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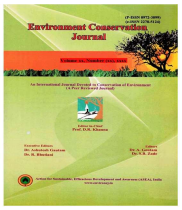

Association, direct and indirect effects of yield, biochemical and physiological characters on seed yield in chickpea (*Cicer arietinum* L.)

Halavath Sai Kumar ✉
Department of Genetics and Plant Breeding, Naini Agricultural institute, Sam Higginbottom University of Agriculture Technology & Sciences, Prayagraj, Uttar Pradesh, India.

Sindhuja Yerrabala
Department of Agricultural Entomology, Naini Agricultural institute, Sam Higginbottom University of Agriculture Technology & Sciences, Prayagraj, Uttar Pradesh, India

G.R. Lavanya
Department of Genetics and Plant Breeding, Naini Agricultural institute, Sam Higginbottom University of Agriculture Technology & Sciences, Prayagraj, Uttar Pradesh, India

G. Babithraj Goud
Department of Crop Physiology, PJTSAU, Rajendranagar, Hyderabad, Telangana, India

Y.Vinod Kumar Reddy
Department of Genetics and Plant Breeding, Naini Agricultural institute, Sam Higginbottom University of Agriculture Technology & Sciences, Prayagraj, Uttar Pradesh, India

Varri Sharmila
Department of Genetics and Plant Breeding, Naini Agricultural institute, Sam Higginbottom University of Agriculture Technology & Sciences, Prayagraj, Uttar Pradesh, India

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ABSTRACT

The present research consists of the 25 genotypes of chickpea (*Cicer arietinum* L.) which was carried out at the field experimentation center, Department of the Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during *Rabi* 2019-20 in Randomized Block Design with three replications with an aim to determine genetic variability, correlation, direct and indirect effects yield, biochemical and physiological characters on seed yield. All the genotypes of chickpea showed significant differences among them, significance variability existed for all the characters. Based on the mean performance, high yield was found for the C-18106 followed by C-18122, C-18103, and C-18101, genotypes C-18123, ICC-15896, C-18102 & GPF-02 showed against pod borer. High heritability (>70%) coupled with high genetic advance (>20%) were being observed for the number of seeds per plant, biological yield. Seed yield per plant exhibited positive and highly significant correlation with biological yield, chlorophyll index, starch content and number of seeds per plant at both genotypic and phenotypic level. Path analysis at phenotypic level identified hundred seed weight followed by chlorophyll index, number of seeds per plant, number of secondary branches, trypsin inhibitor and harvest index important direct components for seed yield per plant. Thus, due consideration should be given to these characters during the selection.

Introduction

Legumes ecologically as well as economically important plants, are considered vital for global food security especially under predicted climatic conditions (Vavilov *et al.,*1926). Chickpea is a cool season legume crop and it grown in several countries worldwide as a food source (Fiaz *et al.,* 2016). Chickpea is the third most important food legume crop and India is the largest producer contributing to 65% of world's chickpea production (DOES, 2019): it imports chickpea from other countries. However the ever-increasing demand for this legume crop; it is essential to improve the

Corresponding author E-mail: saikumarhalavath@gmail.com
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production and area under cultivation (Sain *et al.,* 2020). The area under chickpea cultivation decreased due to lack of high yielding varieties and susceptibility to insect and diseases (Kumar *et al.,* 2018). The yield of chickpea can be improved by selection of superior genotypes which is directly related with the seed yield and utilize these genotypes exclusively in breeding programs to enhance grain yield. Yield is the ultimate goal of a breeding program, (Sain *et al.,* 2020; Muhammad *et al.,* 2003). Seed yield being most important trait is governed by many physiological changes within the plant and influenced by many environmental factors so the breeder needs some index traits to select elite genotypes for higher yield (Manasa *et al.,* 2019).

Seed yield is a polygenic and complex trait which is affected by a large number of other components, so direct selection based on association pattern alone between two variables many sometimes mislead the breeder hence it should split into direct and indirect effects for effective selection (Awol and Alise fikre, 2018; Dehal *et al.,* 2016; Yadav *et al.,*1926). Genetic variation among traits is important for breeding and selecting desirable types on other hand an analysis of the correlation between seed yield and yield components is essential in determining selection criteria however path coefficient analysis helps to determine the direct effect of traits and their indirect effects on other traits (Arora and Jeena, 2001; Chopdar *et al.,* 2017; Dewey and Lu,1959). Correlation does not provide the adequate picture of the relationship between the variables in addition to the degree of such relationship, path coefficient analysis measure the direct influence of one variable upon the other and permits separation of correlation coefficients into components of direct and indirect effects (Kaur and Bhardwaj, 2019; Maloo and Sharma,1987; Saroj *et al.,*2013). It is not sufficient to describe this relationship when the causal association among characteristics is needed. The plus point of this analysis that it allows the partitioning of correlation coefficient into its components (Dewey *et al.,* 1959; Wright *et al.,*1921). Path coefficient analysis examines each and every component and provides information on cause of association between two traits if the association between yield and other characters is due to direct effect. It indicates true and perfect correlation between those two traits and selection would be effective for that character to improve seed yield (Singh *et al.,* 2008; Kumar *et al.,* 2019: Gediya *et al.,* 2019).

Material and Methods

A genotypes collection of 25 strains of chickpea (*Cicer arietinum* L.) comprising indigenous as well as exotic genotypes, constituted the experimental materials for this study. These genotypes exhibiting wide spectrum of variability for various quantitative, biochemical and physiological characters were obtained from the pulse section, field experimentation center, Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj. The present experiment was carried out in *Rabi* 2019-20 in Randomized Block Design. The treatments were being replicated three times. The plot size of 1*1 m^2 the row to row spacing 30 cm and plant to plant distance 10cm. Soil in this region is sandy loam and alkaline in nature. The technique of random sampling was adopted for the observation of the 25 quantitative, biochemical and physiological characters. Recommended practices were applied to raise a healthy crop. Metric data on 25 traits were taken at different stages of growth. The experimental data thus recorded on these characters were subjected to statistical and biometrical analysis for Analysis of variance (Fisher and Yates, 1963; Banik *et al.,* 2018), different genetic parameters Coefficient of variation (GCV, PCV) (Burton, 1952; Shafique, *et al.,* 2016) ,estimation of heritability (Burton and De Vane, 1953), genetic advance, correlation coefficient analysis (Al-Jibouri *et al.,* 1958) and path analysis (Dewey and Lu, 1959).

Correlation coefficient estimates degree of association of different component characters of yield among themselves and with the yield (Hasan and Deb, 2017). The correlation studies between various yields attribute with yield provides a basis for further breeding program (Kishor *et al.,* 2018). Path coefficient analysis measures the direct effect of variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects (Paneliya *et al.,* 2017; Tiwari *et al.,* 2016; Shengel *et al.,* 2018). Information on the variability and correlation studies among the economic characters of the crop

is of great value to plant breeders (Swetha *et al.,* 2019; Shedge *et al.,* 2019). It will not only, help to understand the desirable and undesirable relationship of economic characters but also help in assessing the scope of simultaneous improvement of two or more attributes (Shanmugam and kalaimagal, 2019; Sial *et al.,*2003).

Results and Discussion

Analysis of variance

The mean data for twenty five characters were subjected to analysis of variance for the design of experiment showed that the mean sum of squares due to genotypes were found significant for all the characters under study (Table 1) which indicates that considerable amount of variability is present among the genotypes. Hence there is ample scope for inclusion of promising genotypes in breeding program for yield and its components characters.

Genetic Variability:

A perusal of variability parameters reveled that wide range of genotypic variance was observed highest genetic variance was recorded for number of seeds per plant (525.27) followed by days to maturity (165.52), days to 50% flowering (149.62), biological yield (89.59), plant height (40.09), grain yield per plant (21.00), harvest index (20.59), hundred seeds weight (20.43) and chlorophyll index (21.53), (Table 2). whereas low estimates of genetic variability were observed for leaf area index at 55th day (0.04), number of primary branches (0.07), number of seeds per pod (0.07), canopy temperature at vegetative stage (0.30), canopy temperature at pod filling stage (0.59), leaf area index at 108th day, crude fiber (0.72), number of secondary branches (1.24), and phytic acid (1.46). Then moderate estimates of genetic variability were observed for trypsine inhibitor (13.76), Relative water content at 45th day (12.80), specific leaf weight at 110th day (8.81), Relative water content at 105th day (8.04), starch content (5.11), protein content (3.94) and specific leaf weight at 60th day (3.89). This indicates the influence of environment for the expression of most of the characters in present investigation.

Phenotypic variance was also high for number of seeds per plant (705.98) fallowed by days to maturity (166.10), days to 50% flowering (150.24), biological yield (101.75), plant height (43.54), harvest index (30.47), grain yield per plant (27.02), chlorophyll content (22.64) and hundred seeds weight (20.87). whereas low estimates of phenotypic variance were observed for number of primary branches (0.10), number of seeds per pod (0.10), canopy temperature at vegetative stage (0.61), canopy temperature at pod filling stage (1.01), leaf area index at 55th day (0.05), leaf area index at 108th day (0.6), crude fiber (0.7), number of secondary branches (1.63), and phyticacid (1.54). moderate estimates of phenotypic variance were observed for trypsine inhibitor (13.80), Relative water content at 45th day (16.51), specific leaf weight at 110thday(11.27), Relative water content at 105th day (9.98), starch content (5.40),protein content (4.25),and specific leaf weight at 60th day (5.59), (Table 2).

A wide range of phenotypic coefficient of variation (PCV) was observed for all the traits ranged from canopy temperature at vegetative stage (3.46) to biological yield (25.35). Higher magnitude of PCV were recorded for biological yield (25.35), hundred seeds weight (25.05), grain yield per plant (24.85), number of seeds per plant (22.35), number of seeds per pod (20.28), number of secondary branches (19.49), leaf area index at 55th day (19.23), crude fiber (19.01), leaf area index at 108th day (18.00), low magnitude of PCV were recorded for canopy temperature at pod filling and vegetative stage (2.67) (2.40), relative water content at 45th and 105th day (4.67),(3.97), specific leaf weight at 60th day (4.79) suggested for a limited scope of selection for improvement of these trait, (Table 2).

A wide range of genotypic coefficient of variation (GCV) was observed for all the traits ranged from canopy temperature at vegetative stage (2.40) to hundred seeds weight (24.78). Higher magnitude of GCV were recorded for hundred seeds weight (24.78), biological yield (23.79), grain yield per plant (21.92), moderate for number of seeds per plant (19.27), number of seeds per pod (17.60) crude fiber (18.60), number of secondary branches (17.0) and leaf area index at 55th day (16.92), low magnitude of GCV were recorded for canopy temperature at pod filling and vegetative stage (3.48) (3.46), relative water content at 45th and 105th day (5.31) (4.42), specific leaf weight at 60th day (5.74) (Table 2).

Table 1: Analysis of variance for different characters in chickpea

SN	Characters/ traits.	Mean Suma of Squares.		
		Replication (df =02)	Treatments (df = 24)	Error (df = 48)
01	Days to 50% Flowering	7.85	450.72**	1.87
02	Days to Maturity	16.69	498.30*	1.74
03	Plant height	0.14	0.29**	0.10
04	Number of primary branches/plant	0.26	4.90**	1.17
05	Number of secondary branches/plant	4.72	130.62**	10.34
06	Number of seeds/plant	49.21	2117.95**	542.13
07	Number of pods per plant	0.00	0.29**	0.07
08	Hundred seed weight	1.08	62.61**	1.32
09	Grain yield per plant	43.46	81.05**	18.03
10	Biological yield per plant	74.19	305.25**	36.48
11	Harvest index	9.56	91.42**	29.64
12	Chlorophyll index	4.24	67.92**	3.33
13	CT @ Vegetative stage	0.14	1.84**	0.96
14	CT @Pod filling stage	0.23	3.03**	1.24
15	Leaf Area Index @ 55^{th} day	0.04	0.14**	0.03
16	Leaf Area Index @ 108^{th} day	0.01	0.48**	0.07
17	Specific Leaf Weight @ 60^{th} day	6.42	16.76**	5.08
18	Specific Leaf Weight @110^{th} day	6.14	33.80**	7.36
19	Relative water Content @ 45^{th} day	4.16	49.54**	11.14
20	Relative Water Content @ 105^{th} day	21.28	29.95**	5.83
21	Protein content	8.50	1.47**	0.62
22	Starch content	10.79	0.05**	0.56
23	Crude fiber	1.51	0.21**	0.06
24	Trypsin inhibitor	27.60	6.73**	0.09
25	Phytic acid	3.07	3.35**	0.16

***&** Significant at P<0.05 and P<0.01, respectively**

Heritability estimates ranged from 48.2 to 99.7, heritability was high for Days to maturity (99.7), trypsine inhibitor (99.7), followed by Days to 50% flowering (99.6), Hundred seed weight (97.9), crude fiber (95.8), chlorophyll index (95.1), phytic acid (94.9), starch content (94.8), protein content (92.7), plant height (92.1), biological yield (88.1), leaf area index at108^{th} day (85.0), Relative water content (80.5), specific leaf weight at 110^{th} day (78.2), grain yield per plant (77.8), Relative water content at 45^{th} day (77.5), leaf area index at 55^{th} day (77.4), number of secondary branches (76.2), number of seeds per pod (75.3), number of seeds per plant (74.4), specific leaf weight at 60^{th} day (69.7), Harvest index (67.6), number of primary branches (67.1), canopy temperature at both vegetative & pod filling stage (58.9 &48.2), Higher values for heritability indicates that it may be due to higher contribution of genotypic components, (Table 2). The Characters with high heritability approximate manifest that contrast in these characters mainly control by heritable constituent, considering that both genetics and environment take part analogous bit part in the pronouncement of characters with quite soaring heritability stipulate that the pronouncement of the character was largely affect by environment more willingly than genetic. character with lofty heritability approximate in broad sense can be employ for genetic refinement as they are least form by the environmental sequel and thus possess a possible for huge genetic resolution (Figure 1). Genetic advance varied from 0.3 (leaf area index at 55^{th} day) to 26.5 (days to maturity). The maximum genetic advance for days to maturity (26.5) followed by days to 50%.

Table 2: Estimation of genetic parameters for twenty five characters in twenty five genotypes

SN	Traite	Genotypic variance $\sigma^2 g$	Phenotypic variance $\sigma^2 p$	GCV	PCV	Heritability h^2	Genetic advance (GA)	GA as % of mean
1	Days to 50% flowering	149.62	150.24	15.32	15.35	99.6	25.1	31.5
2	Days to maturity	165.52	166.10	10.54	10.56	99.7	26.5	21.7
3	Number of primary branches	0.07	0.10	9.90	12.90	67.1	0.4	16.7
4	Number of secondary branches	1.24	1.63	17.0	19.49	76.2	2.0	30.6
5	Plant height	40.09	43.54	13.98	14.57	92.1	12.5	27.6
6	Number of seed per plant	525.27	705.98	19.27	22.35	74.4	40.7	34.2
7	Number of seeds per pod	0.07	0.10	17.60	20.28	75.3	0.5	31.5
8	Hundred seed weight	20.43	20.87	24.78	25.05	97.9	9.2	50.5
9	Grain yield per plant	21.00	27.02	21.92	24.85	77.8	8.3	39.8
10	Biological yield	89.59	101.75	23.79	25.35	88.1	18.3	46.0
11	Harvest index	20.59	30.47	8.61	10.48	67.6	7.7	14.6
12	Chlorophyll index	21.53	22.64	11.01	11.29	95.1	9.3	22.1
13	Canopy temperature – vegetative stage	0.30	0.61	2.40	3.46	48.2	0.8	3.4
14	Canopy temperature – pod filling stage	0.59	1.01	2.67	3.48	58.9	1.2	4.2
15	Leaf area index at 55th day	0.04	0.05	16.92	19.23	77.4	0.3	30.7
16	Leaf area index at108th day	0.13	0.6	16.59	18.00	85.00	0.7	31.5
17	Specific leaf weight at 60th day	3.89	5.59	4.79	5.74	69.7	3.4	8.2
18	Specific leaf weight at 110th day	8.81	11.27	7.17	8.10	78.2	5.4	13.1
19	Relative water content at 45th day	12.8	16.51	4.67	5.31	77.5	6.5	8.5
20	Relative water content at 105th day	8.04	9.98	3.97	4.42	80.5	5.2	7.3
21	Protein content	3.94	4.25	9.36	9.72	92.7	3.9	18.6
22	Starch content	5.11	5.40	6.14	6.31	94.8	4.5	12.3
23	Crude fiber	0.72	0.76	18.6	19.01	95.8	1.7	37.5
24	Trypsine inhibitor	13.76	13.80	15.6	15.62	99.7	7.6	32.1
25	Phytic acid	1.46	1.54	10.78	11.06	94.9	2.4	21.6

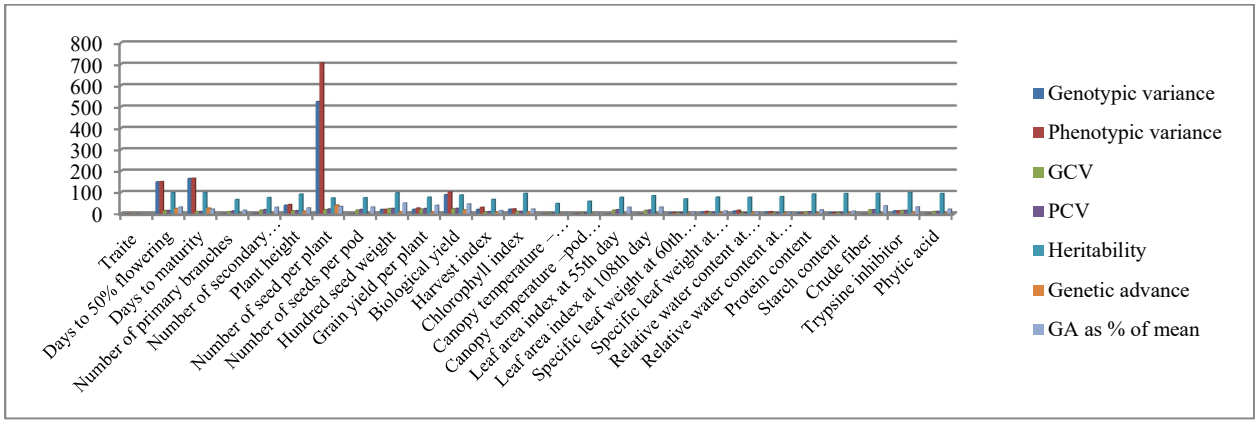

Figure 1: Histogram depicting estimates of genetic parameters for 25 traits in chickpea

Table 3: Genotypic Correlation among different traits in chickpea evaluated under field & laboratory conditions

Traits	*DF50*	*DM*	*NPB*	*NSB*	*PH*	*NSP*	*NSPod*	*HSW*	*BM*	*HI*	*CHI*	*CTD_VS*	*CTD_PS*	*LAI_55*	*LAI_108*	*SLW_60*	*SLW_110*	*RWC_45*	*RWC_105*	*Protein*	*Starch*	*Fibre*	*TI*	*PA*	*GYPP*
DF50	1																								
DM	0.98**	1																							
NPB	0.30	0.34	1																						
NSB	-0.05	0.04	0.66**	1																					
PH	0.71**	0.63**	0.32	-0.21	1																				
NSP	0.36	0.38	-0.05	0.20	-0.06	1																			
NSPod	0.19	0.14	-0.04	-0.14	0.12	0.19	1																		
HSW	0.11	0.08	0.19	-0.15	0.28	-0.14	-0.40*	1																	
BM	0.37	0.40*	-0.20	0.26	0.20	0.57**	-0.22	0.02	1																
HI	0.68**	0.67**	0.62**	-0.07	0.55**	0.14	0.27	0.11	-0.22	1															
CHI	0.74**	0.75**	0.24	0.06	0.43*	0.50*	0.31	-0.30	0.42*	0.57**	1														
CTD_VS	-0.11	-0.06	0.20	0.32	0.00	-0.28	0.13	0.20	-0.48*	0.35	-0.47*	1													
CTD_PS	0.09	0.09	0.29	0.27	0.24	0.49*	-0.18	0.00	0.23	0.31	0.22	-0.19	1												
LAI_55	0.08	0.06	-0.11	0.40*	-0.15	0.33	-0.12	-0.12	0.33	-0.01	0.30	-0.21	0.17	1											
LAI_108	0.01	0.01	-0.05	0.36	-0.14	0.19	0.13	0.06	0.24	-0.13	-0.08	-0.11	-0.04	0.75**	1										
SLW_60	0.32	0.24	-0.09	-0.23	0.45*	-0.44*	-0.47*	0.58**	-0.05	-0.10	-0.02	-0.22	-0.22	0.49*	0.11	1									
SLW_110	0.20	0.13	-0.01	-0.40*	0.54**	-0.03	-0.20	0.01	-0.21	0.38	0.12	-0.49*	0.16	-0.35	-0.62**	0.22	1								
RWC_45	0.06	0.01	-0.22	0.10	0.19	0.18	0.01	0.40*	0.21	-0.18	0.04	0.14	0.31	0.35	0.31	0.57**	-0.08	1							
RWC_105	0.24	0.24	0.02	0.09	0.02	-0.10	0.46*	0.12	0.00	0.16	0.36	0.19	0.15	0.19	0.04	0.14	-0.48*	0.46*	1						
Protein	-0.27	-0.26	0.28	-0.04	-0.19	-0.08	-0.42*	-0.08	-0.26	-0.20	0.02	-0.43*	-0.86**	-0.16	-0.17	-0.33	-0.20	-0.51**	-0.63**	1					
Starch	0.61**	0.61**	0.41*	0.61**	0.08	0.55**	-0.44*	0.01	0.47*	0.14	0.70**	-0.03	0.14	0.26	0.10	0.12	-0.04	0.17	0.27	-0.20	1				
Fibre	-0.23	-0.29	-0.18	0.00	-0.15	-0.01	-0.03	-0.34	-0.38	-0.21	0.18	-0.25	0.29	0.15	0.02	0.09	0.30	0.22	0.05	0.28	-0.27	1			
TI	-0.02	0.01	0.03	-0.02	-0.29	0.19	0.14	-0.44*	-0.30	0.16	0.22	0.17	0.33	-0.13	0.00	-0.37	-0.34	-0.06	0.38	-0.14	-0.17	0.29	1		
PA	0.08	0.07	0.08	0.27	-0.04	0.45*	0.14	-0.06	0.18	0.12	0.32	-0.29	0.31	-0.03	-0.16	-0.15	0.16	0.26	0.32	0.12	0.15	0.33	-0.18	1	
GYPP	0.60**	0.62**	-0.01	0.21	0.41*	0.67**	-0.11	0.06	0.93**	0.14	0.65**	-0.35	0.40*	0.37	0.21	-0.07	-0.04	0.18	0.04	-0.29	0.55**	-0.40*	-0.21	0.28	1

***&** Significant at P<0.05 and P<0.01, respectively**

.DF50: Days to 50% flowering, DM: Days to maturity, PH: Plant height, NPB: No. of primary branch, NSB: No. of secondary branch, NSP: No. of seeds per plant, NSPod: No. of seeds per pod, HSW: 100 seed weight, GYPP: Grain yield per plant, BM: Biomass, HI: Harvest index, CHI: Chlorophyll index, CTD_VS: Canopy temperature depression at vegetative stage, CTD_PS: Canopy temperature depression at pod filling stage, LAI_55: Leaf area index at 55 days, LAI_108: Leaf area index at 108 days, SLW_60: Specific leaf weight at 60 days, SLW_110: Specific leaf weight at 110 days, RWC_45: Relative water content at 45 days, RWC_105: Relative water content at 105 days, TI: Trypsine Inhibitor, PA: Phytic acid content

Table 4: Phenotypic Correlation among different traits in chickpea evaluated under field & laboratory conditions

Traits	*DF50*	*DM*	*NPB*	*NSB*	*PH*	*NSP*	*NSPod*	*HSW*	*BM*	*HI*	*CHI*	*CTD_VS*	*CTD_PS*	*LAI_55*	*LAI_108*	*SLW_60*	*SLW_110*	*RWC_45*	*RWC_105*	*Protein*	*Starch*	*Fibre*	*TI*	*PA*	*GYPP*
DF50	1																								
DM	0.98**	1																							
NPB	0.26	0.29	1																						
NSB	-0.05	0.04	0.57**	1																					
PH	0.67**	0.60**	0.24	-0.20	1																				
NSP	0.32	0.33	0.02	0.19	-0.05	1																			
NSPod	0.12	0.10	-0.04	-0.11	0.09	0.13	1																		
HSW	0.13	0.08	0.16	-0.12	0.28	-0.13	-0.31	1																	
BM	0.36	0.39	-0.06	0.28	0.19	0.55**	-0.16	0.02	1																
HI	0.54**	0.56**	0.44*	0.00	0.44*	0.18	0.12	0.12	-0.15	1															
CHI	0.72**	0.73**	0.21	0.04	0.40*	0.43*	0.19	-0.27	0.41*	0.46*	1														
CTD_VS	-0.08	-0.04	0.20	0.18	-0.03	-0.13	0.12	0.14	-0.24	0.10	-0.32	1													
CTD_PS	0.10	0.09	0.16	0.25	0.19	0.41*	-0.07	-0.02	0.20	0.26	0.22	0.00	1												
LAI_55	0.02	0.03	-0.15	0.27	-0.18	0.27	-0.22	-0.08	0.30	-0.05	0.19	-0.18	0.15	1											
LAI_108	-0.05	-0.01	-0.01	0.27	-0.19	0.17	0.02	0.10	0.24	-0.12	-0.13	-0.11	-0.01	0.51**	1										
SLW_60	0.30	0.22	0.02	-0.11	0.39	-0.25	-0.32	0.45*	-0.01	-0.02	0.03	-0.05	-0.10	0.43*	0.17	1									
SLW_110	0.19	0.12	-0.04	-0.32	0.47*	0.01	-0.12	-0.02	-0.18	0.30	0.13	-0.26	0.13	-0.20	-0.45*	0.18	1								
RWC_45	0.05	0.01	-0.20	0.10	0.15	0.13	0.00	0.35	0.14	-0.10	0.02	0.08	0.28	0.33	0.23	0.40*	-0.07	1							
RWC_105	0.20	0.22	0.04	0.11	-0.01	-0.07	0.32	0.12	0.02	0.15	0.31	0.08	0.15	0.12	0.00	0.17	-0.32	0.36	1						
Protein	-0.27	-0.24	-0.08	-0.16	-0.18	-0.10	-0.25	-0.12	-0.21	0.10	-0.08	-0.15	-0.39	0.10	-0.23	-0.17	0.12	-0.35	-0.45*	1					
Starch	0.52**	0.59**	0.30	0.38	0.08	0.31	-0.34	0.03	0.49**	0.15	0.49**	0.03	0.07	0.26	-0.06	0.19	0.06	0.01	0.10	-0.18	1				
Fibre	-0.26	-0.30	-0.29	-0.15	-0.06	-0.16	0.05	-0.32	-0.35	0.07	0.11	-0.26	0.27	0.38	-0.14	0.07	0.27	0.20	0.08	0.27	-0.27	1			
TI	-0.03	0.00	0.01	-0.09	-0.18	-0.10	0.34	-0.42*	-0.27	0.20	0.20	0.20	0.26	-0.01	-0.08	-0.38	-0.36	-0.15	0.29	-0.14	-0.15	0.29	1		
PA	0.08	0.06	-0.05	0.12	0.02	0.28	0.19	-0.11	0.17	0.20	0.29	-0.22	0.17	0.23	-0.18	-0.09	0.31	0.16	0.20	0.10	0.18	0.33	-0.20	1	
GYPP	0.53**	0.56**	0.11	0.26	0.36	0.63**	-0.11	0.06	0.91**	0.26	0.59**	-0.18	0.34	0.29	0.19	-0.01	-0.03	0.12	0.06	-0.18	0.51**	-0.30	-0.18	0.24	1

***&** Significant at P<0.05 and P<0.01, respectively**

DF50: Days to 50% flowering, DM: Days to maturity, PH: Plant height, NPB: No. of primary branch, NSB: No. of secondary branch, NSP: No. of seeds per plant, NSPod: No. of seeds per pod, HSW: 100 seed weight, GYPP: Grain yield per plant, BM: Biomass, HI: Harvest index, CHI: Chlorophyll index, CTD_VS: Canopy temperature depression at vegetative stage, CTD_PS: Canopy temperature depression at pod filling stage, LAI_55: Leaf area index at 55 days, LAI_108: Leaf area index at 108 days, SLW_60: Specific leaf weight at 60 days, SLW_110: Specific leaf weight at 110 days, RWC_45: Relative water content at 45 days, RWC_105: Relative water content at 105 days, TI: Trypsine Inhibitor, PA: Phytic acid content

Table 5: Direct (in bold) and indirect effects of 23 traits on grain yield in chickpea evaluated

	DF50	PH	NPB	NSB	NSP	NSPod	HSW	HI	CHI	CTD_VS	CTD_PS	LAI_55	LAI_108	SLW_60	SLW_110	RWC_45	RWC_105	Protein	Starch	Fibre	TI	PA	GYPP	Residual
DF50	**-0.815**	0.633	-0.171	-0.023	0.184	-0.067	0.034	0.113	0.523	0.003	-0.020	0.000	0.000	0.012	-0.027	-0.018	-0.010	0.063	0.022	0.095	-0.016	0.013	0.530	0.048
PH	-0.554	**0.932**	-0.157	-0.107	-0.023	-0.050	0.079	0.093	0.294	0.001	-0.041	0.000	-0.017	0.017	-0.067	-0.046	0.000	0.040	0.004	0.023	-0.059	0.000	0.360	0.048
NPB	-0.204	0.214	**-0.682**	0.321	0.012	0.017	0.049	0.088	0.143	-0.007	-0.039	0.000	-0.001	0.001	0.006	0.061	-0.002	0.018	0.012	0.111	0.003	-0.011	0.110	0.048
NSB	0.033	-0.177	-0.389	**0.563**	0.115	0.033	-0.037	0.002	0.036	-0.007	-0.059	-0.001	0.034	-0.005	0.049	-0.031	-0.005	0.036	0.016	0.057	-0.031	0.026	0.260	0.048
NSP	-0.261	-0.037	-0.014	0.113	**0.576**	-0.059	-0.043	0.037	0.308	0.004	-0.098	-0.001	0.022	-0.011	0.000	-0.043	0.003	0.022	0.013	0.061	-0.034	0.071	0.630	0.048
NSPod	-0.130	0.112	0.027	-0.045	0.081	**-0.419**	-0.101	0.033	0.179	-0.005	0.027	0.000	0.016	-0.016	0.021	-0.003	-0.015	0.058	-0.010	-0.015	0.087	0.029	-0.090	0.048
HSW	-0.090	0.242	-0.109	-0.068	-0.081	0.138	**0.305**	0.021	-0.208	-0.005	0.000	0.000	0.006	0.021	0.001	-0.107	-0.004	0.025	0.000	0.118	-0.124	-0.024	0.060	0.048
HI	-0.448	0.419	-0.293	0.006	0.104	-0.067	0.031	**0.206**	0.337	-0.004	-0.059	0.000	-0.009	-0.002	-0.043	0.028	-0.007	-0.020	0.007	-0.027	0.059	0.045	0.260	0.048
CHI	-0.595	0.382	-0.136	0.028	0.248	-0.105	-0.089	0.097	**0.716**	0.010	-0.046	-0.001	-0.007	0.000	-0.016	-0.006	-0.014	0.020	0.021	-0.042	0.053	0.063	0.580	0.048
CTD_VS	0.057	-0.019	-0.136	0.101	-0.069	-0.063	0.040	0.025	-0.208	**-0.036**	0.005	0.000	-0.009	-0.003	0.040	-0.024	-0.004	0.034	0.002	0.099	0.059	-0.061	-0.170	0.048
CTD_PS	-0.065	0.158	-0.109	0.135	0.230	0.046	0.000	0.049	0.136	0.001	**-0.244**	0.000	-0.006	-0.004	-0.021	-0.083	-0.006	0.085	0.002	-0.099	0.084	0.050	0.340	0.048
LAI_55	-0.057	-0.112	0.096	0.152	0.155	0.025	-0.034	0.002	0.179	0.005	-0.022	**-0.003**	0.069	0.016	0.033	-0.098	-0.007	-0.016	0.012	-0.133	-0.012	0.040	0.290	0.048
LAI_108	0.000	-0.130	0.007	0.158	0.104	-0.054	0.015	-0.014	-0.043	0.003	0.012	-0.002	**0.121**	0.005	0.067	-0.067	-0.002	0.054	0.000	0.050	-0.034	-0.058	0.190	0.048
SLW_60	-0.220	0.345	-0.014	-0.068	-0.144	0.146	0.141	-0.008	0.000	0.003	0.020	-0.001	0.015	**0.046**	-0.028	-0.122	-0.007	0.036	0.006	-0.027	-0.112	-0.016	-0.010	0.048
SLW_110	-0.147	0.419	0.027	-0.186	0.000	0.059	-0.003	0.060	0.079	0.010	-0.034	0.001	-0.055	0.009	**-0.150**	0.021	0.014	-0.029	0.002	-0.103	-0.109	0.085	-0.030	0.048
RWC_45	-0.049	0.140	0.136	0.056	0.081	-0.004	0.107	-0.019	0.014	-0.003	-0.066	-0.001	0.027	0.018	0.010	**-0.306**	-0.016	0.078	0.001	-0.076	-0.050	0.040	0.120	0.048
RWC_105	-0.179	0.009	-0.027	0.068	-0.035	-0.146	0.031	0.035	0.236	-0.004	-0.032	-0.001	0.006	0.007	0.049	-0.110	**-0.043**	0.103	0.005	-0.030	0.084	0.045	0.070	0.048
Protein	0.228	-0.168	0.055	-0.090	-0.058	0.109	-0.034	0.019	-0.064	0.005	0.093	0.000	-0.029	-0.007	-0.019	0.107	0.020	**-0.224**	-0.008	-0.103	-0.040	0.029	-0.180	0.048
Starch	-0.440	0.093	-0.198	0.220	0.184	0.100	0.003	0.035	0.365	-0.002	-0.010	-0.001	0.000	0.007	-0.006	-0.006	-0.005	0.043	**0.040**	0.103	-0.053	0.037	0.510	0.048
Fibre	0.204	-0.056	0.198	-0.084	-0.092	-0.017	-0.095	0.014	0.079	0.009	-0.063	-0.001	-0.016	0.003	-0.040	-0.061	-0.003	-0.060	-0.011	**-0.381**	0.090	0.085	-0.300	0.048
TI	0.041	-0.177	-0.007	-0.056	-0.063	-0.117	-0.122	0.039	0.122	-0.007	-0.066	0.000	-0.013	-0.016	0.052	0.049	-0.012	0.029	-0.007	-0.111	**0.310**	-0.048	-0.180	0.048
PA	-0.041	0.000	0.027	0.056	0.155	-0.046	-0.027	0.035	0.172	0.008	-0.046	0.000	-0.027	-0.003	-0.048	-0.046	-0.007	-0.025	0.006	-0.122	-0.056	**0.264**	0.230	0.048

Residual effect: 0.048 , DF50: Days to 50% flowering, PH: Plant height, NPB: No. of primary branch, NSP: No. of seeds per plant, NSPod: No. of seeds per pod, HSW: 100 seed weight, GYPP: Grain yield per plant, HI: Harvest index, CHI: Chlorophyll index, CTD_VS: Canopy temperature depression at vegetative stage, CTD_PS: Canopy temperature depression at pod filling stage, LAI_55: Leaf area index at 55 days, LAI_108: Leaf area index at 108 days, SLW_60: Specific leaf weight at 60 days, SLW_110: Specific leaf weight at 110 days, RWC_45: Relative water content at 45 days, RWC_105: Relative water content at 105 days, TI: Trypsine Inhibitor, PA: Phytic acid content

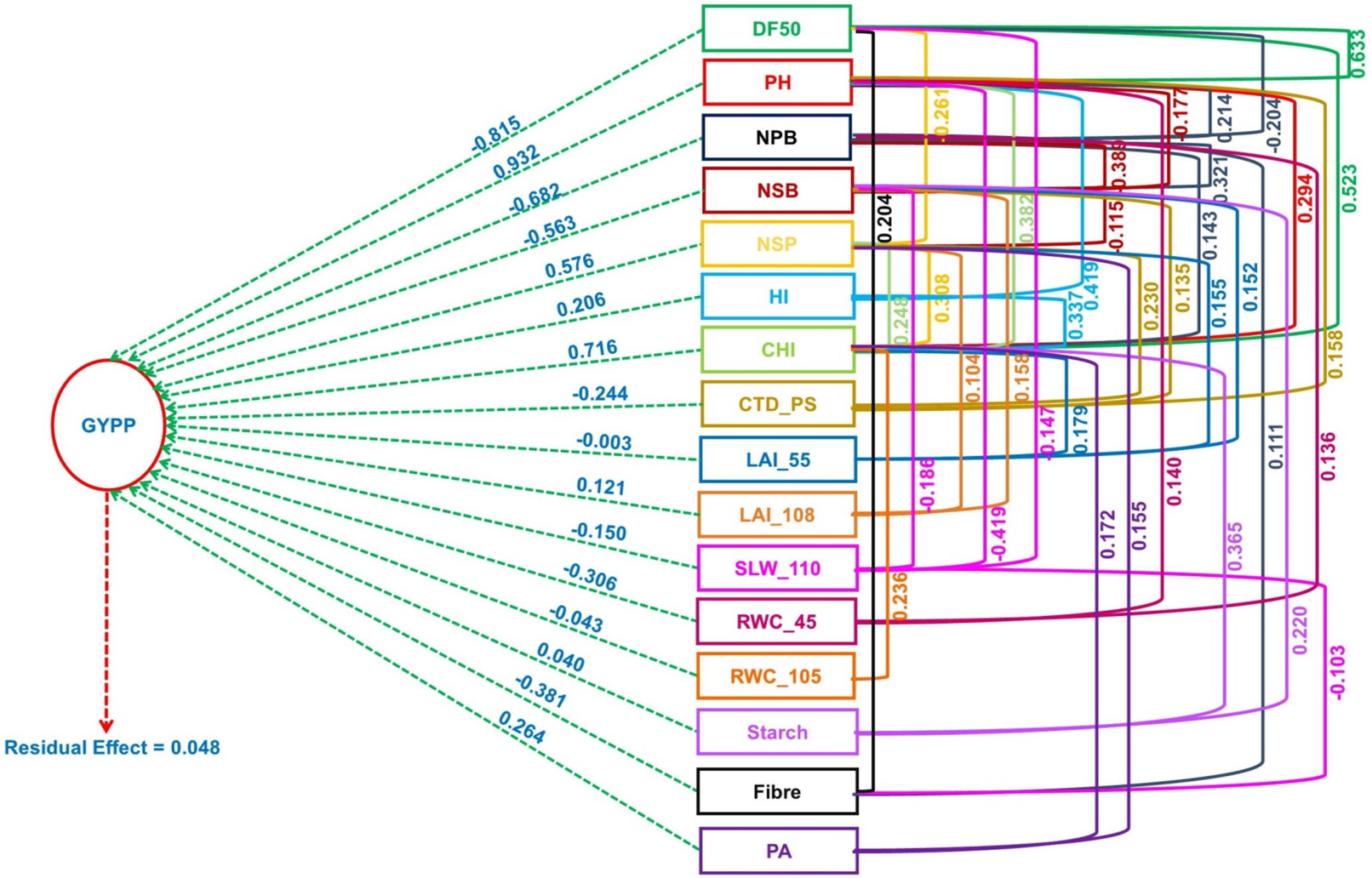

Figure 2: Phenotypic path diagram for seed yield per plant

Residual effect: 0.048 ,

DF50: Days to 50% flowering, PH: Plant height, NPB: No. of primary branch, NSP: No. of seeds per plant, GYPP: Grain yield per plant, HI: Harvest index, CHI: Chlorophyll index, , CTD_PS: Canopy temperature depression at pod filling stage, LAI_55: Leaf area index at 55 days, LAI_108: Leaf area index at 108 days, , SLW_110: Specific leaf weight at 110 days, RWC_45: Relative water content at 45 days, RWC_105: Relative water content at 105 days, TI: Trypsine Inhibitor, PA: Phytic acid content, SC: starch content, CF: crude fiber

flowering (25.1), biological yield (18.3), plant height (12.5), (Table 2). Genetic advance as per percent of mean varied from 8.2 (specific leaf weight at 60th day) to 50.5% (hundred seed weight) . Genetic advance as per percent of mean was high for Hundred seed weight (50.5), biological yield (46.0), grain yield per plant (39.8), crude fiber (37.5), number of seeds per plant (34.2), and moderate for trypsine inhibitor (32.1), days to 50% flowering (31.5), number of secondary branches (30.6)plant height (27.6), chlorophyll index (22.1), than lower for Relative water content at 45th day (8.5), specific leaf weight at 60th day (8.2), Relative water content at 105th day (7.3), canopy temperature at vegetative and pod filling stage (4.2 &3.4) (Table 2).

Correlation coefficient analysis:

The present study in genotypic correlation grain yield per plant showed high significant and positive association with biological yield (0.93**), days to 50% flowering (0.60**), days to maturity (0.62**), number of seeds per plant (0.67**), chlorophyll index (0.65**), starch content (0.55**), Plant height (0.41*), and canopy temperature at pod filling stage (0.40*). It also showed positive but non-significant association with leaf area index at 55th day (0.37), phytic acid (0.28), number of secondary branches (0.21), leaf area index at 108th day (0.21), relative water content at 45th day (0.18), harvest index (0.14), hundred seed weight (0.06), and relative water content at 105th day (0.04), (Table 3). In phenotypic correlation grain yield per plant exhibited positive and significant association with biological yield (0.91**), number of seeds per plant (0.63**), days to maturity (0.56**), days to 50% flowering (0.53**), chlorophyll index (0.59**), and starch content (0.51**). It also showed positive and non-significant association with number of primary branches (0.11), number of secondary branches (0.26), plant height (0.36), hundred seed weight (0.06), harvest index (0.26), canopy temperature at pod filling stage (0.34), leaf area index at 55th and 108th day (0.29) (0.19), relative water content at 45th and 105th day (0.12) (0.06), and phytic acid (0.24) (Table 4).

Path coefficient analysis

The highest direct and positive effect on seed yield was exhibited by Hundred seed weight (0.305), Harvest index (0.206), Chlorophyll content (0.716), Leaf area index at 108th day (0.121), Specific leaf weight at 60th day (0.046), Starch content (0.040), Trypsin inhibitor (0.310), Phytic acid (0.264), Number of seeds per plant (0.576), Number of secondary branches (0.563), Plant height (0.932), The negative direct effect on seed yield was exhibited by Days to 50% flowering (-0.815), Number of primary branches (-0.682), Number of seeds per pod (-0.419), Canopy temperature at vegetative and pod filling stage (-0.036) (-0.244), Leaf area index at 55th day (-0.003), Specific leaf weight at 110th day (-0.150), Relative water content at 45th day and 105th day (-0.306) (-0.043), Protein content (-0.224), Crude fiber (-0.381).Thus these characters turned out to be the major component of seed yield (Table 5 & Figure 1).

Conclusion

It is concluded from the present study that all the 25 genotypes of chickpea showed significant differences. Genotypes C-18106, C-18122, C-18103, and C-18101 showed better performance for seed yield, C-18123, ICC-15896, C-18102 and GPF-02 showed pod borer resistance. Biological yield, Harvest index, Hundred seed weight, Leaf area index at 108th day , Specific leaf weight at 60th day , Starch content, Trypsin inhibitor, Phytic acid number of seeds per plant and chlorophyll index have positive significant correlation and direct effect on seed yield, the genotypes with these characters can be used for further improvement and development of chickpea.

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