**Assessment of Inter-Relation and Multivariate Analysis for Horticultural Traits in Different Genotypes of Garden Peas (*Pisum sativum* var. *hortense*)**

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**Abstract:**

Garden pea is the major food legume & ranks fourth in terms of production in the world but the production of garden peas is influenced by genotypes & environmental conditions thus, the present study was carried out to find out the most suitable genotypes for various horticultural traits in garden pea. Seven genotypes of garden peas were evaluated at two different sites at two different dates of planting & result 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 indicates that these traits can provide a reliable selection for improvement in pod yield. Principal component analysis showed a 93.10% cumulative variation with more than 1 eigenvalue for important traits in 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 maximum positive loading. The PC3 allowed maximum positive loading for the number of nodes to first flower & days to first pod harvest. Based on cluster analysis, Custer-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 or isolate 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 nutritious vegetable as its green seeds contain 7.2 % protein predominantly lysine (Nawab *et al.,* 2008), 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 diminution 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 as compared to broad bean & okra by-products (Kumari & Deka, 2021), phenolic antioxidants (Hanan *et al.,* 2020).

The most important 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; Tan *et al.,* 2012). Many studies show the effect of genetic factor, 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 & the effectiveness of selection (Prabhu *et al.,* 2009; Kumari *et al.,* 2012). The correlation provides an idea concerning the relations of characters & the influence of the environment. However, correlation studies do not give an idea about the nature & extent of the involvement of traits toward yield. This problem is overcome by path analysis, which divides the correlation coefficient into direct & indirect effects. Principal component analysis (PCA) was helping 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 wanted trait might be achieved efficiently. Keeping the above facts in view & lacunas of the research in this aspect, we conducted this study to evaluate the inter-relation & multivariate analysis for 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 summer between March to June & cold winter 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 by 3 to 4 ploughings to obtain 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.

**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 |

**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 followed to test the significant difference as suggested by Panse & Sukhatme (1967). The correlations analysis, path analysis & PCA analysis were done using R studio software version 2023.03.1+446 & cluster analysis was done with the help of Past\_4.03 software.

**Results & Discussion**

**Correlation & path analysis of pea genotypes**

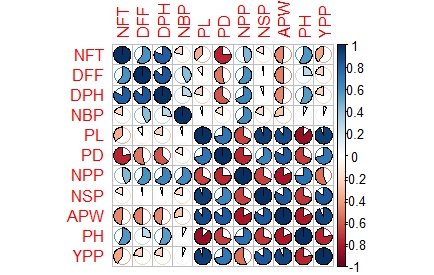
Character association among eleven traits based on Pearson’s correlation analysis is given in table 2 & fig 1. A non-significant correlation was found for the number of nodes to first flower, days to 50% flowering, days to first pod harvest, number of branches per plant, pod diameter & number of pods per plant with yield. Pod length (r=0.942; p≤0.01), number of seeds per 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) relation with yield. Therefore, emphasis given on 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. Pal & Singh (2012) & Rahman *et al.* (2021) reported a positive correlation between yield & the number of seeds per pod. Kumar *et al.* (2015) & Devi *et al.* (2017) also found a positive correlation between pod yield & pod length, number of seeds per pod, suggesting that these are major pod yield contributing traits. Adebisi *et al.* (2004) confirmed that the reflection of correlation values amongst the variables is crucial for the selection of superior genotypes.

**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.

The path coefficient analyses (Table 3) give a clear idea about the nature of the association between the different traits for 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 negative 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). Kaur *et al.* (2007), Kumar *et al.* (2015) & Devi *et al.* (2017) revealed the direct effects of the number of pods per plant & number of seeds per pod on pod yield & suggested that these traits can provide a reliable selection for improvement of 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.

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

**Table 3:** **Direct & indirect effect 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\* |

**Principal component analysis (PCA)**

In the present research, the entirety diversity was divided into seven groups in which PC1 (6.58), PC2 (2.22) & PC3 (1.44) had more than 1 eigenvalue which represents maximum variation (table 4 & fig. 2). The PCs with less than 1 eigenvalue were considered as having 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 with a cumulative variation of 85.92%. Devi *et al.*, in the years 2021 & 2023, noted 74.88% & 70.92% of cumulative variation by principal components having more than 1 eigenvalue.

**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 |



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

The factor loading of traits is represented in table 5 & fig 3 (A) revealed that the PC1 allowed maximum positive loading of traits like 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 maximum positive loading while the rest of the 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 in the direction of variability, having an affinity to stay interrelated (Sinha & Mishra, 2013). Thus, trait-based selection might be helpful to formulate a valuable selection approach for further pea improvement programs. Gixhari *et al.* (2014) reported that the number of seeds per pod & yield contributed positively to variability. Esposito *et al.* (2007) observed that pod length & pod diameter explained positive variability. Umar *et al.* (2014) found that pod length & pod diameter were related to the first principal component.

**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 |

The biplot diagram (Figure 3B) shows the association among the traits & between genotype × traits. The vector length gives a picture of the contribution of traits to total variance, the longer the vector length, the higher the contribution of those traits. The trait days to first pod harvest, pod length & average pod weight showed the highest vector length, representing its involvement in the entire diversity. The genotypes close to the vector trait are probably the best-performing for particular traits. The genotype Punjab 89 performs better for the number of seeds per pod, 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 result revealed (table 6) that the genotypes were grouped into 3 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/22which correspond to 28.57% of total population. The genotypes of different origins show random distribution in single clusters, which indicates that the diversity is not associated with the geological origin (Devi *et al.,* 2023; Sinha *et al.,* 2022). Such a relation between geological allocation & diversity might be due to genetic construction, history of selection, heterogeneity, or closeness of traits (Sureja & Sharma, 2001). Cluster II with single genotypes specifies their unique identity. Our results are in the same tune of Singh *et al.,* (2013), Shubha *et al.,* (2019) & Arif *et al.,* (2020).



**Fig. 3:** Distribution of traits (A) & association between genotypes & traits (B) based on PC1 & PC2.

**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 |

**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 indicates that these traits can provide reliable selection criteria for the improvement of 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 or isolate transgressive segregants in the advanced generation.

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**Conflict of interest**

The Authors declare that there is no conflict of interest.

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