

Elucidation of genetic variability for seed yield and its component traits, along with association studies in pigeon pea (*Cajanuscajan L.*)

Abstract: The experimental material consisted of fifty-five pigeon pea genotypes sown in Randomized Block Design (RBD) with three replications during the kharif, 2020-2021 crop seasons at the N. E. B. Crop Research Centre of the G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The components of genetic variance, correlation, and path coefficient were estimated for seed yield and its component by using fifty-five pigeon pea genotypes. The highest PCV (> 20%) were recorded for character, viz., number of secondary branches per plant (62.34%), number of primary branches per plant (37.65%), number of pods per plant (33.00 %), and seed yield per plant (31.84%), and lowest estimates (< 10%) of PCV were found for days to 50% flowering (9.45%) and days to maturity (5.74%). The high estimates of GCV (> 20%) were recorded for traits viz., number of secondary branches (42.16%), number of pods per plant (32.65 %), and seed yield/plant (30.54%), and lowest estimates of GCV were (<10%) for days to 50% flowering (9.43%) and days to maturity (5.71%) number of seeds per pod (5.28 %) and 100-seed weight (9.51 %). The number of pods per plant (0.858) had high positive direct effects on the seed yield per plant along with a positive and significant correlation ($r_p=0.77$).

Keywords: Genetic variability, correlation, path, heritability and genetic advance.

Introduction: Pigeon pea [*Cajanuscajan* (L.) Millspaugh], commonly known as Arhar, tur and red gram. Pigeon pea is an often-cross-pollinated crop with $2n=2x=22$ (diploid chromosome number) and a genome size of 833.07 Mb (Varshney *et al.*, 2012). Pigeon pea ranked sixth globally after pea, broad bean, lentil, chickpea, and common bean and was cultivated over an area of 5.4 million hectares, producing 4.49 million tons annually (Fatokimi and Tanimonure, 2021). It is the second-most significant pulse crop in India after chickpea, occupying 4.72 million hectares and producing 4.31 million tons annually with an average yield of 914 Kg/ha. It generates 15% of the nation's total pulse output (Directorate of Economics and Statistics, 2021).

The effectiveness of the breeding programme would largely rely on the level of genetic variability available for important economic traits. The genetic variability components like GCV, PCV along with heritability and genetic advance, correlation, and path coefficient are some of the useful parameters that breeders employ at different phases of the crop improvement programme. Heritability estimates are important, as they help in determining the influence of the environment on the expression of genotypes and the reliability of characters. Since the heritability estimate alone does not mean the amount of improvement anticipated from selection, the heritability estimate, along with the genetic

advance, is required to predict the particular impact ~~from~~ of the selection of the most appropriate individuals (Johnson *et al.*, 1955). Since the expression of morphological characters is likely to be affected by environmental influences, therefore, the knowledge of existing genetic variability and heritability of economically important traits is of utmost significance, before executing any crop improvement programme. Similarly, it is essential to find out the genetic association between yield and its component characters, which will facilitate the selection of desirable genotype(s).

In addition to assessing the nature and magnitude of the correlation coefficient, path coefficient analysis, and genetic association between grain yield and its traits, it is crucial to identify traits contributing to yield through variability, correlation, and path coefficient analyses. Understanding the genetic variability and trait associations plays a significant role in selecting elite genotypes and exploiting heterosis breeding programs. While studies on genetic variability and correlation provide valuable insights, they alone may not precisely determine the relative importance of the direct and indirect influences of each component trait on grain yield. In such cases, path coefficient analysis becomes an essential technique for delineating the direct and indirect effects of independent variables on the dependent variable. Consequently, genetic variability, correlation, and path coefficient analyses serve as important tools for breeders aiming to enhance pigeonpea production and productivity. This study was conducted to evaluate genetic variability, heritability, and path coefficient analysis of yield and its component characters, providing essential information for pigeonpea improvement programs focused on enhancing grain yield.

Experimental site, Climate and Weather

The experimental material consisted of fifty-five pigeonpea genotypes sown in Randomized Block Design (RBD) with three replications during the kharif and 2020-2021 crop seasons at the N. E. B. Crop Research Centre of the G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The observations were recorded for nine different morphological characters, viz., days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, 100 seed weight (g), and seed yield per plant (g). The row to row distance of 60 cm and plant to plant distance of 20 cm was maintained. The recommended packages of agronomic practices relevant to the crop were followed throughout the crop period. The observations recorded for all the traits were subjected to an analysis of variance. The genotypic and phenotypic coefficients of variability were calculated by using the formula of Burton and De Vane (1953), heritability and genetic advance by using formula of Burton and De Vane (1953), and the genetic advance as percent of mean was evaluated as per using the formula provided by Johnson *et al.* (1955). The correlation coefficients at phenotypic and genotypic levels were estimated from the analysis of variance and covariance as given by Searle (1961). The direct and indirect effects of various characters on seed yield were estimated with the help of path coefficient analysis, as suggested by Wright (1921) and Dewey and Lu (1959).

Result and Discussion:

Study of ANOVA and genetic variability parameters

The analysis of variance (ANOVA) for the years 2020-2021 revealed that the mean sum of squares for all the traits under study were highly significant, indicating a considerable amount of genetic variability in the experimental material in Table 1. The presence of sufficient genetic variability is an indication that selection would be effective in improving the traits. The significance of ANOVA for these traits was earlier also reported by Pandey *et al.* (2016), Gaur *et al.* (2018), and Pal *et al.* (2018).

The results of variance analysis presented in Table 1, indicated that the mean sum of squares (MSS) due to genotypes were highly significant for all studied characters except the number of seeds/pods. These results indicated the preponderance of genetic variability in the studied experimental material and hence proved the suitability of the experimental materials chosen for the present investigation. Significant differences for different characters among genotypes were also reported earlier by Srivarsha *et al.*, (2017), Meena *et al.*, (2017), Pal *et al.*, (2018), and Gaur *et al.*, (2020).

Table 1: Analysis of variance for nine different characters in fifty-five pigeonpea genotypes.

S.No.	Characters	Mean sum of squares		
		Replication	Treatment	Error
	Degree of freedom	2	54	108
1.	Days to 50% Flowering	3.460**	181.923**	0.355
2.	Days to Maturity	7.460**	193.057**	0.559
3.	Plant Height (cm)	542.986	3152.242**	357.560
4.	Number of Primary Branches / plant	5.115	31.572**	18.695
5.	Number of Secondary Branches/ plant	137.618	177.356**	50.241
6.	Number of Pods/ Plant	60.187	25071.659**	176.058
7.	Number of Seeds/ Pod	0.224	0.646	0.520
8.	100 - Seed Weight (g)	0.004	1.850**	0.133
9.	Seed yield/ Plant (g)	33.049	1251.673**	35.283

* significance at 5 % and ** significance at 1 % level of probability

The GCV of various characters A critical analysis of Table 1 indicated that the Genotypic Coefficient of Variation (GCV) ranged from 5.28 (number of seeds per pods) to 42.16 (number of secondary branches), followed by the number of pods per plant (32.65 %), and seed yield per plant (30.54%). PCV (Phenotypic Coefficients of Variation) estimates were higher than the corresponding GCV (Genotypic Coefficients of Variation) estimates for all the nine characters, indicating the sufficient influence of the environment on these

characters. A higher estimate of PCV than the corresponding GCV estimates for different characters in pigeonpea were also reported earlier by Rangareet *et al.*, (2013), Sharma *et al.*, (2012), Lakhoteet *et al.*,(2015), Pandeyet *al.*,(2015), Pal *et al.*, (2018),and Gaur *et al.*, (2020). In the present study, high estimates of both, the PCV and GCV were recorded for traits like number of secondary branches, number of pods per plant, and seed yield per plant, which indicated that the sufficient genetic variability existed in the experimental genotypes for these traits and that selection may be effective in bringing desirable improvements in these traits. These findings are in conformity with the earlier findings for these traits in pigeonpea by Sharma *et al.*,(2012), Lakhoteet *al.*,(2015), Pal *et al.*, (2018),and Gaur *et al.*, (2020).

Although GCV is indicative of the presence of a high degree of genetic variation, the amount of the heritable portion can only be determined with the help of heritability estimates and genetic gain (Saroj, S. K. 2013).

The ratio of genotypic variance to phenotypic variance, or total variance is known as heritability in a broad sense. It is generally expressed in percentages. The heritability is the heritable portion of phenotypic variance. It is a good index of the transmission of characters from parents to their offspring (Falconer, 1981). The estimates of heritability help the plant breeder in the selection of superior genotypes from diverse genetic populations.

The high estimate of heritability (> 60%) were reported for days to 50% flowering (99.42%), days to maturity (99.14%), number of pods per plant (97.92%), seed yield per plant (91.99%), 100- seed weight (81.14 %), and plant height (72.26 %), and whereas, the heritability estimates were recorded to be low for the traits viz., number of primary branches per plant (18.67%), and number of seeds per pod (7.46%). In the present study though, the high estimates of heritability in broad sense were obtained for the traits like days to 50 % flowering (99.42%), days to maturity (99.14 %), number of pods per plant (97.92%), seed yield per plant (91.99%) 100- seed weight (81.14 %) and plant height (72.26 %) indicating that these traits are least influenced by the environment. A similar results for the estimates of heritability were also reported earlier in pigeonpea by Pal *et al.*, (2018), Bishtet *al.*, (2018) and Gaur *et al.*, (2020). High heritability indicates the scope of genetic improvement of these characters through selection. Similar type of heritability was recorded by Patel and Linge *et al.* (2010).

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According to Johnson *et al.*,(1955), heritability estimates coupled with genetic advance as % of mean together provide a better judgment rather than heritability alone in predicating the resultant effect of selection. High estimates of genetic advance as percent of mean (>20%) were recorded for the number of pods per plant (66.57%), seed yield per plant (60.34%), number of secondary branches per plant (58.75%) and plant height (21.80%), whereas low estimates of genetic advance as percent of mean (< 10%) were obtained for the number of seeds per pod (2.97%). These results suggested that the traits like number of pods per plant, seed yield per plant, number of secondary branches per plant, and plant height are governed by additive genes, and the selection will be rewarding for improvement of these traits. Sharma *et al.*,(2012), Lakhoteet *al.*,(2015), Pal *et al.*, (2018),and Gaur *et al.*, (2020) also reported similar results for different traits for the estimates

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of genetic advance. The traits like plant height, number of secondary branches, number of pods per plant, and seed yield per plant exhibited high heritability coupled with high genetic advance, indicating ~~the-that~~ for these characters, the high estimates of heritability were due to additive gene effects and the selection may be effective. The characters like days to flowering, days to maturity, and 100-seed weight exhibited high heritability, coupled with moderate / low estimates of genetic advance, indicating that for these characters the high heritability is being exhibited due to ~~favourable~~favorable influence of environment rather than genotype, and selection for these characters may not be rewarding. For ~~the~~ rest of the traits, viz., number of primary branches and number of seeds per pods, the low estimates of heritability coupled with moderate/ ~~or~~ low estimates of genetic advance were obtained, indicating that characters are highly influenced by the environment and selection would be totally ineffective. The results of heritability and genetic advance for different traits in the present study were in accordance with the earlier findings of **Shunyuet al., (2013)**, **Vanisreeta al.,(2014)**, **Bhadru, (2011)**, **Chethanaet al.,(2015)**,and **Hemavathyet al.,(2019)**.

Table 2:Estimates of different genetic parameters for different characters in pigeonpea genotypes.

	Characters	PCV	GCV	Heritability	Genetic advance	GA as (%) of mean
1.	Days to 50% Flowering	9.45	9.43	99.42	15.97	19.37
2.	Days to Maturity	5.74	5.71	99.14	16.42	11.72
3.	Plant Height	14.65	12.45	72.26	53.44	21.80
4.	No. of Primary Branches	37.65	16.27	18.67	1.84	14.48
5.	No. of Secondary Branches	62.34	42.16	45.75	9.07	58.75
6.	No. of Pods/ Plant	33.00	32.65	97.92	185.69	66.57
7.	No. of Seeds/ Pod	19.33	5.28	7.46	0.11	2.97
8.	100 Seed Weight	10.56	9.51	81.14	1.40	17.66
9.	Seed yield/ Plant	31.84	30.54	91.99	39.78	60.34

4.3.1. Character association studies

Correlation analysis is conducted in plant breeding experiments to estimate the association among two or more series of variables. The genotypic correlation coefficient (r_g) estimates

the magnitude of genotypic association among various characters, while the phenotypic correlation (r_p) measures both genotypic as well as environmental influences. As seed yield is a complex character, ~~thus~~ correlation analysis is conducted to estimate the mutual relationship between various plant characters based on which seed yield improvement can be ~~done~~ made. It is a well-known fact that yield depends upon a number of component characters ~~those that~~ are less complex and simply inherited. Usually, these component characters are simply interlinked. Thus, selection pressure may be more easily exerted on those characters ~~which that~~ are independent and are ~~inter-associated~~ interrelated among themselves.

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Table ~~no. 3~~ ~~indicated~~ indicates that, in general, both phenotypic (r_p) and genotypic (r_g) correlation coefficients possess similar signs. The magnitude of genotypic correlation coefficients was found to be ~~more~~ higher as compared to the magnitude of corresponding phenotypic correlation coefficients. The higher magnitude of genotypic correlation coefficients than the corresponding phenotypic correlation coefficients clearly indicates that there is a strong genetic association between these two traits ~~genetically~~, however the genotypic values were lessened by the significant interaction of environment. A similar trend of genotypic and phenotypic correlation coefficients in sign and magnitude ~~were~~ was also reported earlier in pigeonpea by **Bisht et al., 2018 and Gaur et al., (2020)**. In general, Seed-seed yield per plant exhibited a positive and significant phenotypic association with all other studied characters. A positive and significant association ~~of~~ between these characters ~~with~~ and seed yield per plant was also reported by several workers (**Bisht et al. (2018)** and **Gaur et al., (2020)**). The character days to 50% flowering showed significant and positive correlation with days to maturity ($r_p=0.75$ and $r_g=0.76$), plant height ($r_p=0.37$ and $r_g=0.44$), number of pods per plant ($r_p=0.66$ and $r_g=0.66$), number of seeds per pod ($r_p=0.28$ and $r_g=1.00$) and hundred seed weight ($r_p=0.43$ and $r_g=0.49$) at both genotypic and phenotypic levels. Plant height exhibited a significant and positive correlation with the number of pods per plant, number of seeds per pod, and the hundred seed weight at both the genotypic and phenotypic levels. The Number of pods in the plant exhibited a significant and positive association with the number of seeds per pod and the hundred seed weight. Similar kinds of results between these traits in pigeonpea were also reported earlier by **Rangareet al., (2013)**, **Sharma et al., (2012)**, **Pal et al., (2018)**, and **Gaur et al., (2020)**.

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Table 3: Phenotypic (r_p) and genotypic (r_g) correlation coefficients among various characters in Pigeonpea.

Characters		DF	DM	PH	NPB	NSB	NPP	NSP	HSW	SYP
DF	rp	1.00	0.75**	0.37*	-0.03	-0.12	0.66**	0.28**	0.43**	0.46**
	rg	1.00	0.76**	0.44*	0.01	-0.19	0.66**	1.00**	0.49**	0.49**
DM	rp		1.00	0.17*	-0.02	-0.14	0.38**	0.24**	0.32**	0.36**
	rg		1.00	0.21	-0.04	-0.20	0.38*	0.91**	0.35*	0.38*
PH	rp			1.00	0.17*	-0.09	0.47**	0.18*	0.29**	0.30*
	rg			1.00	0.01	-0.06	0.55**	0.80**	0.38*	0.56**
NPB	rp				1.00	0.45**	0.21**	0.05	0.16*	0.26**
	rg				1.00	1.00**	0.51**	1.00**	0.39**	0.25
NSB	rp					1.00	0.16*	0.18*	0.06	0.16*
	rg					1.00	0.25	0.52**	0.10	0.32
NPP	rp						1.00	0.31**	0.49**	0.77**
	rg						1.00	1.00**	0.56**	0.81**
NSP	rp							1.00	0.26**	0.28**
	rg							1.00	0.72**	0.99**
HSW	rp								1.00	0.44**
	rg								1.00	0.51**
SYP	rp									1.00
	rg									1.00

* refers to significance at 5 % and ** refers to significance at 1 %

Where, DF= days to 50 % flowering; DM= days to maturity; PH= plant height; NPB= number of primary branch; NSB= number of secondary branch; NPP= number of pods per plant; NSP= number of seeds per pod; HSW= 100-seed weight; SYP= seed yield per plant.

4.3.2.Path Coefficient Studies

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Path coefficient analysis is used to partition the observed correlation coefficient into a series of direct and indirect effects of yield components on yield. The term path coefficient was first used by Wright, (1921), and its use was elaborated by Dewey and Lu, (1959). Path coefficient analysis quantifies the direct effect of an independent variable and its indirect effect through other variables on dependent variable. In the present study, path coefficient analysis was carried out by taking seed yield/plant as a dependent and all other traits as independent variables. The results of path coefficient analysis are presented in Table 4.

A critical preview of Table 3 revealed that the number of pods per plant (0.858) had high positive direct effects on the seed yield per plant, along with a positive and significant correlation ($r_p=0.77$). Since the magnitude of the phenotypic correlation coefficient between the number of pods per plant is almost equal to the direct effect of this trait on seed yield, it revealed the true relationship between these two traits and direct selection for improvement in the number of pods per plant will certainly result in the enhanced seed yield. Similar results for the high direct effect of pods per plant on seed yield / plant were also reported earlier by Gaur *et al.*, (2020). Days to maturity also exhibited a high positive direct effect on seed yield (0.236), along with a positive and significant association ($r_p=0.36$). Rest of the traits exhibited very low direct effect on seed yield and were also non-significantly associated with seed yield. The low magnitude of the direct effect of different traits were also reported earlier by Rangareet *al.*, (2013), Sharma *et al.*, (2012), Lakhoteet *al.*, (2015), Pandeyet *al.*, (2015), and Pal *et al.*, (2018).

Table 4: Path coefficient analysis showing the direct and indirect effects of various characters on seed yield at the phenotypic level.

Characters	Correlation with SYP	Direct effect	Indirect effect via							
			DF	DM	PH	NPB	NSB	NPP	NSP	HSW
DF	0.46**	-0.291	-	0.178	-0.029	-0.001	0.006	0.567	0.010	.028
DM	0.36**	0.236	-0.220	-	-0.014	-0.002	0.006	0.329	0.008	0.021
PH	0.30*	-0.079	-0.109	0.042	-	0.004	-0.079	0.404	0.006	0.019
NPB	0.26**	0.111	0.001	-0.005	-0.013	-	-0.022	0.186	0.002	0.010
NSB	0.16*	-0.049	0.036	-0.033	0.007	0.050	-	0.142	0.006	0.003
NPP	0.77**	0.858	-0.192	0.090	-0.037	0.024	-0.008	-	0.011	0.032
NSP	0.28**	0.036	-0.082	0.058	-0.014	0.006	-0.008	0.272	-	0.017

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HSW	0.44**	0.065	-0.127	0.076	-0.023	0.017	-0.002	0.426	0.009	-
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Table 5: List of 20 selected superior cultivars of pigeonpea on the basis of yield and yield related traits.

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Genotypes	DF	DM	NPB	NSB	PH	NPP	NSP	HSW	SYP
PA 426	80	135	23	32	260	393.3	4.7	8.25	101.6
PUSA 2015-1	95	149	8.7	8.3	280	395	4	8.84	97.3
PA 421	82	137	19	37	222.5	390	3.7	7.66	96
PA 455	92	146	12	18.3	270	406.7	4.7	8.07	95
AL 2046	92	146	11.7	3.3	295	391.7	3	8.37	95
AL 1932	92	147	11.3	6.3	285	330.3	4	8.05	93.3
PA 443	81	135	12.3	11.7	257.5	385	4	9.17	91.7
PA 444	92	147	14.3	14	177.5	384.3	4	8.23	91.7
AL 1758	92	144	9.3	3.7	270	400.7	4.3	7.83	91.7
PA 477	84	135	10.3	14	270	379.3	4	7.89	87.3
PA 493	95	150	11.7	4	270	369.3	3.7	8.84	85
PA 449	92	146	17.3	40.3	237.5	313.3	4.3	8.72	84.7
GAUT 98023	82	147	13.1	15	247.1	258.3	4	7.76	81.9
PA 441	90	148	9.3	13	245	303.3	4.7	8.49	81.7
PA 429	81	134	15	21.7	295	385	4	8.14	81.2
PUSA 992	80	125	15.3	16	250.3	293.3	4	8.15	81
PA 374	81	135	23	33.7	275	376.7	4.3	8.96	80.2
PA 440	81	135	15.7	13	252.5	346.7	4	8.68	80
ICPL 93081	80	147	14	19	252	266.7	4	8.31	78.73
PUSA 2002-1	75	147	12	11	179	260	3	7.44	78.53
PA 426	80	135	23	32	260	393.3	4.7	8.25	101.6

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