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Genetic analysis and path coefficient analysis among yield and yield attributing traits in chickpea

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Abstract
The chickpea (*Cicer arietinum* L.), a self-pollinated pulse crop that is botanically a member of the Fabaceae family, is one of the most significant rabi pulse crops in India and makes up about 20% of all pulse production worldwide. During the rabi seasons of 2020–2021 and 2021–22, the experiment was carried out at the Institute Farm, S.R.K College of Agriculture, Bhopal (M.P.). The findings showed that biological yield/plant had a direct and favorable impact on grain yield/plant and that it also had an indirect impact via 100-seed weight, followed by pods/plant. The trait harvest index significantly affected the number of pods per plant, which in turn affected grain yield per plant.

Keywords: Genetic analysis, path coefficient analysis, chickpea

Introduction
Most of the world's chickpeas are grown in Asia and Africa, which together produce 96% of all pulses. According to Agriculture data at a glance (2019), India has the highest chickpea production rates, area, and productivity in the world at 10.56 mha, 11.23 mt, and 1078 kg/ha. Ninety-one percent of the country's chickpea supply and ninety-eight percent of its land area are distributed over only six states: Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka, and Andhra Pradesh. About 40% of India's entire chickpea output comes from Madhya Pradesh, which has a total area of 1.29 million hectares, produces 2.48 million metric tons, and has a productivity of 1,288 kg per hectare.

Taking steps to increase crop output and quality is part of crop improvement. Any crop's potential for growth is proportional to the crop's inherent variability. Chickpea yield is the sum of various parameters, often referred to as yield components, and is regulated quantitatively by many genes functioning in concert with the environment. Selecting parents based on yield alone may be deceiving, and studying seed yield directly is difficult because of its poor heredity [1-3]. Therefore, an effective selection to create a commercial variety requires information about the link between yield and its contributing features.

Selecting for a certain characteristic is made easier by the combination of heritability data and genetic progress. Correlation of quantitative features would aid in selecting component characters that are favorably connected with yield, providing a more complete picture of the auxiliary characters under consideration. Path coefficient analysis is used so that the breeder may determine the relative importance of each genetic factor in determining the final crop yield [4-6].

Gene recombination is facilitated by knowing the kind and extent of genetic variety already existing, which may be gleaned from data on genetic divergence [7]. found that the odds of enhancing the traits under consideration increased if the parents chosen for hybridization had a varied background [8-10].

Breeders' capacity to choose genotypes with improved yield and other quantitative features relies heavily on the presence of genetic variability and its effective use.

Yucel (2020) [11] reported that highest heritability along with high genetic advance was found for hundred seed weight followed by podding day, plant height, flowering day and first pod height in normal and stress conditions.

Sharma *et al*. (2019) [12] revealed that phenotypic coefficients of variation were marginally higher than the corresponding genotypic coefficient of variation indicating the influence of environment in the expression of the characters under study in different locations of Chhattisgarh.

The aim of this study is to estimate the genetic variability for yield and its contributing traits. Also focus on the Phenotypic & Genotypic Path coefficient analysis.

Materials and Methods

Experimental Material and Methods

The experiment was conducted at the Institute farm, S.R.K College of Agriculture, Bhopal (M.P.) during the rabi season of 2019-2020 and 2020-21. Experimental material consisted of 80 strains of chickpea advanced breeding lines obtained from AICRP on Chickpea, College of Agriculture, Indore (M.P.). The experiment was conducted under Randomized Complete Block Design, used recommended agronomic practices to raised good crop. Experimental area occupied was quite uniform in respect of topography and fertility.

Statistical analysis

The data obtained were subjected the Mean, Range, Analysis of variance, Heritability and Genetic advance statistical analysis.

Path coefficient analysis

The direct and indirect contribution of various characters to yield were calculated through path coefficient analysis as suggested by [13] and elaborated by [14].

Results

Genetic Variability

Mean, range, genotypic and phenotypic coefficient of variation, heritability (broad sense), and genetic advance as a percentage of mean are some of the genetic variability parameters calculated for different traits and presented in table 2 to predict the presence of genetic variability in the population.

Analysis of variance

Analysis of variance describes the variations between people that may be directly seen. Analysis of variance was carried out, and the results are shown in table 2, so that we may learn how much variation there is in the eighty observable qualities. Days to flower commencement, Days to 50% blooming, and Days to maturity were all agronomic and phenological characteristics where genotype-to-genotype variation was statistically significant. Stem diameter, how many pods each plant produces; how many seeds each plant produces; how much 100 seeds weigh; Index of harvest, seed output per plant, and biological yield per plant.

Mean and Range

The table 2 below summarizes the characters' mean and range performance.

Table 1: Variability in yield and its determinants among Chickpea cultivars and their associated genetic characteristics

S. No.	Characters	Mean	Range		GCV (%)	PCV (%)	h^2 (%) (Broad sense)	Genetic advance as % of mean 5%
			Min	Max				
1	Days to flower initiation	44.63	39	51	5.53	6.67	68.93	9.46
2	Days to 50%flowering	60.71	54	67	3.88	5.16	56.44	5.99
3	Days to maturity	116.82	107	131	2.55	3.65	48.96	3.68
4	Plant height (cm)	47.61	33.00	62.00	10.89	11.60	58.80	14.04
5	Lower branch Ht. (cm)	1.87	1.00	3.00	19.71	20.61	52.28	29.43
6	Number of branches per plant	3.36	2.00	4.70	13.29	15.15	82.21	23.81
7	No. of pods per plant	52.06	24.70	92.00	21.50	25.62	70.44	37.16
8	No. of seeds per plant	55.85	36.30	76.70	11.47	17.44	43.23	15.53
9	Seed index (g)	27.31	20.00	42.00	12.06	14.37	49.32	14.51
10	Harvesting index (%)	59.70	34.81	94.63	17.90	20.22	85.37	26.35
11	Biological yield	35.96	22.06	56.24	16.09	19.77	65.56	53.86
12	Yield per plant (g)	19.74	15.56	31.20	13.91	14.82	69.19	52.12

Genotypic and Phenotypic coefficient of variation

Table 4 displays the estimated genotypic and phenotypic coefficients of variation for yield and its ascribed attributes. Coefficient of Genotypic and Phenotypic Variation was divided into three categories: high (>20%), moderate (10-20%), and low (10%). The phenotypic variation must be larger than the genotypic variance in most cases. The study revealed a consistent pattern across all the characters.

The PCV value is higher than GCV for all the traits under study. The GCV was has recorded high for only one trait and it was highest for No. of pods per plant (21.50%). Genotypic coefficient of variation found medium for Lower Branch Ht. (cm) (19.71%) followed by harvest index (17.90%), Biological yield (16.09%), Yield per plant (13.91%), Number of branches per plant (13.29%), seed index (g) (12.06%), Number of seeds per plant (11.47%) and plant height (10.89), whereas low genotypic coefficient of variation were recorded for Days to flowering (5.53%), Days to 50% flowering (3.88%) and Days to maturity (2.55%) respectively.

For three characteristics, the PCV scored above average, with Number of pods per plant (20.62%) had the largest phenotypic coefficient of variation, followed by Lower branch Ht. (cm) (20.61%) and harvesting index (20.22%). Biological yield (19.77%), number of seeds per plant (17.44%), number of branches per plant (15.15%), yield per plant (g) (14.82%), seed index (g) (14.37%), and plant height (11.60%) all had medium phenotypic coefficients of variation. Days to flowering (6.67%), Days to 50% blooming (5.16%), and Days to maturity (3.55%) showed modest levels of genetic variability. Low differences were seen between GCV (%) and PCV (%) for the features *viz*. days to 50% blooming, days to maturity, plant height in centimeters, lower branch height in centimeters, and yield per plant in grams.

Heritability (%)

Heritability was measured throughout a wide range and categorized as either high (>70%), moderate (50-70%), or low (<50%). Table 4.2 displays the estimated heritability of yield and its determinants.

The number of pods produced per plant was found to have the highest heritability (70.54%), followed by the number of branches per plant (82.21%). Plant height (cm), days to 50% flowering (days), and Lower Branch Ht. (cm) were estimated to have moderate heritability (69.19%, 58.80%, 56.44%), low

estimates of heritability were found for seed index (g), days to maturity (d), and seeds per plant (43.23%).

Genetic advance as percentage of mean

High (>35%), moderate (25-35%), and low (25%) genetic progress were defined as percentages of the mean. The estimated genetic improvement, expressed as a percentage of the mean, varied between -3.68% and +53.86%. The greatest percentage increase in genetic progress was found for Biological yield (53.86 percent), followed by Yield per plant (52.12 percent) and Number of pods per plant (37.1 percent). Lower branch Ht. (cm) genetic progress as a proportion of the mean was 29.43% and harvesting index (26.35%), both moderate. Number of branches per plant (23.81%), number of seeds per plant (15.53%), seed index (g) (14.51%), plant height (cm) (14.04%), days to flowering (9.46%), days to 50% blooming (5.99%), and days to maturity (3.68%) all showed poor genetic progress as a percentage of the mean.

- **Path coefficient analysis**

Analysis of path coefficients quantifies the influence of each independent variable on the dependent variable. It shows whether the correlation between these independent characters and seed yield is caused by the independent characters' direct influence on yield or if the effect is caused by the independent characters' indirect effect on yield through other component characters.

Phenotypic path coefficient analysis

Evaluation of phenotypic path coefficients Table 2 shows the direct and indirect impacts of several characteristics on plant yield.

Table 2: Phenotypic path coefficient analysis for yield and its component characters in chickpea genotype

Characters	DFI	DF50%	DM	PH (cm)	LBH (cm)	NBPP	NPPP	NSPP	100SW	HI (%)	BY	SYPP (gm)
DFI	0.0926	0.0590	0.0366	0.0007	-0.0066	-0.0096	0.0060	0.0081	0.0173	0.0011	0.0096	0.2054
DF50%	-0.0503	-0.0789	-0.0192	0.0046	0.0040	-0.0045	-0.0057	-0.0089	-0.0095	0.0044	-0.0109	0.1054
DM	0.0342	0.0210	0.0863	-0.0132	-0.0019	0.0002	0.0205	0.0158	-0.0167	-0.0002	0.0090	0.2159
PH (cm)	0.0002	-0.0019	-0.0050	0.0330	0.0089	0.0085	0.0065	0.0002	0.0032	-0.0022	-0.0047	-0.1731
LBH (cm)	0.0010	0.0007	0.0003	-0.0038	-0.0140	-0.0015	0.0003	0.0023	-0.0015	-0.0011	-0.0006	0.1151
NBPP	-0.0036	0.0020	0.0001	0.0089	0.0037	0.0345	0.0108	-0.0071	-0.0021	-0.0086	0.0050	-0.0285
NPPP	0.0034	0.0038	0.0125	0.0103	-0.0011	0.0164	0.0525	-0.0054	-0.0091	0.0014	-0.0038	0.0336
NSPP	-0.0010	-0.0013	-0.0021	-0.0001	0.0019	0.0024	0.0012	0.0115	0.0012	-0.0006	0.0017	-0.1245
100SW	0.0048	0.0031	-0.0050	0.0025	0.0028	-0.0016	-0.0045	-0.0027	0.0256	-0.0005	-0.0009	-0.0490
HI (%)	0.1128	0.1498	0.1132	-0.1540	0.0467	0.1566	-0.0791	-0.1632	-0.0387	-0.6646	0.9848	0.5223
BY	0.0114	-0.0519	-0.0018	-0.0621	0.0709	-0.2300	0.0251	0.0478	-0.0187	0.9255	-0.5669	0.2547

Where,

DF50%: Days to 50% flowering, DFI: Days to flower initiation, DM: Days to maturity, LBH: Lower branch Ht. (cm), PH: Plant height, NBPP: Number of branches per plant, NPPP: Number of pods per plant, NSPP: Number of seeds per plant, 100SW: 100 seed weight, HI%: Harvest index, BY: Biological yield per plant, SYPP: Seed yield per plant

a) Direct effect

Following days to maturity (0.0863), plant height (0.0330), number of branches (0.0345), number of pods (0.0525), 100 seed weight (0.0256), lower branch height (0.0140), and number of seeds per plant (0.0115), days to flower initiation (0.0926) had the greatest positive direct effect on seed yield per plant. However, harvest index (-0.6646), biological yield (-0.5669), and days to 50% blooming (-0.0789) all had a negative direct influence on seed output per plant.

b) Indirect effect

It exhibited positive indirect effect through days to 50% flowering (0.0590), days to maturity (0.0366) and 100 seed weight (0.0173). Its negative indirect effect showed low through Number of branches per plant (-0.0096) and Lower branch height (-0.0066). Indirect effects of this character via other characters were very low in magnitude.

The low plant height (0.0046) and Harvest index (0.0044) were the channels via which this trait's beneficial indirect effects were made apparent. Time to flowering (-0.0503), time to maturity (-0.0192), and biological yield (-0.0109) all showed negative indirect impacts. The days to 50% blooming had negative and modest impacts on other parameters.

Days to maturity contributed positive indirect effect contributed through days to flower initiation (0.0342), days to 50% flowering (0.0210), number of pods per plant (0.0205) and number of seeds per plant (0.0158) whereas negative indirect effect exhibited through 100 seed weight (-0.0167) and plant height (-0.0132), while indirect effects of days to maturity via other characters were relatively low.

Through days to maturity (-0.0050), biological yield (-0.0047), harvest index (-0.0022), and days to 50% blooming (-0.0019), plant height showed a weak negative indirect influence. Reduced branch height (0.0089), increased branch density (0.0085), and increased pod density (0.0065) all shown weak but favorable indirect impacts.

This trait expressed positive indirect effects were manifested through number of seeds per plant (0.0023), Harvest index (0.0011) and Days to flower initiation (0.0010). Days to 50% flowering (0.0007), days to maturity (0.0003), and number of pods per plant (0.0003) were relatively low. It revealed negative indirect effects via plant height (-0.0038), number of pods per plant (-0.0015) and 100 seed weight (-0.0015) were relatively low.

This trait showed indirect positive effect through number of pods per plant (0.0108) while other remaining characters showed relatively very low amount of values.

Number of pods per plant showed positive indirect effect through number of branches per plant (0.0164), days to maturity (0.0125) plant height (0.0103), whereas rest of the characters showed very low in magnitude.

It revealed positive and very low indirect effect through number of branches per plant (0.0024), Lower branch height (0.0019), biological yield (0.0017), number of pods per plant (0.0012) and remaining characters showed very low negative indirect effect on seed yield.

It showed positive and very low indirect effect showed through Days to flower initiation (0.0048), Days to 50% flowering (0.0031), lower branch height (0.0028) and plant

height (0.0025). Negative and very low indirect effects recorded via days to maturity (-0.0050), Number of pods per plant (-0.0045), Number of seeds per plant (-0.0027).
Biological yield per plant revealed positive indirect effect through harvest index (0.9848), number of branches per plant (0.1566), days to 50% flowering (0.1498), days to flower initiation (0.1128) and days to maturity (0.1132). Negative indirect effect recorded through number of seeds per plant (-0.1632) and plant height (-0.1540).
The biological yield per plant (0.9255), branch height (0.0709), seed yield (0.0478), pod yield (0.0251), and days to bloom initiation (0.0114) were all positively influenced by the harvest index. The number of branches per plant (-0.2300), plant height (-0.0621), and days to 50% blooming (-0.0519) all had a negative indirect influence on seed output per plant.

c) Residual effect

In the phenotypic path analysis 0.1479 residual effect was estimated.
The Genotypic path coefficient analysis direct and indirect effects of various traits on yield per plant are presented in table 3:

Table 3: Genotypic path coefficient analysis for yield and its component characters in chickpea genotype

Characters	DFI	DF50%	DM	PH (cm)	LBH (cm)	NBPP	NPPP	NSPP	100SW	HI (%)	BY	YPP (gm)
DFI	0.5804	0.3592	0.2759	-0.5017	-0.9881	0.9297	0.7011	0.6561	0.6581	0.5424	-0.9385	-0.9802
DF50%	-0.5186	-0.6181	0.2152	0.0950	-0.1200	-0.0796	-0.0987	-0.1848	-0.1515	-0.0839	0.1930	-0.8596
DM	-0.8934	-0.4029	-0.9024	0.2218	0.0387	-0.4572	-0.4702	-0.8502	3.2849	-0.0747	0.9980	-0.1255
PH (cm)	-0.0618	-0.1434	-0.3005	0.9337	0.7723	-0.9815	0.1435	0.1277	0.1023	-0.1885	0.2767	0.4353
LBH (cm)	0.2314	-0.3446	0.0100	-0.4685	-0.7754	0.3746	0.1700	0.4733	-0.6168	-0.9405	-0.0099	-0.2805
NBPP	0.0314	0.0078	0.0128	-0.0702	-0.0128	0.0606	-0.0539	0.1021	0.0134	0.2112	0.0273	0.5518
NPPP	0.0521	0.0900	0.2832	0.0866	-0.0539	-0.5009	0.5633	-0.0718	-0.0780	-0.0025	0.0918	-0.0292
NSPP	-0.9740	-0.3331	-0.1951	-0.6098	0.6999	-0.5090	0.5683	0.4584	0.1096	0.4959	-0.2015	0.8585
100SW	-0.5755	-0.8003	0.4955	-0.8045	-0.5519	-0.6278	0.0168	0.4755	0.3450	0.7220	-0.9448	0.2044
HI (%)	-0.0372	-0.8352	-0.7744	0.7928	0.0149	0.2050	0.4359	0.7210	0.3442	-0.1970	0.6755	-0.8075
BY	0.0850	0.1611	0.1848	-0.2397	0.6958	0.1343	-0.0052	-0.1320	-0.1167	0.1872	-0.9749	0.4285

Where,
DF50%: Days to 50% flowering, DFI: Days to flower initiation, DM: Days to maturity, LBH: Lower branch Ht. (cm), PH: Plant height, NBPP: Number of branches per plant, NPPP: Number of pods per plant, NSPP: Number of seeds per plant, 100SW: 100 seed weight, HI%: Harvest index, BY: Biological yield per plant, SYPP: Seed yield per plant

a) Direct effect

Genotypic path coefficient analysis revealed that plant height (0.9337) had the highest positive direct effect on seed yield per plant followed by days to flower initiation (0.5804), number of pods per plant (0.5633), number of seeds per plant (0.4584), 100 seed weight (0.3450) and number of branches per plant (0.0606). However, maximum negative direct effect on seed yield per plant was found through harvest index (-0.9749) followed by and days to maturity (-0.9024), lower branch height (-0.7754), days to 50% flowering (-0.6181) and biological yield (-0.1977).

b) Indirect effect

Days to flower initiation

It had a beneficial indirect influence on the harvest index (0.5424), the number of days to 50% blooming (0.3592), the number of days to maturity (0.2759), and the number of pods produced per plant (0.7011). Lower branch height (-0.9881), biological yield (-0.9385), and plant height (-0.5017) were all expected to have a negative indirect impact.

Days to 50% flowering

Days to maturity (0.2152), biological yield (0.1930), and plant height (0.0950) all showed favorable indirect impacts due to this feature. Indirectly, it affected things like how long it took for flowers to open (-0.5186), how many seeds each plant produced (-0.1848), how much each seed weighed (-0.1515), and how tall its branches were (-0.1200).

Days to maturity

Biological yield (0.9980), 100 seed weight (3.2849), and plant height (0.2218) were all positively influenced by days to maturity, while days to flower initiation (-0.8934), seeds per plant (-0.8502), pods per plant (-0.4702), branches per plant (-0.4572), and days to 50% flowering (-0.4029) were all negatively influenced by days to maturity.

Plant height (cm)

Plant height had positive indirect effects through Lower branch height (0.7723), biological yield (0.2767), Number of pods per plant (0.1435), Number of seed per plant (0.1277) and 100 seed weight (0.1023). It exhibited negative indirect effect through number of branches per plant (-0.9815), days to maturity (-0.3005), Harvest index (-0.1885) and days to 50% flowering (-0.1434).

Lower branch height (cm)

The number of pods produced per plant (0.1700), days till flowering (0.2314), and seeds produced per plant (0.4733) all showed favorable indirect impacts from this characteristic. The harvest index was negative (-0.9405), the 100 seed weight was negative (-0.6168), the plant height was negative (-0.4685), and the number of days till 50% blooming was negative (-0.3446).

Number of branches per plant

Harvest index (0.2112), seed yield (0.182), days to bloom initiation (0.0314), biological yield (0.0273), hundred seed weight (0.0134), and days to maturity (0.0128) all had a favorable indirect influence. Negative consequences were seen through indirect pathways, such as shorter plants, fewer pods per plant, and thinner branches.

Number of pods per plant

Days to maturity (0.2832), biological yield (0.0918), days to 50% flowering (0.0900), plant height (0.0866), and days to flower initiation (0.0521) were all positively influenced by the number of pods per plant, while the number of branches (-

0.5009), 100 seed weight (-0.0780), and number of seeds (-0.0718) were all negatively influenced by the same factor.

Number of seeds per plant

Lower values for branch height (0.6999), number of pods per plant (0.5683), harvest index (0.4959), and 100 seed weight (0.1096) all indicated a positive and indirect influence. By decreasing the days until flowering (-0.9740), plant height (-0.6098), the number of branches per plant (-0.5090), the percentage of blooming (-0.3331), the biological yield (-0.2015), and the number of days till maturity (-0.1951), it had a negative indirect influence on seed yield.

100 seed weight (g)

Harvest index (0.7220), days to maturity (0.4955), seed yield (0.4755), and pod yield (0.0168) all indicated beneficial indirect effects. The number of branches per plant decreased (-0.6278), the number of days until 50% blooming decreased (-0.8003), the number of days before flower initiation decreased (-0.5755), and the height of the branches decreased (-0.5519).

Biological yield per plant (g)

Harvest index (0.6755), plant height (0.7928), number of seeds (0.7210), number of pods (0.4359), 100 seed weight (0.3442), and number of branches (0.2050) were all shown to have a favorable indirect influence on biological yield per plant. Days to 50% blooming (-0.8352), days to maturity (-0.7744), and days to flower initiation (-0.0372) all show a negative indirect influence.

Harvest index (%)

The harvest index improved indirectly as measured by the number of branches per plant (0.1333), days to maturity (0.11848), days to 50% blooming (0.1611), and days to maturity (0.11848). Relative plant height had a negative indirect influence on seed production (-0.2397), as did relative seed quantity (-0.1320) and relative seed weight (-0.1167).

c) Residual effect

The predicted residual impact size from the phenotypic path analysis was 0.3561.

Conclusion

Number of pods per plant, height of plant, harvest index biological yield, and seed production per plant all showed substantial variance. By taking into account these characteristics, seed producers will have an easier time distinguishing between different genotypes and kinds. According to the analysis of causal relationships between variables, plant height had the greatest positive direct effect on seed yield per plant, followed by days to flower initiation, pod number, seed number, 1000 seed weight, and branch number. Therefore, these characteristics should be taken into account for yield improvement.

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