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Thermal requirements, heat use efficiency and plant responses of chickpea (*Cicer arietinum* L.) cultivars under different environment

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ABSTRACT

A field experiment was conducted to study the thermal requirement of chickpea cultivars during *rabi* seasons of 2012-13 and 2013-14 at Research Farm, College of Agriculture, Tikamgarh (Madhya Pradesh). The experiment was laid out in split-plot design with three replications consisted three sowing dates *viz*., October 25, November 14 and December 4 and three varieties *viz*., JG 322, JG 11 and JG 16 as main plot and sub-plot treatments, respectively. Results revealed that duration of phenological stages and thermal unit during sowing to maturity decreased with successive delay in sowing. October 25 sowing produced significantly higher total dry matter accumulation, more number of pods higher seed yield and biological yield as compared to November 14 and December 4. Among cultivars, JG 16 exhibited significantly higher total dry matter accumulation, HUE, more number of pods higher 100-seed weight higher seed yield and biological yield followed by JG 11 and JG 322.

Key words: Chickpea, cultivars, heat use efficiency, sowing dates, thermal unit, yield attributes.

Chickpea which is commonly known as gram and Bengal gram is grown in India during *rabi* season and it requires cool and dry weather for optimum growth and development. The crop is predominantly grown under rainfed condition and is raised mainly on conserved soil moisture. Optimum sowing time of chickpea may vary from one variety to another and also from one region to another due to variation of agro-ecological conditions. Different planting dates subject the vegetative and reproductive stages of the plant to various temperature, solar radiation and day length (Yadav *et al.*, 1999). Optimum sowing time and selection of improved cultivars play a remarkable role in exploiting the yield potential of the crop under particular agro-climatic conditions. Sowing date has been proved to be one of the most non-monetary inputs affecting the yield of chickpea. Sub-optimal thermal requirement during crop growing season are known to have profound effect on crop productivity. The concept of thermal use efficiency has been used by several workers to compare the performance of different varieties or of several dates in different crops (Rao, *et al.*, 1999, Aggarwal *et al.*, 1999, Mrudula, *et al.*, 2012). The optimum sowing time is important to exploit the environmental conditions during the growth of chickpea for maximum production. Delayed sowing causes early maturity resulted in drastic reduction in yield and can vary between 30% and 60% depending on genotype, sowing time, location, and climatic conditions during sowing season. The productivity of chickpea fluctuates as it responds differently due to their variation in the thermal requirements of given cultivars in a particular climatic conditions. Keeping above facts in view, the present investigation was under taken.

MATERIALS AND METHODS

The field experiment was conducted at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh (24° 43' N latitude, 78° 49' E longitude at an altitude of 358 m above mean sea level), Madhya Pradesh, India during two consecutive *rabi* seasons of 2012-13 and 2013-14. The experimental site is of sub-tropical climate characterized by hot dry summers and cool dry winter lies in the Bundelkhand Zone (Agro-climatic Zone-VIII). The soil of experimental field was medium to deep black and clayey loam in texture having pH 7.0, EC 0.12 dS m^{-1}, organic carbon 0.5%, available N 265.8 kg ha^{-1}, available P_2O_5 25.6 kg ha^{-1} and available K_2O 254.9 kg ha^{-1}, respectively. The average annual rainfall of this region is about 1000 mm, which is mostly received between June to September and a little rainfall (90 mm) is also obtained during October to May. The average temperature ranges between 4.5 °C to 45 °C. The weather parameters during experiment were recorded at the Meteorological Observatory located at Research Farm, College of Agriculture, Tikamgarh.

The experiment was conducted in split-plot design

Table 1: Days taken to attain different growth stages in chickpea and accumloted thermal unit as affected by various treatments (Pooled data over two years)

Treatments	Emergence	First flower flowering	50% formation	First pod	Maturity phase	Vegetative phase	Reproductive
Sowing dates							
Oct. 25	6 (118)	50 (775)	57 (863)	70 (992)	120 (1464)	50 (775)	70 (689)
Nov. 14	6 (93)	53 (697)	62 (769)	72 (855)	114 (1309)	53 (697)	61 (612)
Dec. 4	7 (91)	56 (599)	64 (704)	73 (774)	107 (1188)	56 (599)	51 (589)
S.Em±	0.24	0.53	0.60	0.38	0.58	0.53	0.84
CD at 5%	0.70	1.56	1.77	1.13	1.71	1.56	2.53
Cultivars							
JG 322	7 (105)	58 (740)	66 (845)	76 (911)	115 (1344)	58 (740)	57 (604)
JG 11	6 (97)	45 (604)	52 (664)	64 (805)	110 (1279)	45 (604)	65 (675)
JG 16	6 (100)	57 (726)	65 (827)	76 (905)	115 (1338)	57 (726)	58 (612)
S.Em±	0.21	0.52	0.61	0.61	0.55	0.52	0.69
CD at 5%	0.66	1.62	1.81	1.82	1.60	1.62	2.14

Figure in parenthesis are accumulated thermal units in °C

Table 2: Total dry matter accumulation (g m^{-2}) and heat use efficiency (kg ha^{-1} °C day) of chickpea as affected by various treatments (Pooled data over two years)

Treatments	Days after sowing					
	20	40	60	80	100	Harvest
Sowing dates						
Oct. 25	12.4 (0.357)	37.7 (0.605)	89.8 (0.997)	254.7 (2.405)	379.4 (3.047)	476.4 (2.959)
Nov. 14	11.5 (0.399)	33.6 (0.601)	76.8 (1.013)	212.9 (2.279)	312.3 (2.754)	397.1 (2.775)
Dec. 4	7.98 (0.304)	23.6 (0.486)	59.0 (0.886)	152.4 (1.774)	276.1 (2.231)	301.0 (2.432)
S.Em±	0.48 (0.017)	0.63 (0.011)	0.95 (0.015)	4.9 (0.051)	6.1 (0.051)	8.9 (0.061)
CD at 5%	1.34 (0.051)	1.89 (0.033)	2.82 (0.044)	13.9 (0.153)	18.4 (0.154)	26.6 (0.182)
Cultivars						
JG 322	9.72 (0.325)	29.5 (0.532)	70.6 (0.902)	193.1 (2.011)	298.5 (2.480)	346.3 (2.408)
JG 11	10.6 (0.346)	31.5 (0.557)	74.3 (0.955)	200.0 (2.084)	327.7 (2.723)	401.6 (2.790)
JG 16	11.7 (0.388)	34.0 (0.604)	80.7 (1.039)	226.9 (2.364)	341.7 (2.829)	426.5 (2.967)
S.Em±	0.67 (0.022)	0.78 (0.018)	1.29 (0.028)	2.52 (0.027)	5.3 (0.045)	7.1 (0.055)
CD at 5%	NS	2.34 (0.051)	3.88 (0.083)	7.53 (0.081)	15.7 (0.132)	21.6 (0.164)

Figure in parenthesis are heat use efficiency (kg ha^{-1} °C day)

Table 3: Chickpea yield and its attributes as affected by various treatments (Pooled data over two years)

Treatments	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Sowing dates					
Oct. 25	30.5	1.37	18.1	1715	5291
Nov. 14	24.7	1.23	17.6	1474	4737
Dec. 4	20.2	1.20	17.6	1264	4070
S.Em±	0.40.06	0.23	51	93	
CD at 5%	1.3NS	NS	159	284	
Cultivars					
JG 322	23.3	1.20	15.6	1377	4461
JG 11	24.5	1.27	19.8	1478	4606
JG 16	27.6	1.33	18.0	1597	5030
S.Em±	0.50.05	0.27	26	65	
CD at 5%	1.6NS	0.9	79	199	

with three replications and comprised of three sowing dates *viz.*, October 25 with temperature 24.4 °C, November 14 with temperature 19.9 °C and December 4 with temperature 16.8 °C as main plot treatments and three cultivars *viz.*, JG 322, JG 11 and JG 16 as sub-plot treatments. The chickpea crop was sown in lines 30 cm apart drawn by *kudali* using a seed rate of 80 kg ha^{-1}. The full recommended doses of nitrogen (20 kg N ha^{-1}), phosphorus (40 kg P_2O_5 ha^{-1}) and potassium (20 kg K_2O ha^{-1}) were applied as basal through urea, SSP and murate of potash, respectively just below the soil. All other agronomic and plant protection measures were applied as per recommendations. Total dry matter accumulation (g m^{-2}) was recorded at 20, 40, 60, 80, 100 DAS and at physiological maturity. Yield attributes were recorded from the five plants sample collected at the time of harvest. The crop harvested from net plot area was converted into seed yield (kg ha^{-1}) and biological yield (kg ha^{-1}). The cumulative thermal units (°C) at various phenological stages were determined by summing the daily mean temperatures above the base temperature (T_b= 5 °C) by using the formula as per Nuttonson (1955):

Heat use efficiency (HUE), which is a measure of amount of dry matter production per unit of thermal unit, was worked as per procedures reported by Sahu *et al.* (2007).

RESULTS AND DISCUSSION

Phenophases and thermal units

Duration and accumulated thermal unit of different phenophases during the entire growth period of chickpea decreased with each 20 days successive delay in sowing from October 25 to November 14 and December 4 (Table 1). The October 25 sown crop took longer duration for maturity (120 days) than the later sown crop in all the cultivars due to fulfillment of thermal unit requirements in more days and also due to due to increased vegetative and reproductive phase duration. The total accumulated thermal unit during the entire growth period of the crop decreased from 1464 °C under October 25 sowing to 1309 °C and 1188 °C under late sowings on November 14 and December 4, respectively. October 25 sown crop accumulated higher thermal units for all the growth stages followed by November 14 and December 4 sowings. Twenty-day successive delay in sowing from October 25 to November 14 and December 4 reduced the crop duration by 6 and 13 days, respectively and accumulated thermal units by 55 and 276 °C, respectively. These findings are in confirmation with Singh *et al.* (2012) and Pandey (2013). Among cultivars, JG 322 had higher thermal unit requirement due to comparatively longer duration of maturity followed by *cvs.* JG 16 and JG 11. The varietal differences of chickpea for phasic duration and thermal units was also reported by Pandey (2013).

Dry matter accumulation and heat use efficiency

Total dry matter accumulation (g m^{-2}) varied significantly due to different growing environments at all the phenophases (Table 2). October 25 sown crop produced significantly higher total dry matter at all phenophases followed by sowing on November 14 and December 4. Twenty-day successive delay in sowing from October 25 to November 14 and December 4 decreased the total dry matter accumulation by 16.6% and 36.8%, respectively at maturity. Total dry matter accumulation was also differed significantly among cultivars and JG 16 produced significantly higher total dry matter accumulation at all phenophases followed by JG 11 and JG 322.

The heat use efficiency (HUE) was recorded higher for November 14 sown crop and the lower for December 4 upto 60 days after sowing. However, 60 DAS onwards, October 25 sown crop exhibited higher values of HUE followed by sowing on November 14 and December 4 (Table 2). At maturity, HUE was recorded the maximum for October sown crop (2.959 kg ha^{-1} °C day) followed by November 14 (2.775 kg ha^{-1} °C day) and the minimum in December 4 (2.432 kg ha^{-1} °C day) sown crop. Irrespective of growing environments, the increase in HUE was the maximum after 60 days of sowing to maturity. Varietal difference was also found significant at all phenophases of crop growth except at emergence. Cultivar JG 16 recorded higher value of HUE at all phenophases followed by JG 11 and JG 322. Similar results in chickpea were also reported by Mrudala *et al.* (2012).

Yield attributes and yield

Yield attributes and yield were significantly influenced due to different crop growing environments (Table 3). The crop sown on October 25 produced significantly more number of pods (plant^{-1}), higher seed yield (kg ha^{-1}) and biological yield (kg ha^{-1}) as compared to November 14 and December 4 sown chickpea crops. However, sowing dates were failed to influence the more number of seeds (pod^{-1}) and 100-seeds weight. The maximum temperature during reproductive phase had negative correlation with number of pods and seed yield. The successive increased in temperature from 22.4 °C (October 25) to 24.3°C (November 14) and 28.3°C (December 4) during first pod to maturity decreased the seed yield by 14.1 and 26.3%, respectively and number of pods by 19.0 and 33.8%, respectively. These results corroborate the findings of Pandey (2013) in chickpea.

Among cultivars, JG 16 exhibited significantly more number of pods (plant^{-1}), higher 100-seed weight (g), higher seed yield (kg ha^{-1}) and biological yield (kg ha^{-1}) followed by JG 11 and JG 322. Cultivar JG-16 exhibited 8.10% and 16.0% higher seed yield over *cvs.* JG-11 and JG-322, respectively. Varieties were failed to influence the number of seeds (pod^{-1}) significntly. The varietial differences for yield attributes and yield in chickpea was also reported by Singh *et al.* (2012).

CONCLUSION

The present study concluded that sowing of chickpea on October 25 (24.4 °C) exhibited significantly higher growth and yield due to optimal thermal requirements for various plant processes. The thermal unit requirements of chickpea cultivars decreased with delay in sowing beyond October 25. The maximum temperature during reproductive phase had negative correlation with number of pods and seed yield.

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