Assessment of genetic variability and character association in chickpea (*Cicer arietinum* L.) diverse genotypes for yield and its component traits.

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Abstract:

The present investigation was undertaken to evaluate genetic variability, mean performance, and genetic parameters for yield and its component traits in chickpea using sixteen parental genotypes and their fourteen F_1 crosses. Analysis of variance revealed highly significant differences among genotypes for all thirteen characters studied, indicating the presence of substantial genetic variability and scope for selection. Significant variation was observed for phenological, growth, and yield-attributing traits, confirming the reliability of the experimental material for genetic improvement.

Mean performance analysis of parental genotypes showed wide variability for key traits, with early maturity in AAUC-3 and superior yield performance in Vaibhav. Yield-contributing traits such as number of pods per plant, number of seeds per plant, and hundred seed weight exhibited considerable variation, highlighting their importance in yield improvement. The F_1 hybrids generally outperformed the parental means for several traits, particularly number of pods per plant and seed yield per plant, indicating the presence of heterotic effects. Notably, the cross DPC 92-3 × BGD 72 exhibited superior performance for multiple traits including pods per plant, seed yield, biological yield, and hundred seed weight, demonstrating strong heterotic potential.

Estimates of genetic parameters revealed that phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all traits, suggesting some environmental influence; however, the narrow differences for several traits indicated substantial genetic control. High heritability coupled with high genetic advance was observed for seed yield per plant and biological yield per plant, indicating the predominance of additive gene action and effectiveness of direct selection. Moderate heritability and genetic advance were recorded for traits such as number of pods per plant and hundred seed weight, while low heritability for seeds per pod and number of seeds per plant suggested limited response to direct selection.

Overall, the study identified seed yield per plant, biological yield, number of pods per plant, and hundred seed weight as key traits for selection. The superior performance of specific crosses, particularly DPC 92-3 × BGD 72, highlights their potential for further exploitation in breeding programs aimed at developing high-yielding and stable chickpea varieties.

Key Words: Chickpea, Seed Yield, GCV, PCV, Correlation

Introduction:

Among pulse crops, chickpea (*Cicer arietinum* L.) commonly known as Bengal gram or garbanzo bean is one of the most important food legumes. It ranks first in area and production among pulses in India and accounts for nearly 70% of the country's pulse output. India contributes about 65–70% of the global chickpea production (FAOSTAT, 2023). The crop is cultivated on around 10–11 million hectares with a production exceeding 13 million tonnes and an average productivity of about 1.2 t ha^{-1} in recent years. Madhya Pradesh is the leading chickpea-producing state, contributing more than 40% of the national production. Chickpea is a diploid (2n = 16), self-pollinated legume belonging to the family Fabaceae and is believed to have originated in South-West Asia. It is widely adapted to tropical, subtropical, and temperate regions, particularly the semi-arid tropics (**Muehlbauer and Singh 1987)**.

Chickpea seeds are rich in protein (17–26%), carbohydrates (50–70%), fats (3–10%), and essential minerals such as calcium and iron, making it an affordable source of nutrition for low-income populations. Despite India being the largest producer, the productivity of chickpea remains relatively low compared to several other chickpea-growing countries. Nearly 85–90% of the crop is cultivated under rainfed conditions on receding soil moisture, making it highly vulnerable to drought, heat, salinity, and other abiotic stresses. Biotic stresses such as dry root rot and pod borer further aggravate yield losses. It has been reported that abiotic stresses alone account for yield losses exceeding 6 million tonnes globally (Sarode *et al*., 2022), with drought causing up to 40–50% reduction in yield (Ali Qurban *et al*., 2010).

Enhancing seed yield and stability under such constraints requires systematic genetic improvement. The success of any breeding programme largely depends on the magnitude of genetic variability and gene action controlling the yield attributing trait present in the breeding material. Knowledge of heritability, genetic advance, correlation, gene action and heterosis is essential for effective selection and hybrid development. Since yield is a complex trait

influenced by multiple interrelated components, assessment of genetic variability and heterotic response for seed yield and its attributing traits becomes imperative for identifying superior genotypes and promising cross combinations. Therefore, the present investigation was undertaken to evaluate the extent of genetic variability and heterosis for seed yield and its component traits in chickpea, aiming to provide a scientific basis for identifying high-yielding and stable genotypes suited to diverse agro-ecological conditions which could be utilized in active breeding program to develop high yielding and climate resilient cultivar.

Materials and Methods:

The present research work was carried out at the research farm of FASAI, Rama University, Mandhana, Kanpur during rabi 2025. Experimental material was collected from different research institute like ICAR-IIPR, Kanpur and CSAUAT, Kanpur. In current study 16 diverse genotypes and 14 crosses (Table 1.) made between selected genotypes after screening has been evaluated in randomized block design with three replications. All the recommended agronomic practices had been followed to raise the good crop. Data has been recorded 12 trait such as Days to flower initiation (DIF), Days to 50% flowering (DFF), Days to maturity (DTM), Plant height(cm) (PHT), Number of branches per plant (PB), Number of pods per plant (NPP), Number of seeds per plant (SPP), Number of seeds per pod (NSPP), Seed yield per plant (g) (SYPP), 100 – seed weight (g) (HSW), Biological Yield (g) (BYPP), Harvest Index (%) (HI %) by tagging five randomly selected competitive plants. Their mean value were calculated and compiled data were subjected to further statistical analysis.

Result and Discussion

Analysis of Variance:

The ANOVA table (Table 4.1) revealed highly significant differences among the 30 chickpea genotypes for all thirteen characters studied, as indicated by the significant (**) genotype mean squares for each trait. This clearly demonstrates the presence of substantial genetic variability in the experimental material. Phenological traits such as days to initial flowering (DIF), days to 50% flowering (DFF), and days to maturity (DTM) showed significant variation, indicating scope for selection of early and suitable duration genotypes (Barad *et al.*, 2018). Growth traits including plant height (PHT), primary branches (PB), and secondary branches (SB) also exhibited

highly significant differences, suggesting variability in plant architecture. Yield-attributing traits such as number of pods per plant (NPP), seeds per pod (SPP), number of seeds per plant (NSPP), and 100-seed weight (HSW) showed significant genotypic variation, reflecting strong genetic control and their usefulness in selection programmes (Bhoite *at al*., 2023). Further, seed yield per plant (SYPP), biological yield per plant (BYPP), and harvest index (HI) also recorded highly significant differences, confirming the availability of exploitable variability for yield improvement. Overall, the significantly higher genotype means squares compared to error mean squares for most traits indicate reliable experimental results and ample genetic diversity, which can be effectively utilized for selection and heterosis breeding to enhance seed yield and its component traits in chickpea.

Mean performance of Parental genotypes and its 14 different crosses:

The mean performance of parents and F_1 crosses for yield and its component traits in chickpea revealed considerable variability, indicating ample scope for selection and hybrid exploitation.

Mean Performance of Parents

Among the 16 parental genotypes, the overall mean for days to first initiation (DFI), days to 50% flowering (DFF) and days to maturity (DTM) was 45.88, 59.40 and 104.98 days, respectively. Earliness was observed in AAUC-3 (DTM: 97.33 days), while JG-6 was late maturing (114 days). Plant height ranged from 32 cm (DPC 92-3) to 62 cm (JG-6) with a mean of 45.82 cm. For yield contributing traits, number of pods per plant (NPP) showed wide variation (28–72; mean 45.90), with ICC 12614 recording the maximum (72 pods). Number of seeds per plant (NSPP) ranged from 38 to 108 (mean 60.69), the highest being in JG-14 (108). Seed yield per plant (SYPP) varied markedly from 12.89 g (JG-16) to 34.0 g (Vaibhav) with a mean of 20.83 g. Hundred seed weight (HSW) ranged from 17.5 g (ICC 12614) to 51 g (Vaibhav) with a mean of 33.82 g. biological yield per plant (BYPP) showed a broad range (20.5–92 g; mean 41.00 g), again highest in Vaibhav (Aung et al., 2023). Harvest index (HI) averaged 55%, with maximum value in AAUC-3 (75%). Higher coefficient of variation was observed for SYPP (44.28%), BYPP (47.41%) and SPP (31.38%), indicating substantial variability for these traits and their importance in yield improvement. Our finding is in close agreement with the finding of Baddar *et al*., 2012, Bhatnagar *et al*., 2006,)

Mean Performance of F_1 Crosses

The F_1 hybrids exhibited slightly higher mean DFI (48.86 days) and comparable DTM (104.07 days) compared to parents. Plant height averaged 50.22 cm, showing marginal increase over parents. For yield traits, mean NPP (56.28) and NSPP (62.94) in F_1s were higher than parental means, indicating possible heterotic effects. The cross DPC 92-3 × BGD 72 recorded the highest NPP (77), SYPP (45.5 g) and BYPP (90.8 g), substantially surpassing parental averages (Kumar *et al*., 2017, & Kumar *et* al., 2021). Similarly, JG-14 × JG-315 showed high NSPP (90) and SYPP (29 g). The maximum HSW (67 g) was also recorded in DPC 92-3 × BGD 72. Harvest index ranged from 37% to 80%, with the highest value in DPC 92-3 × IPC 78-151 (80%).. The mean seed yield per plant in F_1s was 22.23 g, slightly higher than parents (20.83 g), reflecting positive hybrid performance (Hussain A. 2027) High variability was observed for BYPP (CV 49.9%) and SYPP (44.4%), suggesting these traits are highly responsive to genetic recombination (Jeena *et al*., 2021).

The superior performance of certain crosses, particularly DPC 92-3 × BGD 72 for yield and its major components (NPP, SYPP, HSW, BYPP), indicates strong heterotic potential and suitability for further selection in segregating generations. Traits such as pods per plant, seeds per plant, hundred seed weight and biological yield emerged as major direct contributors to seed yield and should be emphasized in future breeding programs aimed at yield enhancement and stability in chickpea. Our finding is also in close agreement with the finding of Jagdish et al., 2009, Kulkarni et al., 2004 and Mali et al., 2007.

Estimates of genetic parameters of variability for 12 different traits among 16 genotypes and its 14 crosses:

The estimates of genetic parameters revealed considerable variability among parents and F_1s for yield and its component traits in chickpea in general, PCV values were higher than GCV for all traits, indicating environmental influence; however, the magnitude of difference was narrow for several key traits, suggesting substantial genetic control.

Among phenological traits, days to maturity (DTM) showed moderate GCV (14.34% in parents; 8.66% in F_1s) and moderate heritability (40.00% and 45.66%), indicating scope for selection. Plant height exhibited moderate variability in F_1s (GCV 14.65%; PCV 20.28%) but low heritability (14.21%), suggesting environmental influence (Kulkarni et al., 2004). Primary branches per plant (PBP) recorded high GCV (22.96% in parents;

18.86% in F_1s) coupled with moderate heritability (44.48% and 47.55%) and appreciable genetic advance as percent of mean (7.74% and 8.75%), indicating additive gene action and effectiveness of selection (Pithiya *et al*., 2019). Number of pods per plant (NPPP) showed higher variability in F_1s (GCV 22.76%) with moderate heritability (29.88%) and genetic advance (9.55%), highlighting its importance as a yield component (Munde at al., 2018). Seed yield per plant (SYPP) exhibited high GCV (20.43% in parents; 18.06% in F_1s), high heritability (68.18% and 65.44%) and very high genetic advance as percent of mean (53.10% and 55.77%). Similarly, biological yield per plant (BYPP) showed high heritability (61.40% in parents; 78.55% in F_1s) with high genetic advance (62.50% and 68.91%). Hundred seed weight (HSW) also recorded moderate to high heritability (40.80% and 49.71%) and substantial genetic advance (30.21% and 36.54%). In contrast, traits like seeds per pod (SPP) and number of seeds per plant (NSPP) showed low heritability, indicating greater environmental influence and limited response to direct selection (Ojha *et al*., 2023).

Overall, high heritability coupled with high genetic advance for SYPP and BYPP suggests predominance of additive gene effects, making these traits reliable selection criteria for yield improvement in chickpea breeding programs.

Summary and conclusion:

The present study in chickpea (*Cicer arietinum* L.) revealed significant genetic variability among 30 genotypes (16 parents and 14 F_1s) for all thirteen traits, as confirmed by highly significant ANOVA results, indicating strong scope for selection and hybrid utilization. Wide variation was observed for key yield traits such as pods per plant (28–72 in parents), seed yield per plant (12.89–34.0 g in parents; 22.23 g mean in F_1s), and hundred seed weight (17.5–51 g), with the cross DPC 92-3 × BGD 72 exhibiting superior performance (77 pods per plant, 45.5 g seed yield, 67 g test weight). Genetic parameter estimates showed higher PCV than GCV, but narrow differences for major traits suggested substantial genetic control; notably, seed yield per plant and biological yield per plant recorded high heritability coupled with high genetic advance, indicating predominance of additive gene action. Overall, traits such as pods per plant, seeds per plant, hundred seed weight, and biological yield emerged as reliable selection criteria, and the identified superior crosses can be effectively advanced in segregating

generations for developing high-yielding and stable chickpea varieties.

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Table 1. List of genotypes and cross utilized in experimental trial

S no.	Parents	S. no.	Crosses In F_1 and F_2 generation
1	DPC 92-3	**1**	DPC 92-3 × IPC 78-151
2	IPC 78-151	**2**	DPC 92-3 × Sadabahr
3	Sadabahr	**3**	DPC 92-3 × Radha
4	Radha	**4**	DPC 92-3 × Birsa Chana 03
5	Birsa Chana 03	**5**	DPC 92-3 × JG 11
6	JG 11	**6**	DPC 92-3 × BGD 72
7	BGD 72	**7**	IPC 78-151× Sadabahr
8	ICC 15614	**8**	IPC 78-151× Radha
9	Vaibhav	**9**	IPC 78-151 × Birsa Chana 03
10	ICC 12614	**10**	IPC 78-151× JG 11
11	IPC 18-137	**11**	IPC 78-151× BGD 72
12	JG 16	**12**	Sadabahr × Radha
13	AAUC-3	**13**	Sadabahr × Birsa Chana 03
14	ICC 15-161	**14**	Sadabahr × JG 11
15	JG-6		
16	JG-14		

Table-2: Analysis of variance for twelve characters in 30 genotypes of chickpea (*Cicer arietinum* L.) including crosses showing mean sum of squares.

S. No.	Character	Replication	Genotype	Error
		2	29	58
1	DIF	378.30	455.09**	149.87
2	DFF	67.22	37.94**	24.67
3	DTM	126.14	121.48**	56.10
4	PHT	125.10	245.45**	39.76
5	PB	26.15	19.56**	0.67
7	NPP	124.76	158.76**	66.71
8	SPP	0.08	2.33**	0.88
9	NSPP	4.56	1.88**	0.08
10	SYPP	2.67	8.73**	5.67
11	HSW (g)	0.55	58.77**	0.89
12	BYPP (g)	408.88	671.56**	157.34
13	HI (%)	37678.19	39763.84**	18765.77

* Significant at P = 0.05, **Significant at P = 0.01

Table 3.1: Genetic variability parameters estimate for various traits in chickpea

S. NO.	Characters	PARENTS				F1 CROSSES			
			Range				Range		
		Mean	Min.	Max.	CV %	Mean	Min.	Max.	CV %
1	DFI	45.68	40.8	49.8	8.8	48.37	41.8	53.8	9.8
2	DFF	59.19	54.8	64.8	6.8	60.08	50.8	66.8	10.7
3	DTM	104.77	97.13	113.8	5.8	102.94	99.8	109.8	4.6
4	PHT (cm)	45.61	31.8	61.8	20.8	48.77	34	54.3	15.4
5	PB	11.14	9	16.13	22.8	10.47	9	12.8	15.9
6	NPP	43.82	27.8	71.8	29.04	52.62	32.8	73.8	23.8
7	NSPP	60.49	37.8	107.8	31.5	60.96	32.8	86.8	32.14
8	SPP	3.27	2.81	4.13	31.05	3.17	2.81	4.1	33.18
9	SYPP (g)	20.63	12.69	33.8	33.8	19.86	12.91	28.8	34.06
10	HSW (g)	33.62	17.3	50.8	28.7	32.91	21.8	51.8	32
11	BY (g)	40.8	20.3	91.8	48.21	36.06	22.8	63.8	34.5
12	HI (%)	54.8	23.8	74.8	29.06	55.3	32.8	75.8	22.1

Table 3.2: Mean performance of yield and its components of 16 parental genotypes of chickpea

S.N.	Parents	DFI	DFF	DTM	PHT (cm)	PBP	NPP	NSPP	SPP	SYP(g)	HSW	BYPP(g)	HI (%)
1	DPC 92-3	42	55	104	32	9.4	37	57	3.57	22	34	32	68
2	IPC 78-151	45	58	102	38	10.6	39	52	3.35	26	40	46	56
3	Sadabahr	49	60	100	51.2	8.8	48	49	3.01	20.4	40	42	48
4	Radha	50	59	104	56.4	9.2	50	56	3.12	22.2	39	49	44
5	Birsa Chana 03	41	55	106	37	9	47	56	3.8	18.23	37	49	56
6	JG 11	45	58	107	43.2	10.3	30	38	3.16	14.8	46	36	39
7	BGD 72	46	64	109	52.2	11	46	46.9	3.02	14.6	30	37	24
8	ICC 15614	42	57	105	54.8	12.8	46	72	4.11	30	32	48	62
9	Vaibhav	49	65	106	50	11.6	64	67.28	3.01	34	51	92	37

10	ICC 12614	48	62	112	43.1	10.38	72	82	3.14	18.5	17.5	24	72
11	IPC 18-137	46	57	100	39	12.97	49	60	3.82	19	34	39	64
12	JG 16	50	62	105	50.6	11.8	40	49	3.23	12.89	23	21	59
13	AAUC-3	42	55.33	97.33	39.6	13.36	28	72	3.7	13.36	35.23	24.4	75
14	ICC 15-161	43	59	98.33	38	16.3	36.46	39.8	3.13	19	25.53	20.5	68
15	JG-6	46	64	114	62	11	46	66	4.33	20.65	30.9	32.04	65
16	JG-14	50	60	110	46	13	56	108	3.96	27.6	26	64	43
	AVG.	**45.88**	**59.40**	**104.98**	**45.82**	**11.34**	**45.90**	**60.69**	**3.47**	**20.83**	**33.82**	**41.00**	**55.00**
	S.D.	**3.75**	**5.19**	**2.87**	**6.34**	**1.22**	**11.02**	**17.96**	**0.43**	**8.53**	**10.78**	**16.43**	**10.91**
	VAR.	**14.06**	**26.93**	**8.23**	**40.19**	**1.48**	**121.44**	**322.56**	**0.18**	**72.76**	**116.2**	**269.9**	**119**
	C.V. (%)	**8**	**8.9**	**2.8**	**13.6**	**14.1**	**22**	**30.34**	**31.38**	**44.28**	**35**	**47.41**	**20.3**
	RANGE	**41**	**55**	**97.33**	**32**	**8.8**	**28**	**38**	**3.01**	**12.89**	**17.5**	**20.5**	**24**
		50	**65**	**114**	**62**	**16.3**	**72**	**108**	**4.33**	**34**	**51**	**92**	**75**

Table 3.3: Mean performance of yield and its components for 14 Fi crosses of chickpea

S. N	Crosses	DFI	DFF	DTM	PHT (cm)	PBP	NPP	NSPP	SPP	SYP(g)	HSW	BYPP (g)	HI (%)
1	DPC 92-3 × IPC 78-151	46	56	103	36	10	42	60	3.59	24	41	33.8	80
2	DPC 92-3 × Sadabahr	46	60	102	54.8	9.4	57	60	3.1	26	41	51	50
3	DPC 92-3 × Radha	42	50	101	40	9.8	38	39.4	3.03	18	50	34	44
4	DPC 92-3 × Birsa Chana 03	49	65	112	50.9	11	57	52.9	2.96	13.2	24	31	63
5	DPC 92-3 × JG 11	44	55	101	56.6	9	44	87	4	31	33	44	70
6	DPC 92-3 × BGD 72	45	51	108	57	14.1	77	82	3.43	45.5	67	90.8	58
7	IPC 78-151× Sadabahr	55	66	106	54.6	11.6	74	47	3.32	13.4	23	18.6	53
8	IPC 78-151× Radha	50	59	101	56.4	10	47	49	3.07	13.2	26	25	50
9	IPC 78-151 × Birsa Chana 03	53	66	105	48.6	12.4	70	44.27	3.03	12.9	24	19.8	57
10	IPC 78-151× JG 11	53	62	110	56.4	10.5	48.25	49.64	3.3	18.2	36	35.4	50

11	IG-593 × JG-474		46	54	104	51.6	12	48	80	4.1	24	38	31	70
12	IG-474 × ICCV10314		50	64	101	44.2	10	62	54	3.1	19.8	25	36	37
13	JG-6 × JG-315		52	62	100	45	10.6	66	86	4.27	23	29	32	57
14	JG-14 × JG-315		53	65	103	51	12.36	57.64	90	3.79	29	37	51.8	68
	AVG.		**48.86**	**59.64**	**104.07**	**50.22**	**10.91**	**56.28**	**62.94**	**3.44**	**22.23**	**35.29**	**38.16**	**57.64**
	S.D.		**4.04**	**5.57**	**3.71**	**6.67**	**1.42**	**12.31**	**18.02**	**0.44**	**9**	**12.22**	**18.06**	**11.61**
	VAR.		**16.32**	**31.02**	**13.76**	**44.48**	**1.96**	**151.53**	**324.7**	**0.19**	**81**	**149.3**	**326.1**	**134.79**
	C.V. (%)		**8.62**	**9.66**	**3.63**	**13.8**	**15.9**	**22.67**	**29.5**	**30.5**	**44.4**	**36.7**	**49.9**	**20..80**
	RANGE	**Min**	**42**	**50**	**100**	**36**	**9**	**38**	**39.4**	**2.96**	**12.9**	**23**	**18.6**	**37**
		Max	**55**	**66**	**112**	**57**	**14.1**	**77**	**90**	**4.27**	**45.5**	**67**	**90.8**	**80**

Table 4.2 Estimates of genetic parameters of variability in parent and its crosses for different traits in chickpea

S.N.	Characters	GCV (%)		PCV (%)		Heritability (bs %)		Genetic advance (GA)		GA % of mean	
		Parent	F1s	Parent	F1s	Parent	F1s	Parent	F1s	Parent	F1s
1.	**DFI**	2.85	3.97	5.32	4.1	13.84	15.66	0.53	1.22	1.13	1.67
2.	**DFF**	3.55	4.04	6.41	4.18	13.18	14.21	1.48	1.87	2.56	2.67
3.	**DTM**	14.34	8.66	18.61	11.9	40.00	45.66	3.04	4.51	2.97	2.92
4.	**PHT (cm)**	10.82	14.65	18.73	20.28	9.64	14.21	1.31	2.34	2.71	2.77
5.	**PBP**	22.96	18.86	19.86	20.38	44.48	47.55	0.69	0.89	7.74	8.75
6.	**NPPP**	9.55	22.76	15.96	24.97	19.85	29.88	4.81	5.67	8.86	9.55
7.	**SPP**	13.71	14.57	14.1	14.95	0.65	1.61	0.24	0.52	0.39	0.56
8.	**NSPP**	9.55	9.18	18.28	17.63	5.26	7.21	0.046	0.056	3.19	4.21
9.	**SYPP (g)**	20.43	18.06	19.91	24.61	68.18	65.44	10.75	15.67	53.10	55.77
10.	**HSW (g)**	18.33	13.08	26.5	22.47	40.80	49.71	10.06	14.32	30.21	36.54
11.	**BYPP (g)**	21.56	19.88	24.21	17.66	61.40	78.55	22.60	26.67	62.50	68.91
12.	**HI (%)**	24.31	20.98	27.65	25.42	11.70	17.88	2.62	4.41	4.70	5.42