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Correlation studies on effect of temperature regimes on traits associated with yield components in chickpea (*Cicer arietinum* L.) genotypes

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Abstract
High temperature is an important factor affecting chickpea growth, development and grain yield. Understanding the plant response to higher temperature is a key factor genotype selection for reproductive efficiency in chickpea. Under 48th SMW date of sowing (D_3) seed yield per plant recorded positive association with pod number per plant, pod weight per plant, total flower produced, total dry matter per plant, test weight and harvest index (0.854**, 0.993**, 0.404**, 0.780**, 0.414** and 0.617**, respectively). The degree of association for seed yield was higher in 48th SMW compared to 41st, 44th and pooled dates of sowing. The total flower production and pod number decreased from D1 to D3 and this decrease was attributed to flower abortion due to higher temperature coincided with flowering period. Harvest index recorded positive association with pod number per plant, pod weight per plant and total flower produced (0.610**, 0.616** and 0.462**, respectively) under 48th SMW. However, seed yield per plant was significantly and negatively associated with flower to pod ratio under 41st, 44th, 48th, SMW and pooled date of sowing. Further, total flower count recorded positive association with flower to pod ratio, harvest index and seed yield (0.354**, 0.462** and 0.404**, respectively). This suggested that number of flower produced is not only dependent on total dry matter but also on maximum and minimum temperature. The experiment revealed that dates of sowing place an important role in determining dry matter accumulation and flower production in chickpea.

Keywords: Pod number, harvest index, flower to pod ratio, total flower count and seed yield

Introduction

Chickpea is an important cool-season food legume, widely cultivated around the world, which experiences a range of high temperatures and is reported to be sensitive to heat stress particularly during day temperatures above 35^{0}C during the reproductive stage are particularly detrimental and hence yield potential suffers. A 1 ^{o}C increase in seasonal temperature would decrease chickpea yield by 53 kg ha^{-1} (Kalra *et al.*, 2008) [6]. Reproductive phase in chickpea is reported to be highly susceptible to heat stress (temperatures above 32/20 ^{o}C) as indicated by reduced flower production. Therefore, floral study is being considered as useful indicators for sensitivity of chickpea to temperature stress. The extent of damage to either male or female organs depends upon the stage of microsporogenesis or megasporogenesis (Wang *et al*., 2006) [6]. Heat stress post-anthesis in chickpea reduces seed number, seed weight and hence seed yield. Despite sever threat from increasing temperatures, considerable studies elucidating the high temperature effects on vegetative and reproductive phase using physiological assessment have been reported in chickpea. Exposure to heat stress (≥35 ^{0}C) at flowering and podding in chickpea is known to result in drastic reductions in seed yields. However, heat stress has received relatively more attention in chickpea breeding programs for heat tolerant during recent years. Crop with delayed sowing, experiences higher temperature that coincides with the reproductive phase mainly flowering and pod development stage. The floral parts being sensitive to heat stress leads to lack of pollination, abscission of flower buds, reduced flower production and pods with substantial yield loss. Hot (> 30 ^{o}C) and dry atmospheric conditions lead to profligate loss of flower buds and open flowers in chickpea (Krishnamurthy *et al*., 2011). High temperature after flower opening decreases chickpea seed yield by reducing the number of seeds per plant, dry matter accumulation and seed weight per seed.

Summerfield *et al*. (1984) [12] suggested that the longer the exposure during reproductive development to a high day temperature of 35 °C, the lower the yield. Most chickpea genotypes do not set pods when temperatures reach > 35 ºC (Basu*et al*. 2009). However, there is considerable variation among genotypes for response to high temperature. The period of anthesis and seed set are clearly critical stages for exposure to heat stress. The objective of this research is to investigate the variability for heat tolerance in diverse group of chickpea genotypes and traits that are likely associated with grain yield under varied temperature regimes.

Materials and methods

Chickpea genotypes (44) were evaluated for heat tolerance under three temperature regimes: (D_1: 41st, D_2: 44thand D^3: 48th SMW). The temperature regimes are denoted by the change in temperature prevailing for D_1, D_2 and D_3in field condition during *rabi*, 2015-16 at Main Agricultural Research Station (MARS), Dharwad as detailed bellow. The crop was raised with a spacing of 30 x 10 cm, fertilized with 50:20:0 $N:P_2O_5:K_2O$.At physiological maturity, the aerial parts of the plants were harvested from 2 m row length of each genotype, air dried at 38 ºC for 48 h and total shoot dry weight recorded. At harvest, five plantswere randomly collected and yield components per plant (podnumber, pod weight, total dry matter, flower to pod ratio, test weight and grain yield per plant) were recorded. The period between flower initiation and pod initiation, daily flower production was recorded and computed as total flower production. Harvest Index (%) was calculated by Donald (1962) [5].

Results and discussion

Genotypic correlation coefficient of seed yield per plant was studies with pod number per plant, pod weight per plant, total flower produced, flower to pod ratio, total dry matter per plant, test weight and harvest index are represented in table 1 and 2. Under 48th SMW date of sowing (D_3) seed yield per plant recorded positive association with pod number per plant, pod weight per plant, total flower produced, total dry matter per plant, test weight and harvest index (0.854**,0.993**,0.404**,0.780**,0.414** and 0.617**, respectively). Similar trend was observed under 44th SMW (0.775**, 0.983**, 0.453**, 0.830**, 0.355** and 0.632**, respectively) and pooled dates of sowing (0.789**, 0.840**, 0.446**, 0.336** and 0.479**, respectively). Under early sown condition 41st SMW date of sowing (D_1), seed yield per plant was positively associated with pod number per plant, pod weight per plant, total flower produced and total dry matter per plant, (0.760**, 0.824**, 0.344** and 0.783**, respectively).The degree of association for seed yield was higher in 48th SMW compared to 41st, 44th and pooled dates of sowing. Similar results were also reported by several earlier workers (Rathod and Chimmad, 2016; Manjunath and Chimmad, 2014 and Kiran *et al.*, 2016) [10, 11]. This indicated that under varied temperature regimes yield components and total dry matter at harvest plays as important role in maintain yield levels in chickpea.Further, seed yield per plant was significantly and negatively associated with flower to pod ratio under 41st, 45th, 49th SMW and pooled dates of sowing (-0.461**, -0.462**, -0.430** and -0.392**, respectively). The degree of association decreased as the dates sowing was delayed from 41st SMW dates of sowing (D_1) to 48th SMW dates of sowing (D_3) indicating that the flower production and pod number decreased from D_1 to D_3 and thereby flower to pod ratio decreased. The decrease in total flower production may be attributed to flower abortion due to higher temperature coinciding with the flowering period under delayed dates of sowing as also reported by several workers (Rathod *et al.*, 2016; Asha, 2016; and Devasirvastham *et al.*, 2012) [10, 11]. Under 48th SMW date of sowing (D_3), harvest index recorded positive association with pod number per plant, pod weight per plant and total flower produced (0.610**, 0.616** and 0.462**, respectively). Similar trend was noticed under 44th SMW (D_2) date of sowing (0.547**, 0.696** and 0.442**, respectively) but, the degree of association increased from 41st to 48th SMW. Suggesting that, under late sown condition crop yield was significantly influenced by harvest index as a result of decrease in total flower production thereby reduction in pod number due to higher temperature prevailing during flowering period, the total dry matter accumulation was also reduced. Even under pooled date of sowing, harvest index recorded positive association with pod number per plant, pod weight per plant and total flower produced (0.462**, 0.717** and 0.470**). The partitioning of assimilates was drastically reduced under late sown condition, hence there was reduction in pod number. Further, the dry matter accumulation was decreased under late sown condition there by harvest index was also decreased. The yield components *viz.*, pod weight per plant, pod number per plant, total flower count, total dry matter per plant and harvest index were significantly and positively correlated among themselves as also reported by (Mishra and Barbbar, 2014 and Devasirvastham *et al.*, 2015) [9]. Similar trend was followed even under delayed date of sowing (D_3), wherein pod number was positively associated with, pod weight per plant, total flower produced, total dry matter per plant and harvest index (0.850**, 0.476**, 0.632** and 0.610**) while negative association was recorded with flower to pod ratio. The total flower count recorded positive association with flower to pod ratio, harvest index and seed yield per plant under 44th SMW (0.354**, 0.462** and 0.404**, respectively). Similar observations were recorded under 44th SMW except flower to pod ratio and test weight, which were negatively associated with total flower production. The degree of association was higher under 44th SMW compared to other dates of sowing and pooled dates of sowing. The number of flower produced per plant not only dependent on the total dry matter produced but also the temperature (T_{max} and T_{min}) flowering period. Further, the temperature also played an important role in the total dry matter accumulation during vegetative phase particularly maximum temperature (Wery *et al.*, 1993 and Kulkarni and Chimmad, 2014) [14, 8]. It is inferred that, the varying temperature regimes (dates of sowing) played an important role in determining the total dry matter production accumulation and flower production ultimately influences the yield in chickpea.

Table 1: Correlation coefficient 'r' values on yield and yield attributes in chickpea genotypes under different temperature regimes.

	Pod number plant^{-1}	**Pod weight Plant^{-1} (g)**	**Total Flower count plant^{-1}**	**Flower to pod ratio**	**TDM plant^{-1} (g)**	**Test weight (g)**	**Harvest index (%)**	**Seed weight plant^{-1}**
41st SMW (D_1)								
Pod number plant^{-1}	1							
Pod weight plant^{-1}	0.750**	1						
Total Flower count	0.440**	0.592**	1					
Flower to pod ratio	-0.562**	-0.362*	0.043	1				
TDM plant $^{-1}$(g)	0.697**	0.634**	0.142	-.447**	1			
Test weight (g)	-0.008	0.177	-0.035	-0.024	0.438**	1		
Harvest index (%)	0.230	0.539**	0.450**	-0.269	-0.189	-0.248	1	
Seed weight plant^{-1}	0.760**	0.824**	0.344*	-0.461**	0.783**	0.260	0.186	1
44th SMW (D_2)								
Pod number plant^{-1}	1							
Pod weight plant^{-1}	0.783**	1						
Total Flower count	0.619**	0.459**	1					
Flower to pod ratio	-0.527**	-0.448**	-0.131	1				
TDM plant $^{-1}$(g)	0.652**	0.795**	0.321*	-0.373*	1			
Test weight (g)	-0.121	0.296	-0.060	-0.062	0.416**	1		
Harvest index (%)	0.547**	0.696**	0.442**	-0.446**	0.213	0.051	1	
Seed weight plant^{-1}	0.775**	0.983**	0.453**	-0.462**	0.830**	0.355*	0.632**	1
	**. Correlation is significant at the 0.01 level (2-tailed).							
	*. Correlation is significant at the 0.05 level (2-tailed). n=44							

Table 2: Correlation coefficient 'r' values on yield and yield attributes in chickpea genotypes under different temperature regimes

	Pod number Plant^{-1}	**Pod weight Plant^{-1} (g)**	**Total Flower count plant^{-1}**	**Flower to pod ratio**	**TDM plant^{-1} (g)**	**Test weight (g)**	**Harvest index (%)**	**Seed weight plant^{-1}**
48th SMW (D_3)								
Pod number plant^{-1}	1							
Pod weight plant^{-1}	0.850**	1						
Total Flower count	0.476**	0.383*	1					
Flower to pod ratio	-0.468**	-0.443**	0.354*	1				
TDM plant $^{-1}$(g)	0.632**	0.787**	0.163	-0.415**	1			
Test weight (g)	0.139	0.405**	0.005	-0.164	0.347*	1		
Harvest index (%)	0.610**	0.616**	0.462**	-0.313*	0.050	0.276	1	
Seed weight plant^{-1}	0.854**	0.993**	0.404**	-0.430**	0.780**	0.414**	0.617**	1
Pooled dates of sowing (D_1, D_2 and D_3)								
Pod number plant^{-1}	1							
Pod weight plant^{-1}	0.719**	1						
Total Flower count	0.539**	0.516**	1					
Flower to pod ratio	-0.483**	-0.281**	0.053	1				
TDM plant $^{-1}$(g)	0.658**	0.615**	0.258**	-0.325**	1			
Test weight (g)	0.002	0.241**	-0.016	-0.061	0.393**			
Harvest index (%)	0.462**	0.717**	0.470**	-0.232**	0.053	0.053	1	
Seed weight plant^{-1}	0.798**	0.840**	0.446**	-0.392**	0.798**	0.336**	0.479**	1
	**. Correlation is significant at the 0.01 level (2-tailed).							
	*. Correlation is significant at the 0.05 level (2-tailed). n=132							

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