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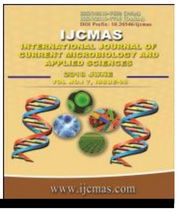

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Morphological Classification of Genetic Diversity of Garlic (*Allium sativum* L.) Germplasm for Bulb and Yield-Related Traits Using Principal Component Analysis

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ABSTRACT

Garlic is the second most important bulbous vegetables after onion and used as a spice and flavoring agent for foods. The present study was carried out at the Horticultural Research Centre, College of Agriculture, S.V.P. University of Agriculture and Technology, Meerut (U.P), India. The results revealed that more than 75% of diversity of the total 131 garlic germplasm is present in first 4 principal components out of 12 and they had Eigen values recorded more than 1. The first PC explained characters *viz.*, plant height, pseudostem height and diameter, polar or equatorial diameter of bulb, bulb weight plant^{-1}and number of cloves bulb^{-1} (NCB) positively related to bulb yield. In case of PC2, characters like PH, PsH, EDB, NCB showed positive correlation. Bi-plot shows that there is a lot of variability present in the studied genotypes. The genotypes *viz.*, K1, TG-F1, PG-20, GHC-1 and punnur local were identified as the best genotypes. Therefore, the above-mentioned variables might be taken into consideration for effective selection of parent's in genetic improvement program for broadening the genetic base in the population as well as to develop elite garlic lines.

Keywords

Garlic, *Allium sativum*, PCA, Morphological traits and Genetic Diversity

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Introduction

Garlic is the second most important bulbous vegetables after onion and used as a spice and flavoring agent for foods. The primary center of origin in Central Asia and secondary origin in China and the Mediterranean area (Vavilov, 1951; Etoh and Simon, 2002). Garlic is also grown for pharmaceutical purposes as it is a rich source of phytonutrients. The cultivation of garlic worldwide is over 244.55 lakh tons of production on 12.25 lakh ha, which implies the productivity of 12.80 tons/ha. China is the world's leader in the production of garlic, with about 192.33 lakh tons contributing to 77.07 % of world's production, this is closely followed by India. In India, the area under garlic production is 2.3 lakh ha with an annual production of 12.5 lakh tons and average productivity of 5.4 tons/ha (Anonymous, 2016). Although, India holds the second in area and production, its productivity is still very low. As it is propagated mainly by cloves so we need to determine the genetic diversity available for crop improvement. Genetic improvement of the crop directly or indirectly depends on the genetic diversity present in the germplasm so we need to find the diversity that helps in selection of desirable parents or genotypes for improvement programs. Evaluation of genetic diversity based on desirable traits like equatorial diameter of the bulb and polar diameter of the bulb, no. of cloves, clove length, helps in characterization of germplasm and also assists in selecting desirable germplasm for the crop improvement (Volk and Stern, 2009). Therefore, it is essential to estimate the genetic diversity among the germplasm for the principal component analysis is done for the assessment of garlic germplasm using morphological traits.

Materials and Methods

The experimental material comprised of 131 garlic accessions obtained from different locations of India. The experimental trail was laid out in Randomized Block Design (RBD) with three replication each during the 2014-Rabi season. Planting of cloves was done with a spacing of row to row 15 cm and plant to plant 10 cm in a bed size of 2.0 m×1.5 m. Standard agronomic practices were followed. The observations were recorded from randomly selected five plants from each replication all characters *viz*., plant height (PH), leaf length (LL), number of green leaves pseudostem^{-1} (NGL), number of dry leaves pseudostem^{-1}(NDL), pseudostem height (PsH), pseudostem diameter (PsD), polar diameter of bulb (PDB), equatorial diameter of bulb (EDB), bulb weight plant^{-1} (BW), number of cloves bulb^{-1} (NCB), length of the clove (CL) and clove weight (CW). The mean data were subjected to principal component (PC) analysis using SPSS version 21 and SAS-JMPSW-12 statistical softwares. The principal component analysis was used to determine the extent of genetic variation in the given germplasm. Eigen values obtained from PC were used to determine the relative discriminative power of the axes and their associated characters (Pradhan *et al.*, 2011). All the field experiments were conducted at Horticultural Research Centre, College of Agriculture, S.V.P. University of Agriculture and Technology, Meerut (U.P), India.

Results and Discussion

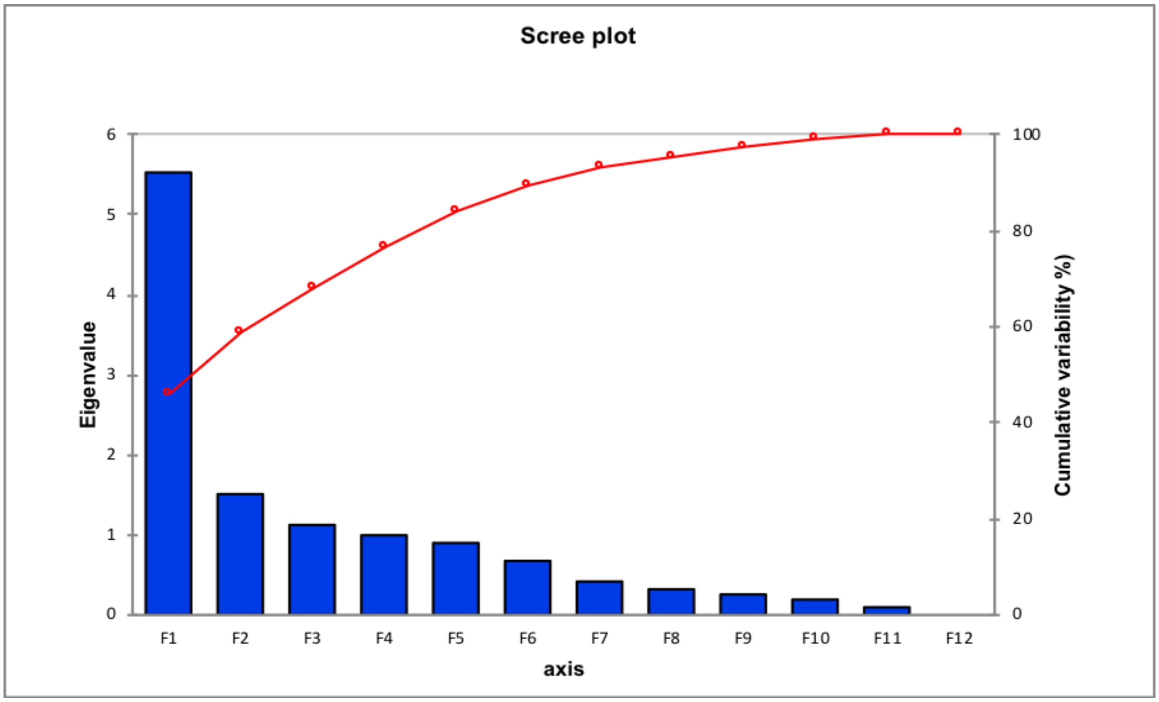
Principal Component Analysis (PCA)

It is evident from table 1 that more than 75% of the total variability present among the 131 genotypes of garlic is explained by first four clusters out of 12 and the eigen values for this first four cluster is more than 1. The principal component one (PC1), with eigen value of 5.525 contributed 46.04 % to total variability and PC2, PC3 and PC4 with eigen values 1.52, 1.17 and 1.0 they accounted for 12.67%, 9.3% and 8.3% of total variability, respectively. The first PC explained all characters *viz*., plant height (PH), leaf length (LL), number of green leaves pseudostem^{-1} (NGL), number of dry leaves pseudostem^{-1}(NDL), pseudostem height (PsH), pseudostem diameter (PsD), polar diameter of bulb (PDB), equatorial diameter of bulb (EDB), bulb weight plant^{-1} (BW), number of cloves bulb^{-1} (NCB), length of the clove (CL) and clove weight (CW) are positively related bulb yield (Table 2.). In case of PC2 characters like PH, PsH, EDB, NCB showed positive correlated. In case of PC3 and PC4 characters like NGL, NDL, PDB and EDB were clearly explained. Although correlation analysis helps in determining the effective traits in order of indirect selection of superior genotypes, principal component analysis is a suitable multivariate technique in identifying and determining independent principal components that are effective on plant traits separately. Therefore, PCA also helps breeders for genetic improvement of traits such as yield that have low heritability specifically in early generations via indirect selection for traits effective on yield (Golparvar *et al.*, 2006).

Principal component Analysis is a technique which identifies plant traits that contribute most to the observed variation within a group of genotypes and it had a practical application in the selection of parental lines for breeding purpose (Ahmadizadeh and Felenji, 2011). The cumulative variance of 76% by the first four principal components with eigen values of more than 1.0 indicated that the identified traits within this axis exhibited great influence on the phenotype of the cultivars and could effectively be used for selection among them (Pradhan *et al.*, 2011) than can be reflected from their principal component analysis that the first two components out of twelve trait components had eigen values up to 1.0, presenting cumulative variance of 84.10%. From the results of the present investigation, it is concluded that the traits *viz*., plant height (PH), leaf length (LL), number of green leaves pseudostem^{-1} (NGL), number of dry leaves pseudostem^{-1} (NDL), pseudostem height (PsH), pseudostem diameter (PsD), polar diameter of bulb (PDB), equatorial diameter of bulb (EDB), bulb weight plant^{-1} (BW), number of cloves bulb^{-1} (NCB), length of the clove (CL) and clove weight (CW) are important for improving yield related traits.

Therefore, these traits might be taken into consideration for effective selection of parents for hybridization program for broadening the genetic base in the population as well as to develop elite lines. Furthermore, selection of the genotypes with the highest bulb weight per plant and other traits like number of cloves per bulb and polar and equatorial diameter of the bulb should be recommended as one of the best breeding traits for genetic improvement of garlic. The similar results were emphasized by many researchers like Khar *et al.*, (2006), Vatsyayan *et al.*, (2013) and Wang *et al.*, (2014)

Fig.1a, b Principal screen Plot between components and Eigen value



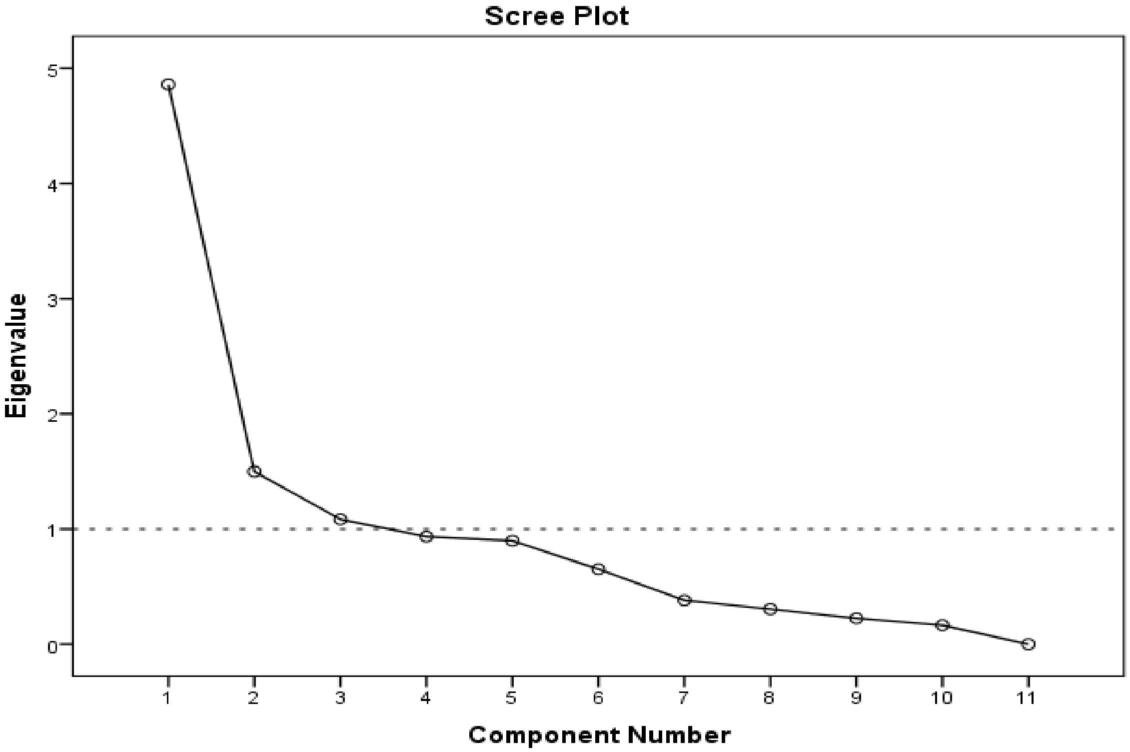


Fig.2 Principal component bi-plot between morphological characters and genotypes

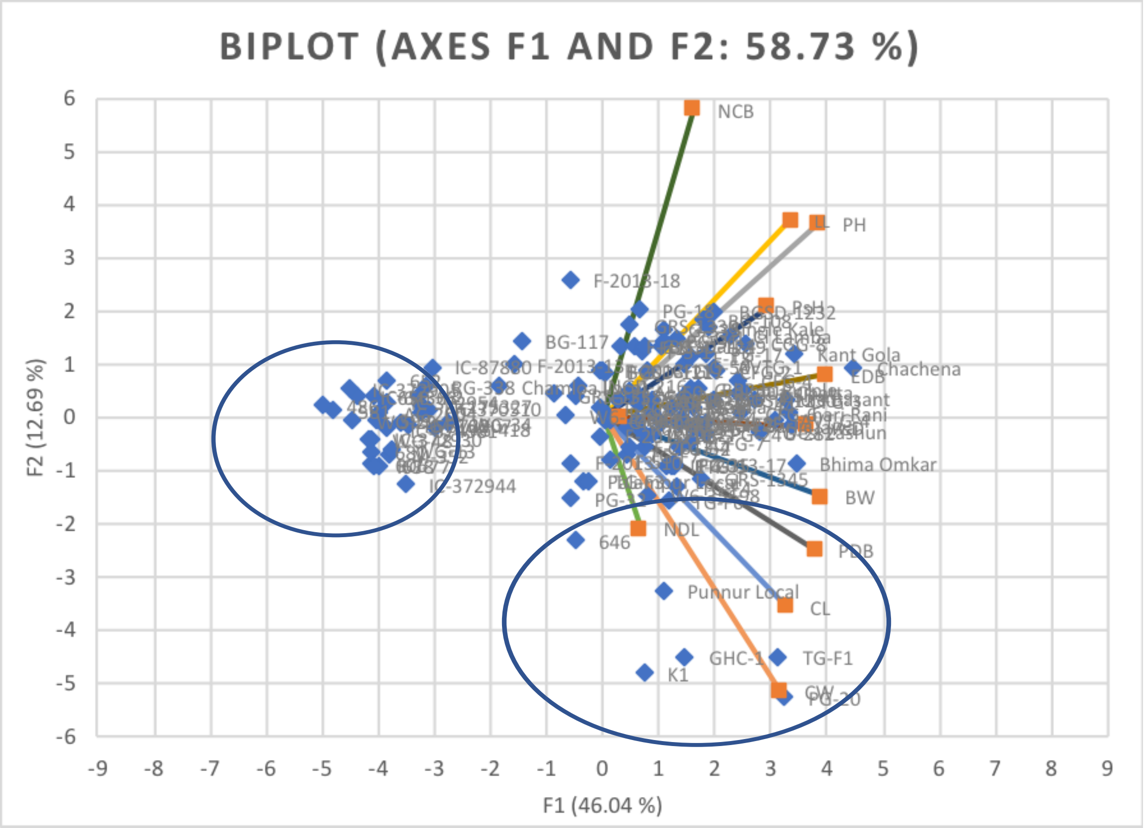


Fig.3 Principal component bi-plot between 12 morphological in garlic

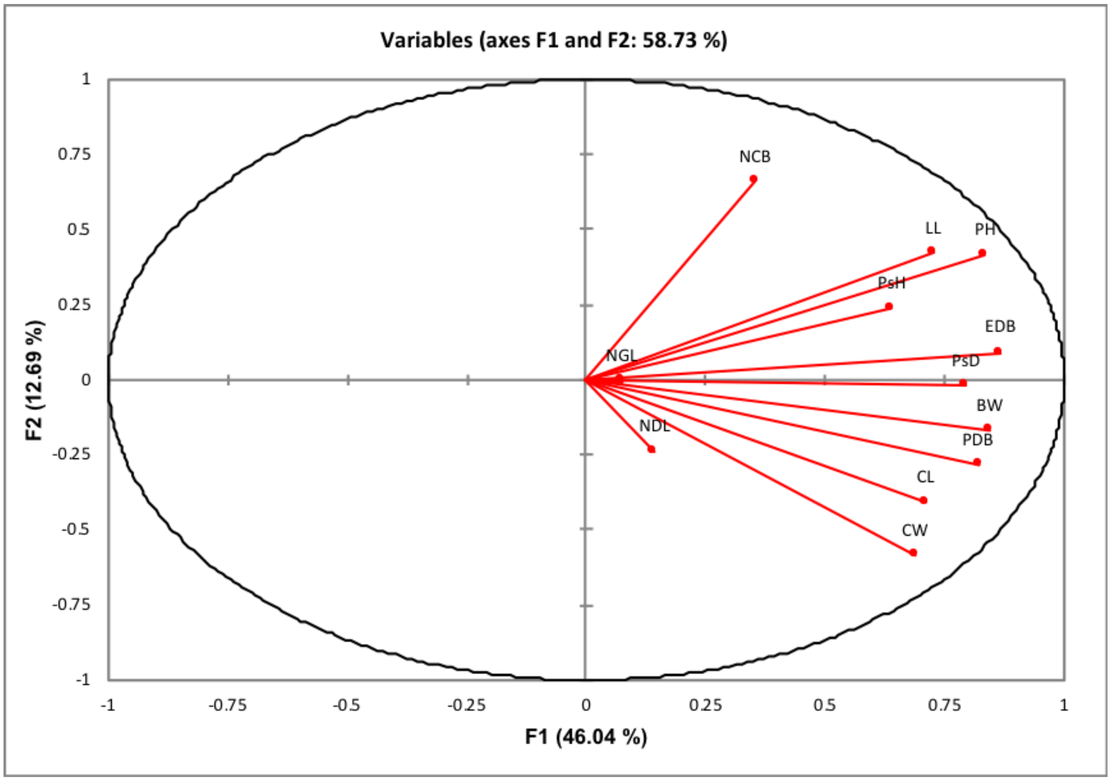


Table.1 Eigen value and contribution of the principal component axes towards variation in garlic germplasm

	Eigenvalue	Variability (%)	Cumulative %
PC1	5.525	46.041	46.041
PC2	1.522	12.687	58.728
PC3	1.117	9.305	68.032
PC4	1.003	8.360	76.392
PC5	0.898	7.483	83.875
PC6	0.677	5.643	89.518
PC7	0.418	3.482	93.000
PC8	0.309	2.575	95.575
PC9	0.236	1.968	97.543
PC10	0.195	1.628	99.172
PC11	0.099	0.828	100.000
PC12	0.000	0.000	100.000

Table.2 Contribution of different qualitative and quantitative traits of garlic towards major principal components

	Trait	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12
1.	**PH**	0.835	0.415	0.221	-0.243	-0.004	-0.005	-0.037	-0.107	-0.087	0.033	-0.029	0.000
2.	**LL**	0.726	0.421	0.087	-0.175	0.073	-0.441	-0.169	-0.135	-0.102	0.019	-0.028	0.000
3.	**NGL**	0.074	-0.003	0.601	0.572	-0.543	-0.102	-0.043	-0.015	-0.003	-0.004	0.013	0.000
4.	**NDL**	0.143	-0.238	0.580	0.222	0.729	0.026	-0.057	0.027	0.032	0.017	0.002	0.000
5.	**PsH**	0.639	0.237	0.311	-0.235	-0.107	0.586	0.157	-0.025	-0.032	0.038	-0.018	0.000
6.	**PsD**	0.794	-0.020	0.176	-0.338	-0.119	-0.175	0.000	0.301	0.290	-0.039	0.052	0.000
7.	**PDB**	0.819	-0.283	-0.148	0.143	-0.015	-0.044	0.050	0.335	-0.273	0.103	-0.065	0.000
8.	**EDB**	0.866	0.091	-0.231	0.237	0.077	0.143	-0.117	-0.006	-0.085	-0.197	0.213	0.000
9.	**BW**	0.844	-0.169	-0.232	0.233	-0.008	0.151	-0.200	-0.068	0.136	-0.159	-0.199	0.000
10.	**NCB**	0.353	0.659	-0.299	0.486	0.158	-0.010	0.187	0.029	0.157	0.176	0.002	0.000
11.	**CL**	0.709	-0.407	-0.001	0.011	0.019	-0.223	0.487	-0.186	0.004	-0.095	-0.003	0.000
12.	**CW**	0.687	-0.586	-0.132	-0.035	-0.098	0.057	-0.173	-0.186	0.083	0.275	0.075	0.000

Principal Component scree plot

Scree plot (fig. 1 a & b) explains the percentage of variance associated with each principal component obtained by drawing a graph between eigen values and PC and thus it helps to determine the appropriate number of principal components; we look for an 'elbow' in the scree plot. The component number is taken be the point at which the remaining eigen values are relatively small (<1) and all about the same size. The scree plot is shown figure 1 exhibited six principal components and showed the highest variation in PC 1 to explain maximum variation in the data set, so the selection of genotypes based on this PC will be useful. Relationships between variables and between genotypes was reviewed based on bi-plot of first and second components, so that the horizontal axis was related to first component and the vertical axis was related to the second component. Based on the component values, the location of genotypes, variables and their grouping were determined in top of bi-plot. From figure 2, it is explained that the traits *viz.*, equatorial diameter of the bulb (EDB) and bulb Weight, pseudo diameter of the bulb and number of cloves per bulb contributed maximum towards the total variability present in the evaluated germplasm.

Thus, selection should be directed towards these traits to have genetic improvement in garlic. Based on the component values, the location of genotypes and their grouping were determined in top of bi- plot (fig. 2 and 3). Therefore, according to bi-plot figures it is clear that there is a lot of variability present in the studied genotypes. The genotypes *viz.*, K1, TG-F1, PG-20, GHC-1 and punnur local were identified as the best genotypes as these genotypes grouped in positive part as well as they can be easily identified as distinct from the rest of the genotype groups of the bi-plot. Bi-plot had been utilized by many researchers such as Ahmadizadeh and Felenji, (2011) in potato, Afuape *et al.*, (2011) in sweet potato to decide the best genotype among the studied ones.

From the above study it can be concluded that plant height (PH), leaf length (LL), number of green leaves pseudostem^{-1} (NGL), number of dry leaves pseudostem^{-1} (NDL), pseudostem height (PsH), pseudostem diameter (PsD), polar diameter of bulb (PDB), equatorial diameter of bulb (EDB), bulb weight plant^{-1} (BW), number of cloves bulb^{-1} (NCB), length of the clove (CL) and clove weight (CW) are important for improving bulb yield in garlic. Based on the performance of genotypes for above mentioned characters few genotypes have been selected *viz*., K1, TG-F1, PG-20, GHC-1 and punnur local as parents to be utilized in future breeding programs.

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