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Research Note

Multivariate insights into selection Indices of farmers' pea (*Pisum sativum* var. *arvense* L.) varieties from Vindhyan zone, Uttar Pradesh

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Abstract
Variability is the prerequisite for selection of superior traits and parents. Multivariate analysis acts as an aid to the process of selection indices. Therefore, twenty-two farmers' varieties of pea (*Pisum sativum* var. *arvense* L.) of Vindhyan zone, Uttar Pradesh were studied at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The varieties were grown in randomized block design (RBD) during *Rabi*, 2019-20 and *Rabi*, 2020-21. The data obtained on 11 traits for the two consecutive years were pooled for principal component (PC) analyses. The result revealed that the four principal components (PC1, PC2, PC3 and PC4) had eigen value greater than unity. They contributed a total of 78.68% of variance. Days to maturity, pod length, pod width, number of effective nodes and yield per plant exhibited maximum variability for the characters, which can be exploited to a greater extent. Days to 50% flowering, days to maturity and harvest index had positive correlation with yield per plant. Number of seeds per pod, number of pods per plant and pod length exhibited negative association with yield per plant. Hence, selection of these traits could be useful to increase the productivity in farmers' pea varieties. To the farmers' varieties viz., PMKK-232 and PKKK-227 could be selected in PC1 for future breeding programme.

Keywords: Pea, PCA, Farmers' varieties, Multivariate analysis

Farmers' varieties or cultivars have historically been cultivated by farmers over years. They may be traditional landraces that are familiar to farmers (Chandrashekaran and Vasudev, 2002). Farmers have been domesticating many wild relatives and/ or traditional landraces (Vodouhe *et al.,* 2011), therefore they have substantially created remarkable genetic diversity among the cultivars that now occurs within species (intraspecific diversity) (Brush, 2004). Genetic heterogeneity of farmers' varieties have increased resilience to biotic and abiotic stresses, which is reducing the likelihood of crop failure (Ceccarelli, 2012). Nevertheless, farmers' varieties occasionally outperform commercial varieties, particularly when grown in stressful environmental conditions (Burdon and Jeirsoz, 1990). However, there is an alarming pace of loss of traditional knowledge and variability. Therefore, the conservation of genetic variability present in the farmers' varieties is needed with the increment of their productivity. Also, to conserve the landraces in gene banks and to protect these genetic resources, estimation of genetic variability is necessary, as it offers fundamental data for conservation (Brondani *et al.,* 2006). Principal component analysis (PCA) reflects the importance of largest contributor to the total variation. Additionally, by reducing the dimensionality of the large data set, it helps in identifying new meaningful underlying variables. Since there is a dearth of information on these varieties, the current investigation was carried out to obtain multivariate insights, particularly PCA, into selection indices of farmers' pea varieties (*Pisum sativum* var. *arvense* L.) from Vindhyan zone, U.P. The study may help to examine more about the principal components (traits that contribute most to variations) and the parents to be used in subsequent breeding programmes.

A total of 22 farmers' varieties of pea (*Pisum sativum* var. *arvense* L.) of Vindhyan zone of Uttar Pradesh were studied at Field Experimentation Centre of Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (Allahabad), U.P. in randomized block design (RBD) with three replications during *Rabi*, 2019-20 and *Rabi*, 2020-21 (**Table 1**). To attain a healthy crop stand, good agricultural practices were followed during the experiment (Beaudoin *et al.,* 2005) in 3m x 3m plot size with 45cm x 10cm row-to-plant spacing. Eleven quantitative traits were recorded on five randomly selected plants in each entry of each replication *viz.,* plant height (cm), number of pods per plant, pod length (cm), pod width (cm), number of effective nodes, number of seeds per pod, harvest index (%), 100-seed weight (g) and seed yield per plant (g), except days to 50% flowering, days to maturity which were recorded on plot basis. The data so obtained for two consecutive years were pooled and then subjected to PCA analysis from Rstudio (R Core Team, 2021; Kassambara and Mundt, 2017).

Principal Component Analysis: Multivariate analysis helps to predict the principal components that contributes maximum to the yield of the crop. The components whose eigen values greater than unity are considered as principal components, as these components are responsible for high magnitude of variance in the farmers' varieties. Since there were eleven variables in the study, eleven components were obtained. In the current investigation, four out of 11 principal components reported eigen values greater than unity, which all together gave 78.68% of

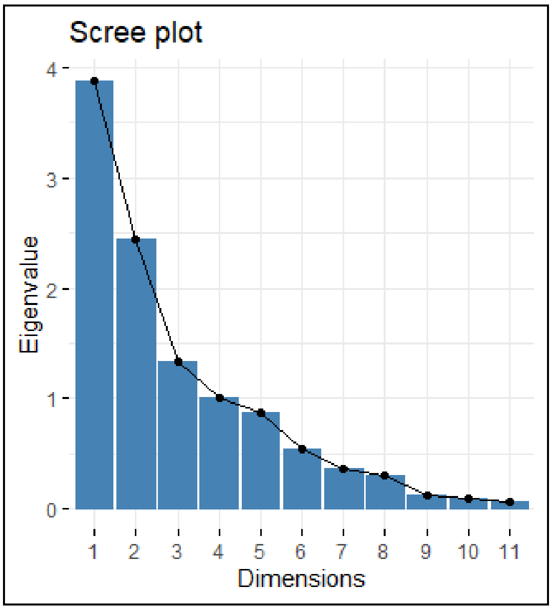
Table 1. List of farmers' varieties used in the present investigation

S. No.	Genotypes	Location
1	PLCM-225	Chittvishram, Mirzapur
2	PSAB-309	Atanpur, Prayagraj
3	PRRA-370	Ramaipur, Prayagraj
4	PRRA-370 A	Ramaipur, Prayagraj
5	PBCM-250	Chittvishram, Mirzapur
6	PSLM-226	Lalthara, Prayagraj
7	FSAB-428	Atanpur, Prayagraj
8	FAIV 425	Itai, Varanasi
9	PARB-223	Ramaipur, Prayagraj
10	PATK-278	Tendui, Prayagraj
11	PARA-308 (2)	Ramaipur, Prayagraj
12	PRBJ-229	Banpurwa, Prayagraj
13	PKKKK-228	Kulhariya, Prayagraj
14	PRAV-230	Arak Pindi, Varanasi
15	PAKA-230	Karanpur, Prayagraj
16	PSAK-307	Amba, Prayagraj
17	PSRA-358	Prayagraj
18	PKKK-227	Kulhariya, Prayagraj
19	PMKK-232	Kulhariya, Prayagraj
20	PARB-223 A (3)	Ramaipur, Prayagraj
21	PARA-501	Jabarapur, Praygraj
22	PMRA-502	Ramaipur, Prayagraj

total variance (**Table 2** and **Fig.1**). In which, 35.27% of total variance was explained by PC 1, followed by PC2 (22.18%), PC3 (12.12%) and PC4 (9.10%). Principal components with eigen value more than unity exhibits more variability among the field pea genotypes for selection of distantly related parents (Christina *et al.,* 2021 and Kumar *et al.,* 2023). Similar approach of PCA for field pea was carried out by Parihar *et al.* (2014), Bhuvaneswari *et al.* (2017), Arif *et al.* (2020), Pratap *et al.* (2024). The large contribution of PC1 (35.27%) indicates that the first principal component captures the most significant variation among the genotypes. The substantial contribution of subsequent components (PC2, PC3, and PC4) further supports the existence of distinct patterns within the genetic variation of the genotypes. The ability to identify and interpret these principal components is crucial for effective selection of distantly related parents for breeding purposes.

Further the individual characters were evaluated for the variance present in each dimensions or principal components. It was noticed that the maximum contribution for variations in PC1 was reflected by days to maturity (22.15 %), followed by pod length (19.16 %) and number of seeds per pod (10.82 %) whereas minimum contributions were of pod width (0.47 %). In PC1, days to maturity contributed the most significant variation, indicating that this trait plays a major role in distinguishing the genotypes based on their maturity periods. This is followed by pod length and number of seeds per pod, which also contributed significantly to the variance in this principal component. The relatively low contribution of pod width suggests that this trait has a lesser impact on the variability captured by PC1. This highlights the importance of selecting genotypes with varying maturity times, pod lengths, and seed counts for hybridization purposes, as these traits may have a substantial effect on yield potential and adaptability. Similarly, pod width (25.06 %) contributed maximum towards the variance in PC2, followed by number of effective nodes (23.21 %) and number of pods per plant (13.68 %), suggesting that these factors are critical for influencing overall plant architecture and pod production. The prominence of pod-related traits in PC2 emphasizes the importance of selecting for pod width and pod production traits when developing breeding strategies to enhance yield potential. Seed yield per plant (24.66 %) followed by pod width (22.31 %) and number of effective nodes (15.32 %) reported maximum contribution in case of PC3. Since seed yield per plant is a crucial trait for improving productivity, selection of genotypes with high seed yield potential, coupled with desirable pod-related traits, would be essential for enhancing the economic value of field pea cultivars. Harvest index (28.70 %) had greater influence in PC4 followed by number of seeds per pod (18.34 %) and days to 50% flowering (17.57 %). The emphasis on harvest index in PC4 suggests that breeding for improved harvest index could enhance the economic returns from field pea cultivation. Therefore, the findings of this study suggest that the respective characters could be emphasized during the selection of parents for hybridization purpose.

Fig.1. Scree plot graph for principal components in farmers' pea varieties



Traits Variability: The visualization of the graph with Dim1 and Dim2 at x-axis and y-axis respectively illustrate the diversity among the traits (**Fig. 2**). The traits, days to 50% flowering and harvest index showed the highest contribution, whereas days to maturity and pod length had the least influence towards the variations. With regards to the variations exhibited by the individual characters, harvest index and days to 50% flowering showed least

Table 2. Eigen value, percentage of variance and cumulative percentage of variance among principal components for farmers' varieties of pea.

Principal Components (PC)	Eigen value	Percentage of variance	Cumulative percentage of variance
PC1	3.88	35.27	35.27
PC2	2.44	22.18	57.46
PC3	1.33	12.12	69.58
PC4	1.00	9.10	78.68

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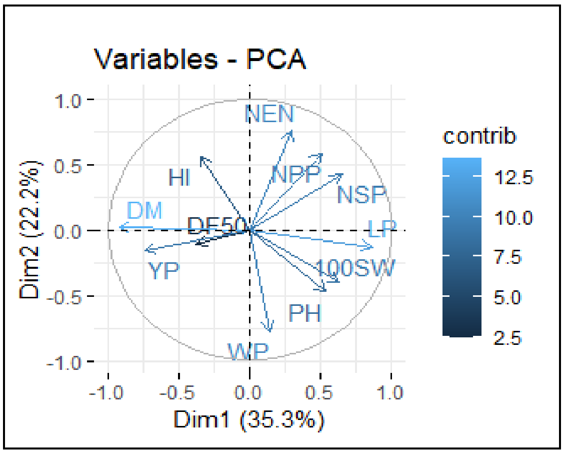
Fig. 2. Graph between Dim1 and Dim2 for the traits of farmers' pea varieties under study



variations and days to maturity, seed yield per plant, pod width, pod length and number of effective nodes showed maximum variations. Days to maturity and pod length had the least influence on the variation, as reflected in their lower contributions. This finding is in line with the PCA results, where these traits showed comparatively smaller impacts on the first principal component (PC1). Despite their smaller contribution to the variance, these traits still hold value for breeding purposes, particularly in selecting genotypes with desirable maturation times or pod sizes that could complement other traits of interest in hybridization programs.

When considering the individual trait variations, it was observed that harvest index and days to 50% flowering exhibited the least variation among the genotypes, suggesting that these traits are relatively stable across the population. In contrast, days to maturity, seed yield per plant, pod width, pod length, and number of effective nodes displayed greater variation, offering ample scope for genetic improvement. The significant variability in these traits provides an opportunity for breeding programs to select genotypes with enhanced traits for improving yield, adaptability, and other agronomic characteristics. As mentioned by Bishnoi *et al.* (2023) in pea, the variations offer the scope for genetic improvement. These variations are therefore, helpful in improving the farmer's varieties of pea.

Characters association among the traits : As illustrated in the graph 2, seed yield per plant showed acute angle with harvest index, days to 50% flowering and days to maturity, indicating positive association. This indicates that genotypes with higher seed yield per plant tend to exhibit earlier flowering, faster maturation, and better harvest indices, which are all indicative of higher productivity. The positive association between seed yield and these traits suggests that optimizing these factors together could be beneficial for improving overall yield in field pea breeding programs. The characters, *viz.*, number of seeds per pod, number of pods per plant and pod length showed approximate 180° angle with seed yield per plant, which means negative correlation with seed yield per plant in farmer's pea varieties. This implies that an increase in these traits may not necessarily lead to an increase in seed yield per plant, and might even be detrimental to it in some farmer's pea varieties. These negative correlations highlight the complexity of breeding for seed yield, where other pod-related traits may need to be balanced carefully to avoid compromising overall yield potential.

Similar trend was also observed in the correlation matrix of the study, conducted by Bishnoi *et al.* (2021) in pea. The characters *viz*. number of effective nodes, pod width and plant height showed right angle with seed yield per plant, indicating no relation with seed yield per plant. These traits do not seem to influence seed yield directly, suggesting that they might not be as critical for improving yield per plant in this particular set of genotypes. While these traits may still be relevant for other agronomic characteristics, their lack of association with seed yield per plant suggests that their improvement alone may not lead to significant increases in yield.

Parental Selection for Breeding: Multivariate analysis can also help in selection of parents for future breeding programme. In the current investigation, as shown in **Table 4**, farmers' variety PMKK-232 (37.68%) showed maximum contribution in PC1, followed by PKKK-227 (30.92%) whereas PRRA-370 A and PKKKK-228 had no contribution. This makes two different groups. Similarly, FSAB-428 (27.41 %), followed by PKKKK-228 (15.78 %) had maximum influence in PC2. PMRA-502 (26.12 %) followed by PRRA-370 (15.49 %) showed greater influence than other genotypes. PATK-278 (33.06 %) had highest contribution in PC4. Therefore, these parents could be selected for exploiting variability. Since PC1 exhibited maximum variation, so the selection of farmers' varieties from PC1 may report to be more favourable.

Variability is the prerequisite for selection of superior traits and parents. Multivariate analysis acts as an aid to the process of selection indices. The result of PCA revealed that PC1, PC2, PC3 and PC4 had eigen values greater than unity and contributed overall 78.68% of total variance. The traits *viz*., days to maturity, seed yield per plant, pod width, pod length and number of effective nodes exhibited maximum variability for the characters. Therefore, these traits could be selected for higher productivity in farmers' pea varieties. The traits *viz*., harvest index, days to 50% flowering and days to maturity had reported positive correlation with seed yield per plant, the change in these characters may positively influence the yield of the crop. Number of seeds per pod, number of pods per plant and pod length had shown negative association with seed yield per plant. In regards to farmers' varieties, PMKK-232 and

Table 3. Variance present in each principal component for individual characters of farmers' pea varieties

Characters	Dim.1	Dim.2	Dim.3	Dim.4
Days to 50% flowering	3.75	0.48	4.33	17.57
Days to maturity	22.16	0.02	1.39	0.02
Plant height	7.29	9.25	8.86	4.97
Number of pods per plant	6.50	13.68	17.11	12.46
Pod length	19.16	0.71	0.10	3.92
Pod width	0.48	25.06	22.31	0.33
Number of effective nodes	2.16	23.21	15.33	4.04
Number of seeds per pod	10.82	7.26	2.61	18.34
Harvest index	3.14	12.66	3.30	28.71
100 Seed weight	10.22	6.66	0.00	7.35
Seed yield per plant	14.32	1.01	24.66	2.31

Table 4. Variance present in each dimensions or principal components for individual farmers' varieties of pea

S. No.	Farmers' pea varieties	Dim.1	Dim.2	Dim.3	Dim.4
1	PLCM-225	1.43	11.57	3.00	1.07
2	PSAB-309	5.33	0.50	3.26	1.66
3	PRRA-370	0.46	0.50	15.49	0.00
4	PRRA-370 A	0.00	4.52	11.30	0.79
5	PBCM-250	0.22	7.17	0.63	2.60
6	PSLM-226	0.10	0.43	2.89	0.17
7	FSAB-428	1.01	27.41	0.05	5.46
8	FAIV 425	0.11	0.01	0.47	0.79
9	PARB-223	3.17	0.85	0.71	10.44
10	PATK-278	6.56	4.99	9.00	33.06
11	PARA-308 (2)	3.07	1.20	0.20	8.47
12	PRBJ-229	0.49	0.28	2.53	6.56
13	PKKKK-228	0.00	15.78	0.00	2.75
14	PRAV-230	0.27	0.09	6.60	0.62
15	PAKA-230	0.36	11.65	0.39	4.59
16	PSAK-307	0.30	0.18	8.09	1.35
17	PSRA-358	0.48	1.12	0.09	3.75
18	PKKK-227	30.92	0.01	5.80	0.20
19	PMKK-232	37.68	0.31	3.36	1.00
20	PARB-223 A (3)	2.35	1.56	0.01	6.61
21	PARA-501	0.04	6.32	0.02	0.01
22	PMRA-502	5.63	3.55	26.12	8.06

PKKK-227 could be selected in PC1 for further breeding programme. Similarly, FSAB-428 and PKKKK-228 in PC2; PMRA-502 and PRRA-370 in PC3 and PATK-278 in PC4 also be selected. As these varieties revealed high variability therefore, they can also be further examined for specific biotic and abiotic stresses for the identification of resistant/tolerant gene, which can be exploited in future breeding program.

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