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Genetic Heritability, Variability, Genetic Advance, Correlation and Path Analysis Assessment in Garden Pea (*Pisum sativum* L.)

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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 objective of the current study was to quantify the genetic variability, heritability, and genetic advance as a percentage of mean among 20 genotypes of pea (*Pisum sativum* L.) using ten quantitative characters at the Horticulture Research Centre (HRC) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P, in the years 2021–2022. The results of the ANOVA revealed substantial variations across the genotypes for each attribute, demonstrating a broad range of genetic variability. The results showed that for the ten traits under study, the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV). According to estimations, the number of pods per plant has the greatest phenotypic

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diversity (26.63), whereas additive genetic variation is the least (26.47). In this assessment, the highest heritability was found to be around 60% (in the broad sense) found in days to maturity (99.39) followed by plant height (98.98), pod yield per plant (98.95), pod yield (98.89), number of pods per plant (98.80), days to 50% flowering (98.25), length of pod (89.35), days to germination (84.57), seeds per pod (83.91) and the minimum heritability was found in width of pod (73.83). Additionally, high heritability in combination with high additive gene action as a percentage of mean (>20%) Number of Pods per plant, Plant height (cm), Pod yield per plant (g), Days to 50% Flowering, Days to Maturity, and Pod yield (q/ha), which appear to suggest presence of additive gene action and imposes for population improvement by selection. We could use particular genotypes with certain characteristics for hybridization.

Keywords: Genetic variability; heritability; genetic advance; phenotypic coefficient of variation.

1. INTRODUCTION

"Pea (2n=2x=14; *Pisum sativum* L.) is one of the oldest vegetable crops. As it does well in temperate climates, it is grown in practically all temperate regions worldwide" [1]. "Peas are used in a multitude of horticultural and agricultural applications. Fresh, frozen, and canned veggies are prepared from the green seeds. It is a crop with a great deal of protein (27%) for human nutrition. Green peas are the vegetable with the highest protein level, with a protein content of 6-7% on a fresh weight basis. In recent years, both the utility of peas as a food crop and as fodder has surged. All of the necessary amino acids required for optimal cellular function are present in pea protein" [2]. According to Ceyhan and Avci [3], "pea protein is high in lysine and other essential amino acids but low in sulfur-containing amino acids like cysteine and methionine". "Vitamins A, B, and C, as well as minerals, dietary fiber, and antioxidant compounds are all found in pea" [4]. "As a component of a nutritious eating routine, particularly for kids and the old, green peas are truly significant when consumed in new, canned or frozen structure. The seeds and immature pods of green peas contain the most vitamins. The inclusion of peas in crop rotation is agronomically very significant. The pea is a good predecessor to other crops as it enriches the soil with the nodule bacteria which live in its roots and it fixes nitrogen which live in its roots and it fixes nitrogen which becomes available to other plants" (Rudnicki and 2002). "Crop improvement depends upon the magnitude of genetic variability and extent of which the desirable characters are heritable for a successful breeding programme" [5].

"Genetic variability, heritability and genetic advance are pre requisite for improvement of any crop for selection of superior genotypes and improvement of any traits" [5].

"Yield is a complex character influenced by several genetic factors interacting with environment. Therefore success of any breeding programme for its improvement depends on the existing genetic variability in the base population and on the efficiency of selection" [6]. "Heritability indicates the proportion of phenotypic variance that is due to genotypes which is heritable. It serve as a useful guide to breeders as the selection for trait having high heritability will be effective and improvement will be brought through selection. The genetic advance is an improvement in the genetic value new population as compared to original one. It will be possible to decide various breeding programmes for improvement of different characters based on the study of heritability and genetic advance" [7]. Therefore, this study was done to assess the genetic variability, heritability, and genetic advances among 20 genotypes of pea.

2. MATERIALS AND METHODS

The experiment was conducted with 20 germplasm Table 1 and laid out in randomized block design with three replications. Data were recorded on days to germination, days to 50% flowering, plant height (cm), number of pod per plant, seed per pod, length of pod (cm), width of pod (cm), days to maturity, pod yield per plant (g) and pod yield (q/ha). The mean values were subjected to statistical analysis to work out ANOVA for all the characters, as suggested by Goulden [8]. The phenotypic and genotypic coefficient of variation was calculated as per the procedure given by Burton [9]. Heritability in broad sense (h^2) was estimated based on the formula proposed by Lush [10]. Correlation coefficient was computed by using formula given by Al-Jibouri et al. Path coefficient analysis is

calculated by the method suggested by Dewey and Lu [11]. Furthermore, genetic advance as per cent of mean was computed adopting the method given by Johnson et al. [12].

3. RESULTS AND DISCUSSION

The analysis of variance for 20 genotypes showed significant differences for all the ten characters, representing a broad spectrum of variability among the genotypes represented in Table 2. Further, the data obtained from the mean performance study (Table 3) also showed high significant difference indicating the existence of sufficient variability for all the characters among the genotypes investigated. Days to germination of all 20 genotypes ranged from 5.80 to 7.67 days. The variety Kashi Ageti took minimum days to germination (5.80). Whereas, maximum days to germination was taken by genotype Kashi Samarth (7.67). Days to 50% flowering of all genotypes showed wide range from 36.47 to 69.07 days. Kashi Shakti was recorded with minimum days to 50% flowering (36.47) and Kashi Samrath with maximum days to 50% flowering (69.07). With respect to plant height tallest plant the in cultivar Solan Nirog (88.64 cm) and shortest plant was recorded AP-3 (39.25 cm). Similarly, Maximum number of pods was observed in genotype Bonneville (16.27) and minimum number of pods per plant in Arka Sampoorna (6.80). The Maximum number of seed per pod was recorded in Kashi Ageti (7.80) and minimum number of pod was recorded in cultivar AP-3 (5.73). The cultivar Kashi Ageti was recorded with maximum length of pod (8.25 cm) whereas Minimum length of pod found in Pant Matar-3 (6.30cm). Genotype PC-531 was recorded with maximum width of pod (1.44 cm) and cultivar VL-3 was recorded with minimum width of pod (1.12 cm). The maximum and minimum days to maturity was recorded in variety Kashi Samrath 114.33 days and Kashi Ageti 56.60 days respectively. Similarly, the variety Kashi Samrath showed maximum pod yield per plant (72.56 gm) whereas, minimum yield per plant (gm) was observed in cultivar VL-3 (34.14) gm. The Maximum pod yield (q/ha) was observed in cultivar Bonneville (120.66 q/ha), and minimum pod yield (q/ha) was found in Pant Matar-2 (56.48 q/ha). Similar findings were reported by Kumar et al. [6], Habtamu and Million [13], Katiyar et al. [14] and Georgieva et al. [15] Gupta et al. [16] and Kumar et al. [17] where significant variability among the genotypes for most of the characters were reported in their studies .

Coefficient of variation studied indicated that estimates of phenotypic coefficient of variation were slightly higher than the corresponding genotypic coefficient of variation for all the characters. High heritability was observed for all the ten characters. The maximum heritability was found in characters days to maturity (99.39) and the minimum heritability was found in width of pod (73.83). The estimates of heritability in broad sense were computed, which includes additive gene effects. High value of heritability in broad sense indicates that the character is least influenced by environmental effects. The genetic advance as percent of mean for various characters are represented in Table 4 and noticed that high genetic advance as percent of mean recorded for number of pod per plant (54.21). Plant height cm (46.50), pod yield per plant (45.43) gm, days to 50% flowering (37.07), moderate was recorded in days to maturity (33.68) , pod yield q/ha(32.22) and lowest was recorded in days to germination (12.97). Expected genetic advance as percent of mean indicates the mode of gene action in the expression of traits, which helps in choosing an appropriate breeding method. In the present study, number of pods per plant, plant height and seed days to maturity showed high estimates of heritability along with high estimates of genetic advance as percent of mean. Similar results reported by Jitendra et al. [18] Sonali et al. [19] Katoch et al. [20] Kumar et al. [21].

The high percent of genotypic co-efficient of variation (>20%) was observed for number of pod per plant (26.47), plant height (22.69) cm, and pod yield per plant (22.17) gm and observed moderate genotypic coefficient of variation (10%-20%) in days to 50% flowering (18.15), days to maturity(16.40), and pod yield q\ha (15.73). Remaining characters showed low coefficient of variation Table 4.

Phenotypic and genotypic correlation coefficient analysis showed in Tables 5 & 6. Phenotypic correlation coefficient showed highly significant positive correlation for pod yield (quintal per hectare) was exerted with number of pod per plant (0.693), pod yield per plant (gm) (0.569) and length of pod (cm) (0.482) and Positive non-significant correlation was found with days to maturity (0.166) followed by seeds per pod (0.131), width of pod (cm) (0.100), days to 50% flowering (0.039) and plant height (cm) (0.22).Whereas negative non-coefficient correlation found with days to germination (-0.008).

Table 1. List of genotypes used in the experiment

Sl. No.	Genotypes	Institute
1.	Kashi Shakti	I.I.V.R, Varanasi
2.	Kashi Mukti	I.I.V.R, Varanasi
3.	Kashi Samrath	I.I.V.R, Varanasi
4.	Kashi Nandini	I.I.V.R, Varanasi
5.	Bonneville	USA
6.	Pant Matar-2	G.B.P.U.A.T, Pantnagar
7.	Arka Ajit	I.I.H.R, Bangalore
8.	Arkel	England
9.	Arka Sampoorna	I.I.H.R, Bangalore
10.	Kashi Samridhi (VRPMR-11)	I.I.V.R, Varanasi
11.	Mithi Fali	PAU, Ludhiyana
12.	Arka Priya (IIHR-1)	I.I.H.R, Bangalore
13.	Azad Pea -3	C.S.A.U.A.T , Kanpur
14.	Pusa Pragati	I.A.R.I, New Delhi
15.	PC-531	PAU, Ludhiyana
16.	Kashi Ageti	I.I.V.R, Varanasi
17.	Solan Nirog	U.H.F, Solan.
18.	Arka Kartik	I.I.H.R, Bangalore
19.	Kashi Uday	I.I.V.R, Varanasi
20.	VL-3	V.P.K.A.S, Almora

Table 2. Analysis of variance (ANOVA) mean sum of square for ten parameters of pea

Source of variation	d.f.	Days to Germination	Days to 50% Flowering	Plant height (cm)	Number of Pods per plant	Seeds per Pods	Length of Pod (cm)	Width of Pod (cm)	Days to Maturity	Pod yield per plant (gm)	Pod yield (q/ha)
Replication	2	0.019	1.20	2.68	0.12	0.115	0.341	0.002	0.57	0.81	0.53
Treatment	19	0.693**	242.63**	627.84**	25.83**	0.939**	0.856**	0.014**	544.89**	374.77**	598.54**
Error	38	0.040	1.43	2.15	0.10	0.056	0.033	0.001	1.12	1.32	2.23
Total	59	0.249	79.10	203.66	8.39	0.343	0.308	0.005	176.21	121.57	194.20

Table 3. Mean performance of the pea cultivars for ten characters

S. No.	Genotypes	Days to Germination	Days to 50% Flowering	Plant height (cm)	Number of Pods per plant	Seeds per Pods	Length of Pod (cm)	Width of Pod (cm)	Days to Maturity	Pod yield per plant (g)	Pod yield (q/ha)
1	Kashi Shakti	6.40	56.33	84.50	15.73	7.53	7.74	1.24	97.47	63.13	101.88
2	Kashi Mukti	6.60	37.80	45.57	10.73	7.67	7.26	1.22	62.80	52.15	93.85
3	Kashi Samrath	7.67	69.07	78.55	15.33	6.60	7.45	1.15	114.33	72.56	106.67
4	Kashi Nandani	5.87	44.73	45.53	12.40	6.93	7.45	1.24	73.13	60.01	92.25
5	Bonneville	7.33	50.67	63.77	16.27	6.80	7.71	1.25	86.53	71.80	120.66
6	Pant Matar 2	7.07	46.00	51.85	7.07	6.20	6.30	1.17	65.40	39.54	56.48
7	Arka Ajit	7.00	57.60	78.24	12.67	6.93	7.18	1.22	94.20	59.71	74.07
8	Arkel	6.73	39.87	50.25	13.67	6.40	7.62	1.21	70.67	53.72	116.53
9	Arka Sampoorna	7.20	45.07	56.32	6.80	7.20	7.09	1.15	91.60	46.09	79.25
10	Kashi Samridhi	7.27	61.33	71.43	7.07	6.07	6.45	1.19	84.93	49.95	84.97
11	Mithi Phali	7.07	46.73	64.69	8.13	6.27	6.67	1.27	76.13	44.93	89.81
12	Arka Priya	7.20	50.60	74.29	7.93	7.27	7.45	1.23	82.00	49.81	83.41
13	AP -3	6.47	39.60	39.25	9.53	5.73	7.57	1.18	83.87	55.56	84.99
14	Pusha Pragati	6.33	55.07	62.40	12.27	6.47	7.57	1.16	77.47	39.86	90.85
15	PC-531	7.00	48.67	61.60	10.60	6.20	6.47	1.44	71.00	41.87	84.37
16	Kashi Ageti	5.80	36.47	52.34	8.93	7.80	8.25	1.20	56.60	37.43	90.98
17	Solan Nirog	7.07	45.07	88.64	9.67	7.27	8.04	1.14	88.80	53.37	86.36
18	Arka Karthik	6.47	64.00	71.29	13.40	6.80	7.45	1.22	89.67	45.68	84.32
19	Kashi Uday	6.87	41.07	50.80	11.93	6.87	6.68	1.22	82.47	35.30	87.18
20	VL-3	6.87	52.07	81.75	11.13	6.60	7.45	1.12	92.73	34.14	83.96
	Mean	**6.81**	**49.39**	**63.65**	**11.06**	**6.78**	**7.29**	**1.21**	**82.09**	**50.33**	**89.64**
	Min (Range)	5.80	36.47	39.25	6.80	5.73	6.30	1.12	56.60	34.14	56.48
	Max	7.67	69.07	88.64	16.27	7.80	8.25	1.44	114.33	72.56	120.66
	SE(d)	0.16	0.98	1.20	0.26	0.19	0.15	0.03	0.86	0.94	1.22
	C.D. at 5%	0.33	1.99	2.43	0.54	0.39	0.30	0.06	1.76	1.91	2.48
	C.V. (%)	2.93	2.43	2.30	2.91	3.50	2.48	3.17	1.29	2.28	1.66

Table 4. Estimation of variability (GCV & PCV), heritability, genetic advance and genetic advance as percent of mean

Genotypes	Heritability (%)	GA	GA as %	GCV (%)	PCV (%)	% Contribution
Days to Germination	84.57	0.88	12.97	6.85	7.45	**14.90**
Days to 50% Flowering	98.25	18.31	37.07	18.15	18.32	9.47
Plant height (cm)	98.98	**29.60**	46.50	22.69	22.80	7.43
Number of Pods per plant	98.80	6.00	**54.20**	**26.47**	**26.63**	7.67
Seeds per Pods	83.91	1.02	15.10	8.00	8.73	13.19
Length of Pod (cm)	89.35	1.02	13.99	7.18	7.60	12.02
Width of Pod (cm)	**73.83**	**0.11**	**9.43**	**5.33**	**6.20**	14.23
Days to Maturity	**99.39**	27.65	33.68	16.40	16.45	**6.06**
Pod yield per plant (g)	98.95	22.86	45.43	22.17	22.29	7.36
Pod yield (q/ha)	98.89	28.88	32.22	15.73	15.82	7.68

Table 5. Estimation of phenotypic correlations (PC) level among ten characters of pea

Characters	Days to Germination	Days to 50% Flowering	Plant height (cm)	Number of Pods per plant	Seeds per Pods	Length of Pod (cm)	Width of Pod (cm)	Days to Maturity	Pod yield per plant (g)	Pod yield (q/ha)
Days to Germination	1.000	**0.381****	**0.393****	-0.073	-0.221	-0.356**	-0.060	**0.487****	0.246	-0.008
Days to 50% Flowering			**0.677****	**0.354****	-0.182	-0.107	-0.066	**0.726****	**0.342****	0.039
Plant height (cm)				0.216	0.175	0.170	-0.147	**0.664****	0.202	0.022
No. of Pods per plant					0.124	**0.400****	0.091	**0.410****	**0.579****	**0.693****
Seeds per Pods						**0.509****	-0.117	-0.066	0.078	0.131
Length of Pod (cm)							-0.284*	0.107	0.311*	**0.482****
Width of Pod (cm)								-0.290*	0.001	0.100
Days to Maturity									**0.493****	0.166
Pod yield per plant (gm)										**0.569****
Pod yield (q/ha)										1.000

*** Significant at 1% level*

Table 6. Estimation of Genotypic correlations level among ten characters in pea

Characters	Days to Germination	50% Flowering	Plant height (cm)	Number of Pods per plant	Seeds per Pods	Length of Pod (cm)	Width of Pod (cm)	Days to Maturity	Pod yield per plant (gm)	Pod yield (q/ha)
Days to Germination	1.000	**0.425****	**0.431****	-0.087	-0.336**	-0.462**	-0.044	**0.532****	0.261*	-0.001
50% Flowering			**0.688****	**0.362****	-0.194	-0.107	-0.094	**0.736****	**0.347****	0.036
Plant height cm				0.221	0.186	0.178	-0.163	**0.669****	0.201	0.020
Number of Pods/plant					0.137	**0.429****	0.118	**0.414****	**0.588****	**0.702****
Seeds per Pods						**0.545****	-0.124	-0.074	0.076	0.149
Length of Pod							-0.397**	0.117	0.326*	**0.513****
Width of Pod cm								-0.336**	0.005	0.113
Days to Maturity									0.498**	0.167
Pod yield /plant (g)										**0.575****
Pod yield (q/ha)										1.000

*** Significant at 1% level*

Table 7. Direct and Indirect effect of nine characters with pod yield (q/ha) Genotypic (GC) level of pea

Characters	Days to Germination	Days to 50% Flowering	Plant height (cm)	Number of Pods per plant	Seeds per Pods	Length of Pod (cm)	Width of Pod (cm)	Days to Maturity	Pod yield per plant (gm)	R with Pod yield (q/ha)
Days to Germination	**0.7740**	0.0844	-0.2240	-0.0439	0.0066	-0.4484	-0.0150	-0.1078	-0.0268	-0.001
Days to 50% Flowering	0.3292	**0.1985**	-0.3575	0.1822	0.0038	-0.1040	-0.0318	-0.1490	-0.0356	0.036
Plant height (cm)	0.3339	0.1367	**-0.5193**	0.1111	-0.0036	0.1725	-0.0551	-0.1355	-0.0206	0.020
No. of Pods per plant	-0.0675	0.0718	-0.1146	**0.5035**	-0.0027	0.4161	0.0397	-0.0838	-0.0603	0.702**
Seeds per Pods	-0.2597	-0.0385	-0.0964	0.0690	**-0.0195**	0.5286	-0.0419	0.0150	-0.0078	0.149
Length of Pod	-0.3577	-0.0213	-0.0923	0.2159	-0.0106	**0.9703**	-0.1341	-0.0238	-0.0335	0.513**
Width of Pod (cm)	-0.0344	-0.0187	0.0848	0.0592	0.0024	-0.3854	**0.3376**	0.0680	-0.0005	0.113
Days to Maturity	0.4119	0.1460	-0.3473	0.2083	0.0015	0.1138	-0.1133	**-0.2026**	-0.0511	0.167
Pod yield /plant (gm)	0.2020	0.0689	-0.1042	0.2958	-0.0015	0.3162	0.0016	-0.1009	**-0.1026**	0.575**

*** Significant at 1% level*

Table 8. Direct and Indirect effect of nine characters with pod yield (q/ha) at Phenotypic (PC) level in pea

Characters	Days to Germination	Days to 50% Flowering	Plant height (cm)	Number of Pods per plant	Seeds per Pods	Length of Pod (cm)	Width of Pod (cm)	Days to Maturity	Pod yield per plant (gm)	R with Pod yield (q/ha)
Days to Germination	**0.2683**	-0.0490	-0.0288	-0.0429	0.0224	-0.1326	-0.0049	-0.0917	0.0508	-0.008
50% Flowering	0.1022	**-0.1287**	-0.0497	0.2082	0.0184	-0.0400	-0.0054	-0.1367	0.0706	0.039
Plant height cm	0.1054	-0.0872	**-0.0733**	0.1273	-0.0177	0.0631	-0.0121	-0.1250	0.0417	0.022
No.of Pods/plant	-0.0196	-0.0456	-0.0159	**0.5881**	-0.0126	0.1488	0.0075	-0.0772	0.1196	0.693**
Seeds per Pods	-0.0594	0.0234	-0.0128	0.0731	**-0.1011**	0.1894	-0.0097	0.0124	0.0162	0.131
Length pf Pod	-0.0956	0.0138	-0.0124	0.2352	-0.0515	**0.3721**	-0.0234	-0.0202	0.0641	0.482**
Width of Pod cm	-0.0160	0.0085	0.0107	0.0533	0.0119	-0.1056	**0.0823**	0.0547	0.0002	0.100
Days to Maturity	0.1306	-0.0934	-0.0487	0.2409	0.0067	0.0399	-0.0239	**-0.1884**	0.1018	0.166
Pod yield /plant (g)	0.0660	-0.0440	-0.0148	0.3406	-0.0079	0.1156	0.0001	-0.0929	**0.2065**	0.569**

*** Significant at 1% level*

In Genotypic correlation coefficient pod yield quintal per hectare showed highly positive significant correlation with number of pod per plant (0.702), pod yield per plant (gm) (0.575), and length of pod (cm) (0.513) and positive non-significant correlation with days to maturity (0.167), seeds per pod (0.149), width of pod (cm) (0.113), days to 50% flowering (0.036) and plant height (cm) (0.020). While negative non-significant correlation with days to germination (-0.001). Therefore, it can be concluded that genotypes with high yields will be identified through selection based on any one of these traits, either individually or in combination would be effective for improvement. Similar findings was reported by Guleria et al. [22] Nawab [23] and Devi et al. [24] previously in their studies [25-29].

When compared to the comparable phenotypic direct and indirect effects, the genotypic direct and indirect effects were slightly greater in terms of magnitude. The highest positive direct effect on pod yield (q/ha) was observed by length of pod (0.9703), days to germination (0.7740), number of pod per plant (0.5035),width of pod (0.3376) and days to 50% flowering (0.1985). Which indicates that these characters play the significant role to increase the pod yield (q/ha) High but negative direct effect was showed by plant height (-0.5193), days to maturity (-0.2026), pod yield per plant (-0.1026) and seeds per pod (-0.0195). Therefore these characters may be selected for pea crop improvement. At the phenotypic level, also the estimates of direct and indirect were exhibited by genotypic level with little variation in magnitude Tables 7 and 8. The magnitude of residual effects at both phenotypic and genotypic level were observed to be low. These results are in agreement with Pandey et al. [30], Lal et al. [31] and Karnwal et al. [32]

4. CONCLUSION

Mean performance values showed that all the characters have significant difference for all the ten characters of twenty genotypes of pea. Phenotypic coefficient of variance (PCV) was higher than the genotypic coefficient (GCV) of variation for all traits indicating that environmental factor influencing their expression and their susceptibility to environmental fluctuations slightly. Variability studies suggest that all the characters revealed that direct selection is more effective to improve all the characters in pea. Pod yield q/ha expressed highly significant and positive correlation with number of pod per plant and length of pod (cm). Positive and significant correlation with number of pod per plant at both genotypic and phenotypic correlation, which indicates that these characters play the significant role to increase the pod yield (q\ha.). It is concluded that Bonneville, Arkel and Kashi Shakti varieties shows better result in terms of yield attributing characters. Therefore these varieties can be used further in breeding improvement programme in pea.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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