



Collection, evaluation and phenotypic diversity assessment of maize (*Zea mays*) germplasm from North Eastern Himalayan region

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ABSTRACT

Primitive landraces and traditional cultivars of maize (*Zea mays* L.) are invaluable resources for the humankind. These need to be collected, evaluated, conserved and utilized for increasing agricultural production and quality enhancement. Based on extensive survey, 75 diverse maize accessions were collected from Nagaland and Manipur states of the North Eastern Himalayan region. These collections were evaluated under two different agro-ecological regions, New Delhi and Shillong during *kharif* 2012 and 2013 using 12 quantitative variables. There was significant morphological variability among the accessions. Trait specific cultivars were identified based on exploration related knowledge and phenotypic valuation. The cluster analysis was performed to assess the variation among genotypes and grouped them into five clusters based on phenotypic traits. The principal component analysis (PCA) was subjected to quantitative datasets to group the accessions and to study contribution of traits for phenotypic variation. The first two principal components explained more than 50% of the phenotypic variation. Plant height, ear height, grain yield, ear width, number of kernel rows and number of kernels per row were major contributing traits towards phenotypic diversity. The different groups obtained can be useful for deriving the inbred lines with diverse features and diversifying the heterotic pools.

Key words: Biplot, Characterization, Clustering, Descriptors, Landraces, Maize, North Himalayan Region, Principal Component Analysis

Food and nutritional security is a challenging issue in view of climate change. The world population will reach 9.2 billion in 2050 (FAO 2014) and to feed the burgeoning population, the global food-crop production need to be increased by about 70%, and almost double the production in developing countries (FAO 2014). Cereals are an important part of food resources of humans and animals. Among all the cereals, maize is an important crop with diverse uses as human food, animal feed and fodder, industrial uses etc. The production of maize in India is 24.17 million tonnes with productivity of 2.56 q/ha (ICAR-IIMR 2015). In order to improve the productivity of this crop, development of improved varieties with high yield potential is required. To get improved cultivars, breeders must use diverse material in their breeding programme for development of crosses and selection of heterotic inbred lines and pools. The traditional landraces and cultivars although less productive, are genetically diversified and better adapted to harsh climate with tolerance to biotic stresses. The landraces of maize (*Zea mays* L.) are

abundant in North Eastern Himalayan (NEH) region of India with extensive variability for plant, tassel, ear and kernel characteristics (Nass *et al.* 1993, Singode *et al.* 2011). These genetic resources could enable development of cultivars not only with improved productivity but also with enhanced quality, biotic and abiotic stress tolerance (Tanksley and Mc Couch 1997). This diversity needs to be collected, conserved, evaluated and effectively utilized. Morphological characterization is the first step for the assessment, description and classification of germplasm collections to enhance their use in maize breeding (Prasanna and Sharma 2005, Wasala *et al.* 2013). Morphological characteristics have the advantage of being easily noticeable and constitute the level of diversity to which farmers and breeders have immediate access. The characterization of collections from NEH region for favourable traits/alleles and genetic diversity within them is urgently required for their use in breeding. Also the collection and identification of local landraces will be useful to preserve the genetic variability and their evaluation will promote their use and provide economic profits to the farmers. Therefore, the present study was undertaken to collect the cultivars/landraces from NEH region, to characterize and evaluate them for agronomic traits, and to analyze phenotypic diversity among the accessions collected.

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MATERIAL AND METHODS

Explorations for collection of indigenous diversity of maize from NEH region were conducted following proper sampling procedure during October-November 2011. Seventy five accessions comprising 58 accessions from Nagaland and 17 from Manipur were collected (Table 1). The altitude of collection site varied from 696 m above sea level (Lanye, Phek; Nagaland) to 2 077 m above sea level (Reku, Phek; Nagaland). These accessions were evaluated in Augmented Block Design at NBPGR, New Delhi NBPGR Regional Station, Umiam, Shillong during *khariif* 2012 and 2013 with four checks HM-4, HQPM-1, Vivek-17 and Pusa Composite 3. The location Umiam was located at 1 000 m elevation, in rainfed, acid alfisol conditions (pH 5.2). The experimental field coordinates were 26°N latitude and 92°E longitude with annual temperature ranged between 6 and 29 °C and average rainfall ranged between 2 300 and 2 500 mm. The Delhi location had sandy loam soil with 7.8 pH. The experimental farm is situated at latitude of 28°40' N and longitude of 77°12' E and an altitude of 228.6 meters above the mean sea level (Arabian Sea). The mean annual rainfall of Delhi was recorded 650 mm and annual temperature ranged between 12 and 32 °C.

The data were recorded for agro-morphological descriptors as per the minimal descriptors and descriptor's states developed by ICAR-NBPGR (Mahajan *et al.* 2000). The agronomic characters included days to tassel, days to silk, plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of kernel rows/ear, number of kernels/row, days to maturity, number of ears/plant, grain weight (g) and grain yield/plant (g). Agronomic traits were recorded on 10 randomly selected competitive plants/plot.

Analysis of variance for individual year was carried out as per augmented block design. The mean values for various yield-related traits of the maize accessions were computed for each of the locations and were statistically analyzed *vis-à-vis* the checks using least squares method, for identification of promising accessions. The quantitative traits were further analysed for various statistical parameters, viz. mean, range, variances, etc. We also tested homogeneity of variance as per Bartlett's test and data were pooled across the locations for multivariate analysis. Genetic diversity analysis was performed using hierarchical algorithm with Euclidean distances and Ward's method of minimum variance for clustering the accessions. A principal component analysis was carried out based on phenotypic correlation

Table 1 Locality details of maize collection from Nagaland and Manipur states of NEH region

Districts	Alt. (m)	Lat.	Long.	Cultivars/landraces (Collection no.) S.No.
<i>Nagaland</i>				
Phek	1522	25.34	94.12	Seko (KC/S/R-1 ^{DRF} , KC/S/R-2 ^{YF} , KC/S/R-3 ^{WF})1-3; Metata (KC/S/R-4 ^{OF} , KC/S/R-5 ^{WD} , KC/S/R-6 ^{YSD} , KC/S/R-7 ^{WF})4-7; Mikreta (KC/S/R-8 ^{WF} , KC/S/R-9 ^{WF} , KC/S/R-10 ^{WF} , KC/S/R-11 ^{WF} , KC/S/R-12 ^{WF})8-12; Sako (KC/S/R-13 ^{WF})13
Longleng	1222	26.3	94.48	Ongchuk (KC/S/I-14 ^{W/YF} , KC/S/I-18 ^{W/Y/VF} , KC/S/I-21 ^{WF} , KC/S/I-22 ^{YF})14-17
Mokokchung	1390	26.13	94.32	Mendi (KC/S/I-24 ^{WSD} , KC/S/I-26 ^{W/YSF} , KC/S/I-28 ^{WF} , KC/S/I-30 ^{VF} , KC/S/I-31 ^{R/OF} , KC/S/I-32 ^{WF})18-23
Zunheboto	1057	26.15	94.28	Kholakithi (KC/S/I-35 ^{LY/O/PF} , KC/S/I-36 ^{WF} , KC/S/I-37 ^{WD} , KC/S/I-38 ^{W/YF})24-27
Tuensang	1127	26.17	94.37	<i>Songton-Jeshou</i> (KC/S/I-40 ^{WF} , KC/S/I-41 ^{O/YSF})28-29; <i>Cheng-hanger</i> (KC/S/I-44 ^{WF} , KC/S/I-45 ^{YF} , KC/S/I-46 ^{WF} , KC/S/I-47 ^{LBSF} , KC/S/I-48 ^{WF} , KC/S/I-49 ^{WF} , KC/S/I-50 ^{YF} , KC/S/I-51 ^{WSD} , KC/S/I-52 ^{WF})30-38
Wokha	1435	25.06	94.15	Tsungro (KC/S/I-55 ^{RF} , KC/S/I-56 ^{YF} , KC/S/I-57 ^{WF} , KC/S/I-58 ^{L^{PF}} , KC/S/I-59 ^{V^{SF}} , KC/S/I-60 ^{PF} , KC/S/I-61 ^{WF} , KC/S/I-62 ^{BF} , KC/S/I-63 ^{LYF} , KC/S/I-65 ^{YF} , KC/S/I-66 ^{BF} , KC/S/I-67 ^{DBF} , KC/S/I-68 ^{L^{BF}} , KC/S/I-69 ^{WF} , KC/S/I-70 ^{WF} , KC/S/I-71 ^{WSD} , KC/S/I-72 ^{D^{YF}} , KC/S/I-73 ^{WF})39-56
Kohima	1438	25.52	94.1	Tsungro (KC/S/I-74 ^{YF} , KC/S/I-75 ^{RF})57-58
<i>Manipur</i>				
Thoubal	786	24.38	93.9	Chujak(DS/NP/RS-12 ^{BD} , DS/NP/RS-13 ^{WF} , DS/NP/RS-14 ^{BD} , DS/NP/RS-15 ^{YD} , DS/NP/RS-16 ^{PF} , DS/NP/RS-17 ^{OF} , DS/NP/RS-18 ^{L^{RSD}})59-65
Churchandpur	912	24.33	93.67	Chujak (DS/NP/RS-24 ^{YF} , DS/NP/RS-25 ^{RSF})66-67
Senapati	881	25.01	93.91	Kolbu(DS/NP/RS-30 ^{PF} , DS/NP/RS-31 ^{OSF} , DS/NP/RS-32 ^{WSD} , DS/NP/RS-33 ^{WSD} , DS/NP/RS-34 ^{YD})68-72
Chandel	800	24.46	94.12	Chujakpui (DS/NP/RS-38 ^{WF})73
East Imphal	798	24.76	94.05	Chujak (DS/NP/RS-42 ^{BF} , DS/NP/RS-43 ^{YF})74-75

Value indicates serial number of accessions used in the study; Detail of the abbreviations for kernel colour and grain type (superscripts) are as follows: YD- Yellow, Dent; DRF- Dark Red, Flint; YF- Yellow, Flint; OF- Orange, Flint; WF- White, Flint; LYD- Light Yellow, Dent; BD-Black, Dent; DRD: Dark Red, Dent; DO/RF- Dark Orange/Red Flint; LRF- Light Red, Flint; OD- Orange, Dent; WD- White, Dent; BF- Black, Flint; WSD-White, Semi-dent; PF-Purple, Flint; WSD- White, Semi-Dent; PF-Purple, flint.

matrix for the 12 descriptors. Each principal component was calculated by taking a linear combination of an Eigen vector of the correlation matrix with a variable. The biplot based on two principal components were also generated to depict the two-dimensional view of accession scores as well as loading of characters. All the statistical analysis was done using SAS 9.3 and JMP12 software. DIVA-GIS software was used for diversity analysis in 100 grain weight coordinated with geographical coordinates.

RESULTS AND DISCUSSION

Collection of maize germplasm

Undertaking exploration in the potential, rich and diverse area is very important for accumulation of variability in plant breeding research. North Eastern Himalayan (NEH) region of India is considered as secondary centre of diversity due to richness of primitive maize (hermaphrodite, pop corn, prolific, etc.) in this pocket (Stonor and Anderson 1949, Dhawan 1964, Brandolini 1970, Singh 1977). The Nagaland and Manipur area of NEH region was less explored based on the gap analysis of explorations conducted so far, hence survey was executed to collect existing diversity at farmer's field and farm store. Seventy five accessions comprising 58 accessions from Nagaland and 17 from Manipur were collected in different villages located in Phek, Longleng, Mokokchung, Zunheboto, Tuensang, Wokha and Kohima districts of Nagaland and Thoubal, Churchandpur, Senapati, Chandel and East Imphal districts of Manipur. Maize is grown in *Jhum* in the entire NEH region. In Nagaland, it is locally known as *Seko*, *Sako*, *Metata*, *Mikreta* (Phek district); *Ongjuk*, *Ongchuk* (Longleng district); *Kholakithi* (Zunheboto district); *Cheng-hanger*, *Songton-Jeshou* in (Tuensang district) and *Tsungro* (Wokha district) and in Manipur *Chujak* (Thoubal, East Imphal and Churchandpur districts), *Kolbu* (Senapati district), *Chujak pui* (Chandel

district) by local tribes (Table 1).

Some local cultivars/landraces, viz. *Pharli Enyimo* (KC/S/I-55), *Epuk* (KC/S/I-56), *Pharli* (KC/S/I-57), *Melungsu* (KC/S/I-58), *Chumtum* (KC/S/I-59), *Omum* (KC/S/I-61), *Yallum* (KC/S/I-62), *Moyue* (KC/S/I-63) were collected from Wokha district and *Kupyaonglik*, *Onglikmansho*, *Nyakmokinglik* from Longleng district of Nagaland. The maize cultivars of this area had specific features of sweet corn type (*Mikreta*, *Onglik*), sticky type (*Seko*, *Isesu*, *Tesu*, *Tsungro*) and pop corn type (*Kholithi*). The maize is mainly consumed as green/immature cobs either as roasted or boiled, and popcorn types. The young cobs of collection KC/S/R-10, KC/S/I-22 are used as vegetable types; matured grains of KC/S/I-19 and KC/S/I-35, KC/S/I-38 as popcorn; KC/S/I-28, KC/S/I-41, KC/S/I-46, KC/S/I-48, KC/S/I-60 as sticky/waxy types; KC/S/I-15 is used for making local biscuits known as *Nyakmokan*. The collected accessions were very diverse in cob size (small, 8-10 cm, medium, 15-20 cm and long, 20-25 cm), grain colour (white, red, orange, yellow, orange-yellow, maroon, violet, black), shank colour (white, pink, violet), ear shape (short and bold, thin and long, conical) with flint, dent and semi-flint types, rows per cob (10-12), tip filled grains, number of cobs (1-3 cobs/plant), sticky and non sticky types (Fig 1). Climatic condition of the collection site and farmers' preference influence the genotypic constitution of landraces during domestication, and hence a relation exists between the agro-ecology in the collection region and morpho-physiological make-up of the plant. This warrants further collection of germplasm from the remaining underexplored areas of the diversity rich maize growing areas.

Phenotypic evaluation of maize germplasm

Agronomic evaluation of germplasm accessions revealed wide range of variation for all the characters (Table 2) for example, days to tassel varied from 44.5 to

Table 2 Descriptive statistics of maize collections and identification of trait specific germplasm

Traits	Min	Max	Mean	Standard error	PCV %	Trait specific germplasm
Days to tasseling	44.50	80.00	61.90	0.64	8.17	DS/NP/RS-13, KC/S/R-9, KC/S/I-67, KC/S/R-13 (<50)
Days to silking	48.50	83.50	66.40	0.64	7.67	DS/NP/RS-13, KC/S/R-9, KC/S/I-67, DS/NP/RS-15(<60)
Plant height (cm)	133.10	331.45	245.28	4.16	13.89	KC/S/I-47, KC/S/I-38, KC/S/I-62, DS/NP/RS-13 (<200 cm)
Ear height (cm)	19.30	202.20	121.55	5.02	31.43	KC/S/R-12, KC/S/I-40, KC/S/I-47 (<70cm)
Ear length (cm)	10.10	26.31	18.88	0.34	14.32	KC/S/R-3, KC/S/I-24, KC/S/R-6, KC/S/R-7, KC/S/I-74 (>22 cm)
Ear width (cm)	2.33	5.60	4.04	0.07	13.12	DS/NP/RS-33, KC/S/I-24, KC/S/R-11, DS/NP/RS-30 (>4.5 cm)
No. of ears/plant	1.00	2.80	1.92	0.02	12.15	KC/S/I-22, KC/S/I-28, DS/NP/RS-18, DS/NP/RS-42 (>2.4)
Days to maturity	89.50	129.50	111.54	0.89	6.34	DS/NP/RS-13, DS/NP/RS-25, DS/NP/RS-17, DS/NP/RS-15 (<100)
Number of kernel rows	8.10	15.80	12.31	0.18	11.37	DS/NP/RS-16, DS/NP/RS-14, KC/S/R-4, DS/NP/RS-25 (13.8)
Number of kernels/row	7.90	41.95	25.12	0.69	21.71	DS/NP/RS-24, DS/NP/RS-32, KC/S/I-67, KC/S/I-21 (>33)
100 seed weight (g)	8.75	33.68	20.65	0.54	20.66	KC/S/I-40, DS/NP/RS-31, DS/NP/RS-34, KC/S/R-11 (>25 g)
Yield /plant (g)	5.95	203.98	82.33	6.02	38.08	KC/S/I-60, DS/NP/RS-25, KC/S/I-67, DS/NP/RS-24 (>110g)

PCV (%), Phenotypic Coefficient of Variance

80 days after sowing with mean value of 61.9 days; days to silk varied from 48.5 to 83.5 days with mean value of 66.4 days; plant height ranged from 133.1 to 331.45 cm with a mean of 245.28 cm; ear height ranged from 19.30 to 202.20 with mean 121.55 cm; ear length varied from 10.1 to 26.31 cm with mean 18.88 cm; ear width varied from 2.33 to 5.60 cm with average being 4.04 cm; number of ears/plant ranged between 1 to 2.8 with mean of 1.92; days to maturity from 89.51 to 129.5 days; kernel rows/cob ranged between 8.10 to 15.80 with mean value of 12.31; kernels/row varied from 7.9 to 41.95 with average of 25.12; 100 grain weight varied between 8.75 to 33.68 g with mean value of 20.65 and yield/plant varied between 5.95 to 203.98 with mean of 82.33 g. Phenotypic coefficient of variance was highest for grain yield/plant followed by ear height, kernels per row and 100 grain weight. Trait specific germplasm identified for different traits are mentioned in Table 2 for example; ear length (KC/S/R-3, KC/S/I-24,

KC/S/R-6), boldseededness (KC/S/I-40, DS/NP/RS-31, DS/NP/RS-34, KC/S/R-11), prolificacy (KC/S/I-22, KC/S/I-28). This study confirmed that traditional maize populations from North eastern Himalayan region of India display a large range of morphological variation with the ample diversity in flowering, height, ear and kernel characteristics, which may result from voluntary and/or involuntary selection process from farmers. Diversity for agronomic traits in maize landrace accessions was also observed in previous studies in French populations (Gouesnard *et al.* 1997), Mexican landraces (Loute and Smalle 2000, Pressoir and Berthaud 2004), European landraces (Rebourg *et al.* 2001), Turkish landraces (Ilarslan *et al.* 2002), Chinese landraces (Li *et al.* 2002, Wei *et al.* 2009), Madeira archipelago landraces (Angelo *et al.* 2008), Indian landraces (Singh 1977, Prasanna and Sharma 2005, Singode *et al.* 2009, Wasala *et al.* 2013, Kumar *et al.* 2015) and Cote d'Ivoire landraces (Hugues *et al.* 2015). These collections with adapted performance could

Table 3 Mean values for five clusters formed by hierarchical clustering and analysis of variance

Traits	Parameters	Clusters					F ratio	Prob>F
		1	2	3	4	5		
DT	Mean	56.50	50.58	57.00	57.27	63.50	11.56	<.0001
	Std Error	0.90	0.97	0.64	0.87	2.37		
DS	Mean	63.14	56.00	63.48	64.53	68.50	13.45	<.0001
	Std Error	0.95	1.02	0.68	0.91	2.50		
PH	Mean	243.98	192.53	181.49	173.85	165.10	13.68	<.0001
	Std Error	7.99	8.63	5.75	6.68	21.13		
EH	Mean	164.74	106.26	103.99	108.44	133.20	12.57	<.0001
	Std Error	7.52	8.12	5.42	6.29	19.90		
DM	Mean	109.43	99.42	109.26	112.07	120.50	11.52	<.0001
	Std Error	1.52	1.64	1.09	1.52	4.01		
EP	Mean	1.21	1.35	1.35	1.27	3.40	43.90	<.0001
	Std Error	0.06	0.06	0.04	0.06	0.16		
EL	Mean	15.56	15.15	13.93	11.49	13.00	4.71	0.00
	Std Error	0.73	0.79	0.53	0.73	1.93		
EW	Mean	3.05	3.43	3.04	2.51	2.15	8.64	<.0001
	Std Error	0.12	0.13	0.09	0.12	0.32		
NR	Mean	10.99	12.37	11.75	9.31	9.00	27.35	<.0001
	Std Error	0.23	0.25	0.17	0.23	0.62		
GW	Mean	22.75	18.96	17.03	16.91	10.60	6.70	0.00
	Std Error	1.12	1.21	0.81	1.12	2.97		
NKR	Mean	21.54	25.60	18.83	15.45	18.20	10.76	<.0001
	Std Error	1.09	1.18	0.79	1.14	2.90		
GY	Mean	63.63	81.65	49.61	19.73	60.25	24.32	<.0001
	Std Error	4.93	5.33	3.55	4.13	13.05		
No. of accessions		16	12	25	13	22		

DT-Day to tasseling, DS-Days to silking, PH-Plant height (cm), EH- Ear height (cm), EL-Ear length (cm), EW-Ear width (cm), EP-Ears per plant; DM- Days to maturity, KR-Number of kernel rows, GW-100 grain weight, NKR-Number of kernels per row, YP-Yield per plant.



Fig 1 Maize collections showing variability in ear size, kernel colour and kernel type

be utilized for diversifying the pools and deriving inbred lines with diverse specific features, prolific popcorn and sticky inbred lines as Chinese landraces were also used for inbred development and hybrid maize breeding (Li 1998).

Diversity analysis using DIVA-GIS software

Application of GIS mapping has been successfully used in the recent past in assessing the genetic diversity and in identifying areas of high diversity of different crops or areas, such as *Phaseolus* bean, wild potatoes, medicinal plants etc. (Pradesh *et al.* 2010). Grid maps were generated for the diversity index of 100 seed weight using DIVA-GIS software. The highest diversity index for 100 seed weight was observed in the accessions collected from western, central and southern parts of Nagaland (Wokha, Tuensang and Phek districts) followed by Zunheboto district. The highest coefficient of variation for 100 seed weight was recorded in central parts of Nagaland specifically Zunheboto district followed by Chandel and Thoubal districts of Manipur (Fig 1). Thus, analysis of phenotypic diversity of

maize collection could identify the potential areas with high variability and richness of allelic diversity for 100 seed weight in germplasm. This will facilitate further reliable classification of accessions and its identification with future utility for specific breeding purposes.

Multivariate Analysis

Cluster analysis

A hierarchical cluster analysis (HCA) was carried out based on quantitative variables. In order to get the best possible classification, several analyses were tested with different agglomeration methods. It appeared that the agglomeration method that provided the best result was the Ward method. This method provided the constellation plot of Fig 2. This plot arranges the individuals as endpoints and each cluster join as a new point, with lines drawn that represent membership. The longer lines represent greater distance between clusters. The multivariate analysis of variance enabled to determine the number of optimal classes. It was after the splitting in five groups that the value of F (9.36) was the highest and significant. The partition into five classes appeared optimal, it was therefore selected.

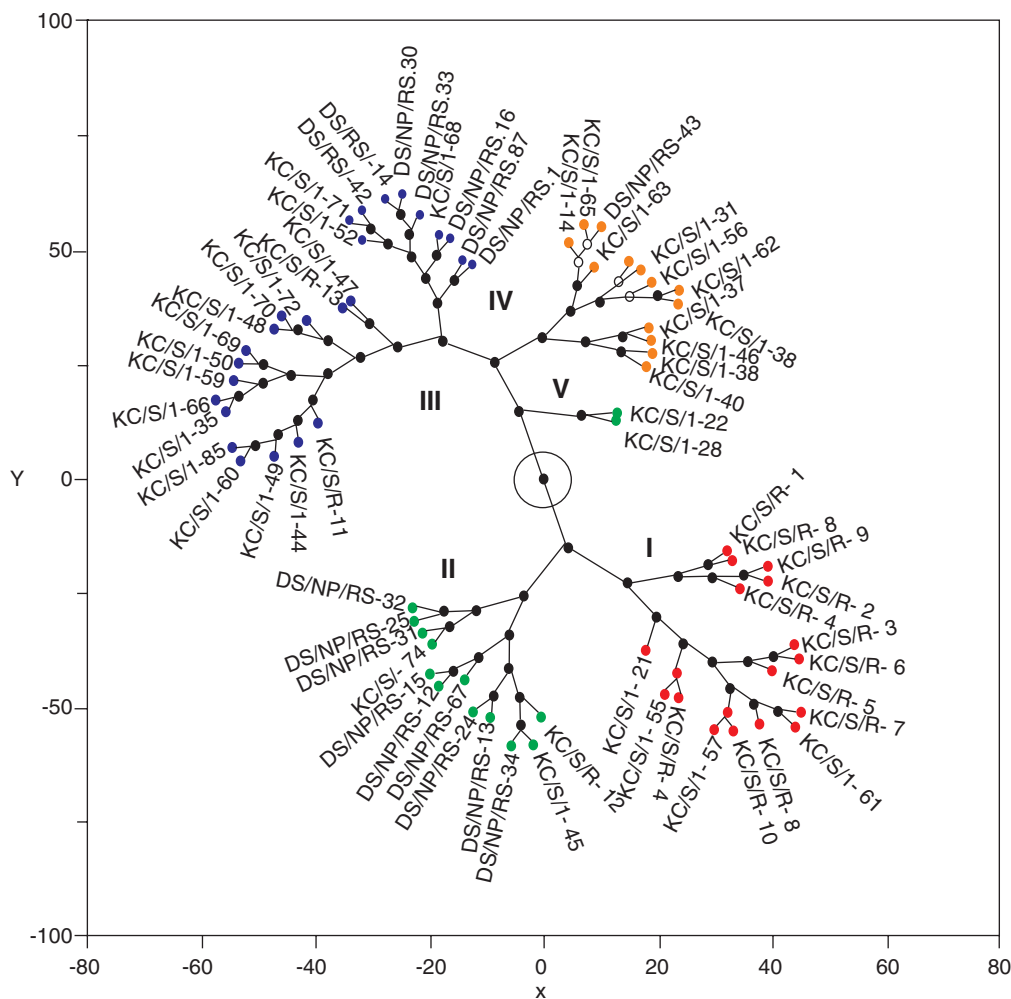


Fig 2 Cluster analysis depicting constellation plot of maize collections (Clusters I, II, III, IV and V represent collections as red, green, blue, orange and indigo points)

Table 4 Eigenvectors, eigenvalues and accumulated variation of the first four principal components (PC) from the correlation matrix based on maize population means

	PC1	PC2	PC3	PC4
Days to tasseling	-0.323	0.320	0.327	0.201
Days to silking	-0.322	0.337	0.275	0.295
Plant height (cm)	0.196	0.483	-0.248	-0.066
Ear height (cm)	0.099	0.507	-0.165	-0.300
Days to maturity	-0.302	0.333	0.109	0.167
No. of ears/plant	-0.100	0.016	0.449	-0.736
Ear length (cm)	0.283	0.274	0.108	0.112
Ear width (cm)	0.370	-0.005	0.180	0.259
Number of kernel rows	0.354	-0.114	0.244	0.286
Number of kernels/row	0.161	0.247	-0.465	0.005
100 seed weight (g)	0.354	0.104	0.351	0.080
Yield /plant (g)	0.385	0.148	0.269	-0.205
Eigenvalues	3.99	2.36	1.62	1.05
Proportion (%)	33.26	19.72	13.54	8.79
Cumulative (%)	33.26	52.98	66.53	75.32

This plot divided the collections into 5 clusters with the membership of 16, 12, 25, 13 and 2 accessions. Table 3 presents the morphological characteristics of the different groups obtained from the HCA. Cluster III is the largest cluster and V is the smallest one. Cluster I comprised of accessions having tall plant and high grain weight, cluster II had early maturing collections with high yield, high kernels per row, high number of rows with large ear width. Cluster III was the medium yielding cluster with medium maturity and medium plant height. Accessions from cluster IV was medium maturing with medium plant height, low yielder with less ear length and ear width. Accessions from cluster V was late maturing with high prolificacy (KC/S/I-22, KC/S/I-28). The clustering pattern also matched with their area of collection, as Chujak type Manipur collections were grouped into cluster II and Kolbu type in group IV except two collections (DS/NP/RS-38 and DS/NP/RS-43). *Tsungro* type maize collection from Wokha district and *Kholakithi* from Zunheboto district of Nagaland grouped in cluster III whereas *Metata* and *Mikreta* types in group I. The characteristics related to yield and morphology of the ear were the most discriminating followed by plant height, ear height and phenology. The plant height, the ear height and the ear length have also enabled to better identify maize accessions in Eastern Serbia (Jaric *et al.* 2010) and in the mountains of Michoacan, Mexico (Mijangos *et al.* 2007). The farmers would choose the biggest and most beautiful ears from the previous harvest to grow their crop in next season. This mass selection might be the cause of a differentiation of varieties in several subgroups. Louette and Smale (2000) through the results of the study on seed selection practices by the farmers of Cuzalapa, Mexico, showed that phenotypic selection based on the characteristics of the ear helps maintain a phenotypic

differentiation between the varieties of maize despite significant gene flow.

Principal component analysis

Each principal component was calculated by taking a linear combination of an eigen vector of the correlation matrix with a variable. The PCA based on correlation was used to reduce the dimension of data set where major share of variance (75.32%) in maize germplasm is explained by first four components (Table 4). The first component (PC1) accounted for 33.26% of variation, was loaded on days to tasseling, days to silking, ear length, ear weight, ear length, days to maturity and grain yield, kernels/row, kernel rows; PC2 accounted for 19.72% of variation, was loaded on plant height, ear height; and PC3 contributed 13.54% variance mainly through ears/plant and grain weight. The Genotype-trait biplot based on two principal components were also generated to depict the two-dimensional view of accession scores as well as loading of characters. The first axis represented both phenological and ear aspects of the accessions, whereas PC2 and PC3 was related with plant architecture and yield traits, respectively. PC1 opposed the early maturing and high yielding accessions (KC/S/I-67, DS/NP/RS-15, DS/NP/RS-12, DS/NP/RS-25, DS/NP/RS-31, DS/NP/RS-32, DS/NP/RS-74) to the late and low yielding accessions (KC/S/I-22, KC/S/I-38, KC/S/I-40). PC2 differentiated accessions mainly on the basis of plant height and ear height (collections with large plant height KC/S/R-3, KC/S/R-5 and KC/S/R-6) and short statured collections (KC/S/I-38, KC/S/I-67, DS/NP/RS-12, DS/NP/RS-15, KC/S/R-12, KC/S/I-45, KC/S/I-47, DS/NP/RS-14 and DS/NP/RS-30). The biplot also revealed positive correlation between phenological, plant architectural (plant height and ear height) and ear related traits as these vectors were aligned at lower angle. Thus the results of principal component analysis used in the study have revealed the high level of genetic variation existing in the collection and explains the traits contributing for this diversity. Hence, the results will be of greater benefit to identify accessions for improving various morphological traits analyzed in this study. Classification methods (cluster analysis) used in conjunction with ordination technique (PCA) applied to the multivariate data confirmed five well defined groups of accessions. In some cases, accessions originating from the same location fall into tight groups within clusters (cluster I, II, IV and V). Assessment of genetic diversity also gives the germplasm curators an opportunity to identify the gaps in the collection, to identify traits for which useful variability is limited in the source collection and also to maximizing variation in the collection thereby suggesting the need of trait specific exploration.

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