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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(11): 343-348

www.thepharmajournal.com
Received: 16-09-2021
Accepted: 18-10-2021

Nilesh D Jadhav
Ph.D. Scholar, M.P.K.V., Rahuri, Maharashtra, India

SR Gadakh
Research Guide and Director of Research, Department Agricultural Botany, M.P.K.V., Rahuri, Maharashtra, India

SB Korade
Ph.D. Scholar, M.P.K.V., Rahuri, Maharashtra, India

NS Kute
Principal Scientist, Pulse Improvement Project, Department Agricultural Botany, M.P.K.V. Rahuri, Maharashtra, India

Corresponding Author
Nilesh D Jadhav
Ph.D. Scholar, M.P.K.V., Rahuri, Maharashtra, India

Morpho-physiological responses of chickpea genotypes under different temperature regimes

Nilesh D Jadhav, SR Gadakh, SB Korade and NS Kute

Abstract
Heat stress is a abiotic stress and directly and indirectly affect on plant growth and its developmental processes. The aim of this study was to screen heat tolerant genotypes on the basis of morpho-physiological and yield parameters. This investigations was carried out in Phytotron unit M.P.K.V., Rahuri on two different temperature regimes *viz*., 20/15 ºC and 25/20 ºC and Fourteen chickpea genotype including checks. Results denoted significant effect of heat stress on Days to flower initiation, days to 50% flowering and days to physiological maturity, Plant height, Total dry matter production, net photosynthetic rate, transpiration rate, stomatal conductance, Canopy temperature, SPAD index, number of pods per plant and grain yield per plant. The interaction effect was significant for all phonological parameters, plant height and SPAD index only. In temperature 20/15 ºC and 25/20 ºC Phule G-1012-15 recorded highest yield plant^{-1} at temperature 20/15 ºC and 25/20 ºC (9.23 and 8.30 g respectively) followed by genotype Phule G-0914-6-17 (8.94 and 8.01 g respectively) and Phule G-171104 (8.77 and 7.83 g respectively). Genotypes like Phule G-1012-15, Phule G-0914-6-17 and Phule G-171104 proved to be promising for heat stress with higher net photosynthetic rate, stomatal conductance and SPAD index, Whereas lower rate of transpiration and canopy temperature produced higher grain yield per plant (9.23 and 8.30 g),(8.94 and 8.01 g), (8.77 and 7.83 g respectively) as compared to stress susceptible genotypes such as JG-16 (G11) (5.36 and 4.57 g), Phule G-16115 (G8) (6.30 and 4.97 g), Phule G-1226-33-14 (G1) (6.39 and 5.38) decreased grain yield per plant.

Keywords: phenology, physiological parameters, growth, heat, temperature, stress, yield

Introduction

The production constraints faced by the farmers in cultivation are Biotic and abiotic stresses like high infestation of pest and diseases, lack of rainfall, low or high temperature. More than 90 per cent of gram production of the country during the period under 10 states of MP, MS, Rajasthan, Karnataka, UP, AP, Gujarat, Jharkhand, CG and Telangana. (Anonymous, 2017) [3]. Chickpea (*Cicer arietinum* L.) is an important grain legume crop. Global warming and changes in cropping systems are driving chickpea production to relatively warmer growing conditions. Studies on the impact of climate change on chickpea production highlighted the effect of warmer temperatures on crop development and subsequent chickpea yield. Assessment of whole plant response, particularly flowering and grain filling in warmer environments, in the field is generally an effective screening method. The identification of heat tolerant genotypes can help to adapt chickpea to the effects of warmer temperatures.

In case of late sown chickpea, this crop faces low temperature during sowing time and high temperature at the end of its cropping season. The low temperature at the initial stage of crop growth results in poor and slow vegetative growth whereas high temperature at the end of cropping season leads to forced maturity and problem of poor biomass. Heat stress at the reproductive stage is thus increasingly becoming a serious constraint to chickpea production in northern India due to climate change (Prasad *et al*. 2018) [14]. Plants have to interact with several abiotic stresses during its growth period. Among the abiotic stress, the high temperature is a major factor, associated with yield reduction. A minimum reduction of 53 kg/ha in the yield chickpea was noticed per 1˚C increase in mean seasonal temperature in India. In case of late sown chickpea, this crop faces low temperature during sowing time and high temperature at the end of its cropping season. Heat stress at the reproductive stage is thus increasingly becoming a serious constraint to chickpea production in northern India due to climate change (Prasad *et al*. 2018) [14].

Flowering and podding stage of chickpea are known to be very sensitive to changes in external environment and exposure to heat stress which results into reduction in seed yield (Summerfield *et al*., 1984) [18]. Drastic reductions in chickpea seed yields were observed when plants at flowering and pod development stages were exposed to high (35 ºC) temperatures (Summerfield *et al*., 1984, Wang *et al*., 2006) [18, 21]. Due to heat stress it affects pollen viability, fertilization and seed development leading to a reduced harvest index. Yet, it is still not clear how heat affects the growth and development of chickpea and whether that can explain part of the differences in seed yield under heat stress. So, a pre-requisite, before undertaking a more thorough physiological analysis of the traits involved in heat stress tolerance, is the identification of heat tolerant genotypes. Also there is an urgent need to develop simple and effective germplasm screening techniques and breeding materials particularly at reproductive stage for heat tolerance in chickpea. Therefore, the present work was conducted to evaluate the effect of high temperature stress on chickpea genotypes.

Materials and Methods

Fourteen chickpea genotypes were grown at two different temperature regimes *viz*., 20/15 ºC and 25/20 ºC in pots filled with 8 kg of soil with compost media. Experiment was laid-out in a Factorial completely randomized design with two replications during *rabi* 2020-21 in the Phytoron unit at M.P.K.V., Rahuri (Maharashtra, India). Water soluble organic fertilizer was applied at sowing time uniformly all pots equally for crop growth. The temperature during growth period is mentain as per treatments. Phenological parameters like days to flower initiation, days to 50% flowering and days to physiological maturity recorded by daily visual observation, whereas physiological parameters *viz*., net photosynthetic rate, transpiration rate, stomatal conductance, Canopy temperature, SPAD index are recorded at 50% flowering. The observations on net photosynthetic rate, transpiration rate and stomatal coductance were recorded with the help of portable Infrared Gas Analyzer (IRGA; Model Portable Photosynthesis System LI 6400, LI-COR Inc., Lincon, Nebraska, USA). Canopy temperature measurements were made using a hand held infrared thermometer (Model OS 530 HR, Omega Engineering Inc. 42 Stamford CT USA). SPAD index was estimated nondestructively, using a SPAD-502 chlorophyll meter (Minolta Corp., Ramsey, NJ, USA) at 50% flowering. Observations was recorded between 12:00 noon to 2:00 p.m. The grain yield per plant was obtained after harvesting and threshing each plant separately. The data were analyzed in Factorial Completely Randomized Block Design (FCRD) given by Panse and Sukhatme (1985) [13].

Results and Discussion

Phenological Characters

Early maturity is an important trait to avoid heat stress. The effect of temperature on phenological parameters was found to be statistically significant. Temperature 25/20 ºC was showed earlier for phonological parameters as compared to temperature 20/15 ºC. The data regarding phonological parameters are presented in Table 1.

The earlier flower initiation of genotype Phule G-1131-31-4 (42.50 and 39.50 days) and Phule G-1131-31-9 (G5) (43.50 and 38.50 days) while genotype JG-16 (G11) (54.00 and 45.50 days) and Phule Vikram (check) (G14) (51.50 and 45.00 days) had late flower initiation at 20/15 ºC and 25/20 ºC, respectively. Genotype, Phule G-1012-15 (47.50 and 46.00 days) and Phule G-16115 (G8) (53.50 and 46.00 days) recorded early days to 50% flowering while genotype Phule G-15109 (G4) (59.50 and 57.50 days) and Phule Vikram (check) (G14) (60.50 and 55.00 days) had late flower initiation at 20/15 ºC and 25/20 ºC, respectively. Genotype, Phule G-1010-14 (107.50 and 104.50 days) and Phule G-0914-6-17 (109.00 and 104.50 days) recorded early physiological maturity at temperature 20/15 ºC and 25/20 ºC (107.50 and 104.50 days) followed by genotype Phule G-0914-6-17 (G7) (109.00 and 104.50 days) while genotype Phule G-15109 (G4) (119.00 and 115.50 days) and Phule G-1131-31-9 (G5) (118.50 and 115.50 days) had late physiological maturity at 20/15 ºC and 25/20 ºC, respectively. Interaction effect shows significant effect for phonological parameters.

Phenology is effect of seasonal changes on life span. Days to initiation flowering, days 50% flowering and days to physiological maturity are the most important phenological parameters that can influence on performance of crop under heat stress conditions. So, temperature 25/20 ºC was showed earlier for phonological parameters as compared to temperature 20/15 ºC. Flowering is mostly depends on genotypes, seasonal fluctuating temperature *i.e* less or more. Similar type of investigations was also earlier reported by Bahuguna *et al.* (2012) [4], Babbar *et al.* (2012), Upadhyaya *et al*. (2011) [20] and Devendra *et al.* (2012) [9] reported similar findings.

Table 1: Days to initiation of flowering, Days to 50% flowering, Days to physiological maturity, plant height (cm) as influenced by varying temperature regimes and their interactions

		Days to initiation of flowering			Days to 50% flowering			Days to physiological maturity			Plant height (cm)		
Sr. No.	Genotype	20/15 ºC	25/20 ºC	Mean	20/15 ºC	25/20 ºC	Mean	20/15 ºC	25/20 ºC	Mean	20/15 ºC	25/20 ºC	Mean
1	Phule G-1226-33-14	44.5	40	42.25	58.5	56	57.25	114	111.5	112.75	63.49	59.48	61.48
2	Phule G-1131-31-4	42.5	39.5	41	55	54.5	54.75	115	114.5	114.75	56.9	53.23	55.07
3	Phule G-171104	44.5	40.5	42.5	60	55	57.5	116.5	114	115.25	57.2	53.2	55.2
4	Phule G-15109	47	42.5	44.75	59.5	57.5	58.5	119	115.5	117.25	52.09	48.42	50.25
5	Phule G-1131-31-9	43.5	38.5	41	51	55	53	118.5	115.5	117	53.54	49.87	51.7
6	Phule G-1010-14	49.5	44.5	47	60	55.5	57.75	107.5	104.5	106	57.77	53.77	55.77
7	Phule G-0914-6-17	45.5	41	43.25	53	51.5	52.25	109	104.5	106.75	63.7	59.37	61.53
8	Phule G-16115	44	39.5	41.75	53.5	46	49.75	109.5	105	107.25	55.62	51.62	53.62
9	Phule G-1012-15	45	40	42.5	47.5	46	46.75	114.5	109.5	112	57.72	54.38	56.05
10	Phule G-1231-5-10	48.5	42	45.25	56.5	56	56.25	110.5	104	107.25	67.92	63.58	65.75
11	JG-16	54	45.5	49.75	58.5	56.5	57.5	116.5	110.5	113.5	46.74	43.4	45.07
12	Vijay (check)	45.5	41.5	43.5	55	55	55	110	107	108.5	46.87	43.53	45.2
13	Digvijay (check)	44	39.5	41.75	57.5	58	57.75	110.5	107	108.75	54.92	50.92	52.92
14	Phule Vikram (check)	51.5	45	48.25	60.5	55	57.75	111.5	107.5	109.5	66.8	62.8	64.8
	Mean	46.39	41.39	43.89	56.14	54.11	55.13	113.04	109.32	111.18	57.23	53.4	55.31
		SEm (±)	CD 5%		SEm (±)	CD 5%		SEm (±)	CD 5%		SEm (±)	CD 5%	

	Treatment (T)	0.1	0.3		0.16	0.46		0.15	0.46		0.03	0.1	
	Genotype (G)	0.13	0.4		0.21	0.61		0.2	0.6		0.04	0.13	
	Interaction (G×T)	0.39	1.14		0.6	1.74		0.59	1.72		0.13	0.38	

Growth parameters

The data regarding growth parameter significant for plant height and total dry matter production. Interaction effect significant for only plant height. The temperature, 25/20 ºC had less mean plant height (53.40 cm) and total dry matter production (16.52 g) while highest at 20/15 ºC (57.23 cm and 19.76 g respectively).

The data regarding plant height and total dry matter production are presented in Table 2 and 3.

Genotype Phule G-1231-5-10 (67.92 and 63.58 cm) and Phule Vikram (check) (G14) (66.80 and 62.80 cm) recorded highest plant height. While genotype JG-16 (G11) (46.74 and 43.40 cm) and Vijay (check) (G12) (46.87 and 43.53 cm), had lowest plant height at 20/15 ºC and 25/20 ºC, respectively. Height of chickpea plants varies with different environmental factors through certain genotypes has their specific expressions. Heat stress mostly reduced plant height by reducing intermodal elongation. Phule G-1231-5-10 and Phule Vikram (check) observed highest plant height at both temperature condition and reduced with increase in temperature. These findings also supported by report of the Brar *et al*. (2004) [7] and Yadav *et al*. (1999) [22].

Genotype, Phule G-1012-15 (21.63 and 19.91 g) and Phule G-0914-6-17 (G7) (21.80 and 19.55 g) recorded highest total dry matter production at temperature 20/15 ºC and 25/20 ºC while genotype JG-16 (G11) (17.38 and 12.91 g) and Phule G-16115 (G8) (17.80 and 13.40 g) had lowest total dry matter production at 20/15 ºC and 25/20 ºC, respectively. Total dry matter production is parameter denotes growth of plant in respective to its environment. Rate of carbon and photosynthate assimilation in chickpea was decreased with increased in temperature in its environment. Rate of dry matter production also dicreases with increase in temperature in chickpea. Due to that temperature, 25/20 ºC had less mean total dry matter production while highest at temperature 20/15 ºC. Genotype Phule G-1012-15 and Phule G-0914-6-17 recorded highest total dry matter production at temperature. The results are in agreement with Chakrabarti *et al*. (2013) [8] and Tatar *et al*. (2013) [19].

Physiological parameters

The data regarding net photosynthetic rate, transpiration rate, stomatal conductance, Canopy temperature and SPAD index was found to be significant. The temperature, 25/20 ºC had less photosynthesis (15.80 μmol of CO_2 m^{-2} s^{-1}), stomatal conductance (0.64 mol H_2O m^{-2} s^{-1}) and SPAD index (41.91%) while highest at temperature 20/15 ºC (16.83 μmol of CO_2 m^{-2} s^{-1}, 0.81 mol H_2O m^{-2} $s^{-1}$and 44.79% respectively). The temperature, 25/20 ºC had highest transpiration rate (5.49 mmol of H_2O m^{-2} s^{-1}) and canopy temperature (26.58 ^{0}C) while lowest at temperature 20/15 ºC (4.77 mmol of H_2O m^{-2} s^{-1} and 21.46 ^{0}C respectively). The data regarding physiological parameters are presented in Table 2 and 3.

Genotype, Phule G-1012-15 (18.79 and 17.98 μmol of CO_2 m^{-2} s^{-1}) and Phule G-0914-6-17 (18.45 and 17.86 μmol of CO_2 m^{-2} s^{-1}) recorded highest net photosynthesis rate. While genotype Phule G-16115 (14.67 and 14.09 μmol of CO_2 m^{-2} s^{-1}), Phule G-1226-33-14 (15.13 and 14.97 μmol of CO_2 m^{-2} s^{-1}) and JG-16 (G11) (16.22 and 15.13 μmol of CO_2 m^{-2} s^{-1}) had lowest net photosynthesis rate at 20/15 ºC and 25/20 ºC, respectively. Rate of photosynthesis is an important physiological parameter which governs the photosynthate accumulation and dry matter production and consequently the yield. More the rate of photosynthesis led to maximum accumulation of photosynthates from source to sink and ultimately gives maximum yield. But in heat stress conition these mechanism destructed so directly affect on rate of rate of photosynthesis. The temperature, 25/20 ºC had less photosynthesis rate and highest at temperature 20/15 ºC. So temperature 20/15 ºC produce higher dry matter and also yield of grain. Genotype, Phule G-1012-15 and Phule G-0914-6-17 observed highest net photosynthesis rate. Similar finding also reported by Singh *et al*. (1987) [16] and Srinivasan *et al*. (1996) [17].

Genotype, Phule G-1012-15(3.79 and 4.44 mmol of H_2O m^{-2} s^{-1}) and Phule G-0914-6-17 (G7) (3.81 and 4.61 mmol of H_2O m^{-2} s^{-1}) recorded minimum rate of transpiration. While genotype JG-16 (G11) (6.35 and 6.95 mmol of H_2O m^{-2} s^{-1}), and Phule G-16115 (G8) (5.87 and 6.77 mmol of H_2O m^{-2} s^{-1}) had lowest rate transpiration at 20/15 ºC and 25/20 ºC, respectively. Transpiration is also a major trait to measure Water Use Efficiency of plants. Transpiration is a physical process neccesory for maintaining canopy temperature in which part of the net radiation energy is converted into latent heat and it was physiologically controlled by changes in stomatal aperture (Jarvis and McNaughton, 1986). Temperature, 25/20 ºC had highest rate of transpiration so having less water use efficiency nd lower dry matter production than temperature 20/15 ºC. Genotype, Phule G-1012-15 and Phule G-0914-6-17 observed lowest rate of transpiration as compared to other genotypes. similar results investigated Machado and Paulsen (2001) [11] and Pinto *et al*. (2010) [15].

Genotype, Phule G-1012-15 (1.09 and 0.80 mol H_2O m^{-2} s^{-1}) and Phule G-0914-6-17 (G7) (1.05 and 0.78 mol H_2O m^{-2} s^{-1}) recorded highest stomatal conductance. While genotype JG-16 (G11) (0.64 and 0.51 mol H_2O m^{-2} s^{-1}) and Phule G-16115 (G8) (0.65 and 0.54 mol H_2O m^{-2} s^{-1}) had lowest stomatal conductance at 20/15 ºC and 25/20 ºC, respectively. Stomatal conductance plays a key role in stomatal movement. The closure of stomata in water and heat stress is an early and one of the first responses of plants under field conditions (Jones, 1992). Stomatal responses were directly related to leaf water status (Ahmadi and Siosemardeh, 2005) [1]. Temperature, 25/20 ºC had lower stomatal conductance for utilizing large number of water for photosynthesis and maintain internal tissue water content than temperature 20/15 ºC. But in same condition Genotype, Phule G-1012-15 and Phule G-0914-6-17 observed higher stomatal conductance as compared to other genotypes. Also observed similar findings by Bodake *et al*. (2014) [6].

Genotype, Phule G-1012-15 (20.97 and 25.99 ºC) and Phule G-0914-6-17 (G7) (20.98 and 26.04 ºC) recorded minimum canopy temperature. While genotype JG-16 (22.17 and 27.24 ºC) and Phule G-16115 (22.16 and 27.25 ºC) had maximum canopy temperature at 20/15 ºC and 25/20 ºC, respectively. Canopy temperature and stomatal conductance are closely related. In heat stress stomata opens to lower and maintain canopy temperature which is rises above ambient temperature. In fact, heat tolerant genotypes Phule G-1012-15 and Phule

G-0914-6-17 had lower canopy temperature and higher water use efficiency than susceptible genotypes so produces higher dry matter. Similar result observed by McMaster *et al*. (2008) and Pinto *et al*. (2010) [15].

Genotype, Phule G-1012-15 (48.88 and 45.59%) and Phule G-0914-6-17 (47.83 and 45.17%) recorded highest SPAD Index (%). While genotype JG-16 (39.44 and 37.84%) and Phule G-16115 (39.48 and 38.02%) had lowest SPAD Index at 20/15 ºC and 25/20 ºC, respectively. Leaf chlorophyll content is a parameter denoting physiological status of a plant and SPAD index is a non-destructive measurement method used to determine leaf chlorophyll content. Chorophyll content is positively correlated with rate of photosynthesis. Heat tolerant genotypes Phule G-1012-15 and Phule G-0914-6-17 had highest SPAD index So having higher rate of photosynthesis and dry matter production than susceptible genotypes. Temperature, 25/20 ºC had lower SPAD index so having lower rate of photosynthesis (15.80 μmol of CO_2 m^{-2} s^{-1}) and dry matter production (16.52) than temperature 20/15 ºC (16.83 μmol of CO_2 m^{-2} s^{-1} and 19.76 g respectively). These findings are in agreements with outcomes of Kumar *et al*. (2011) [10] and Ahmed and Farooq (2013) [2]

Yield parameters

The data Pertaining effect of heat stress on number of pods per plant and yield per plant was found to be significant but interaction effect denotes non significant effect. The temperature, 25/20 ºC had less mean number of pods per plant (32.17) and also on yield per plant (6.71 g) while highest at temperature 20/15 ºC (36.86 and 7.69 g respectively). The data on yield plant^{-1} and number of pods plant^{-1} are presented in Table 3.

Genotype, Phule G-1012-15 (44.00 and 37.50) and Phule G-0914-6-17 (43.83 and 35.00) recorded highest number of pods per plant. While genotype JG-16 (25.33 and 19.50) and Phule G-16115 (25.67 and 24.50) had lowest number of pods per plant at 20/15 ºC and 25/20 ºC, respectively. Increase in temperature at the time of flowering stage decreases pod setting in almost all the field crops. It may be due to lower fertilization caused by pollen sterility or ovule abortion. Reproductive efficiency in terms of percentage of flowers converted to pods is highly sensitive to temperature in chickpea. Both low temperatures (below 10 °C) and high temperatures (above 30 °C) adversely affect the pod set in chickpea (Devasirvatham *et al*., 2012) [9] and sue to that yield is reduced. Heat tolerant genotypes Phule G-1012-15 and Phule G-0914-6-17 have maintain higher internal water content by adjusting stomatal conductance and lower canopy temperature and having higher ability to withstand adverse temperature by hearly heat accumulation so having higher rate of flower set and ultimately higher number of pods than susceptible genotypes. Temperature, 25/20 ºC had number of pods than temperature 20/15 ºC and are in confirmation with findings Brar *et al*. (2004) [7].

Genotype, Phule G-1012-15 (9.23 and 8.30 g) and Phule G-0914-6-17 (8.94 and 8.01 g) recorded highest number of pods per plant. While genotype JG-16 (5.36 and 4.57 g) and Phule G-16115 (6.30 and 4.97) had lowest number of pods per plant at 20/15 ºC and 25/20 ºC, respectively. Morpho-physiological and yield parameters like height, total dry matter production and number of pods reduce seed yield in chickpea. Further, they noticed positive correlation of seed yield with height, number of pods, biological yield and harvest index (Choudhary *et al*. 1989). Heat tolerant genotypes Phule G-1012-15 and Phule G-0914-6-17 had higher grain yield because having higher rate of photosynthesis and dry matter production than susceptible genotypes. Temperature, 25/20 ºC had lower yield because of having lower rate of photosynthesis (15.80 μmol of CO_2 m^{-2} s^{-1}) and dry matter production (16.52) than temperature 20/15 ºC (16.83 μmol of CO_2 m^{-2} s^{-1} and 19.76 g respectively). These investigation were in line with those obtained earlier by Babbar *et al.* (2012) and Puri *et al.* (2013).

Table 2: Total dry matter production (g), Net photosynthesis rate (μmol of CO_2 m^{-2} s^{-1}), Transpiration rate (mmol of H_2O m^{-2} s^{-1}) and Stomatal conductance (mol H_2O m^{-2} s^{-1}) as influenced by varying temperature regimes and their interactions.

		Total dry matter production (g)			Net photosynthesis rate (μmol of CO_2 m^{-2} s^{-1})			Transpiration rate (mmol of H_2O m^{-2} s^{-1})			Stomatal conductance (mol H_2O m^{-2} s^{-1})		
Sr. No.	**Genotype**	**20/15 ºC**	**25/20 ºC**	**Mean**	**20/15 ºC**	**25/20 ºC**	**Mean**	**20/15 ºC**	**25/20 ºC**	**Mean**	**20/15 ºC**	**25/20 ºC**	**Mean**
1	Phule G-1226-33-14	18.5	13.9	16.2	15.13	14.97	15.05	5.8	6.09	5.94	0.67	0.55	0.61
2	Phule G-1131-31-4	18.69	14.8	16.74	16.25	15.22	15.73	4.81	5.72	5.27	0.72	0.56	0.64
3	Phule G-171104	21.16	18.86	20.01	17.91	16.96	17.44	3.93	4.63	4.28	0.94	0.78	0.86
4	Phule G-15109	18.89	14.99	16.94	16.35	15.27	15.81	4.78	5.47	5.13	0.75	0.56	0.66
5	Phule G-1131-31-9	20.79	18.26	19.52	17.68	15.56	16.62	4.12	5.04	4.58	0.89	0.75	0.82
6	Phule G-1010-14	20.49	18.16	19.32	17.52	15.79	16.66	4.34	5.26	4.8	0.85	0.69	0.77
7	Phule G-0914-6-17	21.8	19.55	20.68	18.45	17.86	18.16	3.81	4.61	4.21	1.05	0.78	0.92
8	Phule G-16115	17.8	13.4	15.6	14.67	14.09	14.38	5.87	6.77	6.32	0.65	0.54	0.6
9	Phule G-1012-15	21.63	19.91	20.77	18.79	17.98	18.38	3.79	4.44	4.12	1.09	0.8	0.94
10	Phule G-1231-5-10	20.26	17.67	18.97	16.95	15.44	16.2	4.57	5.3	4.93	0.77	0.59	0.68
11	JG-16	17.38	12.91	15.15	16.22	15.13	15.68	6.35	6.95	6.65	0.64	0.51	0.57
12	Vijay (check)	20.48	17.73	19.1	16.8	15.39	16.1	4.43	5.3	4.86	0.81	0.69	0.75
13	Digvijay (check)	20.12	17	18.56	16.99	15.52	16.25	4.78	5.36	5.07	0.77	0.57	0.67
14	Phule Vikram (check)	18.59	14.11	16.35	16.7	15.31	16	5.42	5.98	5.7	0.71	0.56	0.63
	Mean	19.76	16.52	18.14	16.83	15.8	16.32	4.77	5.49	5.13	0.81	0.64	0.72
		SEm (±)	CD 5%		SEm (±)	CD 5%		SEm (±)	CD 5%		SEm (±)	CD 5%	
	Treatment (T)	0.13	0.39		0.23	0.66		0.08	0.23		0.01	0.02	
	Genotype (G)	0.18	0.52		0.3	0.88		0.1	0.31		0.01	0.03	
	Interaction (G×T)	0.51	NS		0.86	NS		0.3	NS		0.03	NS	

Table 3: Canopy temperature (^{0}C), SPAD index (%), Number of pods per plant and Yield per plant (g) as influenced by varying temperature regimes and their interaction

		Canopy temperature (^{0}C)			SPAD Index (%)			Number of Pods plant^{-1}			Yield plant^{-1} (g)		
Sr. No.	Genotype	20/15 ºC	25/20 ºC	Mean	20/15 ºC	25/20 ºC	Mean	20/15 ºC	25/20 ºC	Mean	20/15 ºC	25/20 ºC	Mean
1	Phule G-1226-33-14	21.71	26.87	24.29	41.85	38.16	40.01	27.83	22	24.92	6.39	5.38	5.88
2	Phule G-1131-31-4	21.59	26.81	24.2	44.87	41.18	43.03	36	30.33	33.17	6.85	6.94	6.89
3	Phule G-171104	20.99	26.1	23.54	46.85	44.6	45.73	43.67	37.83	40.75	8.77	7.83	8.3
4	Phule G-15109	21.57	26.68	24.13	45.22	41.23	43.22	36.33	30.5	33.42	7.28	6.36	6.82
5	Phule G-1131-31-9	21.05	26.21	23.63	46.69	44.53	45.61	43.5	34.83	39.17	8.74	7.83	8.29
6	Phule G-1010-14	21.25	26.31	23.78	46.17	43.6	44.89	41.17	37.83	39.5	8.55	7.44	7.99
7	Phule G-0914-6-17	20.98	26.04	23.51	47.83	45.17	46.5	43.83	35	39.42	8.94	8.01	8.48
8	Phule G-16115	22.16	27.25	24.71	39.48	38.02	38.75	25.67	24.5	25.08	6.3	4.97	5.64
9	Phule G-1012-15	20.97	25.99	23.48	48.88	45.59	47.24	44	37.5	40.75	9.23	8.3	8.76
10	Phule G-1231-5-10	21.4	26.78	24.09	45.36	42.53	43.94	37.5	37	37.25	8.26	7.37	7.82
11	JG-16	22.17	27.24	24.71	39.44	37.84	38.64	25.33	19.5	22.42	5.36	4.57	4.96
12	Vijay (check)	21.28	26.37	23.83	45.75	42.83	44.29	40.67	38	39.33	8.31	7.04	7.68
13	Digvijay (check)	21.56	26.66	24.11	45.26	42.42	43.84	36.67	34.5	35.58	7.77	6.05	6.91
14	Phule Vikram (check)	21.69	26.83	24.26	43.49	39.05	41.27	33.83	31	32.42	6.83	5.85	6.34
	Mean	21.46	26.58	24.02	44.79	41.91	43.35	36.86	32.17	34.51	7.69	6.71	7.2
		SEm (±)	CD 5%		SEm (±)	CD 5%		SEm (±)	CD 5%		SEm (±)	CD 5%	
	Treatment (T)	0.04	0.12		0.11	0.32		0.6	1.76		0.11	0.33	
	Genotype (G)	0.06	0.16		0.14	0.43		0.8	2.34		0.15	0.44	
	Interaction (G×T)	0.16	NS		0.42	1.21		2.28	NS		0.43	NS	

Conclusion

The chickpea genotypes showed a responses for Phenological, growth, physiological and yield parameters over varying temperature. Growth, physiological and yield parameters was reduced by by exposure to higher temperature. However, days required to flower initiation, 50% flowering and physiological maturity decreased when increase in temperature. On overall basis from reaserch, it can be concluded that optimum temperature is essential for chickpea production and in present study temperature 20/15 ºC is suitable for growth of chickpea. Since in future there is increase in temperature therefore, appropriate genotype plantto be sown according to changing temperature.

Acknowledgments

I acknowledge Dr.R.S. Wagh and Dr. D.V. Deshmukh for technical assistance in experiments and compilation of data. I also thankful to Department of Agriculrural Botany, mahatma Phule Krishi Vidyapeeth, Rahuri for supporting the research.

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