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Assessment of genetic variability and character association between yield and yield-regulating traits in Bengal gram (*Cicer arietinum* L.)

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Abstract
Chickpea (*Cicer arietinum* L.) belongs to the subfamily Faboideae in the Papilionaceous family. It is an autogamous legume crop with chromosome number fourteen (2n=14). The main objective of breeders involved in crop improvement programs is to significantly increase grain yield. The present study was conducted in Rabi 2022 to evaluate genetic parameters, correlation coefficients and path coefficients. To study the association between yield and other components, 50 germplasm lines and five check were evaluated for nine quantitative traits. Small differences were found between the phenotypic and genotypic coefficients of variance, suggesting that trait expression is determined by genotype. High heritability and GAM were found for most of the characters studied. A significant and positive correlation with seed yield per plant was found for six traits: Plant height, number of primary branches, number of secondary branches, number of pods each plant, number of seeds each pod and 100-seed weight. Path coefficient analysis showed that number of pods per plant had a positive direct effect on seed yield per plant, followed by number of seeds per pod, 100-seed weight and plant height.

Keywords: Chickpea, genetic variability, heritability (bs), genetic advance (GAM), correlation coefficient, path analysis

Introduction
Chickpea (*Cicer arietinum* L.) belongs to the genus Cicer, of the Fabaceae family. It is the most important crop in the world after dry bean and pea. They are also rich in protein, fiber and vitamins. Other names include chickpeas, Bengal chickpeas, chickpeas, and Egyptian pea. It requires a cool climate for early growth, with optimal temperatures ranging from 15 °C to 25 °C, and a warmer climate for maturation. In India, chickpeas are mostly growing in the states of Madhya Pradesh, Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, Andhra Pradesh, Karnataka, Chhattisgarh, and Bihar, which account for more than 95% of total production in India. The efficiency of any crop breeding programme is heavily dependant on the genetic variation of the population. Estimates of heritability are used to determine how varied a population is. The genetic gain from a selection can be calculated by combining heritability and genetic advancement. It is critical to understand how different attributes interact when breeding traits with low heritability and difficulties in assessment through either direct or indirect selection. It is a self-pollinated crop with a limited range of variation, but studies on chickpea have found significant genetic variation in the number of secondary branches per plant, number of pods per plant, biological yield per plant, seed yield per plant, harvest index, as well as the number of days to flowering, days to maturity, and number of pods per plant (Malik *et al.*, 2014) [15]. Understanding genetic diversity and correlations between germplasm characteristics assists in the selection and breeding of high-yielding, high-quality cultivars that increase productivity. These factors were considered when performing the current study, which used 55 different chickpea germplasm lines to assess the diversity, heritability, genetic progress, and interrelationships between yield and its component attributes. It also helped with the examination of genetic divergence among genotypes as well as the direct and indirect effects of specific quantitative traits.

Materials and Methods
The present investigation was conducted at GPB Field, College of Agriculture, Imphal (Manipur) with fifty-five chickpea genotypes, including five checks (BG-3043, KPG-59, GL-

13001 JG-36 and GNG-2207) in an augmented design during Rabi season 2022-2023. The augmented random block design (augmented design II) had five blocks and each block consisted of fifteen lines of 4m length, keeping row to row and plant to plant distances of 30 x 10 cm, respectively. Data were recorded for nine quantitative traits viz., days of 50% flowering, days to maturity, plant height (cm), number of primary branches, number of secondary branches, number of pods per plant, number of seeds per pod, 100-seed weight (g) and yield per plant (g). Ten competitive plants were choosen randomly for mean data for almost all traits except days to 50% flowering and days to maturity. In days to 50% flowering and days to maturity, observations were based on the plant population of each germplasm line.

The phenotypic and genotypic coefficients of variation (PCV and GCV) for each trait were calculated in accordance with Burton and Devane (1953) [4]. Heritability (h_{bs}) in the broad sense [h (bs)] as suggested by Allard's and each character's genetic advancement (GAM) was calculated in accordance with Burton and Devane (1953) [4] and Johnson *et al.* (1955) [11]. Correlation coefficient between characters were computed utilizing respective components of variance and co-variance by using formula suggested by Miller *et al.* (1958) [16]. Yield per plant was assumed to be a dependent variable (effect), which was influenced by all the other characters studied directly as well as indirectly through other characters. It was calculated using the method adopted by Dewey and Lu. 1959 [7].

Results and Discussion

In the ANOVA the mean sum of squares (Table 2.) due to germplasm lines was found significant for all characters studied viz., days of 50 percent flowering, days of maturity, plant height (cm), number of primary branches, number of secondary branches, number of pods per plant, number of seeds per pod, 100-seed weight (g) and yield per plant (g) at the both 5% and 1% levels of significance, suggesting the wide variability available in this material. Dehal *et al.*, (2016) [6] both reported similar results.

Genetic parameters for all nine quantitative traits are depicted in Table 3. The values of the phenotypic coefficient of variation (PCV) were greater than the genotypic coefficient of variation (GCV) for all of the traits under study. Higher phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values were observed for yield per plant and 100 seed weight, while high PCV and medium GCV were observed in the number of secondary branches and number of pods per plant. Similarly, moderate PCV and GCV were found in plant height, number of primary branches and number of seeds per pod, while low PCV and GCV were estimated in days of 50% flowering and days to maturity. PCV was found greater than GCV value for almost all studied traits but small difference observed, it indicates that the traits are less affected by environmental variations and trait expression was governed by its own genotypes. The findings presented here are consistent with those of Akhtar *et al.* (2011) [1], Ali *et al.* (2012) [2], Hagos *et al.* (2018) [8], Bhanu *et al*. (2017) [3] and Singh *et al.* (2018) [19].

Heritability was calculated in a broad sense for all nine quantitative traits under study. High heritability was found for all the study traits, including including yield per palnt (86.64%), days to maturity (82.54%), 100 seed weight (81.65%), plant height (80.09%), number of primary branches (79.94%), number of pods per plant (77.53%), number of seeds per pod (73.02%), days to 50% flowering (70.44%) and number of secondary branches (63.48%). In all studied traits, high heritability was observed, which shows heritable variation present in the studied traits. Ali *et al*. (2012) [2], Ton and Anlarsal (2017) [21] and Thakur *et al.* (2018) [20] all reported similar results.

Genetic advancement expressed as a percentage of the mean (GAM) was found to be high for all study characters, viz., yield per plant (56.56%), 100 seed weight (42.96%), number of primary branches (32.90%), number of secondary branches per plant (32.48%), number of pods per plant (32.38%), plant height (31.36%) and number of seeds per pod (22.43%), while moderate and low GAM were observed in the days of 50% flowering and days to maturity (8.54%), respectively.

High heritability and high genetic advance were observed for all characters except day to 50% flowering, which suggest the traits were governed by additive gene action. The present results are consistent with the findings of Hagos *et al.* (2018) [8] and Kumar *et al*. (2020) [14].

Correlation studies (Table 4.) help plant breeders in their selection by providing a better understanding of yield components. The present study in chickpea looked at the interrelationships between nine distinct characters as well as seed yield per plant. The independent variables number of seeds per pod (0.624**), pods per plant (0.543**), 100-seed weight (0.495**), secondary branches (r = 0.381**) and number of primary branches (r = 0.288*), were positively and significantly correlated with the dependent variable yield per plant at both 1% and 5% levels of significance. A positive and significant correlation between desirable traits is favourable to the plant breeder because it helps in the simultaneous improvement of both characters. Jeena *et al.* (2005) [9], Padmavathi *et al.* (2013) [17], Pandey *et al.* (2013) [18], and Dehal *et al.* (2016) [6] also reported the same results.

The number of pods per plant was positively and significantly correlated with number of secondary branches (0.757**), number of primary branches (0.511**) and plant height (0.303**). The results above clearly illustrate that these characteristics can be used to influence indirect selection for seed yield per plant in chickpea. Jivani and Yadavendra (1988) [10] also observed similar finding.

Path coefficient (Table 5.) analysis was performed to determine both the direct and indirect effects of various plant characteristics on seed yield per plant. It indicates that the association between these independent characters and seed yield results from either their direct influence on yield or their indirect influence by other component characters.

The maximum positive direct effect on seed yield per plant was shown by the number of seed per pods (0.583), followed by the number of pod per plant (0.576), 100 seed weight (0.518) and plant height (0.034) and Idris *et al.* (2018) [23] also found the same results. A negative direct effect on seed yield per plant was observed at its maximum in the number of secondary branches (-0.106), followed by number of primary branches (-0.086), days to maturity (-0.069) and days of 50% flowering (-0.005), a similarly negative impact finding by Dawane *et al.* (2020) [5] and Yadav *et al.* (2001) [22].

Table 1: Mean performance of 9 traits in 50 chickpea germplasm lines along with 5 checks

S.N.	LINES	DF	DM	PH	PB	SB	PP	SP	SW	PY
1	BG-3043	61.20	119.40	31.86	3.46	6.10	29.46	1.14	23.98	7.62
2	KPG-59	60.20	117.40	34.18	3.24	5.74	26.02	1.74	23.13	8.87
3	GL-13001	57.20	115.20	35.08	3.18	7.86	34.88	1.19	22.63	8.77
4	JG -36	56.0	114.60	34.18	3.54	8.04	35.76	1.23	13.98	5.15
5	GNG-2207	60.20	119.60	35.34	3.36	6.50	30.68	1.85	20.08	9.93
6	ICCX-130135	57.36	117.84	42.99	3.50	6.07	31.98	1.19	19.95	6.63
7	ICCX-130039	52.36	107.84	30.99	2.70	5.67	23.98	1.61	23.92	9.91
8	ICCX-130042	60.36	120.84	37.59	3.70	7.27	32.88	1.42	18.59	7.37
9	ICCX-130051	53.36	113.84	35.99	3.20	5.77	28.18	1.25	19.13	6.01
10	ICCX171028	57.56	111.44	30.81	2.84	4.99	23.14	1.05	13.93	2.75
11	ICCX171031	58.56	120.44	30.71	2.84	4.09	15.54	1.03	13.95	2.09
12	ICCX171044	54.56	106.44	36.61	3.54	8.09	26.94	1.04	17.28	3.97
13	ICCX171047	61.56	113.44	25.51	2.84	5.09	19.94	1.02	11.65	1.88
14	ICCX171050	68.56	123.44	26.51	2.04	4.19	15.24	1.14	20.45	2.56
15	ICCX171051	63.56	119.44	35.71	3.44	6.79	24.44	1.13	21.50	5.10
16	ICCX171056	58.56	115.44	32.11	3.24	6.09	25.24	1.08	13.91	3.06
17	ICCX171057	65.56	121.44	31.11	3.34	6.69	27.14	0.98	15.63	3.41
18	ICCX171065	60.56	114.44	29.91	2.04	4.19	14.74	1.10	14.47	1.89
19	ICCX181002	60.56	118.44	33.01	2.24	4.39	17.24	0.99	24.40	3.13
20	ICCX181004	66.96	122.84	51.37	3.42	8.81	35.14	1.04	30.69	9.46
21	ICCX181005	59.96	117.84	47.17	2.82	8.71	27.04	1.17	29.48	8.75
22	ICCX181026	69.96	123.84	44.57	3.32	7.91	35.24	1.49	17.18	10.05
23	ICCX181027	62.96	118.84	47.47	4.32	6.41	25.74	1.24	17.22	5.72
24	ICCX181028	56.96	103.84	46.17	3.92	6.91	28.54	1.09	21.14	6.89
25	ICCX181029	64.56	118.24	44.97	2.82	5.49	23.58	0.99	20.28	4.52
26	ICCX181030	64.56	115.24	38.07	2.62	3.49	18.78	1.44	18.56	4.74
27	ICCX181031	63.56	114.24	38.57	2.92	5.09	24.28	0.89	19.17	3.75
28	ICCX181033	55.96	103.84	38.17	5.02	6.41	33.94	1.06	22.56	8.04
29	ICCX181034	71.96	124.84	36.07	3.22	5.61	19.54	1.09	23.86	4.75
30	ICCX181035	66.56	118.64	43.17	3.94	7.15	31.56	0.91	20.76	5.84
31	ICCX181036	61.96	116.84	51.57	3.52	4.91	31.74	1.25	17.00	6.91
32	ICCX181037	61.96	115.84	49.97	3.12	5.01	24.04	1.25	18.50	5.61
33	ICCX181039	64.96	118.84	48.47	3.82	5.71	28.44	1.34	18.33	7.14
34	ICCX181073	66.56	121.64	41.97	3.44	4.75	27.46	1.09	20.85	6.27
35	ICCX181076	57.56	111.64	31.67	3.34	8.75	31.96	1.08	19.54	6.40
36	ICCX181077	60.56	114.64	35.07	2.94	6.75	31.16	1.11	19.91	6.50
37	ICCX181078	61.56	119.64	39.87	3.44	6.95	32.16	1.03	17.60	5.26
38	ICCX181079	69.56	124.64	25.07	3.54	2.95	18.56	0.95	19.77	2.42
39	ICCX181084	57.56	104.24	27.77	3.92	5.79	29.08	0.94	31.01	7.56
40	ICCX181086	63.56	118.64	33.37	3.54	8.45	30.06	1.53	16.63	7.60
41	ICCX181093	58.56	115.64	34.27	4.04	4.25	25.26	1.12	21.63	6.32
42	ICCX181095	60.56	118.64	38.07	3.24	7.65	31.26	1.65	16.77	7.27
43	ICCX181111	58.56	120.24	29.17	3.22	8.59	24.38	0.93	23.88	4.33
44	ICCX181113	57.56	115.24	30.07	3.02	5.09	18.88	0.98	22.72	3.55
45	ICCX181122	62.56	122.24	29.77	2.72	7.39	30.08	0.98	23.47	4.42
46	ICCX181125	61.56	113.64	30.67	2.84	5.25	23.36	0.97	22.33	5.13
47	JG-2021-11	53.36	109.84	35.19	3.50	5.77	31.18	1.51	17.93	7.32
48	JG-2021-14	62.36	113.84	33.79	3.30	6.17	23.78	1.42	41.92	9.41
49	JG -2021 -4	65.56	124.24	34.47	2.02	3.89	24.48	1.02	21.86	5.10
50	JG -2021 -6	64.36	124.84	40.39	3.30	6.17	24.78	1.15	20.36	5.20
51	JG -2021 -6-15	58.36	111.84	34.59	4.10	7.37	32.08	1.04	24.90	7.41
52	JG -2021 -7	55.56	108.24	31.27	2.72	5.09	22.98	1.08	19.85	4.70
53	JG -2021 -8	60.56	113.24	29.17	2.92	5.79	25.68	1.27	19.18	5.81
54	PHULE G22	65.36	123.84	34.79	3.70	6.37	33.38	1.33	27.30	7.66
55	PHULE G7	55.36	114.84	31.29	2.90	5.67	27.68	1.13	23.27	6.47
	Overall mean	61.05	116.5	36.14	3.25	6.11	26.74	1.18	20.73	5.90

PH- Plant height (cm), DF- Days to 50% flowering, DM- Days to maturity, PB- Number of Primary Branches, SB- Number of Secondary Branches, PP- Pods per plant, SP- Seeds per pod, SW- 100 seeds weight (g), PY- Plant yield

Table 2: Analysis of variance for 9 different characters.

		Mean sum of squares								
Source	**DF**	**DFF**	**DM**	**PH**	**PB**	**SB**	**PP**	**SP**	**SW**	**PY**
Block (ignoring Treatments)	4	45.75**	54.10**	225.79**	2.15**	4.66**	96.78**	0.03*	80.74**	11.01**
Treatment (eliminating Blocks)	54	20.05**	30.35**	29.67**	0.26**	2.38*	33.76**	0.09**	26.26**	5.40**
Treatment: Check	4	24.94*	26.74*	9.41ns	0.11ns	5.44ns	80.42**	0.58**	82.34**	16.60**
Treatment: Test and Test vs. Check	50	19.66**	30.64**	31.29**	0.27**	2.13*	30.02**	0.06**	21.77**	4.51**
Residuals	16	6.44	5.97	9.36	0.08	0.84	6.58	0.01	5.13	0.47

* P < = 0.05; ** P < = 0.01
PH- Plant height(cm), DF- Days to 50% flowering, DM- Days to maturity, PB- Number of Primary Branches, SB- Number of Secondary Branches, PP- Pods per plant, SP- Seeds per pod, SW- 100 seeds weight(g), PY- Plant yield

Table 3: Estimation of variability parameters for nine different characters studied in chickpea.

Trait	Mean	Min.	Max.	GCV	PCV	hBS	GA	GAM
Days of 50% flowering	61.05	52.36	71.96	6.42	7.65	70.44	6.78	11.11
Days to maturity	116.5	103.84	124.84	4.56	5.02	82.54	9.95	8.54
Plant height (cm)	36.14	25.07	51.57	16.99	18.98	80.09	11.33	31.36
Primary branches	3.25	2.02	5.02	17.84	19.95	79.94	1.07	32.90
Secondary branches	6.11	2.75	8.81	19.76	24.80	63.48	1.98	32.48
Number of pods per plant	26.74	14.74	35.76	17.83	20.24	77.53	8.66	32.38
Number of seeds per pod	1.18	0.89	1.85	12.72	14.89	73.02	0.26	22.43
100 seed weight	20.73	11.65	41.92	23.05	25.51	81.65	8.90	42.96
Yield per plant	5.90	1.88	10.05	29.46	31.65	86.64	3.34	56.56

GCV = Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, h(bs) = Heritability (broad sense), GA= Genetic Advance, GAM= Genetic advance as percent mean value.

Table 4: Estimation of correlation coefficient for different characters in chickpea genotypes

	DF	DM	PH	PB	SB	PP	SP	SW	PY
DF	1	0.763**	0.294*	0.025	-0.164	-0.268*	-0.079	0.177	-0.149
DM	0.763**	1	0.154	-0.122	-0.096	-0.141	0.08	0.015	-0.063
PH	0.294*	0.154	1	0.424**	0.310**	0.303**	-0.015	0.122	0.173
PB	0.025	-0.122	0.424**	1	0.479**	0.511**	0.007	0.189	0.291*
SB	-0.211	-0.097	0.288*	0.418**	1	0.757**	0.025	0.108	0.381**
PP	-0.268*	-0.141	0.303**	0.511**	0.735**	1	0.102	0.021	0.568**
SP	-0.079	0.08	-0.015	0.007	0.013	0.102	1	-0.017	0.613**
SW	0.177	0.015	0.122	0.189	0.158	0.021	-0.017	1	0.508**
PY	-0.137	-0.075	0.184	0.288*	0.381**	0.543**	0.624**	0.495**	1

* P <= 0.05; ** P <= 0.01
PH- Plant height(cm), DF- Days to 50% flowering, DM- Days to maturity, PB- Number of Primary Branches, SB- Number of Secondary Branches, PP- Pods per plant, SP- Seeds per pod, SW- 100 seeds weight(g), PY- Plant yield

Table 5: Direct (diagonal) and indirect effects of yield component traits on seed yield per plant in chickpea germplasm lines.

	DF	DM	PH	PB	SB	PP	SP	SW
DF	-0.005	-0.053	0.010	-0.002	0.023	-0.154	-0.046	0.092
DM	-0.004	-0.070	0.005	0.011	0.010	-0.081	0.046	0.008
PH	-0.002	-0.011	0.035	-0.037	-0.031	0.174	-0.009	0.063
PB	-0.0001	0.009	0.015	-0.087	-0.045	0.295	0.004	0.098
SB	0.0011	0.007	0.010	-0.036	-0.107	0.436	0.014	0.056
PP	0.0014	0.010	0.011	-0.044	-0.081	0.576	0.060	0.011
SP	0.0014	-0.006	-0.0005	-0.0006	-0.003	0.059	0.583	-0.009
SW	-0.0010	-0.001	0.004	-0.016	-0.012	0.012	-0.010	0.518

Residual are 0.09457
PH- Plant height (cm), DF- Days to 50% flowering, DM- Days to maturity, PB- Number of Primary Branches, SB- Number of Secondary Branches, PP- Pods per plant, SP- Seeds per pod, SW- 100 seeds weight (g), PY- Plant yield

Conclusion

As a result, the present investigation suggests that in chickpea, selection for high seed yield should be based on the total number of seeds per plant, the number of pods per plant, the number of secondary branches, the number of primary branches and the 100 seed weight. Therefore, these traits should be given priority when choosing high-yielding genotypes in chickpea. On the basis of mean performance of yield per plant, ICCX-181026 was found to be superior to all five checks, whereas JG-2021-14, ICCX-181004 and ICCX-13039 were found to be superior to all check varieties except GNG-2207. ICCX-130039, JG-2021-7 and ICCX-171044 had desired earliness for days of 50 percent flowering and days to maturity. ICCX-181004 and ICCX-181005 possessed other important studied traits like plant height, number of secondary branches, number of pod per plant, 100 seed weight and yield per plant.

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