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Genetic Variability in Chickpea (*Cicer arietinum* L.) under Heat Stress Condition

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Authors' contributions

This work was carried out in collaboration among all authors. Author SK designed the study, conducted the experiment, performed the statistical analysis and wrote the first draft. Authors BGS and AK managed the analyses and edited the first draft of the study. Author GRL managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present experiment was carried out at field experimentation centre of the Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (Uttar Pradesh) to study genetic variability, correlation and path analysis in fifty germplasm of chickpea during *rabi,* 2017-18. The maximum phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were noticed for 100-seed weight, biological yield per plant, grain yield per plant and number of primary branches per plant. High heritability were recorded by 100 seed weight, biological yield per plant, primary branches per plant, grain yield per plant, effective pods per plant, total number of pods per plant, secondary branches per plant, plant height, days to 50% flowering and days to maturity. High heritability coupled with high genetic advance as percent of mean was observed for 100 seed weight, biological yield per plant, primary branches per plant, grain yield per plant, effective pods per plant, total number of pods per plant, secondary branches per plant and plant height which suggested that these characters can be considered as favorable attributes for the improvement through selection. Path coefficient analysis

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for grain yield per plant revealed that biological yield, harvest index, secondary branches, canopy temperature at vegetative stage, effective pods per plant had given the highest contribution on yield per plant. So the utmost importance should be given to these characters during the selection for yield improvement in late sown chickpea.

Keywords: Cicer arietinum L.; genetic variability; correlation; path analysis and grain yield.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) 2n = 2x = 16, is the third most important food legume belongs to family *Fabaceae.* It is globally, occupying an area of 14.56 m ha with a production of 14.78 mt [1]. India is the largest producer of chickpea in the world sharing about 72% of area and production covering about 10.56 million ha area with annual production of 11.17 million tones grain. The present yield level is 1077 kg/ha which is far below the potential yield (5000 kg/ha) of the crop. In spite of India being the largest chickpea producing country, a deficit exists in domestic production and demand, which is met through imports. Uttar Pradesh is a traditional state for chickpea cultivation covering an area of 501.0 thousand ha with production of 578.66 thousand tones and productivity of 1155 kg/ha (Project Coordinator's Report, AICRP on Chickpea, 2018-19). About 90% of chickpea production occurs on residual soil moisture under rainfed conditions [2], where terminal heat stresses are major limitations to higher productivity (Johansen et al. 1997). Chickpea productivity is constrained by several biotic and abiotic stresses [3] and temperature is one of the most important determinants of crop growth over a range of environments [4] and may limit chickpea yield [5]. Chickpea is a cool season food legume and causes severe yield losses when exposed to high temperatures about 35°C during reproduction. Heat stress is increasingly becoming a major constraint for chickpea production in India because it is expected to increase the area under late sown conditions due to increased crop intensity or late rainy season crop maturity, and to increase overall temperatures due to climate change [3]. Chickpea reproductive stages (flowering and podding) are vulnerable to external environmental changes and heat stress [6]. Frequent decreases in the yields of chickpea seed were observed when plants were exposed to high (> 35°C) temperatures at flowering and pod development stages [7]. Approximately 11.7 million ha of rice area in India is estimated to currently remain fallow in central and north-eastern India after late rice harvest during the winter season [8]. These lands can offer expansion in the cultivation of chickpea provided genotypes are made available that is capable of standing heat stress. Due to climate change and global warming, heat stress is projected to be an increasingly important constraint in the near future. Through 2050, with higher levels of warming in northern parts of India, a temperature rise of at least 2°C, particularly night temperatures, is expected. The predicted climate change will reduce the grain yield in chickpea, particularly at high temperatures. For example, chickpea yield declined by as much as 301 kg/ha per 1°C in India (Karla et al*.,* 2010). There is an urgent need to search for various sources of heat tolerance from the gene bank. In chickpea cultivars, heat tolerance is highly needed to achieve higher yields in all growing conditions that expose chickpea to high temperatures, especially during the reproductive stage. So, heat tolerance varieties are needed for improving chickpea yields in late sown conditions.

Yield is a complex character in general and more complex in chickpea, as it is depending upon a number of components. 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. 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 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.

2. MATERIALS AND METHODS

The experimental material comprised of fifty germplasm of chickpea were sown on15th December 2017 to coincide heat stress with pollination in *rabi,* 2017-18 at field experimentation centre of the Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture,

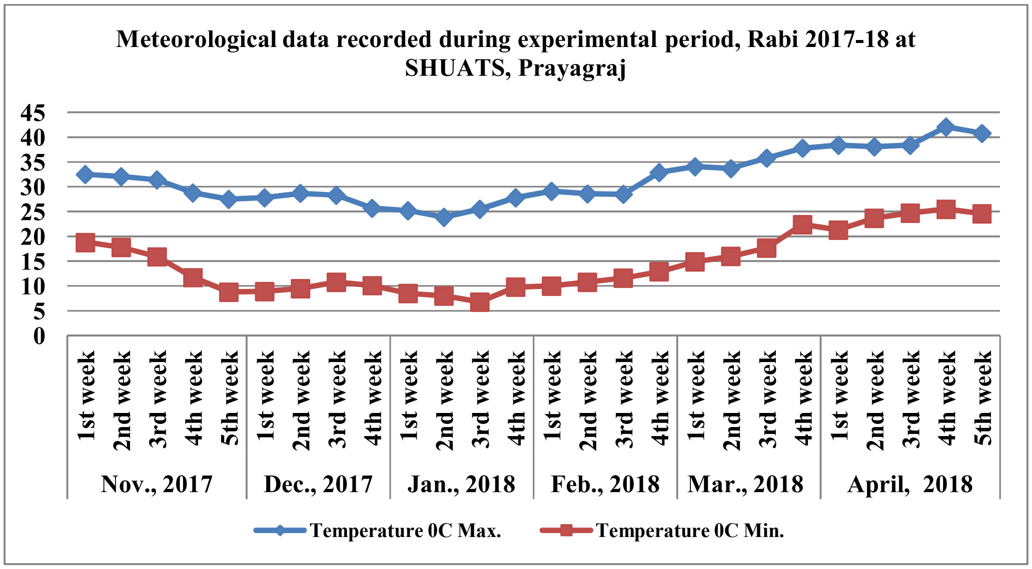

Fig. 1. Metrological data recorded during, rabi 2017-18

Technology and Sciences, Prayagraj (Uttar Pradesh). Chickpea reproductive stages (flowering and podding) are vulnerable to external environmental changes and heat stress. Frequent decreases in the yields of chickpea seed were observed when plants were exposed to high (> 35°C) temperatures at flowering and pod development stages [7]. The meteorological data recorded during crop growing period, (Rabi 2017-18 at SHUATS, Prayagraj (Uttar Pradesh) are shown in Fig. 1. The experiment was laid in randomized complete block design with three replications during *rabi,* 2017-18 with inclusion of the recommended packages and practices needed for a healthy crop. Data for 14 quantitative traits were recorded viz; days to 50% flowering, days to maturity, Chlorophyll content, Canopy temperature, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of total pods per plant, Effective pods/plant, biological yield per plant, harvest index, 100-seed weight and seed yield per plant. The days to 50% flowering and days to maturity were accounted on a plot basis and rest of the characters was documented from random sample of five plants in each plot. Each genotype was planted in a single row of four meters length with a spacing of 30 cm between rows and 10 cm between plants. The recommended agronomic practices and crop protection measures were followed during the crop growth period. Biometrical methods were followed to estimate genotypic and phenotypic coefficient of variation [9], heritability in broad sense [10], genetic advance [11] and correlation and path coefficient analysis (Singh and Chaudhry, 1979).

3. RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among the genotypes (Table 1) for all the studied characters which provide an opportunity for selecting suitable genotypes with better performance for the traits. A wide range of variability was noticed for different agronomic and economic traits The estimates of phenotypic coefficient of variation (PCV) in general, 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 2). The maximum genotypic coefficient of variation was observed in seed index followed by grain yield per plant, biological yield per plant and primary branches per plant. 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 pods per plant and 100-seed weight were also earlier reported by Jeena et al. [12], Younis et al. [13], Alwani et al. [14] and Babbar et al. [15]. The high PCV were recorded by 100-seed weight, grain yield per plant, biological yield per plant, effective pods per plant, primary branches per plant, total number of pods per plant and secondary branches per plant. The magnitude of PCV ranged from 4.44 (days to maturity) to 30.08 (100 seed weight). The characters with high phenotypic coefficient of variation indicated more influence of environmental factors. Therefore, caution has to be exercised during the selection program because the environmental variations are unpredictable in nature and may mislead the results. The heritability for most of the characters ranged from 42.74 (canopy temperature at pod filling stage) to 98.08 (100-seed weight). The heritability estimates were recorded high for 100 seed weight, biological yield per plant, primary branches per plant, grain yield per plant, effective pods per plant, total number of pods per plant, secondary branches per plant ,plant height which, days to 50% flowering and days to maturity suggested that the 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 offspring's. Similar results were also reported by Bicer and Sarkar [16] and Younis et al. [13]. The expected genetic advance was high for grain yield per plot while number of pods per plant showed moderate heritability. High estimates of heritability does not always mean high genetic advance. Johnson et al. [11] suggested that heritability estimates and the genetic advance as percent of mean together would provide a better judgment rather than heritability alone in predicting the resultant effect of selection. High heritability coupled with high genetic advance over mean was observed for 100 seed weight, biological yield per plant, primary branches per plant, grain yield per plant, effective pods per plant, total number of pods per plant, secondary branches per plant and plant height which suggested that these characters can be considered as favorable 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. [17]. 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 [18]. Knowledge of correlation is required when selection is to be made on several characters at a time through some simultaneous selection model [19]. 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

Table 1. Analysis of variance for fourteen characters in fifty chickpea genotypes under heat stress condition

Sl. no.	Characters	Mean sum of squares replication (d. f.=2)	Treatment (d .f.=49)	Error (d. f.=98)
1.	Days to 50% flowering	54.25	91.71**	4.90
2.	Days to maturity	6.21	48.27**	5,19
3.	Chlorophyll index	4.12	51.08**	13.83
4.	Canopy Temperature at Vegetative stage	0.38	7.87**	2.30
5.	Canopy Temperature at pod filling stage	9.53	16.15**	4.98
6.	Plant height (cm)	8.17	113.97**	11.32
7.	Primary branches per plant	0.21	0.46**	0.02
8.	Secondary branches per plant	0.03	2.30**	0.13
9.	Total no. of pods per plant	1.61	79.26**	8.90
10.	Effective pods per plant	0.61	38.49**	4.02
11.	Biological yield per plant	0.16	41.90**	1.22
12.	Harvest index	2.71	28.36**	3.93
13.	100-seed weight	0.06	124.77**	0.81
14.	Grain yield per plant	0.09	3.97**	0.40

** and ** Significant at 5% and 1% levels of significance, respectively*

Table 2. Estimates of genetic parameters for fourteen quantitative characters in fifty genotypes of chickpea under heat stress condition

Sl. no.	Characters	σ^2g	σ^2p	GCV	PCV	h^2 (bs) %	GA	GA as % of mean
1.	Days to 50% flowering	28.94	33.84	7.76	8.39	85.52	10.25	14.78
2.	Days to maturity	14.36	19.54	3.81	4.44	73.47	6.69	6.73
3.	Chlorophyll index	12.42	26.25	5.95	8.65	47.30	4.99	8.43
4.	Canopy Temperature at Vegetative stage	1.86	4.16	5.13	7.69	44.64	1.88	7.07
5.	Canopy Temperature at pod filling stage	3.72	8.71	5.22	7.98	42.74	2.59	7.03
6.	Plant height (cm)	34.22	45.54	13.56	15.65	75.14	10.44	24.22
7.	Primary branches per plant	0.15	0.17	21.19	22.26	90.72	0.76	41.59
8.	Secondary branches per plant	0.72	0.85	17.55	19.06	84.89	1.61	33.32
9.	Total no. of pods per plant	23.45	32.36	18.73	21.99	72.48	8.49	32.84
10.	Effective pods per plant	11.49	15.51	19.61	22.78	74.08	6.01	34.76
11.	Biological yield per plant	13.56	14.78	22.91	23.93	91.74	7.26	45.22
12.	Harvest index	8.14	12.07	8.41	10.25	67.45	4.83	14.23
13.	100-seed weight	41.32	42.13	29.79	30.08	98.08	13.11	60.78
14.	Grain yield per plant	1.19	1.59	20.14	23.30	74.70	1.94	35.85

σ^2g = Genotypic variances, σ^2p = Phenotypic variances, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, h2(bs) = heritability in broad sense and GA = genetic advance

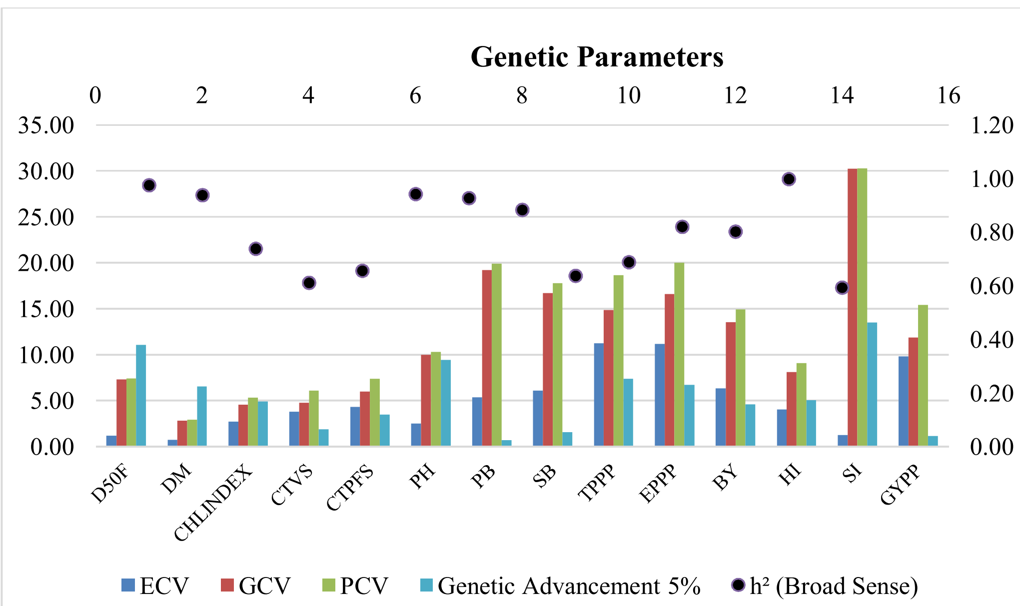

Fig. 2. Histogram showing estimates of genetic parameters for fourteen quantitative characters in chickpea under heat stress condition

strong inherent association exists for the traits studied and phenotypic selection may be rewarding. Similar results were also reported by Pathak et al*.* (1986). 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).

Table 3. Genotypic and phenotypic correlation for 14 characters in fifty genotypes of chickpea under heat stress condition

Characters		Days to 50% flow.	Days to maturity	Chlorophyll index	CT @ VS	CT @ PFS	Plant height	Primary branches plant^{-1}	Sec. branches plant^{-1}	Total no. of Pods plant^{-1}	Effective pods plant^{-1}	Biological yield plant^{-1}	Harvest Index	100-seed weight	Grain yield plant^{-1}
Days to 50%	G	1.000	0.822**	-0.486**	0.491**	0.387**	0.373**	-0.119	0.020	-0.132	-0.073	-0.219**	-0.088	-0.041	-0.264**
flowering	P	1.000	0.711**	-0.336 **	0.313**	0.211**	0.310**	-0.120	0.027	-0.098	-0.049	-0.194*	-0.086	-0.039	-0.217**
Days to maturity	G		1.000	-0.433**	0.599**	0.384**	0.324**	0.064	0.159	-0.096	-0.130	-0.190*	-0.161*	-0.121	-0.261**
	P		1.000	-0.270**	0.332**	0.190*	0.211**	0.052	0.106	-0.094	-0.120	-0.159	-0.121	-0.100	-0.199*
Chlorophyll	G			1.000	-0.165*	-0.429**	-0.147	0.280**	-0.006	-0.188*	-0.131	0.170*	0.183*	0.249**	0.255**
index	P			1.000	-0.117	-0.163*	-0.136	0.183*	-0.010	-0.106	-0.087	0.131	0.097	0.164*	0.167*
CT @ VS	G				1.000	0.435**	0.094	-0.003	-0.036	-0.005	0.076	-0.175*	-0.084	0.149	-0.210**
	P				1.000	0.199*	0.114	0.051	0.011	-0.010	0.033	-0.098	-0.021	0.084	-0.090
CT @ PFS	G					1.000	-0.239**	-0.058	0.010	-0.202*	-0.147	-0.447**	-0.343**	-0.355**	-0.612**
	P					1.000	-0.124	0.052	0.156	0.076	0.095	-0.177*	0.023	-0.238**	-0.149
Plant height	G						1.000	0.167*	-0.113	-0.039	-0.054	0.183*	-0.362**	0.299**	0.047
	P						1.000	0.129	-0.062	0.019	0.007	0.181*	-0.206*	0.263**	0.089
Pri. branches	G							1.000	0.442**	-0.091	-0.112	0.150	0.032	0.236**	0.176*
plant^{-}	P							1.000	0.438**	-0.090	-0.110	0.140	0.028	0.223**	0.149
Sec. branches	G								1.000	0.334**	0.201	0.276**	0.121	0.305**	0.405**
plant^{-1}	P								1.000	0.358**	0.251**	0.306**	0.187*	0.263**	0.433**
Total no. of	G									1.000	0.814**	0.308**	-0.184*	-0.068	0.280**
Pods plant^{-1}	P									1.000	0.862**	0.376**	0.097	-0.060	0.436**
Effective pods	G										1.000	0.134	-0.111	-0.064	0.117
plant^{-1}	P										1.000	0.229**	0.138	-0.057	0.306**
Biological yield	G											1.000	-0.462**	0.569**	0.920**
plant^{-1}	P											1.000	-0.256**	0.539**	0.895**
Harvest Index	G												1.000	0.185*	-0.091
	P												1.000	0.146	0.188*
100-seed weight	G													1.000	0.723**
	P													1.000	0.614**

** , ** Significant at 5% and 1% levels of significance, respectively;*

CT@VS= Canopy temperature at vegetative stage; CT@PFS= Canopy temperature at pod filling stage

Table 4. Direct (diagonal) and indirect genotypic and phenotypic effects of different characters on grain yield in chickpea under heat stress condition

Characters		Days to 50% flowering	Days to maturity	Chlorophyll index	CT @ VS	CT @ PFS	Plant height	primary branches plant^{-1}	Secondary branches plant^{-1}	Total no. of Pods plant^{-1}	Effective pods plant^{-1}	Biological yield plant^{-1}	Harvest Index	100-seed weight	Grain yield plant^{-1}
Days to 50%	G	0.011	0.009	-0.005	0.005	0.004	0.004	-0.001	0.0002	-0.0014	-0.001	-0.002	-0.001	-0.0004	-0.264
flowering	P	-0.002	-0.001	0.001	-0.0005	-0.0004	-0.0005	0.0002	0.0000	0.0002	0.0001	0.0003	0.0001	0.0001	-0.217
Days to	G	-0.007	-0.009	0.004	-0.005	-0.003	-0.003	-0.0005	-0.001	0.001	0.001	0.002	0.001	0.001	-0.261
maturity	P	0.001	0.002	-0.0004	0.0005	0.0003	0.0003	0.0001	0.0002	-0.0001	-0.0002	-0.0002	-0.0002	-0.0002	-0.199
Chlorophyll	G	0.001	0.0005	-0.001	0.0002	0.0005	0.0002	-0.0003	0.000	0.0002	0.0002	-0.0002	-0.0002	-0.0003	0.255
index	P	-0.001	-0.001	0.004	-0.0005	-0.001	-0.001	0.001	0.000	-0.0004	-0.0004	0.0005	0.0004	0.001	0.167
CT @ VS	G	0.005	0.006	-0.002	0.010	0.004	0.001	0.000	-0.0003	-0.0001	0.001	-0.002	-0.001	0.001	-0.210
	P	0.005	0.005	-0.001	0.015	0.003	0.002	0.001	0.0002	-0.0001	0.0005	-0.001	-0.0003	0.001	-0.090
CT @ PFS	G	-0.010	-0.010	0.011	-0.011	-0.026	0.006	0.002	-0.0003	0.005	0.004	0.012	0.009	0.010	-0.612
	P	0.002	0.002	-0.001	0.002	0.009	-0.001	0.0004	0.001	0.001	0.001	-0.002	0.0002	-0.002	-0.149
Plant height	G	-0.009	-0.008	0.004	-0.002	0.006	-0.025	-0.004	0.003	0.001	0.001	-0.005	0.009	-0.007	0.047
	P	0.002	0.001	-0.001	0.001	-0.001	0.006	0.001	-0.0004	0.0001	0.000	0.001	-0.001	0.002	0.089
Pri. branches	G	0.004	-0.002	-0.009	0.0001	0.002	-0.005	-0.031	-0.014	0.003	0.003	-0.005	-0.001	-0.007	0.176
plant^{-}	P	0.004	-0.002	-0.006	-0.002	-0.002	-0.004	-0.033	-0.014	0.003	0.004	-0.005	-0.001	-0.007	0.149
Sec. branches	G	0.002	0.012	-0.0005	-0.003	0.001	-0.009	0.033	0.075	0.025	0.015	0.021	0.009	0.023	0.405
plant^{-1}	P	0.002	0.007	-0.001	0.001	0.010	-0.004	0.027	0.062	0.022	0.016	0.019	0.012	0.016	0.433
Total no. of	G	0.0001	0.0001	0.0002	0.000	0.0002	0.000	0.0001	-0.0003	-0.001	-0.001	-0.0003	0.0002	0.0001	0.280
Pods plant^{-1}	P	0.001	0.001	0.001	0.0001	-0.001	-0.0002	0.001	-0.004	-0.012	-0.010	-0.005	-0.001	0.001	0.436
Effective pods	G	0.0003	0.0005	0.0005	-0.0003	0.0005	0.0002	0.0004	-0.001	-0.003	-0.004	-0.0005	0.0004	0.0002	0.117
plant^{-1}	P	-0.0005	-0.001	-0.001	0.0003	0.001	0.0001	-0.001	0.003	0.009	0.010	0.002	0.001	-0.001	0.306
Biological yield	G	-0.227	-0.197	0.176	-0.181	-0.462	0.189	0.155	0.286	0.319	0.139	1.035	-0.479	0.589	0.920
plant^{-1}	P	-0.193	-0.158	0.130	-0.097	-0.176	0.180	0.138	0.303	0.373	0.227	0.992	-0.254	0.535	0.895
Harvest Index	G	-0.031	-0.057	0.065	-0.030	-0.121	-0.128	0.012	0.043	-0.065	-0.040	-0.163	0.353	0.065	-0.091
	P	-0.037	-0.052	0.042	-0.009	0.010	-0.089	0.012	0.081	0.042	0.060	-0.111	0.431	0.063	0.188
100-seed	G	-0.002	-0.006	0.012	0.008	-0.018	0.015	0.012	0.015	-0.003	-0.003	0.028	0.009	0.050	0.723
weight	P	-0.0002	-0.0005	0.001	0.0005	-0.001	0.001	0.001	0.001	-0.0003	-0.0003	0.003	0.001	0.005	0.613

G (R SQURE = 0.9964 RESIDUAL EFFECT = 0.0601) CT@VS= Canopy temperature at vegetative stage
P (R SQURE = 0.9886 RESIDUAL EFFECT = 0.1070) CT@PFS= Canopy temperature at pod filling stage

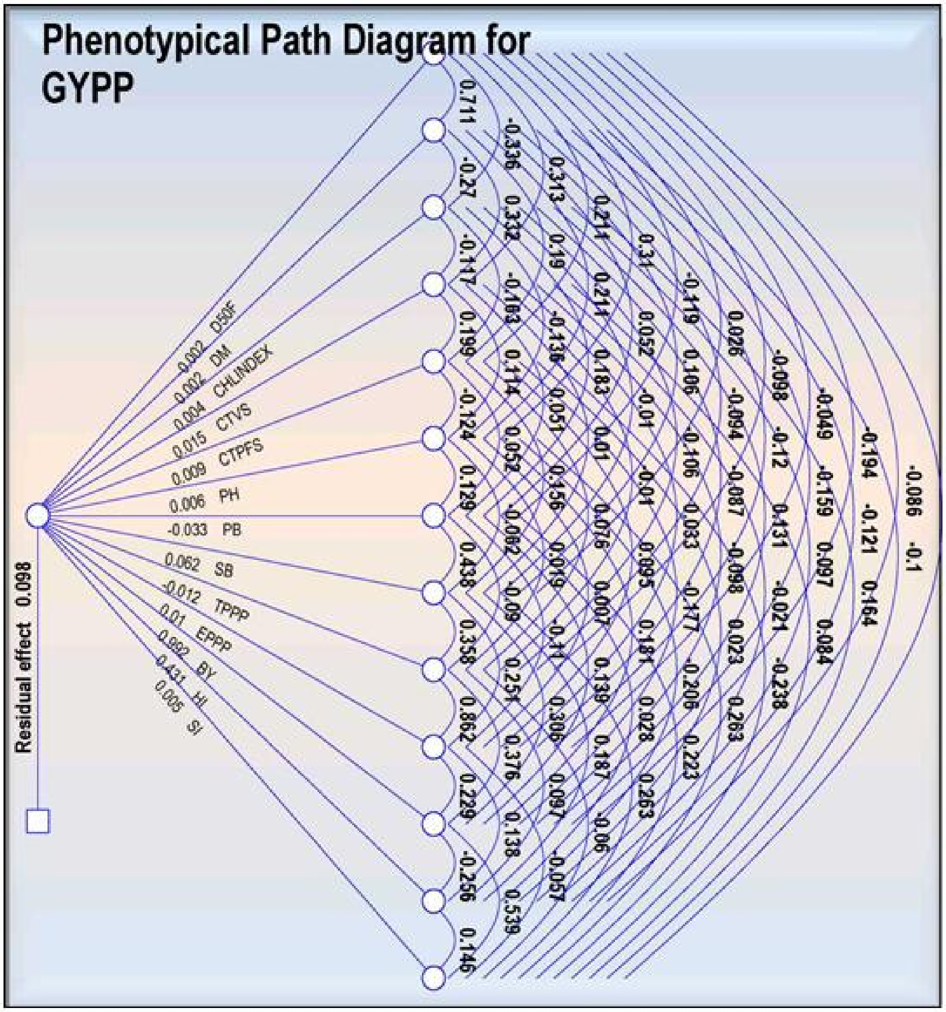

Fig. 3. Phenotypic path diagram for grain yield per plant under heat stress condition at Prayagraj during *rabi,* 2017-18

Grain yield per plant exhibited positive significant correlations with biological yield per plant, 100-seed weight, secondary branches/plant, total no. of pods/plant and chlorophyll index respectively at genotypic and phenotypic level. However, primary branches/plant exhibited significant and positive association at genotypic level only while effective pods/plant and harvest index at phenotypic level. Negative and significant correlations were observed with days to 50% flowering, days to maturity at both genotypic at phenotypic level while canopy temperature at pod filling stage, canopy temperature at vegetative stage showed significant and negative correlation at genotypic level only (Table 3). Kuldeep et al. [20] suggested that yield could be raised by selecting for more number of pods per plant and plant stand, which is evident in the present study. Similar findings were reported by Telebi et al. [21], Hahid et al. [22] and Ali et al. [23].

Path coefficient analysis (Table 4) for grain yield per plant revealed that biological yield, harvest index, secondary branches, canopy temperature at vegetative stage, effective pods per plant had highest positive direct effect towards seed yield. These results are agreement with the earlier reports of Priti et al. [24]. It means a slight increase in any one of the above traits may directly contribute towards seed yield. Similar results were reported by Talebi et al. [21] and Babbar et al. [15].

Breeding strategies for improvement of yield potential in chickpea genotypes under heat stress would aim on selection of plants having high biological yield per plant, 100-seed weight, secondary branches/plant, total no. of pods/plant, chlorophyll index and using these associated characters may be useful to the breeder to formulate appropriate breeding plans for selection of the genotype which tolerate high temperature condition.

4. CONCLUSION

The above findings revealed that under heat biological yield, harvest index, secondary branches, canopy temperature at vegetative stage, effective pods per plant had showed the maximum contribution towards seed yield. On the basis of seed yield and its attributing traits Sabour chana-1, BRC-1084-127, BRC-1047-33 and ICCV15112 were identified as promising heat tolerant genotypes. The identified promising heat tolerant genotypes may be used as donor in chickpea hybridization programme. Breeding strategies for improvement of yield potential in chickpea genotypes under heat stress would aim on selection of plants having higher number of effective pods, biological yield, harvest index and 100-seed weight and using these associated characters may be useful to the breeder to formulate appropriate breeding plans for selection of the genotype which tolerate high temperature conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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