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Mritunjaya Behera
Department of Horticulture, B.N College of Agriculture, Assam Agricultural University, Biswanath, Chariali, Assam, India

Kanchan Kumari Gupta
Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India

Nitesh Kushawha
Division of Genetics, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi, India

Corresponding Author:
Kanchan Kumari Gupta
Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India

Principal component analysis of exotic lettuce varieties in North Bank plain zone of Assam

Mritunjaya Behera, Kanchan Kumari Gupta and Nitesh Kushawha

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Abstract
Lettuce (*Lactuca sativa* L.) is a widely cultivated leafy vegetable known for its nutritional value and culinary uses. Although its cultivation is expanding in India, there has been limited research on identifying varieties suited to the agro-climatic conditions of Assam, particularly in the North Bank Plain Zone. This study evaluated genetic divergence among seven exotic lettuce genotypes using Principal Component Analysis (PCA), based on 20 quantitative morphological and physiological traits. The experiment was carried out during the rabi season of 2018-2019 at the Biswanath College of Agriculture, Assam Agricultural University, in a Randomized Block Design with three replications. PCA results revealed that the first four principal components, each with eigenvalues exceeding one, accounted for 93.66% of the total variation. The first principal component alone explained 57.20% of the variance and was largely influenced by traits such as plant height, canopy spread, leaf dimensions, head diameter, and fresh head weight. These traits emerged as major contributors to variability among genotypes. The study highlights the utility of PCA in simplifying complex trait data and identifies key parameters for selecting high-yielding lettuce varieties adaptable to Assam's growing conditions.

Keywords: Lettuce, principal component analysis (PCA), variance

Introduction

Lettuce (*Lactuca sativa*) is one of the most widely consumed leafy vegetables worldwide, prized for its crisp texture, mild flavor, and nutritional benefits. A member of the Asteraceae family, it has a chromosome number of 2n = 18 and is primarily cultivated for fresh consumption in salads, sandwiches, and garnishes. Lettuce is a cool-season crop that thrives in temperate climates and is grown in several distinct forms, including butterhead, romaine, iceberg, and loose-leaf types. Originating from the Mediterranean region, lettuce has been cultivated for thousands of years and has undergone extensive diversification. It was likely introduced to India by the Portuguese or the British in the 16th century (Squire *et al*., 1987) [8]. Lettuce is an annual, self-pollinated plant that forms a short stem early in the season. It develops a cluster of leaves that vary greatly in shape, texture, and color across different varieties.

Lettuce is primarily cultivated for its edible leaves. It is classified into four major types: Leafy lettuce (*Lactuca sativa* var. *crispa*), Cos or Romaine lettuce (*Lactuca sativa* var. *longifolia*), Head lettuce (*Lactuca sativa* var. *capitata*), and Stem lettuce (*Lactuca sativa* var. *aspergina*) (Herbst, 2001) [4]. Lettuce is a rich source of essential vitamins and minerals, making it a valuable component of a nutritious diet. It provides Vitamin A (502 IU per 100 g), along with B-complex vitamins such as B1 (0.041 mg), B2 (0.025 mg), B5 (0.123 mg), and B6 (0.042 mg) per 100 g serving. It also contains Vitamin C (2.8 mg/100 g) and Vitamin K (24.1 µg/100 g).In terms of minerals, lettuce offers calcium (18 mg/100 g), iron (0.41 mg/100 g), and magnesium (7 mg/100 g), all of which support overall health. Additionally, its high cellulose content (1.1%) contributes to digestive health. while compounds like lactucin and lactucopicrin have been linked to reducing insomnia (Anonymous, 2020) [1].

Lettuce cultivation in India performs best during the winter season and has emerged as a promising value chain with significant growth potential. Although lettuce is a relatively new crop in the region, the North Bank Plain Zone of Assam presents favorable agroclimatic conditions for its successful cultivation. However, no systematic research has yet been Consequently, there is a pressing need for scientific studies aimed at identifying superior varieties that can be effectively adopted for commercial farming in Assam.

Principal Component Analysis (PCA) is a powerful statistical tool used to assess genetic variation by reducing the dimensionality of complex datasets while preserving their essential variability. In this study, PCA was employed to analyze divergence among seven lettuce accessions based on morphological and physiological traits. By transforming multivariate data into a set of principal components, PCA facilitates the visualization of patterns, clustering of similar accessions, and identification of key traits contributing to overall variation. This analysis offers valuable insights into the genetic structure of lettuce populations, thereby supporting the selection of promising cultivars for future breeding programs.

Materials and Methods

The investigation was conducted at the Instructional-cum-Research Farm, Department of Horticulture, Biswanath College of Agriculture, Assam Agricultural University, Biswanath Chariali, during December 2018 to March 2019. The experiment comprised seven exotic varieties of lettuce, treated as seven distinct treatments. It was laid out in a Randomized Block Design (RBD) with three replications, maintaining a spacing of 45 cm × 30 cm. All recommended agronomic practices and protective measures were followed to ensure healthy crop growth.

Material used in the experimentation were seven exotic lettuce varieties which have been illustrated in table (1):

Table 1: Genotypes used in the experiment

Images of the treatments used in the experiment			
	T_1: Till	T_2: Red Salad Bowl	T_3: Lollo Rossa
			
T_4: Lollo Bionda	T_5: Batavia Rossa	T_6: Corcarda	T_7: Pasha

Observations recorded

A total of 16 characters were taken for the study, which are listed below under their respective subgroups.

a) Morphological characters

- Plant height (cm) [PH]
- Number of leaves per plant [NL]
- Leaf area per plant(cm^2) [LAPP]
- Leaf Length
- Leaf breadth
- Canopy Spread (cm) [CS]

b) Phenological characters

- Duration (days) from planting to last harvest

c) Physiological parameter

- Leaf area index [LAI]
- Moisture content

d) Yield and yield attributing characters

- Days to first Harvest
- Harvest duration
- Fresh Weight (g/plant)
- Dry Weight (g/plant)
- Yield per hectare (t/ha)

e) Biochemical character

- Ascorbic acid content (mg/100 g fresh leaves).
- Vitamin A

For statistical analysis, data were collected from five randomly selected plants per genotype in each replication, and the mean values were used. The contribution of different traits to genetic divergence among the seven lettuce varieties was estimated through Principal Component Analysis (PCA) based on yield and its 19 component traits. The analysis was performed using GraphPad Prism statistical software.

Results and Discussion

Principal Component Analysis (PCA) offers an efficient approach to identify superior genotypes with greater accuracy and within a shorter time frame. As a multivariate statistical tool, PCA is particularly useful when multiple correlated traits are analyzed simultaneously. Principal components are newly derived variables formed as linear combinations of the original traits; these components are mutually uncorrelated and are ranked based on the amount of variance they explain.

In this study, PCA was conducted on seven exotic lettuce varieties, based on yield and associated morphological and physiological traits. The analysis yielded six eigenvalues (eigen roots), representing the principal components. The eigenvalues, along with the percentage of total variance explained by each component, are presented in Table 2. According to the Kaiser-Guttman criterion (Guttman's lower bound principle), only components with eigenvalues greater than 1 were retained for interpretation, as they explain a substantial portion of the total variation (Fig. 1). The first four principal components have eigen values of 11.44, 3.896, 2.066, and 1.33, respectively. These four components collectively explained 93.66% of the total variation observed among the seven lettuce accessions. Specifically, PC1 accounted for 57.20%, PC2 for 19.48%, PC3 for 10.33%, and PC4 for 6.65% of the variation.

Table 2: Principal components (eigenvectors) of seven in lettuce varieties in 20 traits

	PC 1	PC 2	PC 3	PC 4
Eigen value	11.44	3.896	2.066	1.33
% variance	57.20%	19.48%	10.33%	6.65%
Cumulative variation	57.20%	76.67%	87.00%	93.66%
30 PH	0.913	-0.099	0.369	-0.090
PH Harvest	0.899	0.223	0.262	0.119
CS 30 DAT	0.948	0.133	-0.232	0.139
CS Harvest	0.943	0.242	-0.067	-0.201
30 DAT NL	0.764	-0.632	0.029	-0.090
Harvest NL	0.772	-0.560	-0.186	-0.146
Leaf length	0.924	0.126	0.228	0.119
Leaf breadth	0.384	0.852	0.176	0.132
Days to 1st harvest from transplanting	-0.151	0.499	0.805	0.187
Harvest duration	0.408	-0.897	-0.027	0.162
Days from transplanting to last Harvest	0.495	-0.761	0.272	0.268
30 DAT LAPP	0.877	0.372	-0.080	0.275
Harvest LAPP	0.941	0.264	-0.018	-0.197
30 DAT LAI	0.976	-0.045	0.141	-0.082
Harvest LAI	0.881	0.018	-0.284	0.299
Diameter of head (cm)	0.943	0.242	-0.067	-0.201
Fresh weight of Head (g/plant)	0.655	0.497	-0.453	-0.001
Vitamin-A (mg/100 g)	0.362	-0.082	0.333	-0.860
Vitamin-C (mg/100 g)	-0.640	0.385	-0.368	-0.249
Moisture Content (%)	0.390	0.003	-0.630	-0.037

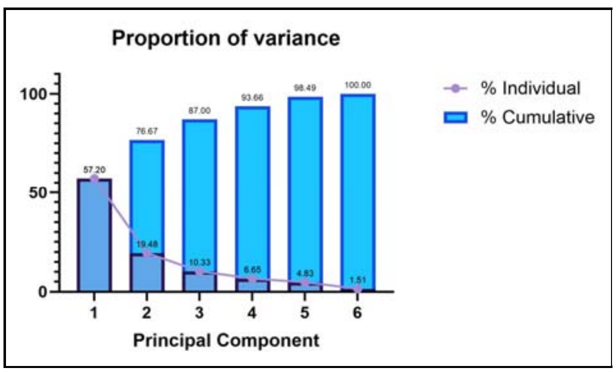

Fig 1: Proportion of variance of lettuce varieties for 20 traits

All 20 quantitative traits contributed to these components, though to varying extents. Each data point's position on the new PCA axes is a weighted combination of its original variable scores, allowing for simplified yet insightful visual and statistical interpretation of genetic diversity (Bhargava *et al*., 2005) [2]. The first principal component extracted in the PCA analysis was primarily defined by a combination of the following traits: plant height at 30 DAT and harvest, canopy spread at 30 DAT and harvest, number of leaves at 30 DAT and harvest, leaf length, leaf area per plant (LAPP) at 30 DAT and harvest, leaf area index (LAI) at 30 DAT and harvest, head diameter, and fresh weight of head per plant. All these traits exhibited high positive loadings, indicating their strong contribution to the variability observed among the seven lettuce accessions. This component effectively differentiated the genotypes based on head weight, head size (equatorial diameter), and overall yield. The second component was primarily defined by leaf breadth, fresh weight of head per plant, and days to first harvest, all of which had high positive loadings. These traits contributed moderately to the total variance, highlighting their secondary role in genotype differentiation. The third principal component was predominantly associated with days to first harvest from transplanting, suggesting its isolated but significant contribution to divergence.

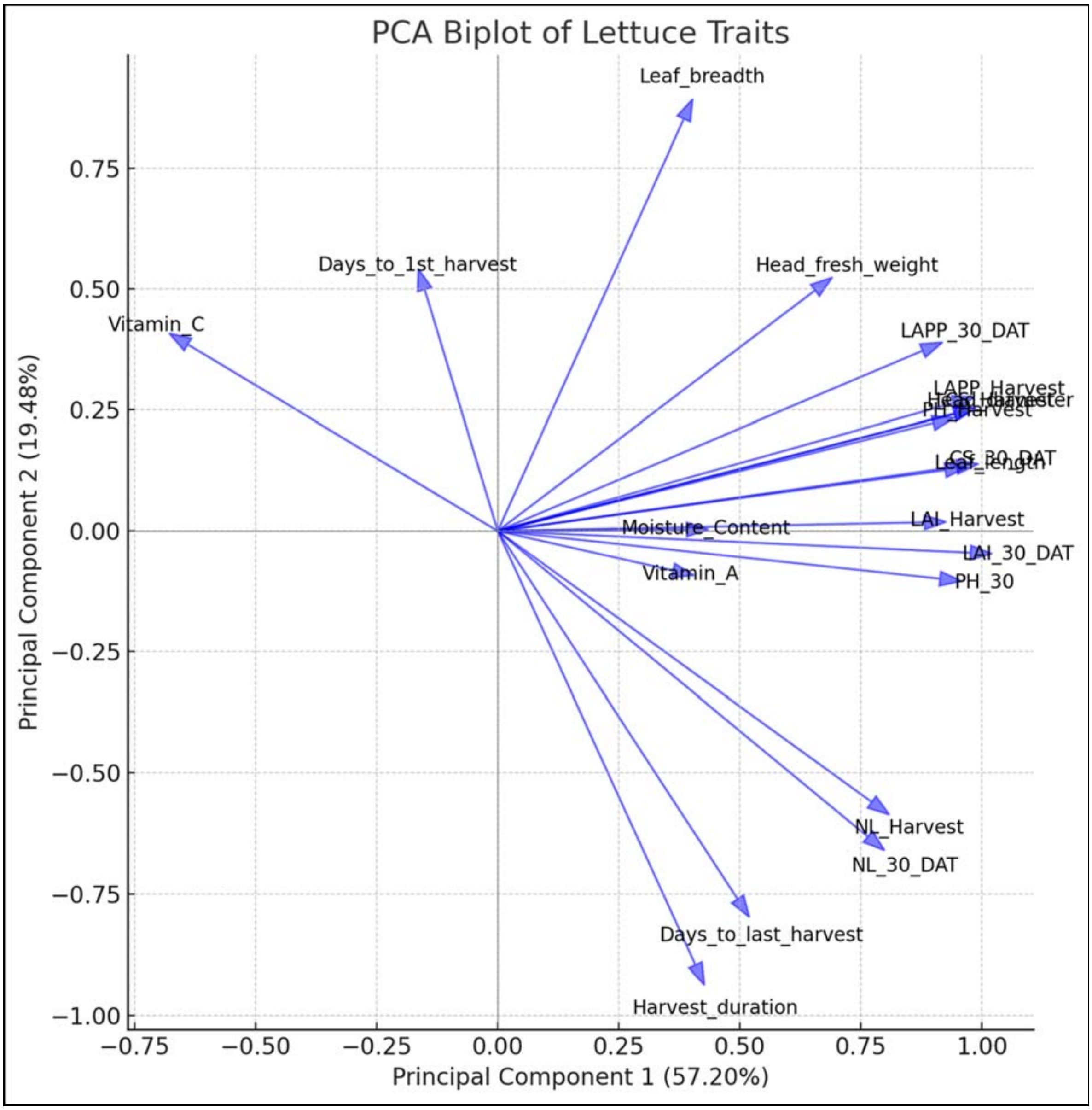

Fig 2: PCA Biplot of different characters based on first principal components

Overall, traits with high positive loadings in each principal component highlight their importance in explaining the divergence among the lettuce genotypes, while negative values suggest minimal contribution. Based on the first principal component loadings (Fig. 2), the most influential traits driving divergence among the seven varieties included: plant height, canopy spread, leaf metrics, head diameter, and fresh head weight. In contrast, vitamin C content showed the least contribution to genetic variation. Therefore, selection based on traits such as canopy spread at harvest and head diameter is likely to be more effective in improving lettuce yield, as these traits capture a significant portion of the total variability. Similar findings have been reported in lettuce by Kumar *et al*. (2016) [6] and Gupta *et al*. (2014) [3], and in other vegetable crops like cucumber, peppers, and okra by Zhang and Cui (1993) [9], Portis *et al*. (2006) [7], and Koutsos *et al*. (2000) [5], respectively.

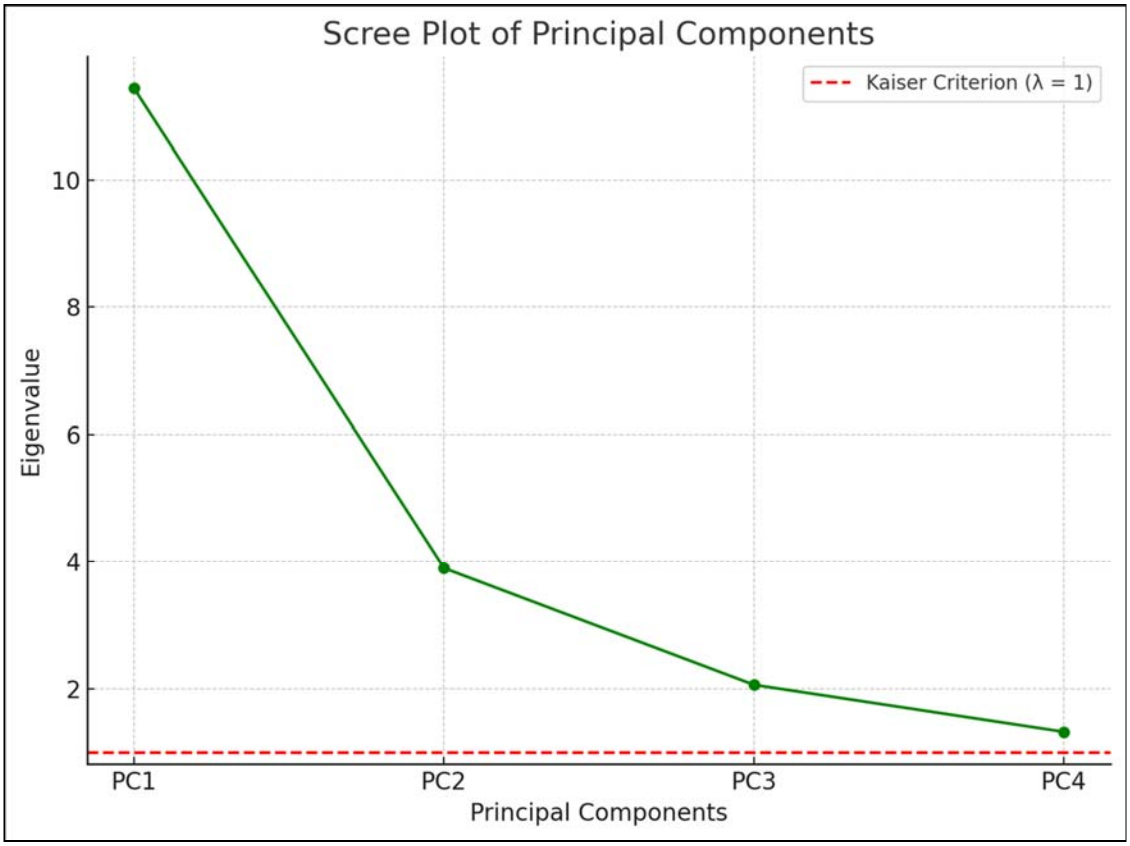

Fig 3: Scree plot displaying the eigen values of the first four principal components:

Conclusion

The Principal Component Analysis (PCA) performed on seven exotic lettuce varieties indicated significant genetic diversity among the accessions, mainly influenced by morphological and physiological traits that contribute to yield. The first four principal components accounted for 93.66% of the overall variation, effectively capturing the intricate relationships between traits. Important traits such as plant height, canopy spread, leaf area, head diameter, and fresh head weight were identified as the primary factors driving genetic variation, highlighting their importance for selection in lettuce breeding programs. In contrast, traits like vitamin C content had a minimal effect on differentiating genotypes. These results imply that focused selection based on key traits—especially those related to canopy structure and head shape—can greatly improve breeding efficiency and yield potential in lettuce. Therefore, PCA has proven to be an effective method for simplifying trait complexity and aiding in the informed selection of superior genotypes for further assessment and genetic improvement.

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