ESTIMATION OF CORRELATION AND PATH COEFFICIENT ANALYSIS FOR QUANTITATIVE TRAITS IN CHICKPEA (*Cicer arietinum* L.)

ABSTRACT

The present investigation was carried out with 22 genotypes of chickpea at the Field Experimentation Center. Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology & Sciences, Praygraj during Rabi 2021-2022 in Randomized block design with three replications. The data was recorded for 13 quantitative traits to study Analysis of variance, assessment of variability, Heritability, genetic advance, correlation coefficient analysis and path coefficient for yield and yield components traits. It is concluded from the results of present investigation, that significant differences were observed from for all the characters among chickpea germplasm included in the study, indicating sufficient variation present among them. High estimates of GCV and PCV were seen for the character number of primary branches per plant, harvest index. High heritability coupled with genetic advance was recorded for number of primary branches, number of seeds per plant and harvest index. The characters harvest index, number of branches per plant had positive significant association with seed yield per plant at both genotypic and phenotypic levels. The characters number of secondary branches, number of pods per plant, number of seeds per pod, biological yield, harvest index, days to maturity had positive direct effect on seed yield per plant. The genotype GNG-1958 recorded the maximum pod yield per plant.

Key words: GCV, PCV, Variability, Heritability, Correlation, Path coefficient analysis.

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INTRODUCTION

Chickpea (*Cicer arietinum* L.) is known by different names in various countries such as gram, chana, Bengal gram, kadle, etc. The word *Cicer* is a derivative from the Greek word ‘Kiros’ referring to a well-known roman family Cicero. *Arietinum* is derived from the Latin word arise meaning ‘ram’ which refers to the ram’s head shape of the chickpea. Chickpea is an important Rabi season legume having extensive geographical distribution. Chickpea is a diploid species with chromosome number 2n = 2X = 16. It is a self-pollinated crop and belonging to sub family papilionoidae and tribe, *Cicereae* of the leguminosea. Bengal gram is called as “King of Pulses”.

Pulses occupy a unique position in agriculture because of their characteristics to maintain and restore soil fertility, besides high nutritional value. Pulses restore soil fertility through biological nitrogen fixation with the help of symbiotic bacteria. Rhizobium in roots enhances the sustainability of the agriculture system. Among the pulses, chickpea is important rabi crop of India. Pulses are the richest and cheapest source of protein and from major ingredient of diet of the vegetarian population of the country. Chickpea is the rich source of proteins, carbohydrates, minerals, and possesses 358 calories of energy which is higher as any of the legume except groundnut and lupine seeds.

Chickpea is the third most important pulse crop, produced in the world. The desi type chickpea contributes around 80% and the kabuli type around 20% of the total production. India is the world leader in chickpea production followed by Pakistan and Turkey. Major producers of chickpea include India, Pakistan and Mexico.

MATERIALS AND METHOS

The present investigation was carried out at the Field Experimentation Center of Department of Genetics and Plant Breeding, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj, U.P. during *Rabi* 2020-2022. The university is situated on the left side of Prayagraj – Rewa National Highway, about 5km away from Prayagraj city. A Randomized Block Design(RBD) was adopted with three replications and row to row spacing is 30cm and plant to plant spacing is 10cm with plot size 1m x 1m.

The observations were recorded on five randomly selected plants from each replication for 13 different quantitative traits. Analysis of variance showed significant difference for all the 13 characters viz., Days to 50 percnt flowering, days to 50 percent pod setting, days to maturity, plant height, number of primary branches per plant, number of secondry branches per plant, number of pods per plants, number of seeds per plant, number of seeds per pod, biologiacal yield per plant, harvest index, seed yield per plant, 100 seed weight.

The character association estimated from variance and co variance components as given. While the direct and indirect effects of component traits on grain yield were measured by path analysis.

EXPERIMENTAL DETAILS

The experiment was conducted in Randomized Block Design (RBD) with 22 genotypes of chickpea under three replications.

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Chart 1: Experimental Details

Crop	Chickpea
Season	*Rabi*, 2021 – 2022
Experimental design	Randomized Block Design (RBD)
No. of Replications	3
No. of genotypes	22
Plot size	1x1 m^2
Net area	66 sq.mt
Gross area	136.5 sq.mt
Spacing	30x10 cm
Date of sowing	04/12/2021
Fertilizer Dose	20:40:25 (N:P:K) kg/ha
Date of Harvesting	16/04/2022

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RESULTS AND DISCUSSION

The analysis of variance for different yield related characters are presented in Table 1. The analysis of variance revealed significant difference among all the 13 characters under study at 1% level of significance. This indicates that the presence of significantly higher amount of genetic variability among the genotypes present in the investigation for all the yield characters studied. So, there was a sample scope for selection of promising lines from the present gene pool.

The mean values, the coefficient of variation (C.V.), standard error of the mean (Sem+), the critical difference (C.D.) at 5% and 1%, range of 22 genotypes for 14 quantitative characters

are presented in which revealed a wide range of variation for all traits studied. Among 22 genotypes, genotypes GNG-1958 (11.00gm), IPC–08–103 (10.93gm), HIMACHAL–CHANA–2 (10.53gm), IPC-94-94 (10.47gm), were found to be superior in grain yield.

The variability is classified as low if coefficient of variation (<10%), moderate (10-20%) and high (>20%) by Subramanian and Menon (1973). High PCV and GCV were observed for the Number of Secondary branches (21.839), Harvest index (21.158). Moderate PCV and GCV were observed for the seed yield per plant (16.12), Number of seeds per pod (11.479), Plant height (11.351). Low PCV and GCV were observed for the Days to maturity (1.157), Days to 50% pod setting (2.063).

HERITABILITY:

The heritability classified as low (<30%), medium (30-60%) and high (>60%) by Johnson *et al.*,(1955). In the present investigation traits having the higher heritability are number of secondary branches (90.093), Seed yield per plant (87.277), Harvest Index (85.062). Medium heritability observed for Days to 50% pod setting (32.46), days to maturity (30.412).

The high heritability values of the considered traits in the present study indicated that those were less influenced by the environment and thus help in effective selection of the traits based on the phenotypic expression by adopting simple selection method and suggested the scope of genetic improvement.

GENETIC ADVANCE AS PERCENT MEAN(5%):

The estimation of genetic advance as percent mean is classified as low (<10%), moderate (10 to 20%) and high (>20%) proposed by Johnson *et* al., (1955).

High Genetic Advance as percent mean were observed for Number of primary branches (40.532), Harvest Index (37.074), seed yield per plant (31.023). The following characters show low for Genetic Advance as percent mean are Days to 50% flowering (2.874), Days to 50% pod setting (2.421), Days to maturity (1.314).

CORRELATION And PATH ANALYSIS:

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Correlation analysis among the yield and its contributing characters revealed that the genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating the association was largely due to genetic reason. At both genotypic and phenotypic levels. The grain yield per plant showed positive significant association with harvest index (0.975**), number of secondary branches (0.501**). Negative significant association with plant height (-0.361*), biological yield (-0.660**), days to 50% flowering (-0.273*), days to 50% pod setting (-0.438**) which indicate strong association of these traits with the yield. Positive direct effect was showed by number of secondary branches per plant (0.090), number of pods per plant (0.172), number of seeds per pod (0.046), biological yield (0.103), harvest index (0.814), days to maturity (0.015).

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Table 1: Analysis of Variance for 13 quantitative characters in chickpea

Sl.No.	**Source**	**Replication**	**Treatment**	**Error**
	Degrees of freedom	**2**	**21**	**42**
1	Plant height (cm)	1.6530	100.715**	28
2	Number of primary branches	0.0410	0.821**	0.029
3	Number of secondary branches	0.2470	0.687**	0.198
4	Number of pods per plant	25.7130	60.216**	18.971
5	Number of seeds per pod	0.0060	0.099**	0.022

6	Number of seeds per plant	83.4850	215.385**	41.57
7	Seed yield per plant	0.3770	6.546**	0.303
8	Biological yield	10.4770	16.41**	5.262
9	Harvest Index	1.3420	117.706**	6.509
10	Days to fifty percent flowering	13.3330	17.766**	6.049
11	Days to fifty percent pod setting	25.7070	26.087**	10.683
12	Days to maturity	1.7480	16.2*	7.01
13	Seed Index	3.3810	10.745**	1.589

**** and * indicate significant at 1% and 5% level of significance respectively**

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Table 2: Estimation of Genetic parameters for 13 quantitative characters

Sl.No.	Characters	GCV	PCV	h2 (Broad Sense)	Genetic Advancement	Gen.Adv as % of mean
1	Plant height (cm)	7.732	11.351	46.399	6.908	10.85
2	Number of primary branches	20.729	21.839	90.093	1.005	40.532

3	Number of secondary branches	6.475	9.646	45.051	**0.558**	8.952
4	Number of pods per plant	5.265	8.123	42.019	4.951	7.031
5	Number of seeds per pod	8.461	11.479	54.328	0.243	12.846
6	Number of seeds per plant	5.366	7.032	58.225	11.965	8.435
7	Seed yield per plant	16.12	17.255	87.277	2.776	31.023
8	Biological yield	6.363	9.89	41.389	2.555	8.432
9	Harvest Index	19.514	21.158	85.062	11.567	37.074
10	Days to fifty percent flowering	2.227	3.556	39.233	2.55	2.874
11	Days to fifty percent pod setting	2.063	3.621	32.46	2.659	2.421
12	Days to maturity	**1.157**	**2.098**	**30.412**	1.988	**1.314**
13	Seed Index	7.936	9.785	65.768	2.919	13.258

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Table 3: CORRELATION COEFFICIENT ANALYSIS:

Traits		PH	NPB	NSB	NPP	NSP	NSPL	BY	HI	DF50	DP50	DM	SI	SYP
PH	P	1	0.0269	-0.1837	0.2136	-0.0502	0.2122	0.0756	-0.1766	-0.2175	-0.247*	0.0033	-0.0439	-0.2262
	G	1	-0.0197	-0.486**	0.296*	-0.1901	0.318*	0.1968	-0.362*	-0.653**	-0.423**	0.325*	-0.1295	-0.361*
NPB	P		1	0.2043	0.0837	-0.1648	0.1926	-0.1716	0.0133	-0.0184	-0.1173	0.0572	0.2091	-0.1127
	G		1	0.1997	0.2145	-0.264*	0.291*	-0.2233	0.0509	0.1044	-0.1452	0.1370	0.2287	-0.0941
NSB	P			1	0.0216	0.275*	0.1115	0.0215	0.2046	0.1093	0.246*	0.1157	0.1200	0.2186
	G			1	-0.0230	0.373*	0.1210	0.0737	0.333*	0.469**	0.410**	0.0767	0.246*	0.501**
NPP	P				1	-0.1272	0.629**	0.2107	-0.0075	-0.0924	-0.1152	0.0265	0.1694	0.0906
	G				1	-0.0747	0.841**	-0.0818	0.0395	-0.305*	-0.545**	0.1079	0.440**	0.0756
NSP	P					1	-0.0327	-0.0079	-0.0150	0.2242	0.1005	-0.0928	0.0820	0.0365
	G					1	-0.0681	0.245*	-0.0576	0.569**	0.254*	0.0702	0.2215	-0.0221
NSPL	P						1	0.0330	0.0922	-0.1501	-0.245*	-0.0815	0.2398	0.0648
	G						1	-0.0673	0.0461	-0.379*	-0.559**	0.1476	0.372*	0.1421
BY	P							1	-0.579**	0.1988	0.1542	0.1526	0.284*	-0.362*
	G							1	-0.935**	0.307*	0.756**	0.0981	0.377*	-0.660**
HI	P								1	-0.1351	-0.270*	-0.0018	-0.1694	0.832**
	G								1	-0.376*	-0.508**	0.1684	-0.244*	0.975**
DF50	P									1	0.244*	-0.2166	0.0098	-0.1318
	G									1	1.0676	-0.649**	0.393*	-0.273*
DP50	P										1	0.0600	0.1989	-0.284*
	G										1	0.320*	0.543**	-0.438**
DM	P											1	0.1262	0.0388
	G											1	0.386*	0.1080
SI	P												1	-0.1615
	G												1	-0.2324
SYP	P													1
	G													1

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PH: Plant height, **NPB:**No.of Primary branches per plant, **NSB:** No.of secondary branches per plant, **NPP:**No.of pods per plant, **NSP:** No.of seeds per pod, **NSPL:** No.of seeds per plant, **BY:** Biological yield, **HI:** Harvest index, **DF50:** Days to 50% flowering, **DP50:** Days to 50% pod setting, **DM:** Days to maturity, **SI:** Seed index, **SYP:** Seed yield per plant.

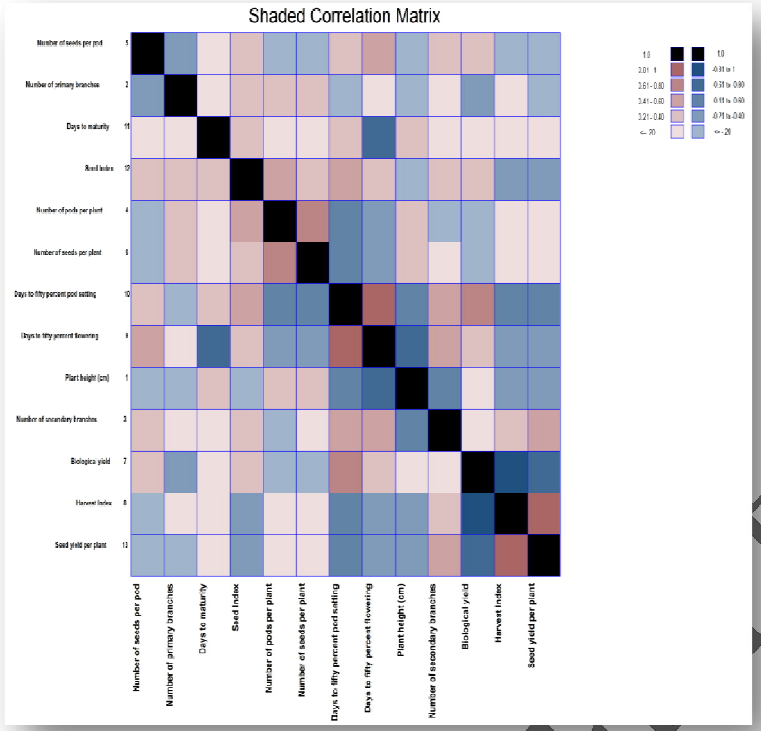

Fig 1: Genotypic Correlation Matrix

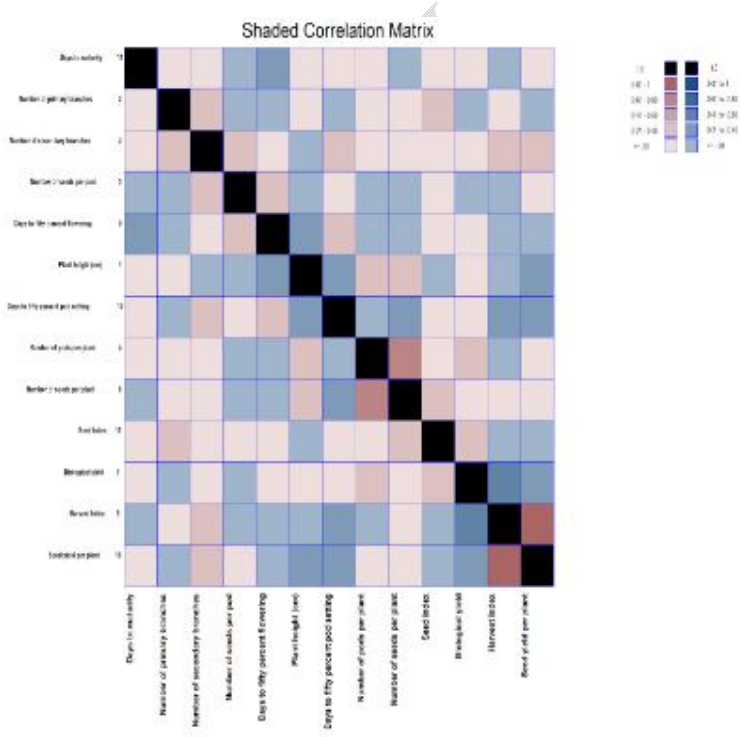

Fig 2: Phenotypic Correlation Matrix

Table 4: PATH COEFFICIENT ANALYSIS:

Traits		PH	NPB	NSB	NPP	NSP	NSPL	BY	HI	DF50	DP50	DM	SI	SYP
PH	P	**-0.1287**	-0.0035	0.0236	-0.0275	0.0065	-0.0273	-0.0097	0.0227	0.0280	0.0317	-0.0004	0.0057	-0.2262
	G	**-0.1073**	0.0021	0.0522	-0.0317	0.0204	-0.0341	-0.0211	0.0389	0.0701	0.0453	-0.0348	0.0139	-0.361*
NPB	P	-0.0032	**-0.1188**	-0.0243	-0.0099	0.0196	-0.0229	0.0204	-0.0016	0.0022	0.0139	-0.0068	-0.0248	-0.1127
	G	0.0065	**-0.3325**	-0.0664	-0.0713	0.0879	-0.0968	0.0743	-0.0169	-0.0347	0.0483	-0.0455	-0.0761	-0.0941
NSB	P	-0.0165	0.0184	**0.0900**	0.0019	0.0248	0.0100	0.0019	0.0184	0.0098	0.0222	0.0104	0.0108	0.2186
	G	-0.3338	0.1371	**0.6866**	-0.0158	0.2563	0.0831	0.0506	0.2289	0.3220	0.2815	0.0527	0.1689	0.501**
NPP	P	0.0368	0.0144	0.0037	**0.1725**	-0.0219	0.1086	0.0363	-0.0013	-0.0159	-0.0199	0.0046	0.0292	0.0906
	G	-0.0271	-0.0196	0.0021	**-0.0916**	0.0068	-0.1149	0.0075	-0.0036	0.0279	0.0499	-0.0099	-0.0403	0.0756
NSP	P	-0.0023	-0.0077	0.0129	-0.0060	**0.0468**	-0.0015	-0.0004	-0.0007	0.0105	0.0047	-0.0043	0.0038	0.0365
	G	0.0184	0.0256	-0.0361	0.0072	**-0.0966**	0.0066	-0.0237	0.0056	-0.0550	-0.0245	-0.0068	-0.0214	-0.0221
NSPL	P	-0.0252	-0.0229	-0.0132	-0.0747	0.0039	**-0.1187**	-0.0039	-0.0109	0.0178	0.0291	0.0097	-0.0285	0.0648
	G	-0.0135	-0.0124	-0.0051	-0.0533	0.0029	**-0.0425**	0.0029	-0.0020	0.0161	0.0237	-0.0063	-0.0158	0.1421
BY	P	0.0078	-0.0177	0.0022	0.0217	-0.0008	0.0034	**0.1032**	-0.0597	0.0205	0.0159	0.0158	0.0293	-0.362*
	G	-0.0571	0.0648	-0.0214	0.0238	-0.0712	0.0195	**-0.2903**	0.2714	-0.0892	-0.2193	-0.0285	-0.1094	-0.660**
HI	P	-0.1439	0.0109	0.1667	-0.0061	-0.0122	0.0751	-0.4715	**0.8149**	-0.1101	-0.2199	-0.0015	-0.1380	0.832**
	G	-0.1026	0.0144	0.0944	0.0112	-0.0163	0.0131	-0.2648	**0.2832**	-0.1065	-0.1439	0.0477	-0.0690	0.975**
DF50	P	0.0123	0.0010	-0.0062	0.0052	-0.0127	0.0085	-0.0113	0.0077	**-0.0568**	-0.0139	0.0123	-0.0006	-0.1318
	G	0.2276	-0.0364	-0.1634	0.1061	-0.1983	0.1320	-0.1070	0.1310	**-0.3484**	-0.3719	0.2262	-0.1367	-0.273*
DP50	P	0.0357	0.0170	-0.0356	0.0167	-0.0145	0.0354	-0.0223	0.0390	-0.0353	**-0.1446**	-0.0087	-0.0288	-0.284*
	G	0.0869	0.0299	-0.0843	0.1120	-0.0522	0.1150	-0.1554	0.1045	-0.2196	**-0.2057**	-0.0658	-0.1118	-0.438**
DM	P	0.0000	0.0006	0.0012	0.0003	-0.0010	-0.0009	0.0016	0.0000	-0.0023	0.0006	**0.0105**	0.0013	0.0388
	G	-0.0323	-0.0137	-0.0076	-0.0108	-0.0070	-0.0147	-0.0098	-0.0168	0.0647	-0.0319	**-0.0997**	-0.0385	0.1080
SI	P	0.0009	-0.0044	-0.0025	-0.0035	-0.0017	-0.0050	-0.0059	0.0035	-0.0002	-0.0042	-0.0026	**-0.0209**	-0.1615
	G	-0.0264	0.0466	0.0501	0.0898	0.0452	0.0758	0.0769	-0.0497	0.0800	0.1108	0.0787	**0.2039**	-0.2324
SYP	P	-0.2262	-0.1127	0.2186	0.0906	0.0365	0.0648	-0.362*	0.832**	-0.1318	-0.284*	0.0388	-0.1615	**1.0000**
	G	-0.361*	-0.0941	0.501**	0.0756	-0.0221	0.1421	-0.660**	0.975**	-0.273*	-0.438**	0.1080	-0.2324	**1.0000**

PH: Plant height, **NPB:**No.of Primary branches per plant, **NSB:** No.of secondary branches per plant, **NPP:**No.of pods per plant, **NSP:** No.of seeds per pod, **NSPL:** No.of seeds per plant, **BY:** Biological yield, **HI:** Harvest index, **DF50:** Days to 50% flowering, **DP50:** Days to 50% pod setting, **DM:** Days to maturity, **SI:** Seed index, **SYP:** Seed yield per plant.

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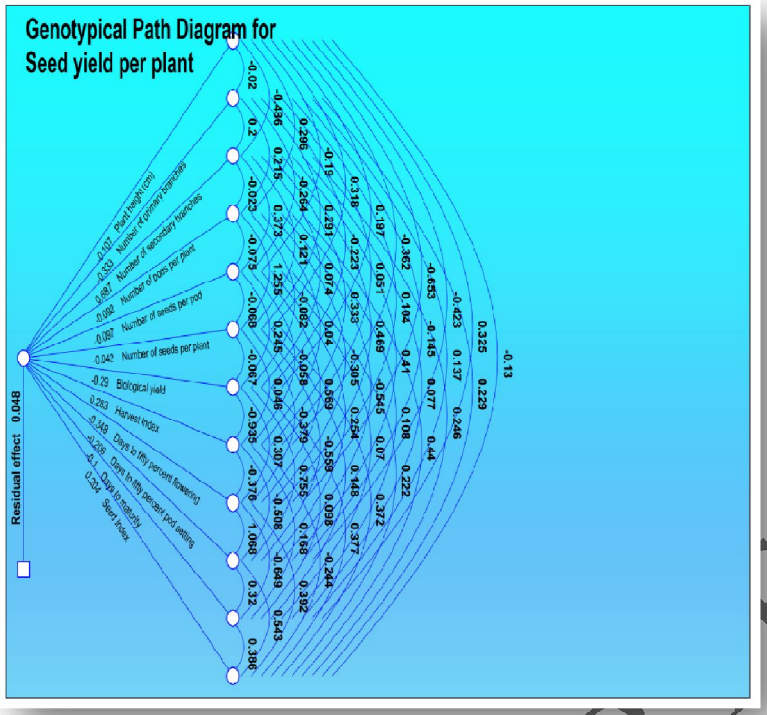

Fig 3: GENOTYPIC PATH DIAGRAM

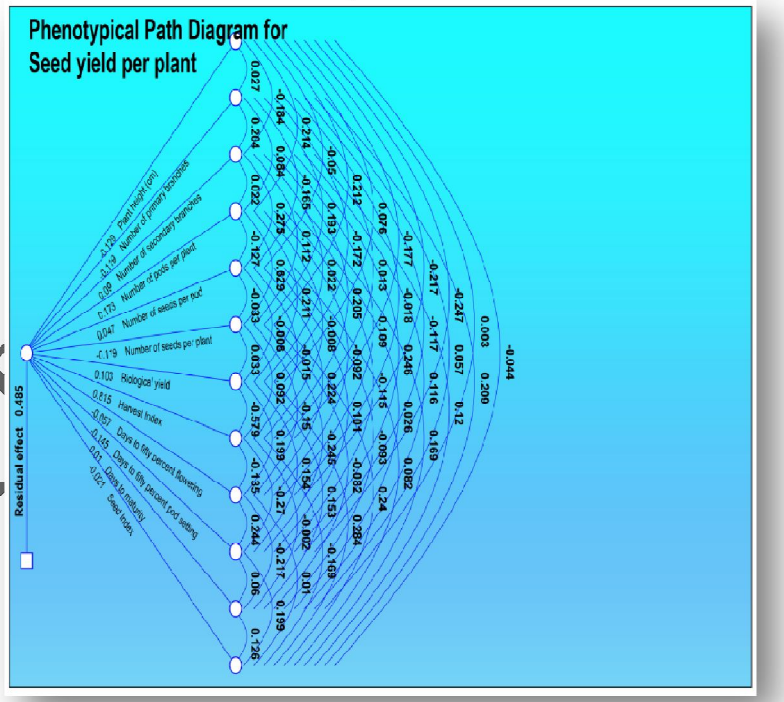

Fig 4: PHENOTYPIC PATH DIAGRAM

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CONCLUSION:

It is concluded that among 22 genotypes of Chickpea based on mean performance GNG-1958(11.00gm) was found to be superior in seed yield per plant. Number of secondary branches had recorded with high estimates of GCV and PCV and high heritability values were recorded for number of secondary branches. High estimates of heritability coupled with high genetic advance as percent of mean was observed for harvest index. Correlation between seed yield and other traits showed the positive significant correlation with number of secondary branches, number of pods per plant, harvest index. Path analysis showed that the trait had positively direct effect on harvest index, number of secondary branches, number of pods per plant, number of seeds per pod, biological yield, days to maturity.

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REFERENCES:

1. **Abdul, G., Niaz, H., Muhammad, A., Muhammad, I., Muhammad, N., Khalid, H., Zubeda, P. and Muneer, A. (2018).** Correlation and path coefficient analysis study for yield improvement in chickpea (*Cicer arietinum* L.). *International Journal of Current Agriculture Sciences*, 8(5):293-295.
2. **Arora, R. N. and Kumar K. (2018).** Genetic variability studies for yield contributing traits in kabuli chickpea (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry*, 7(2): 2675-2677.
3. **Avinalappa, H., and Raghunath, S. (2018).** Analysis of genetic variability parameters for seed yield and its attributing traits of desi chickpea (*Cicer arietinum* L.) under different environments in West Bengal. *Journal of Agriculture Research*, 5(2): 105-109.
4. **Ali, Q., Tahir, M. H. N., Sadaqat, H. A., Arshad, S., Farooq, J., Ahsan, M., Waseem, M. and Iqbal, A. (2011).** Genetic variability and correlation analysis for quantitative traits in chickpea genotypes (*Cicer arietinum* L.). *ournal of Bacteriology Research*, 3: 6-9.
5. **Babbar, A., Pandey, S. and Singh, R. (2015).** Genetic studies on chickpea genotypes grown in late sown under rice conditions of Madhya Pradesh. *Electronic Journal of Plant Breeding* 6(3): 738-748.
6. **Babbar, A., Prakash, V., Tiwari, P. and Iquebal, M. A. (2012).** Genetic variability of chickpea under late sown season. *Legume Research*, 35: 1-7.
7. **Barad, S. H., Javia, R. M., Solanki H.V. and Panera A. (2018).** Estimation of genetic variability for kabuli chickpea (*Cicer arietinum* L.) ubder timely and late sowing condition. *Journal of Pharmacognosy and Phytochemistry*, **7(4)**: 421-423.
8. **Chauhan, M. P. and Singh, I. S. (2000).** Variability estimates and identifying chickpea genotypes for yield and yield attributes in salt affected soil. *Madras Agriculture Journal*, 81(9):463-465.
9. **Desai, K., Tank, C. J., Gami, R. A., Patel, A. M. and Chauhan, R. M. (2015).** Genetic variability in indigenous collection of chickpea (*Cicer arietinum* L.) genotypes for seed yield and quality traits. An *International Journal of Environmental Sciences*, 9(1&2):59-62.
10. **Dhuria, N, and Babbar, A. (2015).** Assesment of genetic variability and traits association in kabuli chickpea (*Cicer arietinum* L.). *Progressive Research – an International Journal*, 11(1):455-458.

UNDER PEER REVIEW

11. **Falconer, D. S. (1960).** Introduction to quantitative genetics. *Ronald Press*, New York.
12. **Gaur, R. S., Tiwari, A. and Mishra, S. P. (2014).** Correlation and path coefficient analysis for seed yield and its components in chickpea (*Cicer arietinum* L.). *Trends in Biosciences,* 7(1):54-57.
13. **Hasan, M. T., and Deb, A. C. (2017).** Assessment of genetic variability, heritability for quality traits in bengal gram. *Indian Journal of Bioscience,* 10(2): 111-129.
14. **Indu, B., Rama, K. and Bhupender, K. (2015).** Exploitation genetic variability and determination of selection criteria using path coefficient analysis in chickpea. *Bangladesh Journal of Botany,* 44(1):139-142.
15. **Kumar, A., Kumar, A., Yadav, A. K., Nath, S., & Kumar, J. K. Y. D. (2018).** Correlation and path coefficient analysis for various quantitative traits in chickpea (*Cicer arietinum* L.) *SPI* : 2695-2699.
16. **Manikanteswara, O., Lavanya, G. R., Ranganatha, Y. H. and Manikanta, S. C. M. (2018).** Estimation of Genetic variability, correlation and path analysis for seed yield characters in chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences,* 7(9):843-849
17. **Manoj, K. S., Singh, A. and Devi, S. R. (2018).** Correlation, path analysis and genetic variability, of yield and yield components in chickpea (*Cicer arietinum* L.). *International Journal of Fauna and Biological Studies,* 5(3).
18. **Shara, J. H. (2019).** Correlation and path analysis for seed yield and yield components in chickpea under rainfed condition. *Journal of Kerbala for Agriculture Sciences,* 6(1).
19. **Singh, M. K., Singh, A. and Rhods, D. S. (2018).** Correlation, path analysis and Genetic variability for yield and yield components in chickpea (*Cicer arietinum* L.). *International Journal of Fauna and Biological Sciences,* 5(3):131-135.
20. **Singh, U. (1985).** National quality of chickpea (*Cicer arietinum* L.) current status and future research needs. *Plant foods for Human Nutrition*, 35(4): 339-351.
21. **Tadesse, M., Fikre, A., Eshete, M., Girma, N., Korbu, L. and Ridwan, M. (2016).** Correlation and path coefficient analysis for various quantitative traits in chickpea (*Cicer arietinum* L.) under rainfed conditions in Ethiopia. *Journal of Agricultural Sciences,* 8(12):112-118.

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22. **Zena, A. S., Arora, P. P. and Upreti, M. C. (2008).** Path coefficient analysis in chickpea for enhancing the yield of chickpea. *Bhartiya Krishna Anusandhan Patrika*, 23: 3-4.

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