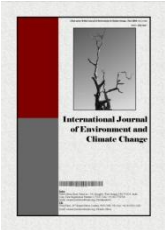

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Direct and Indirect Effects of Yield Contributing Characters on Seed Yield in Greengram (*Vigna radiata* (L.) Wilczek)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The goal of the current experiment was to estimate the correlation coefficients and to study the direct and indirect effects of various yield contributing traits on seed yield in forty greengram genotypes. The experiment was carried out during *Kharif* 2021 in a randomized block design with three replications. Correlation studies among the characters revealed that seed yield per plant has highly positive and significant association with characters like plant height (cm) (0.438**, 0.326**), number of primary branches (0.366**, 0.387**), number of clusters per plant (0.786**, 0.669**), number of pods per plant (0.561**, 0.629**), no. of seeds/pod (0.279*, 0.222*), harvest index (%) (0.680**, 0.621**) and biological yield per plant (0.870**, 0.862**) at both genotypic and phenotypic level as per values, respectively, depicting that these are important yield contributing traits. Path coefficient analysis of various quantitative traits indicated that the days to fifty percent pod sett (0.0625, 0.0152), plant height (0.0202, 0.0224), number of pods per plant (0.0050, 0.0259), no. of seeds/pod (0.0375, 0.0046), harvest index (0.5088, 0.5113) and biological yield per plant (g) (0.7233, 0.7621) had the positive direct effect on seed yield per plant followed by days to 50% flowering (-0.0032, -0.0062) and pod length (-0.0556, -0.0011) exhibited the negative direct effect on seed yield per plant in greengram. Therefore, direct selection for these characteristics would help in isolating high-yielding genotypes from highly segregating population.

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Keywords: Seed yield; correlation; path analysis; greengram.

1. INTRODUCTION

Pulses have been regarded as a crucial part of the Indian diet, due to their high protein content (25%). Greengram [*Vigna radiata* (L.) Wilczek] also known as mungbean, is an important pulse crop cultivated round the year in almost all parts of India. It is a self-pollinating, diploid (2n=22), legume that is cultivated for its dry seeds, which are significant sources of readily digested proteins that are added to the diet in place of the staple grain, rice. The foliage and bhusa form nutritious feed to the livestock. Additionally, it prevents soil erosion while enhancing soil fertility via biological nitrogen fixation. It may also be grown as green manure.

The family Leguminosae, subfamily papillionaceae, genus Vigna, and species radiata all include the diploid mungbean (2n = 22, 24). India, one of the world's top producers of pulses, produces 14.76 million tonnes of them over an area of 23.63 million hectares. To fulfil local demand, however, around 1-2 million tonnes of pulses are imported each year. As a result, more extensive interventions are required to boost the production and productivity of pulses throughout the nation. “Rajasthan (30.81%), Maharashtra (19.51%), Karnataka (15.35%), Andhra Pradesh (12.79%), Orissa (7.41%), Tamil Nadu (4.97%), and Uttar Pradesh (2.09%) contribute to the total production in india. In India, mung bean was grown on over 33.6 lakh hectares of land with annual production of 21.6 lakh tonnes and productivity of 642 kg/ha” (FAOSTAT, 2019-20).

“Greengram is referred to as "poor man's meat" since it offers a less expensive source of protein and has a protein level of 24.7%. Lysine, an amino acid that is lacking in cereal grains, is rather abundant in the protein. Ascorbic acid, thiamine, riboflavin, niacin, pantothenic acid, and vitamin A are among the vitamins and minerals found in abundance in greengram seeds” [1].

Correlation coefficient analysis is a useful technique for determining the degree and extent of relationship among important plant characteristics. It also offers fundamental selection criteria and develops directional models based on yield and its constituent parts in field trials. However, the details it provides regarding the type of association are frequently lacking. On the other hand, path coefficient analysis is a powerful statistical method created specifically to quantify the relationships between various components and their direct and indirect effects on seed production.

2. OBJECTIVES

1. To estimate genetic variability parameters for yield and its attributing characters in Greengram genotypes
2. To assess genotypic and phenotypic association among yield traits
3. To estimate direct and indirect effects of yield contributing characters on seed yield

3. MATERIALS AND METHODS

The study of correlation and path analysis in greengram for yield and yield attributing traits was carried out under the field condition during *Kharif* 2021 in a randomized block design with three replications at the field experimental center and Seed Testing Laboratory, Department of Genetics and Plant Breeding, Sam Higginbottom Institute of Agriculture, Technology and Sciences Deemed to be University, Allahabad. The experimental area is situated on the left side of Allahabad Rewa Road. It is nearly 5 km away from Allahabad city and very near to the river Yamuna. The experimental plot had uniform topography with homogenous fertility and this condition was suitable for the cultivation of greengram. For a plot size of 5x2m, the spacing between rows is 30 cm and the spacing between plants is 10 cm. For the purpose of cultivating a healthy crop, the suggested packages of procedures were followed, and all required steps were made to protect the plants from pests and diseases.

3.1 Experimental Material

The experimental material for present study is obtained from the Department of Genetics and Plant Breeding, SHUATS, Prayagraj (Allahabad). The details of experimental material the experimental material consisted of 40 diverse lines of greengram are as follows in Table 1.

The observation was recorded on ten randomly selected individual plant of each genotype for each replication for the following thirteen characters except days to 50% flowering, days to maturity which were recorded on plot basis. The characters included in the study were days to 50% flowering, days to 50% pod setting, plant height (cm), number of primary branches per plant, days to maturity, number of clusters per

plant, number of pods per plant, pod length, number of seeds per pod, biological yield, seed index, harvest index, and seed yield per plant. The data recorded for these characters were subjected to biometrical and statistical analysis and the results were obtained on above mentioned characters.

3.2 Statistical Analysis

The estimation of correlation coefficient was done using formula given by Searle [2] and test of significance was carried out by method described by Snedecor and Cochran [3]. The correlation coefficient was further partitioned into direct and indirect effect with the help of path coefficient analysis as suggested by Wright [4] and elaborated by Dewey and Lu [5]. Seed yield was regarded as a dependent variable since it was thought to be a factor that was influenced by the other features, also known as independent variables, as causes. The software called "R-Language" and INDOSTAT was used to perform the analysis mentioned above.

4. RESULTS AND DISCUSSION

4.1 Correlation Analysis

The correlation coefficients were estimated for all the combinations of ten characters under study at genotypic (rg) and phenotypic (rp) levels. The associations at phenotypic levels are generally considered, as there is no tangible test for knowing the statistical significance of correlation at genotypic level. The estimates of genotypic correlation coefficient were in general similar in direction but higher in magnitude than their corresponding phenotypic correlation coefficients, which revealed strong effect of environment on the expression of characters. However, the difference between genotypic and phenotypic correlation coefficient was negligible. The genotypic and phenotypic correlation coefficients were computed among all characteristics presented in Tables 4,5.

Seed yield per plant (g) was found significant and positively correlated with plant height (cm) (0.438**, 0.326**), number of primary branches (0.366**, 0.387**), number of clusters per plant (0.786**, 0.669**), number of pods per plant (0.561**, 0.629**), no. of seeds/pod (0.279*, 0.222*), harvest index (%) (0.680**, 0.621**) and biological yield per plant (0.870**, 0.862**) at both genotypic and phenotypic level as per values, respectively. A similar finding was earlier reported by Kumar *et al.* [6], Ghimire *et al.* [7], Muthuswamy *et al.* [8], Asari *et al.* [9], Ahmad and Belwal [10].

Table 1. List of experimental material used in the present investigation

S. No.	NAME OF THE GENOTYPE	S. No.	NAME OF THE GENOTYPE
1	PDM -11	21	Pant Mung 5
2	PDM -54	22	TM 96-2
3	ADT -3	23	SML 832
4	PUSA 9072	24	MH 3-18
5	Pant Mung 4	25	SML 668
6	PUSA 9531	26	CO -4
7	PUSA VISHAL	27	CO -5
8	TMB -37	28	CO -6
9	HUM 16	29	HUM -1
10	MH 2-15	30	COGG -912
11	Pant Mung 6	31	COGG -8
12	KM 2241	32	PDM 139 (Samrat)
13	IPM 2-3	33	IPM 302-2 (Kanika)
14	PUSA 0672	34	IPM 2K14-9 (Varsha)
15	IPM 2-14	35	IPM 312-20 (Vasudha)
16	DGGV -2	36	IPM 409-4 (Heera)
17	MH -421	37	LGG 574
18	IPM 410-3 (Shikha)	38	IPMD -604-1-7
19	IPM 205-7 (Virat)	39	OBGG -58
20	LGG 460	40	IPM 99-125 (Check Variety)

Table 2. Analysis of Variance for 13 quantitative characters in greengram in *kharif*, 2021

S. No	Source	Replication	Treatment	Error
	Degrees of freedom	**2**	**39**	**78**
1	Days to 50% flowering	4.5750	22.454**	4.139
2	Days to fifty percent pod setting	14.80	58.132**	12.612
3	Days to maturity	2.80	39.528**	2.484
4	Plant height (cm)	3.9450	49.225**	3.751
5	Number of Primary Branches	0.0090	0.729**	0.03
6	Number of clusters per plant	0.1120	2.164**	0.527
7	Number of pods per plant	4.5840	42.066**	5.794
8	Pod length(cm)	0.1690	2.4**	0.147
9	No. of seeds/pod	0.0210	4.99**	0.431
10	Seed Index (g)	0.0060	1.024**	0.004
11	Harvest index (%)	6.5060	36.414**	3.155
12	Biological yield per plant (g)	5.8520	22.203**	3.155
13	Seed yield per plant (g)	0.5780	4.227**	0.401

Table 3. Genetic parameters for 13 quantitative traits of 40 Greengram genotypes

S. No	Parameters	GCV	PCV	h^2 (Broad Sense)	Genetic Advance 5%	Gen. Adv as % of Mean 5%
1	Days to 50% flowering	6.687	8.662	59.595	3.929	10.634
2	Days to fifty percent pod setting	7.752	10.49	54.609	5.93	11.801
3	Days to maturity	4.951	5.426	83.254	6.605	9.306
4	Plant height (cm)	14.218	15.88	80.163	7.181	26.224
5	Number of Primary Branches	35.082	37.281	88.552	0.936	68.006
6	Number of clusters per plant	12.756	17.889	50.843	1.085	18.737
7	Number of pods per plant	16.861	20.507	67.602	5.889	28.558
8	Pod length(cm)	11.575	12.657	83.642	1.633	21.808
9	No. of seeds/pod	11.584	13.126	77.891	2.241	21.061
10	Seed Index (g)	16.083	16.182	98.782	1.194	32.93
11	Harvest index (%)	10.181	11.539	77.847	6.052	18.505
12	Biological yield per plant (g)	14.036	17.172	66.808	4.243	23.633
13	Seed yield per plant (g)	19.184	21.991	76.097	2.03	34.474

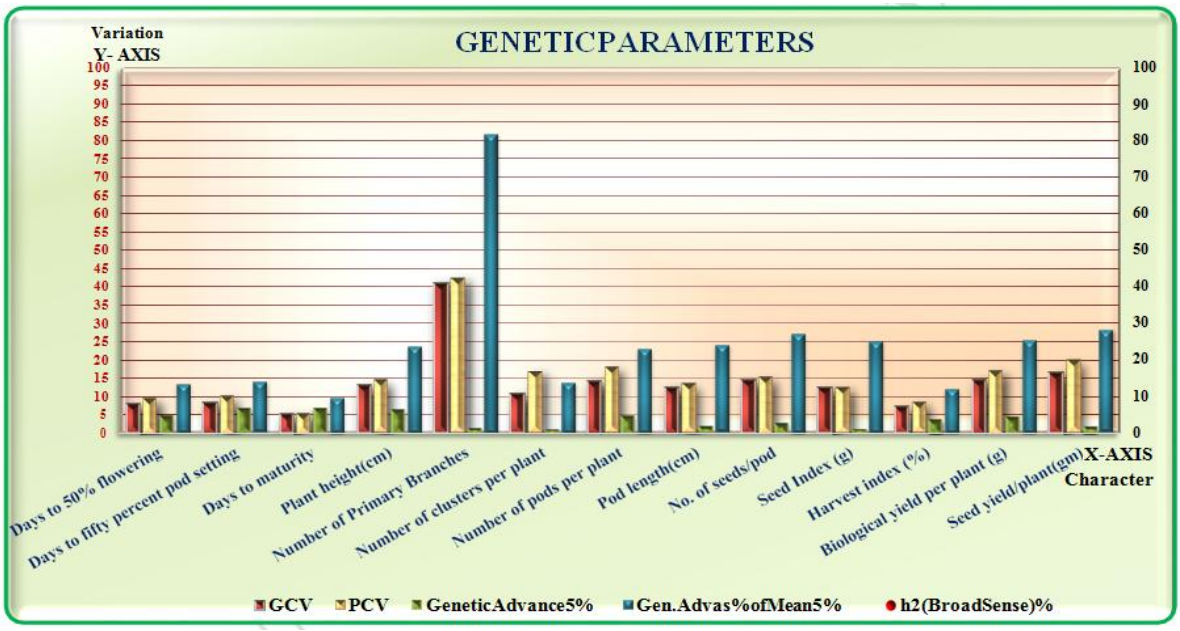

Fig. 1. Graph depicting GCV, PCV, Genetic advance and Heritability for 13 quantitative characters of Greengram genotypes

Table 4. Estimation of Phenotypic correlation coefficient between yield and yield attributing traits in 13 quantitative traits of 40 Greengram genotypes

	Days to 50% flowering	Days to fifty percent pod setting	Days to maturity	Plant height (cm)	Number of Primary Branches	Number of clusters per plant	Number of pods per plant	Pod length(cm)	No. of seeds/pod	Seed Index (g)	Harvest index (%)	Biological yield per plant (g)	Seed yield per plant (g)
Days to 50% flowering	1.0000	0.873**	0.535**	0.216*	-0.0427	0.0824	0.0459	0.197*	0.1731	-0.238*	-0.211*	0.1434	0.0233
Days to fifty percent pod setting		1.0000	0.514**	0.183*	-0.0553	0.0194	-0.0031	0.1735	0.201*	-0.1528	-0.1621	0.1546	0.0578
Days to maturity			1.0000	0.245*	0.0984	0.0613	0.1758	0.0415	0.1373	-0.0953	-0.289*	0.317**	0.1245
Plant height (cm)				1.0000	0.1095	0.1607	0.264*	0.183*	0.221*	-0.1749	-0.0577	0.422**	0.326**
Number of Primary Branches					1.0000	0.302**	0.239*	0.1309	0.0455	0.0231	0.249*	0.333**	0.387**
Number of clusters per plant						1.0000	0.695**	0.0349	0.0777	-0.0634	0.422**	0.577**	0.669**
Number of pods per plant							1.0000	-0.0838	-0.0041	-0.1521	0.379**	0.535**	0.629**
Pod length(cm)								1.0000	0.561**	0.214*	0.0508	0.184*	0.1709
No. of seeds/pod									1.0000	-0.1275	0.0491	0.242*	0.222*
Seed Index (g)										1.0000	0.0018	-0.1415	-0.1184
Harvest index (%)											1.0000	0.1450	0.621**
Biological yield per plant (g)												1.0000	0.862**
Seed yield per plant (g)													1.0000

Table 5. Estimation of Genotypic correlation coefficient between yield and yield attributing traits in 13 quantitative traits of 40 Greengram genotypes

	Days to 50% flowering	Days to fifty percent pod setting	Days to maturity	Plant height (cm)	Number of Primary Branches	Number of clusters per plant	Number of pods per plant	Pod length(cm)	No. of seeds/pod	Seed Index (g)	Harvest index (%)	Biological yield per plant (g)	Seed yield per plant (g)
Days to 50% flowering	1.0000	0.934**	0.761**	0.373**	-0.1149	-0.0215	0.0693	0.312**	0.232*	-0.318**	-0.360**	0.191*	-0.0177
Days to fifty percent pod setting		1.0000	0.743**	0.316**	-0.181*	-0.1023	-0.0363	0.302**	0.247*	-0.211*	-0.282*	0.1635	0.0067
Days to maturity			1.0000	0.300**	0.0909	0.0031	0.1540	0.0758	0.1052	-0.1068	-0.401**	0.345**	0.0721
Plant height (cm)				1.0000	0.1197	0.414**	0.397**	0.197*	0.248*	-0.198*	-0.1250	0.645**	0.438**
Number of Primary Branches					1.0000	0.355**	0.210*	0.1595	0.0711	0.0182	0.256*	0.317**	0.366**
Number of clusters per plant						1.0000	0.855**	0.0799	0.0833	-0.0985	0.619**	0.624**	0.786**
Number of pods per plant							1.0000	-0.1411	-0.0081	-0.182*	0.388**	0.470**	0.561**
Pod length(cm)								1.0000	0.722**	0.230*	0.0921	0.208*	0.197*
No. of seeds/pod									1.0000	-0.1443	0.0538	0.329**	0.279*
Seed Index (g)										1.0000	-0.0018	-0.185*	-0.1463
Harvest index (%)											1.0000	0.236*	0.680**
Biological yield per plant (g)												1.0000	0.870**
Seed yield per plant (g)													1.0000

Table 6. Estimation of phenotypic path between yield and yield attributing traits in 13 quantitative traits of 40 Greengram genotypes

	Days to 50% flowering	Days to fifty percent pod setting	Days to maturity	Plant height (cm)	Number of Primary Branches	Number of clusters per plant	Number of pods per plant	Pod length(cm)	No. of seeds/pod	Seed Index (g)	Harvest index (%)	Biological yield per plant (g)	Seed yield per plant (g)
Days to 50% flowering	-0.0062	-0.0054	-0.0033	-0.0013	0.0003	-0.0005	-0.0003	-0.0012	-0.0011	0.0015	0.0013	-0.0009	0.0233
Days to fifty percent pod setting	0.0133	0.0152	0.0078	0.0028	-0.0008	0.0003	0.0000	0.0026	0.0031	-0.0023	-0.0025	0.0024	0.0578
Days to maturity	0.0087	0.0083	0.0162	0.0040	0.0016	0.0010	0.0028	0.0007	0.0022	-0.0015	-0.0047	0.0051	0.1245
Plant height (cm)	0.0048	0.0041	0.0055	0.0224	0.0025	0.0036	0.0059	0.0041	0.0050	-0.0039	-0.0013	0.0094	0.326**
Number of Primary Branches	0.0000	0.0000	0.0000	0.0000	-0.0002	-0.0001	-0.0001	0.0000	0.0000	0.0000	-0.0001	-0.0001	0.387**
Number of clusters per plant	-0.0008	-0.0002	-0.0006	-0.0016	-0.0029	-0.0097	-0.0067	-0.0003	-0.0008	0.0006	-0.0041	-0.0056	0.669**
Number of pods per plant	0.0012	-0.0001	0.0046	0.0068	0.0062	0.0180	0.0259	-0.0022	-0.0001	-0.0039	0.0098	0.0138	0.629**
Pod length(cm)	-0.0002	-0.0002	0.0000	-0.0002	-0.0001	0.0000	0.0001	-0.0011	-0.0006	-0.0002	-0.0001	-0.0002	0.1709
No. of seeds/pod	0.0008	0.0009	0.0006	0.0010	0.0002	0.0004	0.0000	0.0026	0.0046	-0.0006	0.0002	0.0011	0.222*
Seed Index (g)	0.0002	0.0001	0.0001	0.0002	0.0000	0.0001	0.0001	-0.0002	0.0001	-0.0010	0.0000	0.0001	-0.1184
Harvest index (%)	-0.1078	-0.0829	-0.1477	-0.0295	0.1275	0.2159	0.1936	0.0260	0.0251	0.0009	0.5113	0.0741	0.621**
Biological yield per plant (g)	0.1093	0.1179	0.2414	0.3215	0.2534	0.4398	0.4074	0.1400	0.1840	-0.1078	0.1105	0.7621	0.862**
Seed yield per plant (g)	0.0233	0.0578	0.1245	0.326**	0.387**	0.669**	0.629**	0.1709	0.222*	-0.1184	0.621**	0.862**	1.0000

Table 7. Estimation of genotypic path between yield and yield attributing traits in 13 quantitative traits of 40 Greengram genotypes

	Days to 50% flowering	Days to fifty percent pod setting	Days to maturity	Plant height (cm)	Number of Primary Branches	Number of clusters per plant	Number of pods per plant	Pod length(cm)	No. of seeds/pod	Seed Index (g)	Harvest index (%)	Biological yield per plant (g)	Seed yield per plant (g)
Days to 50% flowering	-0.0032	-0.0030	-0.0024	-0.0012	0.0004	0.0001	-0.0002	-0.0010	-0.0007	0.0010	0.0011	-0.0006	-0.0177
Days to fifty percent pod sett	0.0584	0.0625	0.0465	0.0198	-0.0113	-0.0064	-0.0023	0.0189	0.0155	-0.0132	-0.0177	0.0102	0.0067
Days to maturity	-0.0176	-0.0172	-0.0231	-0.0069	-0.0021	-0.0001	-0.0036	-0.0018	-0.0024	0.0025	0.0093	-0.0080	0.0721
Plant height (cm)	0.0075	0.0064	0.0061	0.0202	0.0024	0.0084	0.0080	0.0040	0.0050	-0.0040	-0.0025	0.0131	0.438**
Number of Primary Branches	-0.0021	-0.0033	0.0016	0.0022	0.0181	0.0064	0.0038	0.0029	0.0013	0.0003	0.0046	0.0057	0.366**
Number of clusters per plant	-0.0002	-0.0011	0.0000	0.0046	0.0040	0.0111	0.0095	0.0009	0.0009	-0.0011	0.0069	0.0070	0.786**
Number of pods per plant	0.0003	-0.0002	0.0008	0.0020	0.0010	0.0042	0.0050	-0.0007	0.0000	-0.0009	0.0019	0.0023	0.561**
Pod length(cm)	-0.0173	-0.0168	-0.0042	-0.0109	-0.0089	-0.0044	0.0079	-0.0556	-0.0402	-0.0128	-0.0051	-0.0116	0.197*
No. of seeds/pod	0.0087	0.0093	0.0039	0.0093	0.0027	0.0031	-0.0003	0.0271	0.0375	-0.0054	0.0020	0.0123	0.279*
Seed Index (g)	-0.0069	-0.0046	-0.0023	-0.0043	0.0004	-0.0021	-0.0039	0.0050	-0.0031	0.0216	0.0000	-0.0040	-0.1463
Harvest index (%)	-0.1833	-0.1437	-0.2040	-0.0636	0.1301	0.3148	0.1972	0.0469	0.0274	-0.0009	0.5088	0.1201	0.680**
Biological yield per plant (g)	0.1379	0.1183	0.2493	0.4666	0.2291	0.4512	0.3398	0.1503	0.2382	-0.1334	0.1707	0.7233	0.870**
Seed yield per plant (g)	-0.0177	0.0067	0.0721	0.438**	0.366**	0.786**	0.561**	0.197*	0.279*	-0.1463	0.680**	0.870**	1.0000

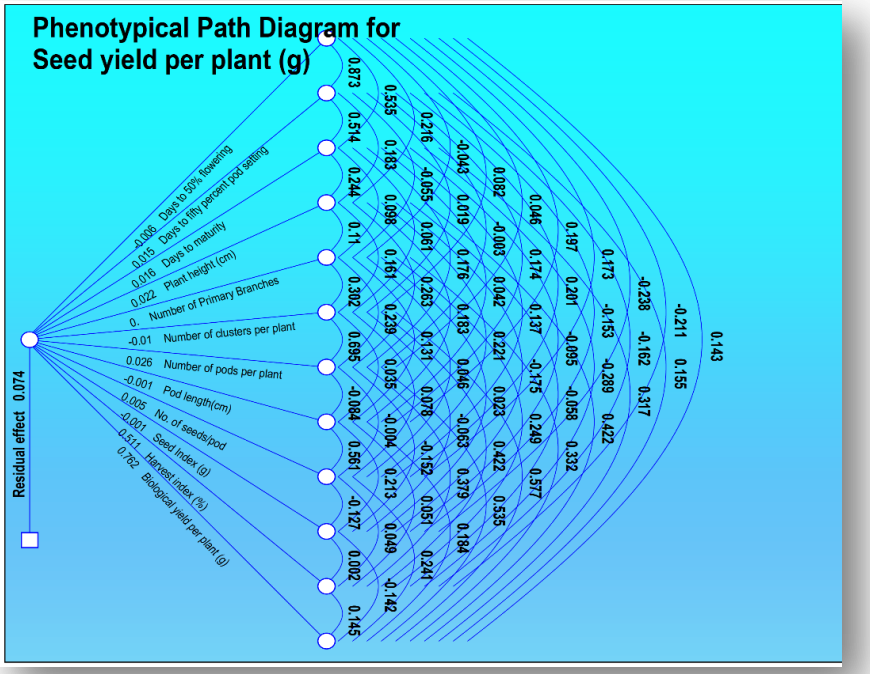

Fig. 2. Phenotypic path diagrams for seed yield per plant

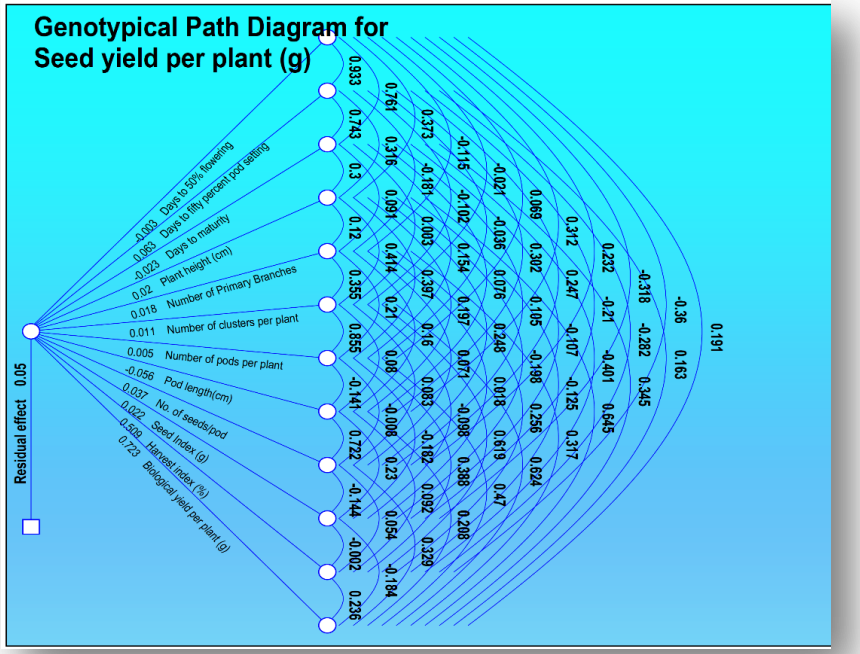

Fig. 3. Genotypic path diagrams for seed yield per plant

Seed index had positive and significant correlation with days to 50% flowering (-0.318**, -0.238*) and negative correlation with pod length (0.230*, 0.214*) at both genotypic and phenotypic level as per values, respectively. Harvest index had positive and significant correlation with number of primary branches (0.256*, 0.249*), number of clusters per plant (0.619**, 0.422**) and number of pods per plant (0.388**, 0.379**) and negative correlation with days to 50% flowering (-0.360**, -0.211*) and days to maturity (-0.401**, -0.289*) at both genotypic and phenotypic level as per values, respectively. Similar finding was earlier reported by Azam *et al.* [11], Kumar *et al.* [6] and Muthuswamy *et al. [8]*.

4.2 Path Analysis

In a breeding programme, we are often concerned with improvement in yield as an overall product dependent on a number of morpho-physiological attributes, such characters are often interrelated, hence their effect on yield is also modified by others. Path coefficient analysis helps in separating the direct effect of a component character on yield from indirect effects via others traits. The genotypic and phenotypic correlation coefficients of seed yield with its contributing characters were partitioned into direct and indirect effects through path coefficient analysis and are presented in Table 6, 7 and Figs 2,3.

Each factor influenced the yield by a direct contribution and indirect contribution through other variables with which it was correlated. Among all the characteristics, positive direct effects on seed yield per plant was recorded by days to fifty percent pod sett (0.0625, 0.0152), plant height (0.0202, 0.0224), number of pods per plant (0.0050, 0.0259), no. of seeds/pod (0.0375, 0.0046), harvest index (%) (0.5088, 0.5113) and biological yield per plant (g) (0.7233, 0.7621) at both genotypic and phenotypic levels, respectively. On the other hand, negative direct effects on seed yield per plant were recorded by days to 50% flowering (-0.0032, -0.0062) and pod length(cm) (-0.0556, -0.0011) at both genotypic and phenotypic levels, respectively. Similar findings were reported by Bhutia *et al.* [12], Ghimire *et al.* [7], Parihar *et al.* [13], and Muthuswamy *et al.* [8].

Number of pods per plant exerted positive indirect effect *via* plant height (cm) (0.0080, 0.0059), pod length(cm) (0.0079, 0.0001) and harvest index (%) (0.1972, 0.1936) and biological yield per plant (g) (0.3398, 0.4074) at both genotypic and phenotypic levels, respectively.

Biological yield per plant exerted positive indirect effect *via* days to fifty percent pod sett (0.0102, 0.0024), plant height (cm) (0.0131, 0.0094), number of primary branches (0.0057, -0.0001), number of pods per plant (0.0023, 0.0138), no. of seeds/pod (0.0123, 0.0011) and harvest index (%) (0.1201, 0.0741) both at genotypic and phenotypic levels, respectively.

5. CONCLUSION

From the present investigation, it can be concluded that the plant height, number of pods per plant, no. of seeds/pod, harvest index (%) and biological yield per plant were the major yield contributing characteristics which had a positive and significant association with grain yield per plant and also exhibited high direct effect on grain yield per plant. Therefore, due emphasis should be given to these characteristics in the selection which would help in isolating high-yielding genotypes from highly segregated populations to improve the yield potential of greengram.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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