exptl. Bot. 2010; 61:1959-1968.