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RESEARCH ARTICLE

Assessment of Inter-Relation & Multivariate Analysis for Horticultural Traits in Garden Pea (*Pisum sativum* var. *hortense*)

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ABSTRACT

The garden pea is the major food legume & ranks fourth in terms of production worldwide. However, the production of garden peas is influenced by genotypes & environmental conditions. Thus, the present study was carried out to identify the most suitable genotypes for various horticultural traits in garden peas. Seven genotypes of garden peas were evaluated at two different sites and at two different dates of planting. The results revealed significant variability in different horticultural traits under study. Pod length, number of seeds per pod & average pod weight had highly significant positive & strong relations with pod yield per plant. This suggests that these traits can be used as a reliable selection criterion for improving pod yield. Principal component analysis revealed a cumulative variation of 93.10% with more than one eigenvalue for important traits across different genotypes. Pod length, pod diameter, number of seeds per pod, average pod weight & yield per plant were found to be important traits toward PC1, while in PC2, plant height showed the maximum positive loading. The PC3 allowed maximum positive number of nodes to first flower & days to first pod harvest. Based on cluster analysis, cluster I contained 57.14% of genotypes, while cluster II had the lowest number (0.14%) of genotypes. Thus, hybrids resulting from diverse crosses are thought to exhibit a large amount of variability & have ample scope to identify to select transgressive segregants in the advanced generation.

Keywords: *Garden pea, Multivariate analysis, Principal Component Analysis, Yield*

INTRODUCTION

Garden pea (*Pisum sativum* var. *hortense* L.) is the major food legume & ranks fourth in terms of production in the world (*Vohra et al., 2015*). It is a very protein rich and nutritious vegetable (*Yadav et al., 1996*) as its green seeds contain 7.2 % protein, vitamin A (139 I.U.), vitamin C (9 mg), phosphorus (139 mg), calcium (20 mg), carbohydrates (14.5 g) (*Peter et al., 2012*). Furthermore, it encompasses various health benefits by reducing colon cancer, coronary disease & LDL-cholesterol (Kour *et al., 2020*). In addition, pea pods radiating from mature, fresh green peas represent a copious source of dietary fiber, calcium & protein compared to broad bean & okra by-products (Kumari & Deka, 2021), as well as phenolic antioxidants (*Hanan et al., 2020*).

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The most crucial objective of pea breeding is to enhance productivity, but pod yield is an intricate character influenced by polygenic traits & its expression depends on genetic factor, environment & their interaction (*Burstin et al., 2015*). Many studies have shown the effect of genetic factors, environment & their interaction on the pod yield of peas (*Bocianowski et al., 2019*). Thus, the improvement of crops depends upon the amount of variability present in the base material & effectiveness of selection (*Kumari et al., 2012*). The correlation provides insight into the relationships between characters & the influence of the environment. However, correlation studies do not provide an indication of the nature & extent of the involvement of traits in yield. This problem is overcome by path analysis, which divides the correlation coefficient into direct & indirect effects. Principal component analysis (PCA) helps in effective selection by identifying important traits & curtailing negligible, non-significant traits. This data gives proper weightage during the selection of traits, so that the enhancement of the desired trait can be achieved efficiently. Keeping the above facts in view the present study was conducted to evaluate the interrelation and multivariate analysis of horticultural traits in garden peas.

MATERIALS AND METHODS

Experiment Location

This research was conducted from 2022 to 2023 at the experimental station of the Agricultural Research Institute, Patna, Bihar. This place is characterized by a humid, sub-tropical climate with hot summers between March and June & cold winters between late October & early February.

Genetic Materials

Seven genotypes of garden peas (table 1) were collected from different sources & sown at two different sites on two dates, *viz*., 8 November 2022 (Early Sowing) & 10 December 2022 (Late Sowing). Before sowing, the field was prepared through 3 to 4 ploughings to achieve good soil tilth. Then, seed was sown at a row-to-row & plant-to-plant spacing of 30cm × 10cm. The standard package of practices as recommended by the Agricultural Research Institute, Patna, for vegetable crops was followed to raise the crop.

Experimental Design and Statistical Analysis

All genotype was shown in a randomized block design with three replications. Data of eleven yield contributing characters *viz.*, number of node to first flower (NFT), days to 50% flowering (DFF), days to first pod harvest (DPH), number of branch per plant (NBP), plant height in cm (PH), pod length in cm (PL), pod diameter in cm (PD), number of pod per plant (NPP), number of seed per pod (NSP), average pod weight in g (APW) & yield per plant in g (YPP) were taken by following the descriptors. The statistical analysis of pooled data was conducted to test for significant differences, as suggested by *Panse & Sukhatme* (1967). The correlation analysis, path analysis & PCA analysis were performed using RStudio software version 2023.03+446 & cluster analysis was conducted with the help of Past 4.03 software.

RESULTS & DISCUSSION

Correlation & path analysis of pea genotypes

Character association among eleven traits based on Pearson's correlation analysis is given in Table 2 & figure 1. A non-significant correlation was found for the number of nodes to first flower, days to 50% flowering, days to first pod harvest, number of branches per plant, pod diameter & number of pods per plant with yield. Pod length ($r=0.942$; $p\leq0.01$), number of seeds per

Table 1: List of genotypes

Sl. No.	Genotypes	Source
1	Arkel	ICAR-IARI, New Delhi
2	Azad Pea 3	CSAUA&T, U.P.
3	Punjab 89	PAU, Punjab
4	01L/22	Locally Collected from the Lakhisarai district of Bihar
5	02L/22	Locally Collected from the Lakhisarai district of Bihar
6	03L/22	Locally Collected from the Lakhisarai district of Bihar
7	Kashi Mukti	ICAR-IIVR, Varanasi

pod (r=0.848; p≤0.05) & average pod weight (r=0.918; p≤0.01) had highly significant positive & strong (0:75 ≤r <1:00) relations with yield. Therefore, emphasis given to these traits during selection could be helpful for the genetic improvement of garden peas. Plant height (r=0.763; p≤0.05) had a significant negative & strong (0:75 ≤r <1:00) association with yield. *Rahman et al. (2021)* reported a positive correlation between yield & the number of seeds per pod. *Kumar et al. (2015)* also found a positive correlation between pod yield & pod length, as well as the number of seeds per pod, suggesting that these are significant traits contributing to pod yield. *Adebisi et al. (2004)* confirmed that the reflection of correlation values among the variables is crucial for selecting superior genotypes.

The path coefficient analyses (Table 3) provide a clear understanding of the nature of the association between the different traits in forming a proficient selection approach. The results revealed that the days to first pod harvest, number of branches per plant, number of pods per plant, number of seeds per pod & average pod weight had a positive direct effect on yield. However, the highest positive direct effect on yield was exhibited by average pod weight. Plant height showed a direct adverse effect on fruit yield per plant (-1.486), similar to its rYPP (-0.763), implying that a true relation exists between these traits. Moreover, plant height has a high indirect effect on yield per plant through pod length (2.281). *Kumar et al. (2015)* revealed the direct effects of the number of pods per plant & number of

Table 2: Correlation analysis of eleven traits in garden pea genotypes

Traits	NFT	DFF	DPH	NBP	PL	PD	NPP	NSP	APW	PH
DFF	0.597									
DPH	0.826*	0.849*								
NBP	-0.204	0.424	0.273							
PL	-0.366	-0.106	-0.222	-0.040						
PD	-0.765*	-0.533	-0.627	-0.176	0.724					
NPP	0.446	0.591	0.659	0.626	-0.676	-0.753				
NSP	-0.154	-0.012	-0.043	-0.200	0.941**	0.658	-0.686			
APW	-0.487	-0.507	-0.487	-0.278	0.899**	0.839*	-0.820*	0.833*		
PH	0.579	0.265	0.553	0.068	-0.872*	-0.697	0.746	-0.711	-0.807*	
YPP	-0.396	-0.229	-0.221	0.061	0.942**	0.716	-0.556	0.848*	0.918**	-0.763*

Legends: *P<0.05; ** P<0.01.

Table 3: Direct & indirect effects of eleven yield contributing characters in garden pea

Traits	NFT	DFF	DPH	NBP	PL	PD	NPP	NSP	APW	PH	rYPP
NFT	-0.340	-0.208	0.969	-0.054	0.944	0.046	0.203	-0.160	-0.937	-0.862	-0.396
DFF	-0.204	-0.347	0.992	0.115	0.288	0.032	0.266	-0.011	-0.975	-0.386	-0.229
DPH	-0.282	-0.295	1.167	0.075	0.577	0.038	0.297	-0.043	-0.937	-0.817	-0.221
NBP	0.068	-0.149	0.327	0.268	0.105	0.011	0.284	-0.214	-0.536	-0.104	0.061
PL	0.122	0.038	-0.257	-0.011	-2.622	-0.043	-0.306	1.005	1.721	1.293	0.942**
PD	0.258	0.184	-0.735	-0.048	-1.888	-0.060	-0.338	0.705	1.607	1.025	0.716
NPP	-0.153	-0.205	0.770	0.169	1.783	0.045	0.451	-0.738	-1.568	-1.114	-0.556
NSP	0.051	0.003	-0.047	-0.054	-2.465	-0.040	-0.311	1.069	1.587	1.055	0.848*
APW	0.166	0.177	-0.572	-0.075	-2.360	-0.051	-0.369	0.887	1.913	1.204	0.918**
PH	-0.197	-0.090	0.642	0.019	2.281	0.042	0.338	-0.759	-1.549	-1.486	-0.763*

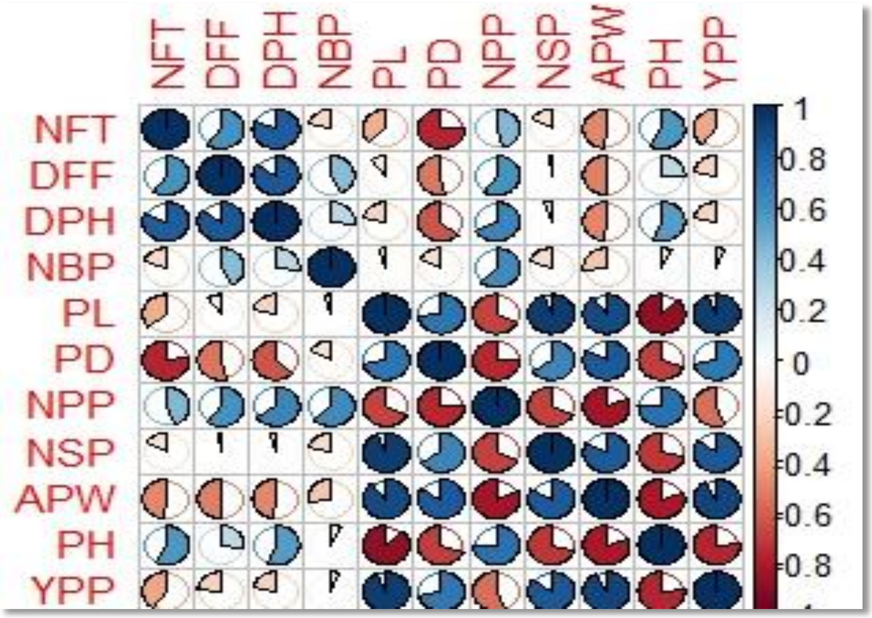

Figure 1: Correlation matrix of different characters in garden pea genotypes.

seeds per pod on pod yield & suggested that these traits can provide a reliable basis for improving pod yield in garden peas. In the same way, pod length had a positive indirect effect on yield through the number of seeds per pod (1.005), average pod weight (1.721) & plant height (1.293). Thus, correlation & path analysis confirms that the number of seeds per pod & average pod weight lead to an increase in yield in peas. Hence, selection based on the above-selected characters would be effective in increasing the yield of garden peas.

Principal component analysis (PCA)

In the present research, the entire diversity was divided into seven groups, in which PC1 (6.58), PC2 (2.22) & PC3 (1.44) had more than 1 eigenvalue, representing the maximum variation (Table 4 & Figure 2). PCs with less than 1 eigenvalue were considered to have no practical significance (*Tejaswini et al., 2018*). Thus, it is inferred that vital features of the data correspond to the first three PCs, explaining 93.10% of the cumulative variation. Among all PCs, the highest was marked in PC1 (59.86%) while PC7 had the least proportion of variance, *i.e.*, 0.00%. *Ouafi et al., (2016) reported 3 PCs with more than 1 eigenvalue, accounting for* a cumulative variation of 85.92%. Devi *et al.,* (2021 & 2023) noted that 74.88% & 70.92% of the cumulative variation by principal components had more than one eigenvalue.

The factor loading of traits, as represented in Table 5 & fig 3(A), revealed that PC1 allowed for maximum positive loadings of traits such as pod length, pod diameter, number of seeds per pod, average pod weight & yield per plant, while other traits showed negative loadings. In PC2, plant height showed the maximum positive loading, while the other traits showed negative loading. The PC3 allowed maximum positive loading for the number of nodes to first flower & days to first pod harvest. The distinguished traits come collectively from diverse PCs & contribute to variability, having an affinity to remain interrelated (*Sinha & Mishra, 2013*). Thus, trait-based selection may be helpful in formulating a valuable selection approach for further pea improvement programs. *Gixhari et al. (2014)* reported that the number of seeds per pod &

Table 4: Eigenvalues, variability % & cumulative variation % in garden pea

Principal Components	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalue	6.58	2.22	1.44	0.42	0.28	0.06	0.00
Proportion of variance (%)	59.86	20.16	13.08	3.78	2.57	0.55	0.00
Cumulative variation (%)	59.86	80.02	93.10	96.88	99.45	100.00	100.00

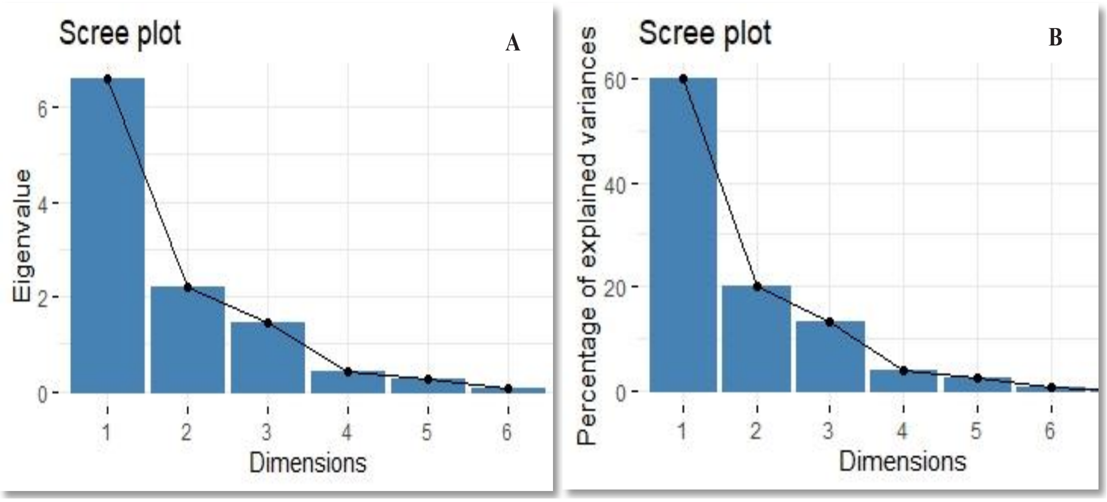

Figure 2: Scree plot showing the Eigenvalue (A) & percent proportion of variance (B)

Table 5: Principal loading factor of different traits in three principal factors

Traits	PC1	PC2	PC3
Number of nodes to the first flower	-0.25	-0.30	0.49
Days to 50% flowering	-0.21	-0.50	-0.07
Days to first pod harvest	-0.25	-0.49	0.12
Number of branches per plant	-0.10	-0.22	-0.75
Pod length (cm)	0.34	-0.33	-0.03
Pod diameter (cm)	0.35	0.07	-0.11
Number of pods per plant	-0.34	-0.12	-0.32
Number of seeds per pod	0.30	-0.38	0.17
Average pod weight (g)	0.38	-0.09	0.08
Plant height (cm)	-0.34	0.10	0.11
Yield per plant (g)	0.33	-0.29	-0.11

yield contributed positively to variability. *Umar et al. (2014)* found that pod length & pod diameter were related to the first principal component.

The biplot diagram (Figure 3B) shows the association among the traits & between genotype × traits. The vector length provides a measure of the contribution of traits to total variance; the longer the vector length, the greater the contribution of those traits. The traits days to first pod harvest, pod length & average pod weight showed the highest vector length, representing their involvement in the entire diversity. The genotypes closest to the vector trait are likely to be the best performers for particular traits. The genotype Punjab 89 performs better for the number of seeds per pod, while Azad Pea 3 performs best for pod diameter. The genotype 03L/22 is the best performing for plant height & 02L/22 performs better for the number of pods per plant.

Cluster analysis

The results (Table 6) revealed that the genotypes were grouped into three major clusters. Cluster I had the highest (57.14%) number of genotypes, *viz*., Kashi Mukti, Arkel, Azad Pea 3 & 01L/22, while cluster II had the lowest number (0.14%) of genotypes & cluster III contains two genotypes, *viz*., 02L/22 & 03L/22, which correspond to 28.57% of the total population. The genotypes of different origins show a random distribution in single clusters, indicating that the diversity is not associated with the geological origin (*Devi et al., 2023*). Such a relationship between geological allocation & diversity might be due to genetic construction, the history of selection, heterogeneity, or the closeness of traits (*Sureja & Sharma, 2001*). Cluster II with single genotypes specifies their unique

Table 6: Cluster analysis of pea genotypes

Cluster	Genotype number	Genotypes
Cluster I	4	Kashi Mukti, Arkel, Azad Pea 3, 01L/22
Cluster II	1	Punjab 89
Cluster III	2	02L/22, 03L/22

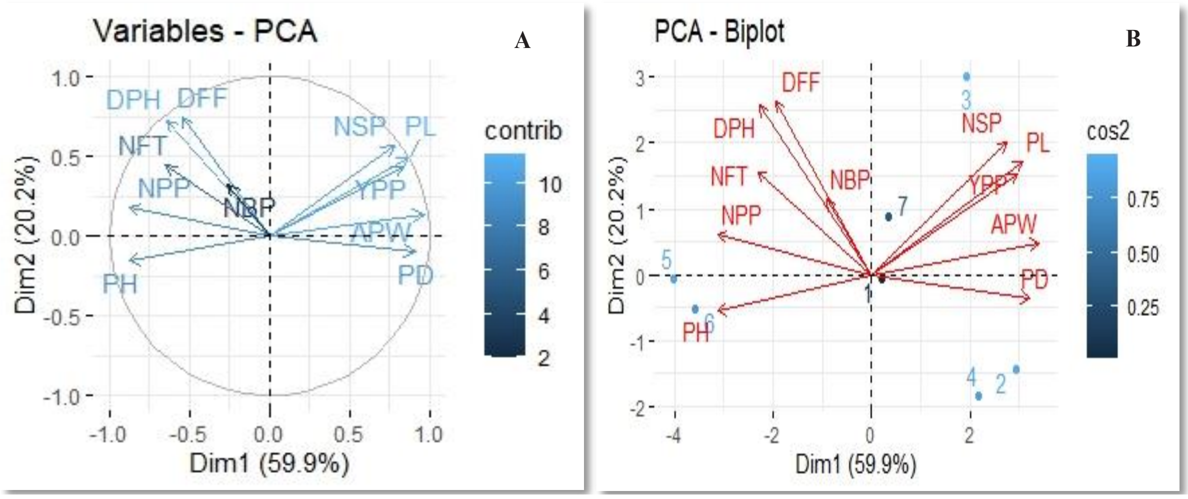

Figure 3: Distribution of traits (A) & association between genotypes & traits (B) based on PC1 &

identity. Our results align with those of *Singh et al., (2013)* & *Arif et al., (2020).*

CONCLUSION:

In the present investigation, it is found that pod length, number of seeds per pod & average pod weight had a highly significant positive & strong correlation with pod yield per plant. This suggests that these traits can serve as reliable selection criteria for enhancing pod yield in garden peas. The PCA analysis revealed three major PCs with around 93.10% of the cumulative variation. Further, it may be concluded that hybrids resulting from diverse crosses are thought to exhibit a large amount of variability & thus ample scope to identify transgressive segregants in the advanced generation.

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AUTHOR CONTRIBUTION

S.S.S.- conceptualization, design, performed field work & editing of Manuscript; R.K.- supervision & editing; A.S.- data analysis, Writing & editing of Manuscript; S.A.- supervision & editing; A.A.- reviewing & editing, Preparation of figures & plagiarism check. All authors read & approved the final manuscript.

Conflict of interest

The Authors declare that there is no conflict of interest.

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