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Identification and evaluation of Heat Tolerant Chickpea genotypes for Enhancing its Productivity in Rice Fallow area of Bihar and Mitigating Impacts of Climate Change

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Abstract
Chickpea (*Cicer arietinum* L.) is a cool-season food legume and suffers heavy yield losses when exposed to heat stress at the reproductive (flowering and podding) stage. Heat stress is increasingly becoming a severe constraint to chickpea production due to the changing scenario of chickpea cultivation and expected overall increase in global temperatures due to climate change. A temperature of 35 °C was found to be critical in differentiating heat-tolerant genotypes in chickpea under field conditions. An experiment was conducted during Rabi 2016-17 at Pulses Research farm, Bihar Agricultural University, Sabour (Bhagalpur) to study the genetic variability, correlation and path analysis for seed yield and its component characters in thirty six Desi chickpea genotypes. The sowing was carried out on15th December 2016 (late sown) at Pulse Research farm, Bhitti, Bihar Agricultural University Sabour. In field condition, in case of late sowing, chickpea plants met to high of these genotypes environment temperature (≥ 35 °C) during its reproductive stage which creates an unfavorable heat stress condition and affects its seed yield. The analysis of variance revealed the significant differences among the genotypes for all the traits indicating presence of sufficient variability among the genotypes for various traits. The high GCV and PCV were observed for grain yield per plot followed by biological yield, effective pods per plant, total number of pods per plant, 100-seed weight and primary branches per plant. High heritability coupled with high genetic advance over mean was observed for plant height, number of primary branches per plant, number of secondary branches per plant, total number of pods per plant, effective pods per plant, biological yield, 100 seed weight, grain yield per plant and grain yield per plot which suggested that these characters can be considered as favourable attributes for the improvement through selection and this may be due to presence of additive genes effect and thus, could be improved upon by adapting selection without progeny testing.. Seed yield per plant was positively and significantly correlated chlorophyll index, number of primary branches per plant, total number of pods per plant, effective pods per plant, biological yield, harvest index and 100- seed weight indicating that these three traits were main yield attributing traits. The path analysis revealed that the chlorophyll index, effective pods per plant and 100 -seed weight had maximum direct effect on seed yield. On the basis of seed yield, IPC2010-62, BRC-2, Sabour chana-1 and GNG2215 were identified as promising heat tolerant genotypes. Therefore, these genotypes in future may prove better for developing heat tolerant genotypes for rice fallow area of Bihar and can be used in hybridization programme of chickpea.

Keywords: Chickpea, Genetic variability, Correlation, Heat Tolerance, Path Coefficient

Introduction
Chickpea (*Cicer arietinum* L.) is the largest produced food legume in South Asia and the third largest produced food legume globally, after common bean (*Phaseolus vulgaris* L.) and field pea (*Pisum sativum* L.). Chickpea is grown in more than 50 countries (89.7% area in Asia, 4.3% in Africa, 2.6% in Oceania, 2.9% in Americas and 0.4% in Europe).Chickpea (Cicer arietinum L.) is the third most important pulse crop globally, with a production of 7.33 m t from an area of 8.25 m ha (Project Coordinator's Report 2015-16). It is even more important for India as the country's production accounts for 67% of the global chickpea production and chickpea constitutes about 40% of India's total pulse production. In spite of India being the largest chickpea producing country, a deficit exists in domestic production and demand which is met through imports (Kumar *et al*., 2017). In India, the total area under chickpea is 8.25 M ha with 7.33 million tonnes production with productivity 889 kg/ha and the total area in Bihar reached 60.0 thousand ha with 57.50 thousand tonnes of production with productivity of 958 kg/ha (2014-15: Agricultural Statistics Division, Directorate of Economics & Statistics, Dept. of Agriculture & Cooperation). 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. Predicted climate change, particularly high temperature will reduce grain yield in chickpea. For example, the yield of chickpea declined by up to 301 kg/ha per 1˚C increase in mean seasonal temperature in India (Karla *et al*. 2008). Chickpea have been exposed to high temperature stress in the growing season, mainly in reproductive phase. Chickpea production mostly occurs in residual soil moisture under rainfed conditions, where terminal drought and heat stresses are major limitations to chickpea grain yield. The chickpea grain yield is related to its phenology which is influenced by temperature. 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 (>30 ºC) by reducing the crop duration. The different developmental stages of chickpea are affected by high temperature. Finally, the grain yield is reduced. High temperature also affects physiological traits such as canopy temperature in chickpea plants. Canopy temperature reflects the interactions between plants, soil and atmosphere and canopy temperature depression (CTD) can be used to predict the performance of genotypes under heat stressed environments. This will help to identify the sources of heat tolerance in chickpea. The factors that affect crop yield in chickpea during the reproductive development are flower abortion due to pollen sterility, lack of pollination, stigma receptivity and pod abortion. Failure of any of these functions can decrease pod formation, number of seeds and grain yield. Although the male and female parts are sensitive to high temperature, pollen can be used as a trait to estimate the genetic variability to high temperature during the reproductive phase. Therefore it is essential to study the effect of high temperature during reproductive phase. So, there is an urgent need to search the gene bank for diverse sources of heat tolerance. Heat tolerance is greatly needed in chickpea cultivars for realizing higher yields in all growing conditions that expose chickpea to high temperature, particularly at the reproductive stage. So, heat tolerant varieties are needed for improving chickpea yields in late sown conditions. The genetic variability presents in the base population for desired characters play an important role in development of desirable plant type. Less information is present in the cultivated chickpea lines grown under heat stress conditions. Therefore, the identification of heat tolerant genotypes is essential for development of high yielding chickpea variety under heat stress condition, considering this, the present investigation was carried out to assess the genetic variability, association of different traits towards yield and selection of high yielding genotypes with better architecture under heat stress conditions.

Material and Methods

The experimental material consisted of thirty six chickpea genotypes were sown on 15th November, 2016 for normal sown condition and 15th December 2016 to coincide heat stress with pollination time and grain filling period at Pulses Research farm, Bhitti, Bihar Agricultural University, Sabour (Bhagalpur). Atmospheric temperature varied from 3.8°C minimum in January to 45.0°C maximum in May. The experiment was laid out in a randomized complete block design with three replications during Rabi 2016-17 under All India Coordinated Research Project on Chickpea. The plot size was 4.8 m^2, with 1 row of 4 m length. Inter row spacing distance was kept 30 cm and plant to plant spacing was 30 x 10 cm. The recommended packages of practices were followed to raise a healthy crop. Data were recorded on fifteen quantitative traits viz. days to 50% flowering, days to maturity, chlorophyll index, canopy temperature at vegetative stage, canopy temperature at reproductive stage, primary branches per plant, secondary branches per plant, plant height (cm), total number of pods per plant, effective pods per plant, 100 seed weight (g), grain yield per plant (g), biological yield per plant, harvest index and grain yield per plot (g).The days to 50% flowering, days to maturity, and grain yield per plot were recorded on a plot basis and plant height and number of pods per plant and 100-seed weight were recorded from a random sample of five plants in each plot. Data were subjected to statistical analysis to work out genotypic (GCV) and phenotypic (PCV) coefficients of variation, heritability and genetic advance as per cent of mean as per standard methods. Standard statistical procedure were used for the analysis of variance, genotypic and phenotypic coefficients of variation (Burton, 1952), heritability (Hanson *et al*., 1956) and genetic advance (Johnson *et al.*, 1955). The genotypic and phenotypic correlation coefficients were computed using genotypic and phenotypic variances and co-variances (Al Jibouri *et al*., 1958). The path coefficient analysis was done according to the method by Dewey and Lu (1959).

Results and Discussion

The results related to yield attributes of chickpea genotypes under heat stress at flowering and podding stage have been presented in Table 1. Chickpea genotypes grown under heat stress condition produced significantly lower grain yields than normal sown condition. Yield decline was observed almost in all the chickpea genotypes grown under heat stress condition. The range of yield decline per plant was observed between -50.21 to 71.06 percent under heat stress condition in comparison with normal sown condition. Genotype mean yields ranged from 3.9 g to 27.79 gram/plant under normal condition and from 3.97 g to 24.99 gram/ plant under heat stress condition. For grain yield per plot, range of yield decline was -30.37 to 73.73 percent under heat stress condition in comparison with normal sown condition. Genotype mean yields ranged from 1096.0 kg to 2988.7 kg per ha under normal condition and from 607.67 kg to 2033.8 kg per ha under heat stress condition. Out of 36 chickpea genotypes evaluated, three were identified as promising genotypes viz., IPC2010-62, BRC-2, SABOUR CHANA-1 and GNG2215 which performed better than check and existing high yielding varieties (BG372 and PG186) of north east plain zone. The high differences in grain yield between heat stress and non-stress treatment was 73.73% in GL29098, 66.96% in GNG2264 and 64.81% in JG74315-14 whereas it was 49.82% in PG186 and 1.58% in BG372. Under non-stress condition, maximum grain yield was observed in GNG2299 (29988.7 kg/ha) followed by GNG2264 (2783.2 kg/ha) and IPC2010-62 (2636.90 kg/ha). Canopy temperature at vegetative stage ranged from 19.19 (NDG14-24) to 24.84(PG 186) in normal sown condition and 25.74 (DCP 92-3) to 30.56 (GNG 2207) in late sown condition with general mean 21.912 °C and 27.65 ˚C respectively. Among the checks, GCP 105(20.64) in normal sown condition and PG 186 (28.26) in late sown condition showed high canopy temperatures. All the thirty six genotypes in both the conditions were found statistically at par with check. Canopy temperature at pod filling stage ranged from 28.86(PG 186) to 37.97(GL 29098) in normal sown condition and 39.48(NBeG 507) to 44.78(GNG 2304) in late sown condition with general mean 34.338˚C and 42.36˚C respectively. Among the checks, KWR 108 (35.40) in normal sown condition and PG 186 (43.16) in late sown condition showed high canopy temperatures. NBeG 507 under late sown condition showed significantly low canopy temperature than the check. Rest all were at par. However under normal condition, 16 genotypes GNG 2299, H12-62, PBC 501, BG 3043, DCP 92-3, PG 170, GNG 2264, JG 16, ICCV 15112,GL 29098,BRC 4, BRC 3,KPG 59,NDG 14- 24, BG 3068 and GNG 2304 showed significantly high canopy temperatures at pod filling stage. Remaining 20 genotypes were at par with the check. Under heat stress condition, genotypes had low pollen viability percentage, pod filling percentage than normal sown chickpea. Heat tolerant genotypes *viz.*, IPC2010-62, BRC-2, SABOUR CHANA-1 and GNG2215 had high chlorophyll index, low canopy temperature at vegetative stage and pollen formation stage. Kumar *et al.*, (2012) and Krishnamurthy *et al*., (2011) also reported similar results in chickpea.

The analysis of variance revealed significant differences among genotypes (Table-2) for all the characters studied which provides an opportunity for selecting suitable genotypes with better performance for the traits. The estimates of phenotypic coefficient of variation (PCV) were higher than the estimates of genotypic coefficient of variation (GCV) for all the characters, which suggested that the apparent variation is not only due to the genotypes but also due to the influence of environment (Table-3). The higher magnitude of genotypic coefficient of variation and phenotypic coefficient of variation were recorded for grain yield per plant followed by effective pods per plant, biological yield, total number of pods per plant, 100-seed weight and grain yield per plant, indicative of less amenability of these traits to environmental fluctuations and hence, greater emphasis should be given to these characters, while breeding cultivars from the present material. while, moderate to low estimates for other characters suggested the presence of sufficient variability in genotypes which broaden the scope for genetic improvement through selection of these characters. Lower magnitude of difference between PCV and GCV revealed that particular trait was less affected by environment in expression of these attributes. number of primary branches per plant, total pods per plant, effective pods per plant, biological yield, 100-seed weight and grain yield per plant in both the conditions. This is an indicative of less amenability of these traits to environmental fluctuations and hence, greater emphasis should be given to these characters, while breeding cultivars from the present material. High GCV for number of effective pods per plant and 100-seed weight were also earlier reported by Jeena *et al.* (2005), Younis *et al*. (2008), Alwani *et al.* (2010) and Babbar *et al*.(2012). Similar results were reported by Shreelakhsmi *et al*., (2010) and Kumar *et al.*, (2017) for characters showing high genotypic coefficient of variation coupled with high heritability and genetic advance as percentage of mean were taken as selection criteria in breeding programme. The estimates of heritability in broad sense were observed high for 100-seed weight, grain yield per plant, number of effective pods per plant, biological yield, total number of pods per plant, primary branches per plant, plant height, secondary branches per plant and grain yield per plot, which suggested that these characters are least influenced by the environmental factors and also indicates the dependency of phenotypic expression which reflects the genotypic ability of cultivars to transmit the genes to their offsprings. Similar results were also reported by Bicer and Sarkar (2008) and Younis *et al*. (2008). High genetic advance were recorded for total number of pods per plant, number of effective pods per plant, and grain yield per plot while, traits like plant height, 100 seed weight and biological yield showed moderate genetic advance whereas, remaining traits showed low genetic advance (<10) in their environment. Genetic advance as percent of mean was ranged from 1.52 to 105.42 and high genetic advance as percent of mean was observed for grain yield per plant, number of effective pods per plant, biological yield, total number of pods per plant, 100-seed weight, primary branches per plant, grain yield per plot, plant height and secondary branches per plant.

High estimates of heritability does not always mean high genetic advance. Johnson *et al*. (1955) suggested that heritability estimates and the genetic advance as percent of mean together would provide a better judgement rather than heritability alone in predicting the resultant effect of selection. High heritability coupled with high genetic advance over mean was observed for grain yield per plant, 100-seed weight, biological yield, number of effective pods per plant, total number of pods per plant, grain yield per plant, plant height and primary branches per plant which suggested that these characters can be considered as favourable attributes for the improvement through selection and this may be due to additive gene action and thus, could be improved upon by adapting selection without progeny testing. Similar results have also been reported by Yadav *et al.* (2003). Effectiveness of any selection programme depends upon the existence of genetic variability within the population. The variability at phenotypic level arises due to genotypic and environmental influences, which contribute towards the development of phenotype. Therefore, caution has to be exercised during the selection program because the environmental variations are unpredictable in nature and may mislead the results. The results on the extent of phenotypic variability showed the presence of great amount of variation for grain yield per plant, total pods per plant, effective pods per plant, biological yield, 100 seed weight, grain yield per plot and number of primary branches per plant,. This large amount of phenotypic variability is expected in chickpea genotypes as different genotypes were developed at different research institute by hybridizing different parents. The presence of large amount of variability indicates that there is ample scope of improvement for these characters through selection.

The study of inter-relationship among various characters in the form of correlation is, in fact, one of very important aspects in selection programme for the breeder to make an effective selection based on the correlated and uncorrelated response. Knowledge of nature and magnitude of associations among different characters are important on three counts. Indirect selection is important when desirable characters have low heritability measure in one sex only. The efficiency of indirect selection is measured as a correlated response (Falconer, 1960). Knowledge of correlation is required when selection is to be made on several characters at a time through some simultaneous selection model. Even if, the objective is to make selection on a single trait, the knowledge of correlation is essential to avoid the undesirable correlated changes in other characters. In general, magnitude of genotypic correlation was higher than their corresponding phenotypic correlation coefficients in most of the characters suggesting that a strong inherent association exists for the traits studied and phenotypic selection may be rewarding.

Similar results were also reported by Kumar *et al*. (2017). Higher magnitude of genotypic correlation helps in selection for genetically controlled characters and give a better response for seed yield improvement than that would be expected on the basis of` phenotypic association alone (Robinson *et al*., 1951).

Grain yield per plant showed positive and significant association with chlorophyll index, number of primary branches per plant, total number of pods per plant, effective pods per plant, biological yield per plant, harvest index and 100-seed weight (Table-4). Therefore, it is suggested that these traits should be used as selection criteria for yield improvement in chickpea for development of high yielding chickpea genotypes for rice fallow condition (Table 3). Similar findings were reported by Telebi et al. (2007), Hahid *et al*. (2010), Ali *et al*. (2011) and Kumar *et al*. (2017).

Path coefficient analysis revealed that chlorophyll index, effective number of pods per plant and 100-seed weight had high positive direct effects on grain yield per plant (Table-5). It was observed that effective pods per plant had high positive direct effect on grain yield per plant, indicating true relationship of these characters with grain yield and direct selection for these characters will be rewarding. In rest of the characters correlation was mainly due to indirect effects through component characters and hence indirect selection will lead to yield improvement in chickpea. The potential for indirect selection for heat stress tolerance using these associated characters may be useful to the breeder to formulate appropriate breeding plans for the selection of the genotype which tolerate high temperature condition. These results are agreement with the earlier reports of Priti *et al*. (2003). It means a slight increase in any one of the above traits may directly contribute towards seed yield. Days to 50% flowering had positive direct effect on grain yield per plant however an indirect positive effect via days to maturity, canopy temperature at vegetative stage, plant height, number of primary branches harvest index and 100-seed weight and an indirect negative effect via chlorophyll index, canopy temperature at pod filling stage, number of secondary branches, total pods per plant, effective pods per plant and biological yield. Positive direct effect of number of pods plant and indirect positive effect via 100-seed weight and plant height were the main reason for strong positive correlation of this character with seed yield. Similar results were reported by Talebi *et al*. (2007) and Babbar *et al.* (2012).

Conclusion

Grain yield per plant had positive and significant association with chlorophyll index, number of primary branches per plant, total number of pods per plant, effective pods per plant, biological yield per plant, harvest index and 100-seed weight, it is suggested that these traits should be used as selection criteria for yield improvement in chickpea for development of high yielding chickpea genotypes for rice fallow condition. The above findings revealed that under heat stress high chlorophyll index, effective number of pods per plant and 100-seed had showed the maximum contribution towards seed yield. On the basis of seed yield and its attributing traits., IPC2010-62, BRC-2, SABOUR CHANA-1 and GNG2215 were identified as promising heat tolerant genotypes. Therefore, it is concluded that these genotypes in future may prove better for developing heat tolerant genotypes for rice fallow in Bihar and can be used in hybridization programme of chickpea.

Table 1: Yield and yield attributes response of chickpea genotypes and check varieties to heat stress

Genotypes	Dayfs to 50% Flowering		Days to maturity		CHL. INDEX		Canopy temperature at vegetative stage		Canopy temperature at pollen formation stage		Grain yield per plant (g)		% Reduction in yield	Grain Yield/plot (kg/ha)		% Reduction in yield
	N	S	N	S	N	S	N	S	N	S	N	S		N	S	
GL 29098	81.49	75.1	136.29	116.86	62.82	56.43	21.46	27.86	38	40.67	17.87	6.01	66.368	2312.8	607.67	73.73
JG 24	81.97	68.7	137.06	116.04	63.12	55.02	21.28	29.63	34	40.34	11.91	5.33	55.248	1945.2	1003.1	48.43
JG 74315-14	79.98	66.3	130.72	114.03	64.38	58.63	21.54	29.11	29.3	43.42	17.92	6.71	62.556	2091.5	736.06	64.81
BRC-4	80.48	62.9	129.12	115.31	60.67	59.56	24.74	27.42	35.9	41.98	15.19	8.73	42.528	2441.4	1200.8	50.81
BRC-3	74.98	65.7	135.59	115.79	66.9	60.45	22.74	28.38	35.3	40.75	15.31	7.49	51.078	2265.1	1129.5	50.14
KPG-59	77.98	70	133.29	114.5	61.03	56.67	21.1	28.23	37.4	41.67	5.34	5.13	3.933	2182	1313.6	39.80
NDG14-24	67.	60.3	133.29	112.4	61.55	62.57	19.19	30.41	36.3	43.37	9.27	6.71	27.616	1461.9	1282.7	12.26
PG 186(NC)	79.01	68.4	134.06	115.58	65.1	58.43	24.84	28.26	28.9	43.16	5.29	4.81	9.074	2278.5	1143.4	49.82
IPC 2012-98	75.52	65.5	128.22	112.06	62.22	55.85	21.64	26.52	34.8	43.42	14.07	5.72	59.346	2332.1	1657.9	28.91
NBeG 507	76.02	70.6	130.12	114.35	66.73	60.93	21.22	27.05	33.3	39.48	19.36	14.66	24.277	1817.6	999.89	44.99
BG 3067	77.02	66.4	129.59	114.33	64.76	60.76	21.79	27.73	32.5	42.5	15.62	6.33	59.475	2096.5	1049.1	49.96
IPC 2012-49	87.02	78.2	138.29	115.54	58.98	57.83	21.88	29.1	34.6	41.66	12.48	11.65	6.651	1845.8	804.4	56.42
PhuleG-13110	76.03	67.4	137.73	113.85	62.7	62.52	23.2	26.6	34.4	43.26	75.8	24.99	67.032	1772.7	1172.3	33.87
CSJ 887	78.01	66.5	137.5	113.03	58.35	58.68	22.3	26.5	32.4	43.93	3.90	3.97	-1.795	1220.8	1316.3	-7.82
BG 3068	81.49	67.5	136.29	114.01	62.82	56.15	21.46	26.61	38	43.31	6.99	10.5	-50.215	1096	1428.8	-30.37
H12-55	81.97	66.6	137.06	113.3	63.12	61.21	21.28	28.81	34	42.8	50.94	20.23	60.287	1652.5	1334.3	19.26
BG372(NC)	79.98	71.5	130.72	112.78	64.38	59.13	21.54	27.17	29.3	42.36	3.94	5.79	-46.954	1373.1	1351.5	1.58
GNG 2304	80.48	66.3	129.12	111.99	60.67	57.47	24.74	26.87	35.9	44.78	6.34	4.98	21.451	1699.4	741.97	56.34
GNG 2299	76.51	65.7	129	111.71	60.9	60.17	21.88	27.1	35.2	43.29	14.8	5.31	64.122	2988.7	1087.2	63.62
H12-62	77.99	65.8	129.77	111.39	62.66	55.87	21.85	27.52	34.9	41.89	23.69	6.89	70.916	2434.7	899.95	63.04
GL 12003	82	71.8	133.43	111.87	63.86	55.98	21.6	26.13	34.2	41.72	15.24	4.88	67.979	2370.6	1119.7	52.77
PBC 501	78.5	64.9	128.33	112.16	68.12	63.57	20.78	27.24	35.3	43.43	20.43	10.25	49.829	2417.5	1368.9	43.38
GNG 469	78.99	67.3	132.8	113.14	66.2	58.81	21.93	28.12	34.3	42.55	27.68	9.05	67.305	2457.7	1256.9	48.86
BG 3043	75	63.6	130.5	111.85	65.96	61.82	21.25	26.35	35.2	44.09	22.56	19.01	15.736	2385.1	1220.3	48.84
DCP 92-3	80.5	66.9	137.87	114.57	59.08	57.04	21.14	25.74	34.7	40.87	22.99	8.32	63.810	2412.4	1308.2	45.77
GCP 105(NC)	80.98	64.5	133.14	114.75	66.36	62.16	20.64	26.11	30.7	43.41	14.66	7.96	45.703	1613.9	1267.9	21.44
IPC 2010-62	77.99	67.1	130.8	112.73	64.42	56.95	21.76	25.04	34.4	40.32	19.28	8.72	54.772	2636.9	2033.8	22.87
BRC-2	80.49	67.2	133.7	114.02	62.2	58.4	21.64	25.22	34.5	40.28	19.52	7.80	60.041	2569.3	1625.4	36.74
SABOUR CHANA-1	80.99	69.5	138.17	116.5	65.48	62.01	21.06	24.21	33.8	39.75	26.57	10.83	59.240	2446.2	1343.6	45.07
GNG 2215	81.49	69.4	136.87	117.21	62.88	57.6	22.03	25.38	33.3	40.07	27.79	8.04	71.069	2327.7	1526.7	34.41
GNG 2207	80.51	68.5	137.48	115.25	63.48	55.49	23.54	30.56	34.5	41.75	15.33	8.84	42.335	1759.7	900.53	48.83
PG 170	78.99	64.6	138.75	115.93	61.23	55.95	23.11	27.28	34.8	41.45	8.37	6.57	21.505	2362.9	1269.5	46.27
KWR 108(NC)	84.99	73.7	133.41	113.41	60.99	55.93	19.61	27.47	35.4	41.88	13.79	9.18	33.430	2578.8	1240.7	51.89
GNG 2264	75.49	66.8	132.81	115.2	56.68	61.27	20.59	29.55	35	41.42	12.45	5.17	58.474	2783.2	919.6	66.96
JG 16	76.99	66.6	134.28	115.68	58.21	57.03	20.96	26.98	35.4	42.23	18.51	6.35	65.694	2912.9	1254.6	56.93
ICCV 15112	73.49	64.5	138.48	116.39	64.63	65.03	23.98	30.25	35.8	41.85	18.53	13.14	29.088	1442.6	683.7	52.61
G.M.	78.68	67.6	133.9	114.15	62.44	58.87	21.91	27.65	34.3	42.36	18.15	8.68		2132.9	1177.8	
CV (%)	3.929	3.74	1.205	0.729	4.84	4.043	4.533	4.335	5.41	2.115	9.96	11.94		10.943	11.242	
S.E. (m)	3.091	2.53	1.613	0.833	3.022	2.38	0.993	1.199	1.86	0.896	1.807	1.036		1.807	132.4	
CD (5%)	6.367	5.21	3.322	1.715	6.224	4.9	2.046	2.469	3.83	1.845	3.722	2.134		3.722	272.69	
CD (1%)	8.617	7.05	4.496	2.321	8.423	6.634	2.769	3.341	5.18	2.497	5.038	2.889		5.038	369.07	

Table 2: Analysis of variance for fifteen quantitative characters in thirty six genotypes under normal and heat stress conditions

S. No.	Characters	Mean Sum of Squares					
		Replication (d.f.=1)		Treatment (d.f.=35)		Error (d.f.=35)	
		N	L	N	L	N	L
1	Days to 50% flowering	0.014	0.681	23.38**	23.80**	9.56	6.45
2	Days to maturity	9.389	6.125	19.34**	4.48**	4.65	1.56
3	Chlorophyll index	9.329	0.025	19.34*	15.10*	9.14	8.04
4	CT @ VS	2.029	0.016	3.22*	2.93*	1.720	1.67
5	CT@ PFS	4.093	2.286	6.82*	2.42*	3.48	1.16
6	Plant height (cm)	0.250	0.356	211.58**	86.72**	16.22	8.12
7	Primary branches plant^{-1}	0.142	0.002	0.27**	0.33**	0.034	0.03
8	Secondary branches plant^{-1}	0.020	0.405	1.56**	1.47**	0.34	0.35
9	Total number of pods plant^{-1}	4.799	3.911	2011.73**	403.35**	101.17	25.5
10	Effective pods plant^{-1}	2.534	1.237	2015.82**	340.52**	79.48	13.83
11	Biological yield plant^{-1} (g)	0.086	11.211	5508.29**	174.99**	179.74	8.05
12	Harvest index (%)	0.091	21.275	44.66**	97.59**	15.86	36.41
13	Seed index (g)	2.170	0.586	110.37**	86.46**	1.21	0.74
14	Grain yield plant^{-1} (g)	0.0361	3.849	342.21**	42.60**	8.31	1.08
15	Grain yield (kg/ha)	86863.12	3096.47	410704.19**	146866.58**	54481.85	35022.62

N= Normal sown condition; L=Late sown condition; CT@VS= Canopy temperature at vegetative stage; CT@PFS= Canopy temperature at pod filling stage; d.f.= degree of freedom; N= Normal , L =Late sown
* and ** = Significant at 5% and 1% probability level, respectively

Table 2: Estimates of genetic parameters of different quantitative traits of chickpea genotypes under heat stress condition for fifteen characters in chickpea under heat stress condition

Parameters	Days to 50% Flowering	Days to Maturity	Chlorophyll Index	Canopy Temperature @vs	Canopy Temperature @pfs	Plant Height (cm)	Primary Branches/ Plant	Secondary Branches/ Plant	Total no. of Pods/ Plant	Effective no. of Pods/ Plant	Biological Yield (g)	harvest Index (%)	100 Seed Weight (g)	Grain Yield/ Plant (g)	Grain Yield/ Plot (kg/ha)
Var Environmental (σ2e)	6.45	1.56	8.04	1.67	1.16	8.12	0.03	0.35	25.60	13.83	8.05	36.41	0.74	1.08	35023.01
ECV	3.76	1.09	4.82	4.67	2.54	5.98	9.19	12.10	16.37	14.26	15.18	14.53	3.95	11.95	15.89
Var Genotypical (σ2g)	8.68	1.46	3.53	0.63	0.63	39.30	0.15	0.56	188.88	163.35	83.47	30.59	42.86	20.76	55921.78
GCV	4.36	1.06	3.19	2.88	1.88	13.15	22.28	15.27	44.48	49.02	48.88	13.32	30.15	52.49	20.08
Var Phenotypical (σ2p)	15.13	3.02	11.57	2.30	1.79	47.42	0.18	0.91	214.48	177.17	91.52	67.00	43.60	21.84	90944.79
PCV	5.76	1.52	5.78	5.49	3.16	14.45	24.10	19.48	47.39	51.05	51.18	19.71	30.41	53.83	25.60
h^2 (Broad Sense)	0.57	0.48	0.30	0.28	0.35	0.83	0.85	0.61	0.88	0.92	0.91	0.46	0.98	0.95	0.61
Genetic Advancement 5%	4.60	1.73	2.14	0.86	0.97	11.76	0.75	1.21	26.57	25.28	17.97	7.70	13.37	9.15	382.00
Genetic Advancement 1%	5.89	2.22	2.74	1.10	1.25	15.07	0.96	1.55	34.05	32.40	23.03	9.87	17.14	11.73	489.55
Gen.Adv as % of Mean 5%	6.80	1.52	3.63	3.11	2.30	24.67	42.42	24.67	85.98	96.95	96.16	18.54	61.58	105.42	32.43

Gen.Adv as % of Mean 1%	8.72	1.94	4.65	3.99	2.94	31.61	54.36	31.61	110.19	124.25	123.23	23.76	78.92	135.11	41.57
General Mean	67.57	114.15	58.87	27.65	42.36	47.65	1.76	4.89	30.90	26.07	18.69	41.53	21.72	8.68	1177.79
Exp Mean next Generation	72.16	115.88	61.01	28.51	43.33	59.41	2.51	6.10	57.47	51.35	36.67	49.23	35.09	17.83	1559.78

Table 3: Estimation of phenotypic correlation coefficient for different quantitative characters in chickpea under heat stress condition

Characters	**Days to Maturity**	**Chlorophyll Index**	**CT@VS**	**CT @PFS**	**Plant Height (cm)**	**Primary Branches Plant^{-1}**	**Secondary Branchs Plant^{-1}**	**Total Number of Pods Plant^{-1}**	**Effective Pods Plant^{-1}**	**Biological Yield Plant^{-1} (g)**	**Harvest Index (%)**	**100-Seed Weight (g)**
Days to 50% Flowering	0.28*	-0.37**	0.011	-0.425**	0.278*	0.067	-0.053	-0.107	-0.151	-0.11	0.045	0.005
Days to Maturity		0.17	0.250*	-0.350**	0.149	0.064	-0.09	-0.069	-0.082	0.049	-0.063	0.208
Chlorophyll Index			0.157	0.278*	-0.197	0.303**	0.019	0.085	0.134	0.319*	-0.015	0.270*
CT.@VS				-0.218	0.156	0.145	0.109	-0.104	-0.094	0.068	-0.208	0.172
CT@PFS					-0.460**	-0.08	-0.073	0.143	0.196	0.059	-0.059	-0.192
Plant height(cm)						0.122	0.044	-0.215	-0.249*	-0.137	0.176	0.251*
Primary Branches Plant^{-1}							0.616**	0.575**	0.582**	0.696**	0.279*	0.530**
Secondary Branches Plant^{-1}								0.541**	0.524**	0.592**	0.144	0.340**
Total no. of pods Plant^{-1}									0.986**	0.775**	0.406**	0.338**
Effective no. of pods Plant^{-1}										0.775**	0.400**	0.351**
Biological Yield Plant^{-1} (g)											0.234*	0.641**
Harvest Index (%)												0.311**
Seed Index (g)												**1**
Grain yield plant^{-1} (g)	**0.08**	**0.370****	**-0.016**	**0.028**	**0.04**	**0.403****	**0.222***	**0.395****	**0.407****	**0.423****	**0.264***	**0.399****

*,**= Significant at 5% & 1% levels, respectively

Table 5: Direct and indirect effect of different characters on grain yield in chickpea under heat stress condition

Characters	**Days to 50% flowering**	**Days to Maturity**	**Chlorophyll Index**	Canopy Temp.@VS	**Canopy Temp @PFS**	**Plant Height (cm)**	**Primary Branches Plant^{-1}**	**Secondary Branchs Plant^{-1}**	**Total Number of Pods Plant^{-1}**	**Effective Pods Plant^{-1}**	**Biological Yield Plant^{-1} (g)**	**Harvest Index (%)**	**100 Seed Weight (g)**
Days to 50% flowering	**0.12**	0.034	-0.045	0.001	-0.051	0.033	0.008	-0.006	-0.013	-0.018	-0.013	0.005	0.001
Days to maturity	-0.009	**-0.033**	-0.006	-0.008	0.012	-0.005	-0.002	0.003	0.002	0.003	-0.002	0.002	-0.007
Chlorophyll index	-0.15	0.067	**0.401**	0.063	0.111	-0.079	0.121	0.007	0.034	0.054	0.128	-0.006	0.108
CT@VS	-0.001	-0.02	-0.012	**-0.078**	0.017	-0.012	-0.011	-0.009	0.008	0.007	-0.005	0.016	-0.013
CT@PFS	0.013	0.011	-0.009	0.007	**-0.032**	0.015	0.003	0.002	-0.005	-0.006	-0.002	0.002	0.006
Plant height (cm)	0.03	0.016	-0.021	0.017	-0.05	**0.109**	0.013	0.005	-0.023	-0.027	-0.015	0.019	0.027
Primary	0.001	0.001	0.003	0.001	-0.001	0.001	**0.009**	0.005	0.005	0.005	0.006	0.002	0.005

Branches Plant-1													
Secondary Branches Plant-1	0	0	0	0	0	0	-0.001	**-0.002**	-0.001	-0.001	-0.001	0	-0.001
Total no. of pods/plant	-0.021	-0.014	0.017	-0.021	0.029	-0.043	0.115	0.109	**0.201**	0.198	0.156	0.082	0.068
No. of effective pods Plant-1	-0.032	-0.017	0.028	-0.02	0.041	-0.053	0.123	0.111	0.208	**0.211**	0.164	0.085	0.074
Biological yield Plant-1	0.014	-0.006	-0.041	-0.009	-0.008	0.018	-0.09	-0.077	-0.101	-0.101	**-0.13**	-0.03	-0.083
Harvest index (%)	0.001	-0.001	0	-0.005	-0.001	0.004	0.006	0.003	0.009	0.009	0.005	**0.023**	0.007
Seed Index (g)	0.001	0.043	0.056	0.036	-0.04	0.052	0.11	0.07	0.07	0.073	0.133	0.064	**0.207**
Grain yield (g)	**-0.033**	**0.08**	**0.37**	**-0.016**	**0.028**	**0.04**	**0.403**	**0.222**	**0.395**	**0.407**	**0.423**	**0.264**	**0.399**
Partial R2	-0.004	-0.003	0.148	0.001	-0.001	0.004	0.004	-0.001	0.079	0.086	-0.055	0.006	0.083

* Significant at P=0.05(0.3125)

Residual effect (Genotypic) = 0.2369

** Significant at P=0.01(0.4032)

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