Indian J. Genet., 69(3): 191-198 (2009)

Evaluation of yield performance of selected North East Himalayan (NEH) maize landrace accessions of India, outside their habitat

Avinash Singode[1], J. C. Sekhar[2], Kalyani Srinivasan[3] and B. M. Prasanna[1]*

[1]Division of Genetics, Indian Agricultural Research Institute, New Delhi 110 012
[2]DMR Winter Maize Nursery, ARI Campus, Rajendranagar, Hyderabad 500 030
[3]Division of Germplasm Conservation, National Bureau of Plant Genetic Resources, New Delhi 110 012

(Received: January 2009; Revised: April 2009; Accepted: August 2009)

Abstract

The study pertains to evaluation of yield performance of a selected set of North East Himalayan (NEH) landrace accessions of maize in locations outside their habitat. The geographical coordinates of the collection sites of these accessions were first mapped, followed by trials at Delhi and Hyderabad during 2005-2006. The analysis revealed considerable variation among the accessions for grain yield and its components, besides G x E interactions. Although the grain yields of the NEH accessions are, in general, not encouraging at Delhi and Hyderabad, due to drastically different climatic conditions, the study resulted in identification of 10 highly promising accessions for different yield-related traits at Delhi and/or Hyderabad. These were IML216 (IC130749; Arunachal Pradesh), IML347 (Sikkim), IML315 (IC251354; Tripura), IML390 (Sikkim), IML384 (Sikkim), IML264 (IC131166; Sikkim), IML365 (Nagaland), IML303 (IC251290; Nagaland), IML308 (IC251313; Sikkim) and IML242 (IC130980; Assam). Among these, IML216, IML347, IML315 and IML390 are particularly worth-noting due to their excellence performance for various yield attributes across both locations. Such accessions could be potentially utilized in developing broad-based pools/populations for improving diverse agronomically important traits in maize.

Key words: Maize, landraces, North Eastern India, yield components

Introduction

Maize (*Zea mays* L.) can be grown in varied environmental conditions both in the tropical and temperate regions due to its unparalleled genetic diversity and adaptability among the cereals. Landraces in maize are genetically diverse, heterogeneous populations that are typically selected by farmers for their adaptation to specific local environment and are understood to differ in agronomic and nutritional characteristics, including prolificacy, biotic and abiotic stress resistance, maturity, nutritive value, etc. They have evolved under subsistence agriculture and are still cultivated by farmers in diverse regions worldwide [1,2], including India.

Approximately 65,000 accessions of maize exist in the germplasm banks around the world, and nearly 7500 accessions of landraces/locals are in the National Gene Bank at the National Bureau of Plant Genetic Resources (NBPGR), New Delhi. Most of these landrace accessions have specific characteristic features, and some of them have been utilized in maize improvement programmes in India [3]. However, it is relevant to note that genetic resources used in maize breeding programmes around the world represent less than 10% of all landraces [4], indicating that much of this diversity remains to be effectively evaluated and utilized. These genetic resources could enable development of cultivars not only with improved productivity but also biotic and abiotic stress tolerance [5]. For better conservation and utilization of such germplasm, it is important to generate proper agronomic and genetic knowledge [6,7].

In India, maize landraces are mostly prevalent in the areas of rainfed farming in the North Eastern Himalayan (NEH) region [8] as well as in other regions, extending from the extreme semi-arid to sub-humid and humid regions [3,9,10]. The NEH region of India, comprising Assam, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Meghalaya and Tripura), Sikkim and also parts of Northern region of West Bengal, stretches from 22°N to 29.3°N latitude and 88.05°E to 97.24°E

*Corresponding author's e-mail: bmprasanna@gmail.com

longitude. The altitude of the region ranges from 97 m in plains to as high as 5000 m above mean sea level in the hills. The NEH maize landraces have extensive variability for plant, tassel, ear and kernel characteristics [8, 11].

Germplasm explorations of maize have been undertaken by both IARI and NBPGR over the last few decades. Intensive cytological analysis of some of these accessions, particularly from the NEH region, was undertaken and reviewed earlier [12]. However, there is a need for systematic evaluation of agronomic performance of these landraces. Keeping this in view, the present study was undertaken (i) to evaluate the yield performances of selected landrace accessions in India, specifically those representing the NEH region, in locations outside their natural habitat, and (ii) to identify genotypes that showed promising performance in specific environment and/or across environments.

Material and methods

A set of 57 landrace accessions were included in the study, including the flint and dent kernel types, with different kernel colors conditioned by endosperm (yellow, orange, yellow-orange, white, red, purple/black) or by pericarp (red and purple/black). The accessions were obtained from two sources: (i) National Gene Bank, NBPGR, New Delhi, India; and (ii) some collections made by the Maize Genetics Unit, Indian Agricultural Research Institute (IARI), New Delhi. Details of these accessions are provided in Table 1.

Based on the passport data (Village, District and State of collection) available, we determined the geographical coordinates for each of the landrace accessions, using the software 'GOOGLE EARTH' (www.googleearth.com) in combination with detailed State/District maps obtained from the Geographical Survey of India Office in New Delhi.

During *Kharif*-2005, a trial including 52 NEH accessions was conducted at IARI Experimental Farm, New Delhi, in a Randomized Complete Block Design (RCBD) with two replications per entry. The three checks used were PC3 (Pusa Composite-3), and two single-cross hybrids, PEHM1 (Pusa Early Hybrid Makka-1) and Parkash. Another trial, comprising 23 selected accessions, was conducted at Hyderabad (*Rabi* 2005-06) in RCBD with two replications per entry at the DMR Maize Winter Nursery, Amberpet Farm, Hyderabad. Delhi and Hyderabad belong to Zone 2 and 4, respectively, as defined under the All-India Coordinated Research Project on Maize, while all the NEH accessions analyzed in the study were collected from different NEH States in Zone 1.

Data was recorded on various yield-related traits, including ear length (EL), ear diameter (ED), number of kernel rows (KR), number of kernels per ear row (KPR), number of kernels per ear (KN), grain yield per plot (GYPP) and 100-kernel weight (HKW). Analysis of variance (ANOVA) was done using PROC GLM SAS (SAS Institute, Version 9.1). The mean values for various yield-related traits of the selected landraces accessions were computed for each of the locations and were statistically analyzed vis-à-vis the checks using the least squares method, for identification of promising accessions.

Results and discussion

Besides genetic factors, several environmental factors including soil, elevation, temperature and photoperiod, play a vital role in determining the patterns of diversity at both intra- and inter-specific levels in crop plants. Therefore, it is important to obtain proper geographical coordinates for each accession's collection site. In this study, the missing geographical coordinates for the collection sites of several maize landrace accessions were determined using the GOOGLE EARTH software (Table 1).

Analysis of the data showed significant variation with respect to latitude/longitude of collection sites within the country for the selected accessions, besides the elevation of collection sites. The elevations of the accessions ranged from 62 masl (IML241, IML242 and IML243 from Assam) to 2312 masl (IML240 from Arunachal Pradesh). Considering this, the collection sites for these accessions could be classified as lowland (<400masl), mid-altitude (400–1500 masl), and highland (>1500masl). This classification resulted in identification of 25 lowland, 21 mid-altitude, and 41 highland accessions. The skewedness with regard to elevation (highland) is because of the fact that most of the NEH states, particularly Sikkim, come under highland region (Zone 1).

Intensive phenotypic characterization of genetic resources is important in our efforts to conserve, evaluate and utilize these genetic resources, for studying the diversity of pre-breeding and breeding germplasm [6,7,13]. Multi-location evaluation of accessions is essential for identifying promising accessions for each environment/location as well as across environments/locations.

Table 1. List of selected NEH Indian maize landrace accessions with the available passport data.

S.No.	IML No.*	Gene bank No.	Village	District	State	Elevation (masl)	Kernel type
1	IML106	IC 77113	Lowshita	East Khasi Hills	Meghalaya	1191	Y F
2	IML155	IC 83242	Amlakha Karbi	Karbi Anglong	Assam	170	Y F
3	IML194	IC 130591	Sibilon	Tengnoupal	Manipur	682	P F
4	IML200	IC 130623	Tikholi	Central Manipur	Manipur	768	W F
5	IML201	IC 130626	M. Ningthouphan	Central Manipur	Manipur	768	Y/W F
6	IML202	IC 130631	Hengbang	Central Manipur	Manipur	768	W/P F
7	IML204	IC 130644	Jaluki	Kohima	Nagaland	782	Y F
8	IML207	IC 130697	Aperikarani	Karbi Anglong	Assam	170	Y F
9	IML216	IC 130749	Boying	East Siang	Arunachal Pradesh	157	Y F
10	IML219	IC 130768	Passg\in	East Siang	Arunachal Pradesh	157	W F
11	IML220	IC 130772	Boleng	East Siang	Arunachal Pradesh	157	W F
12	IML222	IC 130806	Bow	West Siang	Arunachal Pradesh	822	W/R F
13	IML229	IC 130869	Pading	West Siang	Arunachal Pradesh	822	Y/W F
14	IML240	IC 130969	Sing Chung	West Kameng	Arunachal Pradesh	2312	Y/W F
15	IML241	IC 130975	Pabamukh	Kamrup	Assam	62	Y F
16	IML242	IC 130980	Kemi	Kamrup	Assam	62	Y F
17	IML243	IC 130981	Telam Nepaligaon	Kamrup	Assam	62	Y F
18	IML251	IC 131073	Saibalggre	West GaroHills	Meghalaya	302	Y O
19	IML252	IC 131076	Rambbagiri	West GaroHills	Meghalaya	302	Y O
20	IML258	IC 131129	Rangpogiri	West GaroHills	Meghalaya	302	P F
21	IML263	IC 131164	Mendongong	North Sikkim	Sikkim	2010	O F
22	IML264	IC 131166	Phensong	North Sikkim	Sikkim	2010	O/Y F
23	IML265	IC 131174	Chung	North Sikkim	Sikkim	2010	O F
24	IML266	IC 131177	Sanpheng	North Sikkim	Sikkim	2010	Y/W F
25	IML268	IC 131189	Tingchim	North Sikkim	Sikkim	2010	Y/W/P F
26	IML270	IC 131204	Dikling	North Sikkim	Sikkim	2010	Y/W F
27	IML271	IC 131217	Sangkhola	East Sikkim	Sikkim	302	W F
28	IML273	IC 131229	Majilar	East Sikkim	Sikkim	302	W F
29	IML275	IC 131245	Temi Tarku	East Sikkim	Sikkim	302	W F
30	IML276	IC 131254	Temi Tarku	East Sikkim	Sikkim	302	W F
31	IML277	IC 131257	Gompa Gurpesha	East Sikkim	Sikkim	1706	Y/W/P F
32	IML279	IC 131267	Rumtek Raute	East Sikkim	Sikkim	302	W F
33	IML280	IC 131272	Mindo	East Sikkim	Sikkim	302	Y/W F
34	IML300	IC 251284	Bonsagiri	West Garo Hills	Meghalaya	302	W F
35	IML301	IC 251285	Dokgamgiri	West Garo Hills	Meghalaya	302	Y/W F
36	IML302	IC 251288	Seitie (Angami)	Kiruphema	Nagaland	895	W F
37	IML303	IC 251290	Kiriphema	Kohima	Nagaland	304	Y F
38	IML305	IC 251297	Kemecha	Kohima	Nagaland	304	Y/W F
39	IML306	IC 251298	Jharnapani	Kohima	Nagaland	304	Y F
40	IML308	IC 251313	Bichu	Lachung	Sikkim	2010	Y F

41	IML312	IC 251347	Pelong	South Sikkim	Sikkim	1308	Y F
42	IML313	IC 251348	Bomtar	South Sikkim	Sikkim	1676	Y F
43	IML315	IC 251354	Harinchora	Kamalpur	Tripura	1613	Y F
44	IML347	NA	NA	NA	Sikkim	NA	Y F
45	IML351	NA	NA	Shillong	Meghalaya	1613	R F
46	IML365	NA	NA	Kohima	Nagaland	304	Y F
47	IML377	NA	NA	East Sikkim	Sikkim	1510	P/R F
48	IML380	NA	NA	East Sikkim	Sikkim	1613	Y F
49	IML384	NA	NA	NA	Sikkim	NA	Y F
50	IML390	NA	NA	East Sikkim	Sikkim	1613	Y F
51	IML391	NA	NA	NA	Sikkim	NA	W F
52	IML489	IC 410302	Tapohou kuki	Senapati	Manipur	1613	Y/W F
53	IML491	IC 413475	Kamalpur	Dhalai	Tripura	1510	R F
54	IML494	IC 423221	Heningkunglwa	Peren	Nagaland	933	Y/P F
55	IML553	NA	NA	East Sikkim	Sikkim	1071	Y F
56	IML590	IC 565893	Simphok	West Sikkim	Sikkim	1067	O F
57	IML608	IC 565885	Thingmoo	North Sikkim	Sikkim	1533	O Pc

*The IML numbers are given by the Maize Genetics Unit, IARI, for the purpose of convenience for analyses and presentations.
NA: Not available
#Kernel type: Y – Yellow; O – Orange; P – Purple; R – Red; W – White; Tr-P/R – Transposon induced variegation for purple/red pericarp color;
F – Flint; D – Dent; Pc – Popcorn

ANOVA revealed significant genotypic differences among the accessions for the yield-related traits at Delhi and Hyderabad. At Delhi, out of the seven traits analysed, only ear length was found to be significant at 5% level, while the variation for the rest of the traits (ear diameter, number of kernel rows, kernel number per ear row, 100-kernel weight, kernel number per ear and grain yield) was significant at 1% level. The coefficient of variation (C.V.) for kernel number per ear was the highest (39.94) and the lowest was recorded for ear diameter (8.03).

The mean performance of the maize accessions for various characters at Delhi trial is presented in Table 2. The performances of the accessions of various traits were compared among the IMLs as well as for the IMLs vs. the checks. For ear length IML201 (16.34 cm) exceeded the mean performance of the checks PC3 (14.95 cm), Parkash (14.13 cm) and PEHM4 (15.34 cm). IML222 (15 kernel rows per ear) was found to perform better than all the three checks used in the study for number of kernel rows per ear. IML315 (32.90) was found to be highly promising for number of kernels per ear row and also for number of kernels per ear. Fourteen accessions outperformed the three checks for 100-kernel weight. IML276 (29.13 g) and IML207 (29.30 g) recorded the highest values for 100 kernel weight among the accessions as well as the checks. The highest grain yield per plot (1300 g) was recorded by IML365, and the least grain yield (150 g) was found in IML263. The overall mean for grain yield per plot was low (602.55 g), indicating the poor performance of most of the highland NEH accessions to the plains of Delhi, which was as per expectation.

In general, most of the 52 NEH accessions were not found to be adaptable to the hot and humid conditions during *Kharif*-2006 at Delhi. However, the study resulted in identification of at least six accessions that performed at par or better than the checks at Delhi; these include IML365 (Nagaland), IML390 (Sikkim), IML303 (Nagaland), IML308 (Sikkim) and IML242 (Assam) and IML315 (Tripura) could be considered promising with respect to grain yield and its components.

The mean performances of all the accessions for the yield-related traits at Hyderabad are presented in Table 3. ANOVA revealed significant genotypic variation for all the yield-related traits analyzed, except for number of kernels per ear row. The C.V. for grain yield was the highest (39.94), indicating the genetic heterogeneity of

Table 2. Means for various agronomic traits based on Delhi trial (*Kharif* 2005)

S. No.	Accession	EL (cm)	ED (cm)	KR	KPR	KNO	GYPP (g)	HKW (g)
1	IML 106	14.68	3.59	10.80	25.45	274.5	625	22.25
2	IML 155	9.53	**3.94**[c]	12.80	19.60	250.5	675	21.01
3	IML 194	9.97	3.39	**14.00**[c]	18.67	255.5	275	13.59
4	IML 200	13.41	3.40	12.01	13.90	166.9	150	17.88
5	IML 201	16.34	3.75	11.67	26.21	307.5	475	**27.66**
6	IML 202	12.35	3.13	10.00	14.50	158.0	175	21.9
7	IML 204	9.62	3.42	13.20	16.40	216.5	500	16.32
8	IML 207	11.70	3.84	13.45	17.10	236.5	700	**29.3**[a]
9	IML 216	**15.66**[b]	3.87	13.20	27.88	**370.5**[c]	870	20.95
10	IML 219	12.45	2.78	8.34	17.00	142.0	350	18.59
11	IML 220	12.42	3.12	12.95	18.14	235.0	400	15.87
12	IML 222	9.21	2.82	**15.00**[a]	18.80	282.5	450	9.76
13	IML 229	13.92	3.81	12.90	23.20	299.5	750	23.73
14	IML 240	14.67	3.13	11.09	16.09	177.0	300	19.49
15	IML 241	13.3	3.84	12.15	15.75	192.5	505	22.21
16	IML 242	13.99	**4.08**[b]	12.20	26.00	317.5	**1070**[c]	23.85
17	IML 244	11.61	3.04	9.59	15.47	149.0	400	20.10
18	IML 251	9.25	3.65	12.14	14.34	174.5	300	17.9
19	IML 252	12.07	3.78	13.75	18.63	256.5	275	20.18
20	IML 258	12.25	3.02	12.40	18.80	233.5	350	14.29
21	IML 263	14.14	2.10	7.67	16.00	122.0	150	21.54
22	IML 264	15.1	2.82	9.75	18.38	183.0	225	22.75
23	IML 265	13.58	3.48	10.54	19.84	209.5	500	23.89
24	IML 266	**15.58**[a]	3.68	10.67	26.09	279.5	500	26.01
25	IML 268	11.03	3.46	10.80	20.50	227.0	250	19.39
26	IML 270	13.3	3.57	9.85	20.05	199.5	625	**27.66**[c]
27	IML 271	11.43	3.58	10.98	22.20	244.5	550	19.19
28	IML 273	10.93	3.60	10.20	21.73	222.0	650	21.92
29	IML 275	12.87	3.08	8.67	19.17	163.0	375	23.52
30	IML 276	13.23	3.54	10.20	18.75	190.5	300	**29.13**[b]
31	IML 277	12.49	3.48	10.35	20.53	221.5	400	23.74
32	IML 279	11.37	2.82	10.00	20.90	209.5	375	19.10
33	IML 280	10.45	3.30	11.30	16.27	178.5	500	21.00
34	IML 300	12.4	3.63	12.30	25.20	309.5	750	20.47
35	IML 301	11.24	3.85	**14.10**[b]	22.50	317.5	650	15.11
36	IML 302	13.68	3.51	11.70	25.40	297.0	800	16.37
37	IML 303	12.94	3.78	13.00	23.50	306.5	**1025**	21.02
38	IML 305	13.12	3.83	13.00	23.48	310.5	800	23.15
39	IML 308	13.81	3.92	13.59	**28.10**[c]	**385.1**[b]	**1000**	17.17
40	IML 312	13.33	3.82	13.10	27.80	364.0	825	22.92
41	IML 313	12.51	3.58	12.80	23.20	296.5	650	22.35

42	IML 315	**15.66[b]**	**4.22[a]**	12.98	**32.90[a]**	**427.0[a]**	850	22.11
43	IML 347	**15.64[c]**	3.81	11.25	**29.35[b]**	330.0	700	21.55
44	IML 351	15.08	3.67	12.35	27.95	343.5	450	19.72
45	IML 365	14.94	3.22	11.40	25.25	286.5	**1300[a]**	17.51
46	IML 377	9.11	3.81	12.74	18.09	230.5	775	15.70
47	IML 380	11.63	3.72	12.80	25.18	322.0	375	21.71
48	IML 384	14.05	3.56	11.50	27.30	315.0	895	23.27
49	IML 390	14.79	3.91	11.90	25.65	305.5	**1175[b]**	22.13
50	IML 489	12.99	2.94	11.00	12.50	135.0	175	23.79
51	IML 491	11.34	3.59	12.92	20.50	265.0	675	17.4
52	IML 494	12.45	3.35	12.20	19.20	234.5	425	21.59
53	PARKASH	14.13	3.87	12.80	**30.70**	**393.0**	**1300**	22.76
54	PC 3	14.95	3.83	13.60	25.13	341.5	950	19.19
55	PEHM 4	15.34	**4.30**	**14.75**	**33.60**	**500**	**1600**	21.95
	Mean	**12.89**	**3.45**	**11.86**	**21.71**	**259.82**	**602.55**	**20.82**
	C.V. 5%	15.15	8.03	9.61	19.85	23.93	39.94	13.94
	F. Prob	0.010	0.000	0.000	0.000	0.000	0.000	0.000
	S.E.	1.38	0.63	0.8	3.05	44.1	0.65	2.07
	C.D. 5%	3.91	0.78	2.28	8.66	125.41	350.84	5.86
	C.D. 1%	5.21	1.37	3.04	11.54	16.74	412.45	7.81

EL: Ear length (cm), ED: Ear diameter (cm), KR: No. of kernel rows per ear, KPR: No. of kernels per ear row, KNO: No. of kernels per ear, HKW: Hundred kernel weight (g), and GYPP: Grain yield per plot (g)
The top three accessions are given alphabetical ranking ('a', 'b' and 'c') and the values equal to or higher than those of the checks for specific traits are depicted in bold letters.

the accessions. Highest value for ear length (17.25 cm), number of kernels per ear row (30.63) and number of kernels per ear (476.25) were recorded by IML216. IML229 recorded highest value for ear diameter. For 100 kernel weight the highest values were recorded in IML264 (26.79 g). Ten accessions exceeded the overall mean of 17.16 g. Among the 24 accessions evaluated at Hyderabad, the highest mean grain yield of 575 g was recorded in two accessions (IML384 and IML390) and the least grain yield (30 g) was found in IML270. Based on this analysis, a few accessions, namely IML384 (Sikkim), IML390 (Sikkim), IML216 (Arunachal Pradesh), IML264 (Sikkim) and IML347 (Sikkim), could be considered promising with respect to agronomic performance at this location.

Diversity for agronomic traits in maize landrace accessions was also observed in previous studies. Ilarslan et al. [14] found considerable genetic variation for morphological and agronomic traits in a collection of Turkish maize landraces. Pressoir and Berthaud [15,16] observed high levels of population differentiation in maize landraces in Mexico and concluded that farmers select for genes of major and pleiotropic effects, and that farmers' decisions and selection strategies have a great impact on phenotypic diversification in maize landraces. Harlan et al. [17] stated that agronomic and ecological characteristics could 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. There is no published literature available so far with regard to performance of NEH maize accessions outside their habitat.

The NEH accessions that performed well at both Delhi and Hyderabad are listed in Table 4. Although the grain yields of the NEH accessions are in general not very encouraging at Delhi and Hyderabad, due to drastically different climatic conditions, it is significant to note that at least ten accessions recorded promising performance at Delhi and/or Hyderabad. These were IML216 (Arunachal Pradesh), IML347 (Sikkim), IML315 (Tripura), IML390 (Sikkim), IML384 (Sikkim), IML264 (Sikkim) IML365 (Nagaland), IML303 (Nagaland), IML308 (Sikkim) and IML242 (Assam). Among these, four accessions were particularly worth-noting, as these have recorded excellent performance for different yield-

Table 3. Means for various agronomic traits based on Hyderabad trial (*Rabi* 2005-06)

S. No.	Accession	EL (cm)	ED (cm)	KR	KPR	KNO	GYPP (g)	HKW (g)
1	IML 106	13.57	3.75	12.75	25.25	322.63	21.19	225.00
2	IML 216	**17.25**[a]	**4.22**[b]	**15.50**[a]	**30.63**[a]	**476.25**[a]	19.26	148.00
3	IML 229	**15.05**[c]	**4.26**[a]	14.20	27.44	388.71	19.51	350.00
4	IML 242	11.60	3.02	12.00	20.84	250.00	7.99	83.00
5	IML 264	14.56	3.38	9.34	21.00	198.67	**26.79**[a]	**415.00**[b]
6	IML 265	11.88	3.14	10.00	23.90	236.80	15.85	165.00
7	IML 270	10.73	2.88	14.00	21.00	294.00	13.83	30.00
8	IML 273	12.18	3.52	12.00	26.25	316.38	14.05	300.00
9	IML 276	12.44	3.39	10.00	27.21	272.09	16.55	275.00
10	IML 300	11.73	3.69	**14.50**[c]	25.00	365.50	12.90	125.00
11	IML 306	14.42	3.75	**14.67**[b]	26.17	383.89	16.65	200.00
12	IML 308	9.22	3.59	13.00	14.13	183.63	15.74	150.00
13	IML 312	13.79	**3.88**[c]	13.34	27.50	366.34	21.24	215.00
14	IML 315	12.91	3.60	13.25	27.88	369.44	15.39	275.00
15	IML 347	14.66	3.87	12.85	29.38	376.82	**22.32**[c]	**400.00**[c]
16	IML 365	14.56	3.36	12.25	27.09	333.13	19.21	325.00
17	IML 377	10.62	2.88	13.67	20.50	283.67	8.34	100.00
18	IML 380	11.46	3.84	**14.67**[b]	25.25	373.34	15.44	175.00
19	IML 384	12.43	3.78	14.05	26.80	373.93	16.28	**575.00**[a]
20	IML 390	14.10	3.77	12.80	**30.50**[b]	**390.48**[c]	20.49	**575.00**[a]
21	IML 391	12.40	3.51	11.00	20.71	226.75	20.57	160.00
22	IML553	10.71	3.13	9.60	20.90	199.48	16.52	145.00
23	IML590	**15.38**[b]	3.48	9.00	24.50	220.50	**26.30**[b]	125.00
24	IML608	14.26	2.87	13.50	**30.43**[c]	**426.71**[b]	9.54	263.00
	Mean	**12.99**	**3.52**	**12.58**	**25.01**	**317.88**	**17.16**	**242**
	C.V.	13.46	2.8	9.25	16.17	20.06	18.63	43.87
	F Prob.	0.03	0.01	0.000	0.006	0.000	0.000	0.006
	S.E.	1.24	0.7	0.82	2.86	45.1	2.26	46.54
	C.D. 5%	3.62	1.06	2.41	6.75	131.93	6.61	108.64
	C.D. 1%	4.91	1.8	3.27	10.26	179.04	8.97	134.56

EL: Ear length (cm), ED: Ear diameter (cm), KR: No. of kernel rows per ear, KPR: No. of kernels per ear row, KNO: Kernel no. per ear, HKW: Hundred kernel weight (g), and GYPP: Grain yield per plot (g)
The top three accessions are given alphabetical ranking ('a', 'b' and 'c') and the values equal to or higher than those of the checks for specific traits are depicted in bold letters.

related traits at both locations. These were IML216 (Arunachal Pradesh), IML347 (Sikkim), IML315 (Tripura) and IML390 (Sikkim). The study, thus, clearly indicated that at least some of the NEH accessions could be utilized in Zones other than Zone 1 from which these were collected. Such accessions could be of considerable value in breeding programmes for diversifying the pools and deriving inbred lines with greater productivity and adaptability.

Acknowledgements

The first author thanks Council for Scientific and Industrial Research (CSIR) for Research Fellowship during the Ph.D. programme. The study was carried out under the ICAR National Fellow Project titled "Molecular characterization of Indian maize landraces and allele

Table 4. Promising NEH accessions identified based on their performance in the trials at Delhi and Hyderabad

Trait	Location	Promising accessions
EL	D	IML 201, **IML 216**, IML 315, **IML 347**, IML 266,
	H	**IML 216**, IML590, IML 229, **IML 347**, IML, 264,
ED	D	IML 315, IML 242, IML 155, IML 308, IML 390
	H	IML 229, IML 216, IML 312, IML 347, IML 380
KR	D	IML 222, IML 301, IML 194, IML 252, IML 308
	H	IML 216, IML 380, IML 306, IML 300, IML 229
KPR	D	**IML 315**, **IML 347**, IML 308, IML 351, IML 216, IML 312
	H	IML 216, IML 390, IML608, **IML 347**, **IML 315**
KNO	D	IML 315, IML 308, IML 216, IML 312, IML 351, IML 347
	H	IML 216, IML608, IML 390, IML 229, IML 306
100 KW	D	IML 207, IML 276, IML 270, IML 201, IML 266, IML 265, IML 242, IML 489, IML 277
	H	IML 264, IML590, IML 347, IML 312, IML 106
GYPP	D	IML 365, **IML 390**, IML 377, IML 384, IML 312, IML 242
	H	IML 384, **IML 390**, IML 264, IML 347, IML 229

EL: Ear length (cm), ED: Ear diameter (cm), KR: No. of kernel rows per ear, KPR: No. of kernels per ear row,
KNO: No. of kernels per ear, HKW: Hundred kernel weight (g) and GYPP: Grain yield per plot (g).
D: Delhi; H: Hyderabad
Accessions indicated in bold letters showed promising performance for more than one trait.

mining for some agronomically important traits" awarded to BMP. The authors thank Division of Germplasm Conservation, NBPGR for providing some of the landrace accessions used in this study.

References

1. **Louette D. and Smale M.** 2000. Farmers' seed selection practices and traditional maize varieties in Cuzalapa, Mexico. Euphytica, **113**: 25-41.
2. **Louette D., Charrier A. and Berthaud J.** 1997. *In situ* conservation of maize in Mexico: genetic diversity and maize seed management in a traditional community. Econ. Bot., **51**: 20-38.
3. **Prasanna B.M. and Sharma L.** 2005. The landraces of maize (*Zea mays* L.): diversity and utility. Indian J. Plant Genet. Resour., **18**: 155-168.
4. **Dowswell C.R., Paliwal R.L. and Cantrell R.L.** 1996. Maize in the Third World. Westview Press, USA.
5. **Tanksley S.D. and McCouch S.R.** 1997. Seed banks and molecular maps: unlocking genetic potential from the wild. Science, **277**: 1063-1066.
6. **Nass L.L., Pellicano I.T. and Valois A.C.C.** 1993. Utilization of genetic resources for maize and soybean breeding in Brazil. Brazilian J. Genet., **16**: 983-988.
7. **Nass L.L. and Paterniani E.** 2000. Prebreeding: a link between genetic resources and maize breeding. Scientia Agricola, **57**: 581-587.
8. **Singh B.** 1977. Races of Maize in India. Indian Council of Agricultural Research (ICAR), New Delhi.
9. **Dhillon B.S. and Prasanna B.M.** 2001. Maize. In: Breeding Field Crops (ed. V.L. Chopra), Oxford & IBH, New Delhi, pp. 147-189.
10. **Dhillon B.S., Vasal S.K. and Prasanna B.M.** 2002. Maize. In: Evolution and Adaptation of Cereal Crops (eds. V.L. Chopra and Shyam Prakash), Oxford & IBH, New Delhi, pp.99-133.
11. **Grant U.J. and Wellhausen E.J.** 1955. A study of corn breeding and production in India. Ministry of Food and Agriculture, Govt. of India.
12. **Sachan J.K.S.** 1991. Origin and evolution of maize. In: Maize Genetics Perspectives (eds. K.R. Sarkar, J.K.S. Sachan and N.N. Singh). Indian Society of Genetics and Plant Breeding, New Delhi, pp. 16-34.
13. **Franco J., Crossa J., Ribaut J.-M., Betran J., Warburton M.L. and Khairallah M.** 2001. A method for combining molecular markers and phenotypic attributes for classifying plant genotypes. Theor. Appl. Genet., **103**: 944-952.
14. **Ilarslan R, Kaya Z., Kandemir I. and Bretting P.K.** 2002. Genetic variability among Turkish pop, flint and dent corn (*Zea mays* L.) races: Morphological and agronomic traits. Euphytica, **128**: 173-182.
15. **Pressoir G. and Berthaud J.** 2004. Patterns of population structure in maize landraces from the Central Valleys of Oaxaca in Mexico. Heredity, **92**: 88-94.
16. **Pressoir G. and Berthaud J.** 2004. Population structure and strong divergent selection shape phenotypic diversification in maize landraces. Heredity, **92**: 95-101.
17. **Harlan J.R., de Wet J.M.J. and Price E.G.** 1973. Comparative evolution of cereals. Evolution, **27**: 311-325.