STUDY ON THE PERFORMANCE OF CHICKPEA (CICER ARIETINUM L.) GENOTYPES UNDER HEAT STRESS CONDITION FOR SEED YIELD AND ATTRIBUTING TRAITS.

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Abstract

Chickpea (Cicer arietinum L.), a cool-season legume, faces significant yield reductions when exposed to heat stress, particularly during the reproductive stages (flowering and podding). With climate change leading to rising global temperatures, heat stress is becoming an increasing challenge for chickpea cultivation. Research has identified 35 °C as a critical temperature for distinguishing heat-tolerant chickpea genotypes under field conditions. An experiment was conducted during the Rabi season of 2021-22 and 2022-23 at the Pulses Research Farm of Rama University, Mandhana Kanpur-209217. Thirty-six Desi chickpea genotypes were studied to analyse genetic variability, correlation, and path analysis for seed yield and its components. The sowing took place on December 15, 2021 (late sowing), at the Pulse Research Farm of Rama University, Mandhana Kanpur-209217. Due to late sowing, the chickpea plants encountered high temperatures (≥ 35 °C) during their reproductive stage, creating unfavourable heat stress conditions that impacted seed yield. The analysis of variance indicated significant differences among genotypes for all traits, demonstrating considerable variability. High genetic coefficient of variation (GCV) and phenotypic coefficient of variation (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. Traits such as 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 showed high heritability combined with high genetic advance over the mean. This suggests that these traits are influenced by additive gene effects and could be effectively improved through selection.

Seed yield per plant was positively and significantly correlated with the 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 these traits are key contributors to yield. Path analysis showed that the chlorophyll index, effective pods per plant, and 100-seed weight had the highest direct effects on seed yield. Based on seed yield performance, genotypes IPC2010-62, BRC-2, Sabour Chana-1, and GNG2215 were identified as promising heat-tolerant varieties. These genotypes hold potential for developing heat-tolerant chickpeas for the rice fallow areas of Bihar and could be utilized in future hybridization programs.

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 experiment involved thirty-six chickpea genotypes, sown on November 15, 2021, under normal conditions, and on December 15, 2021, to align heat stress with the pollination and grain-filling periods. The study was conducted at the Agricultural Research Farm of FASAI, Rama University, Kanpur, where temperatures ranged from a minimum of 3.8°C in January to a maximum of 45.0°C in May. The experiment was arranged in a randomized complete block design with three replications during the Rabi season of 2021-22, under the All India Coordinated Research Project on Chickpea. Each plot measured 4.8 m² and consisted of one row 4 meters in length, with a spacing of 30 cm between rows and 30 x 10 cm between plants. Standard agricultural practices were followed to ensure a healthy crop. Data were collected on fifteen quantitative traits: days to 50% flowering, days to maturity, chlorophyll index, canopy temperature at the vegetative stage, canopy temperature at the 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). Days to 50% flowering, days to maturity, and grain yield per plot were recorded for each plot, while plant height, number of pods per plant, and 100-seed weight were measured from a random sample of five plants per plot. Statistical analyses were conducted to determine the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), heritability, and genetic advance as a percentage of the mean using standard methods. Analysis of variance, GCV, PCV (Burton, 1952), heritability (Hanson et al., 1956), and genetic advance (Johnson et al., 1955) were computed according to established procedures. Genotypic and phenotypic correlation coefficients were calculated using genotypic and phenotypic variances and covariances (Al Jibouri et al., 1958). Path coefficient analysis was performed following the method of Dewey and Lu (1959).

Results and Discussion

The results regarding the yield attributes of chickpea genotypes under heat stress during the flowering and podding stages are summarized in Table 1. Chickpea genotypes exposed to heat stress produced significantly lower grain yields compared to those grown under normal conditions. All evaluated genotypes experienced yield reductions under heat stress, with the decline in yield per plant ranging from 50.21% to 71.06% compared to normal conditions. Grain yields per plant ranged from 3.9 g to 27.79 g under normal conditions and from 3.97 g to 24.99 g under heat stress. For grain yield per plot, the reduction ranged from 30.37% to 73.73% under heat stress, with mean yields varying from 1096.0 kg to 2988.7 kg per hectare under normal conditions and from 607.67 kg to 2033.8 kg per hectare under heat stress. Among the thirty-six genotypes evaluated, three were identified as particularly promising: IPC2010-62, BRC-2, SABOUR CHANA-1, and GNG2215. These genotypes performed better than the check varieties and existing high-yielding varieties (BG372 and PG186) in the North East Plain Zone. The highest yield reductions under heat stress were observed in GL29098 (73.73%), GNG2264 (66.96%), and JG74315-14 (64.81%), while PG186 and BG372 experienced reductions of 49.82% and 1.58%, respectively. Under normal conditions, the highest grain yields were recorded in GNG2299 (2998.7 kg/ha), followed by GNG2264 (2783.2 kg/ha) and IPC2010-62 (2636.9 kg/ha). Canopy temperatures at the vegetative stage ranged from 19.19°C (NDG14-24) to 24.84°C (PG 186) under normal conditions and from 25.74°C (DCP 92-3) to 30.56°C (GNG 2207) under heat stress, with average temperatures of 21.91°C and 27.65°C, respectively. Among the checks, GCP 105 showed high canopy temperatures under normal conditions (20.64°C) and PG 186 showed high temperatures under heat stress (28.26°C). All thirty-six genotypes were statistically similar to the checks in both conditions. At the pod-filling stage, canopy temperatures ranged from 28.86°C (PG 186) to 37.97°C (GL 29098) under normal conditions and from 39.48°C (NBeG 507) to 44.78°C (GNG 2304) under heat stress, with average temperatures of 34.34°C and 42.36°C, respectively. KWR 108 exhibited high canopy temperatures under normal conditions (35.40°C), while PG 186 showed high temperatures under heat stress (43.16°C). NBeG 507 had significantly lower canopy temperatures than the check under heat stress. In contrast, under normal conditions, sixteen genotypes, including GNG 2299, H12-62, PBC 501, and others, showed significantly higher canopy temperatures at the pod-filling stage, while the remaining twenty genotypes were comparable to the check. Under heat stress, genotypes exhibited lower pollen viability and pod-filling percentages compared to normal conditions. The heat-tolerant genotypes IPC2010-62, BRC-2, SABOUR CHANA-1, and GNG2215 had higher chlorophyll indices, lower canopy temperatures at the vegetative and pollen formation stages. These findings are consistent with previous studies by Kumar et al. (2012) and Krishnamurthy et al. (2011).

The analysis of variance showed significant differences among the genotypes for all traits studied, indicating the potential for selecting superior genotypes. The phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all traits, suggesting that environmental factors also contribute to the observed variation. Grain yield per plant, effective pods per plant, biological yield, total number of pods per plant, and 100-seed weight had high GCV and PCV, indicating less environmental influence and highlighting these traits as important for selection in breeding programs. Traits with moderate to low GCV and PCV still exhibited sufficient variability for genetic improvement. Traits with lower differences between PCV and GCV, such as number of primary branches per plant and grain yield per plant, were less affected by environmental changes. High heritability in broad sense was observed for traits like 100-seed weight, grain yield per plant, effective pods per plant, and biological yield, indicating these traits are less influenced by environmental factors and reflect the genotypic potential for transmission to offspring. High genetic advance was noted for total number of pods per plant, effective pods per plant, and grain yield per plot, while traits like plant height, 100-seed weight, and biological yield showed moderate genetic advance. Overall, high genetic advance as a percentage of the mean was observed for several key traits, suggesting good potential for improvement through selection.

High heritability does not always guarantee a high genetic advance. According to Johnson et al. (1955), both heritability estimates and genetic advance as a percentage of the mean should be considered together for a more accurate prediction of selection outcomes. In this study, high heritability coupled with high genetic advance was observed for traits such as grain yield per plant, 100-seed weight, biological yield, number of effective pods per plant, total number of pods per plant, plant height, and primary branches per plant. These traits are favorable for improvement through selection, likely due to additive gene action, and could be enhanced without the need for progeny testing. Similar findings were reported by Yadav et al. (2003). The effectiveness of a selection program depends on the presence of genetic variability within the population. Phenotypic variability arises from both genotypic and environmental influences, which contribute to the development of phenotypes. Therefore, care must be taken during selection, as environmental variations can be unpredictable and may affect results. The observed phenotypic variability was substantial for grain yield per plant, total number of pods per plant, effective pods per plant, biological yield, 100-seed weight, grain yield per plot, and number of primary branches per plant. This high level of variability is expected in chickpea genotypes, as they have been developed from different research institutes through hybridization of diverse parents. The large amount of variability indicates significant potential for improvement in these traits through selection.

The study of how different traits are related through correlation is a crucial aspect of breeding programs. It helps breeders make effective selections by understanding both correlated and uncorrelated responses. Knowing the nature and strength of these associations is important for several reasons. First, indirect selection becomes valuable when desirable traits have low heritability in only one sex. The efficiency of this indirect selection is gauged by the correlated response (Falconer, 1960). Second, understanding correlations is essential when selecting multiple traits simultaneously through a selection model. Even when focusing on a single trait, awareness of correlations is necessary to prevent unintended changes in other traits. Generally, the magnitude of genotypic correlations is higher than that of phenotypic correlations for most traits, indicating a strong inherent association. This suggests that phenotypic selection can be effective. Kumar et al. (2017) found similar results, and Robinson et al. (1951) noted that higher genotypic correlations are beneficial for selecting genetically controlled traits, leading to better improvements in seed yield compared to phenotypic correlations alone.

Grain yield per plant was found to have a positive and significant association with several traits, including 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). Consequently, these traits are recommended as selection criteria to improve yield in chickpea, particularly for developing high-yielding genotypes suitable for rice fallow conditions (Table 3). Similar observations were reported by Telebi et al. (2007), Hahid et al. (2010), Ali et al. (2011), and Kumar et al. (2017). Path coefficient analysis indicated that chlorophyll index, effective number of pods per plant, and 100-seed weight had strong positive direct effects on grain yield per plant (Table 5). Effective pods per plant showed a high positive direct effect on grain yield, highlighting its strong relationship with yield and suggesting that direct selection for this trait could be beneficial. For other traits, correlations were primarily due to indirect effects through related characters, implying that indirect selection could improve chickpea yield. The potential for using these associated traits to select for heat stress tolerance may help breeders develop genotypes that can withstand high temperatures. These findings are consistent with Priti et al. (2003). An increase in any of these traits could directly enhance seed yield. Days to 50% flowering showed a positive direct effect on grain yield per plant, but also had indirect positive effects via days to maturity, canopy temperature at the vegetative stage, plant height, number of primary branches, harvest index, and 100-seed weight, and indirect negative effects via chlorophyll index, canopy temperature at pod-filling stage, number of secondary branches, total pods per plant, effective pods per plant, and biological yield. The positive direct effect of the number of pods per plant and its indirect positive effects through 100-seed weight and plant height were key factors in the strong positive correlation between this trait and seed yield. Similar results were observed 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	Days 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
	TS	LS	TS	LS	TS	LS	TS	LS	TS	LS	TS	LS		TS	LS	
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	130.1	114.3	66.7	60.9	21.22	27.05	33.3	39.48	19.36	14.66	24.277	1817.6	999.89	44.99

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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	134.2	115.6	58.2	57.0	20.96	26.98	35.4	42.23	18.51	6.35	65.694	2912.9	1254.6	56.93

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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

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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 3: 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 4: Estimation of phenotypic correlation coefficient for different quantitative characters in chickpea under heat stress condition

Characters	**Days to**	**Chlorop**			**Plant**	**Primary**	**Secondary**	**Total Numbe**	**Effectiv**	**Biological Yield**	**Harve**	**100-**
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								0.541*	0.524*	0.592*	0.144	0.340*

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Plant⁻¹								*	*	*		*
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%**	**Days to Maturit**	**Chlorop hyll**	**Canop y**	**Canopy Temp**	**Plant Heigh**	**Prima ry**	**Second ary**	**Total Number of**	**Effective Pods**	**Biologica l Yield**	**Harvest Index**	**100 Seed**
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

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Primary Branches Plant-1	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
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

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