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RESEARCH ARTICLE

Comprehending the Diversity in the Regenerated Set of Maize (*Zea mays* L.) Landraces Conserved in the Indian National Genebank

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The present study was undertaken made to reveal the extent of diversity in the regenerated landraces from the National Genebank, which were collected from traditional maize growing regions of India. The perpetuation of diversity in these regions is explained because of the availability of primitive cultivars, diversity in the eco-geography and presence of ethnic groups. The present set of regenerated maize landrace are cultivars of domesticated agricultural plant species which have developed over a long period of time and as a result have adapted to the local natural environment. The quantification of diverse germplasm in the present study contributes in the development of new germplasm, broadening the genetic base and also fills the gaps between available genetic resources and their utilization in maize breeding programmes. Significant variation was observed among the landraces for the eleven traits recorded. The principal component analysis revealed that first four PCs had eigen values >1 and explained up to 70 % of the variation. The multivariate hierarchical clustering resulted into three major clusters and cluster III being the largest (45 accessions) followed by cluster I (32 accessions) and cluster II (23 accessions). The study revealed that the landraces were diverse and heterogenous and were patronized by the farmers for their in- built ability to withstand the climatic challenges [e.g. wide Anthesis Silking Interval (ASI)].

Key Words: Cluster Analysis, Diversity, Landrace, Maize, Regeneration

Introduction

Mexico is the centre of origin, domestication and dispersion of maize. Maize then followed a very complicated pattern of introduction to different continents, including the North and South Americas, Europe, Africa and Asia (Rebourg *et al*, 2003; Dubreuil *et al*, 2006; Marilyn Warburton *et al,* 2013). Most of such introductions happened several centuries ago, and maize landraces with better adaptability have been selected by the farmers to the new environments, leading to several new derivatives in the process. The heterogeneity of the environments in which plants are grown is one of the major factors involved in the generation of diversity (Garcia *et al*, 1989; Linhart and Grant, 1996) that have contributed significantly to the variability of maize includes farmer selection to deal with different hygrothermal and environmental regimes that occur in the niches of the agricultural areas (Munoz, 2005) and seed exchange among farmers (Badstue *et al*, 2007). A greater amount of attention has been paid to breeding for attributes that are related to grain yield (Herrera *et al*, 2002), whereas farmer selection practices have focused heavily on ear characteristics (Louette and Smale, 2000). The considerable amount of genetic variation in the attributes related to grain suitability for different traditional uses has been documented (Mauricio *et al*,

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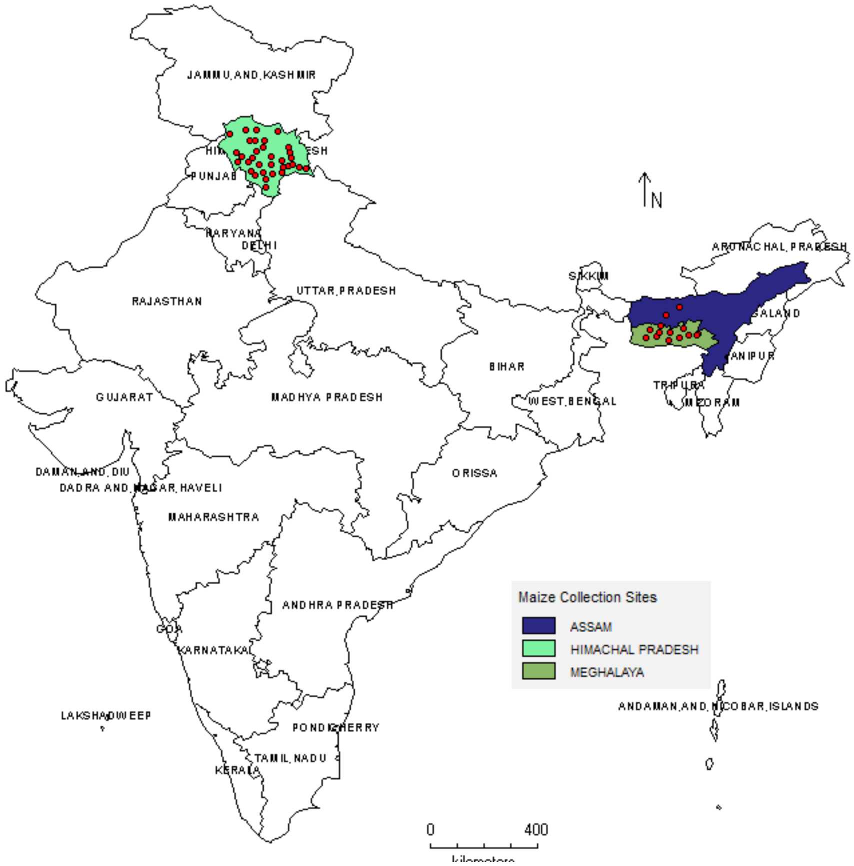

Fig. 1. Collection sites of the maize landraces under study

2004; Rangel *et al*, 2004). It is these diverse landraces that offer immense scope for genetic enhancement of maize yield to ensure food security under climate change (Vasconcelos *et al*, 2013).

Globally, however, the utilization of maize genetic resources has been very meagre (Nass *et al*, 1993). Some of the reasons for low utilization of maize genetic resources have been listed as lack of documentation and adequate description of collections, inadequate seed regeneration programme, lack of desired information by breeders.

In India, National Genebank located at National Bureau of Plant Genetic Resources conserves about 7,500 accessions of maize landraces including few distinct and diverse collection from North Eastern Himalayan (NEH) region of India (Prasanna, 2012). Under the Consortium Research Project on Agro-biodiversity in India (CRP-AB), the characterization, evaluation and regeneration of maize genetic resources has been initiated to fill this gap. The purpose of the present investigation was to evaluate the extent of genetic diversity in a set of 100 maize landraces.

Materials and Methods

4 set of 100 maize landraces originated and collected in India and conserved at the National Genebank located at National Bureau of Plant Genetic Resources, New Delhi, India were subjected to regeneration and data were recorded for various agro-morphological traits.

The accessions were grown at the farm located at Agriculture Research Institute, Rajendra Nagar, Hyderabad, India 2013-14. During the post rainy season, accessions were sown in October/November and harvested in March of subsequent season. The plot consisted of 2 rows of 3 m length with a spacing of 75 cm between ridges and 20 cm between plants. Recommended package of practices of the region were followed.

Data were recorded for both qualitative and quantitative traits. The quantitative traits *viz*., plant height (PH), ear height (EH), number of leaves above the ear (NL), ear length (EL), ear diameter (ED) and kernel row number (KRN) were taken on ten randomly selected plants whereas days to 50% anthesis (DA), days to 50% silking (DS), number of ears harvested and 100 kernel

Table 1. Descriptive statistic of the 11 quantitative traits in maize landrace collection

	DA	DS	ASI	PH	EH	NL	NE	EL	ED	KRN	KW
Mean	74.6	81.3	6.7	170.2	86.0	5.2	12.6	12.3	3.4	11.1	25.6
Standard Error	0.4	0.6	0.3	1.9	1.7	0.1	0.4	0.2	0.0	0.2	0.6
Standard Deviation	4.5	6.2	3.1	19.0	17.0	0.5	4.0	2.0	0.4	2.0	6.9
Range	23.0	29.0	15.0	108.3	91.7	3.0	21.0	12.0	2.6	12.0	32.6
Minimum	61.0	63.0	1.0	108.3	40.0	4.0	3.0	7.0	2.5	8.0	11.7
Maximum	84.0	92.0	16.0	216.7	131.7	7.0	24.0	19.0	5.1	20.0	44.3

DA= Days to anthesis; **DS**= Days to Silking, **ASI**= Anthesis Silking Interval, **PH**=Plant height, **EH**= Ear height, **NL**= Number of leaves above the ear, **NE**= Number of ears harvested (per accession), **EL**=Ear length, **ED**= Ear diameter, **KRN**= Kernel row number, **KW**=100-Kernel weight

weight (KW), tassel type, kernel color and kernel type were taken on plot basis as per the standard descriptors (Sharma 2000).The descriptive statistics were worked out for all the traits using Excel-stat. Further data was subjected to multivariate analysis using the principal coordinate/component analysis (PCA) and cluster analysis using PRINCOMP and CLUSTER procedure respectively in SAS Enterprise Guide 4.3.

Results

The descriptive statistics for eleven quantitative traits indicated presence of variation among the traits (Table 1). Based on flowering traits, most of the landraces were medium to late maturity group. The days to anthesis ranged between 61 to 84 days, days to silking between 63-92 days and anthesis to silking interval, an important trait for seed set and productivity of an accession ranged between 1 to 16 days. Approximately, 50% of the landraces exhibited ASI between 1-6 days, for all traits except which is a desirable trait in maize. Significant variation was observed for number of leaves above the ear and ear width, which had relatively moderate variation.

The tassel type is another important trait in maize, 32 landraces recorded primary tassel type and remaining had primary-secondary tassel type. The kernel color varied from white (6), white cap (5), yellow (30), Orange (48), purple (1), brown (3) and red (2). There were five kernel textures were observed viz., dent (1), semi dent (8), flint (89), pop (2) and sweet (1). The presence of variation for qualitative and quantitative traits in the maize landrace collection from three states provided subtle indication to the diversity among the collection.

The principal component analysis of maize landrace collection revealed that first four PCs had eigen values >1 and explained up to 70 % of the variation indicating the presence of wide variation in maize landrace collection. The PC 1 explained 29.8 % of the total variation followed by second, third and fourth PCs which explained 16.7 %, 12.4 % and 11.0 % of the total variation, respectively. The traits *viz*., days to 50 % silking, days to 50 % anthesis, plant height and ear height were the dominant positive factor loadings contributed for the variation in PC I. The PC II was dominated by positive factor loadings of ear width, number of kernel rows and number of leaves above the ear. Whereas, PC III was dominated by positive loadings of number of ears/plot and plant height and PC IV was dominated by number of ears, number of leaves above the ear and number of ears per plot.

The multivariate hierarchical clustering using Ward's minimum method resulted into three major clusters and cluster III being the largest (45 accessions) followed by cluster I (32 accessions) and cluster II (23 accessions). The grouping of maize accessions in to different clusters was not based on geographical origin of the landraces hence there is no clear geographical demarcation. However, accessions in cluster I were tall and late flowering with more number of leaves above the ear and long ears, in cluster II consisted short to medium tall and early flowering types along with long and more number of harvested ears. Cluster III had accessions with less days to anthesis to silking interval and ears with highest diameter, more kernel row number and high-test weight. Cluster means indicated that cluster II had highest mean for number of ears harvested (13.40) and kernel row number (11.80). Cluster I had highest mean for days to anthesis (77.10), days to silking (85.10), anthesis to silking interval (8.00), plant height (188.80 cm), ear height (104.20 cm), number of leaves above ear (5.30), ear length (12.50 cm) and cluster III for 100 kernel weight (27.70g).

Table 2. Trait-wise promising lines in the regenerated germplasm set of maize landraces for future evaluation

Trait	Particulars	Promising sources
Plant height (cm)	>200 cm	IC77122 (206.7), IC77242 (211.7), IC77246 (216.7) and IC77312 (208.3)
Anthesis Silking Interval	= 1 day	IC77039, IC77053,IC77118,IC77128, IC77140,IC77249
Ear height (cm)	< 50 cm	IC77094 (40) and IC77220 (48.3
Number of leaves above ear	> 6	IC77242 (7) and IC77249 (6.7)
Ear length (cm)	>15 cm	IC77220 (19 cm)
Ear diameter (cm)	>4 cm	IC77267 (4.5)
Kernel row number	>15 cm	IC77246 (16)
100- kernel weight (g)	>40 g	IC77254 (44.4), IC77257(43.6), IC77265 (41) and IC77267 (40.1)

Discussion

The variation in present maize germplasm collection reflected the heterogeneous and heterozygous nature of the landraces. Obvious differences were observed in the entire collection as well as the collection from each state indicating the diverse utilization and choice of the local farmers. The results of the PCA based on 11 traits exhibited 70 % variation by four PCs. Days to anthesis, days to silking, anthesis to silking interval, plant height, ear height, ear width, number of kernel rows and number of leaves above ear were of high discriminating level and were consistent in their contribution in the first two components and therefore could be used for maize characterization. On the other hand, Number of ears per plot, 100 kernel weight and number of leaves above ear were consistently present in 3rd and 4th components and therefore contributed less to the total genetic variation present among maize landraces. The traits under study were good enough to discriminate the accessions based on their geographical origin, evolution of maize landraces under specific crop management practices and ecological niches.

The cluster analysis showed high degree of genetic diversity among the maize landraces collection. Crossing contrasting and diverse parents for plant height cluster I (tall) and cluster II short); for ear height cluster I (long ears) with cluster II (short ears) may be suggested. Interestingly, accessions with narrow ASI (IC77039, IC77053, IC77118, IC77128, IC77240 and IC77249) distributed in cluster III mostly collected from Meghalaya state and accessions having high range for ASI were mostly from Himachal Pradesh were distributed across all the three clusters. Identification of such landraces (narrow ASI) would help in developing maize varieties/ hybrids esilient to abiotic stresses.

Promising accessions for different traits were identified (Table 2). Four accessions, IC77122 (206.7 cm), IC77312 (208.3 cm), IC77242 (211.7 cm) and IC77246 (216.7 cm) were promising for tall and two short plant types were also identified (IC77094; 108.3 cm, IC77134; 108.3 cm). A characteristic of maize under drought stress is a delay in silking resulting in an increase in the anthesis-silking interval (ASI), incomplete fertilization and decreased kernel development (Hall *et al,* 1984). Hence, Anthesis to silking interval is an important trait in developing resilient maize and six landraces (IC77039, IC77053, IC77118, IC77128, IC77140 and IC77249) were found to be promising for narrow ASI. The recommended secondary traits for developing drought tolerant maize, routinely used by CIMMYT, for use in maize breeding programs are: flowering date (anthesis-silking interval, ASI), ears per plant (bareness), leaf rolling, tassel size and stay green (Monneveux *et al,* 2008). For ear height (< 50 cm) IC77094 and IC77220), for number of leaves (>6 no. per plant) IC77242 (7) and IC77249 (6.7), for ear height (>20 cm) IC533461 (20), IC77229 (20), IC77258 (20), IC77304 (24) and IC77311 (20), for ear length (> 15cm) IC77220 (19 cm), for ear diameter (> 4 cm) IC77267 (4.5 cm), for Number of kernel rows (> 15) IC77246 and for kernel weight (> 40 g) IC77254 (44.4), IC77257 (43.6), IC77265 (41) and IC77267 (40.1). However, IC77242 was promising for more than one trait (tallness and more number of leaves above ear). IC77246 found to be promising for tall plant types and kernel row number. IC77094 was superior for anthesis to silking interval and ear height and IC77249 for anthesis to silking interval and number of leaves above the ear, these accessions would be useful in maize breeding programme particularly for drought tolerance. IC77220 for ear height and ear length, IC77267 for ear diameter and kernel weight were the promising sources. Similar efforts have been undertaken in different regions of the globe with broader objective of identification of drought tolerance (Andjelovic *et al*, 2010), CMS lines (Vidakovic *et al*, 2002) and concentration of phytate (Drinnic *et al*, 2009). Ashok Kumar *et al* (2014) reported that maize landraces from Himachal Pradesh had high oil content and seed weight which would be useful in population or inbred development.

Conclusion

Efforts for characterization and regeneration of maize landraces contribute to their utilization in maize breeding programmes. The diverse landraces identified for different traits in this study may be utilized in the development of the diverse inbred lines. Accessions with narrow ASI (IC77039, IC77053, IC77118, IC77128, IC77240 and IC77249) would provide a source of resilience to abiotic stresses.

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