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Performance of maize (*Zea mays* L.) inbred lines for various yield and its related traits

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Abstract
Maize has higher productivity potential among the cereals and is the third most important grain crop after wheat and rice with wide adaptability. The present investigation was undertaken to assess the genetic variability among various traits on grain yield, and to identify potential donor parents among the forty inbreds on the basis of genetic divergence for their use in future breeding programs. Data were recorded on grain yield per plot and various morphometric traits. The four inbred lines *viz;* CML189, CML192, BAJIM-08-26 and KI-30 were found to be significantly superior for yield per se performance and other related traits. The inbred line CML192 was significantly superior for seven traits *viz.*, days to 50 per cent pollen shed, plant height, cob placement height, 100-seed weight, cob length, cob girth and grains per row. Whereas, line KI-30 was found to be significantly superior to best check(s) for three traits *viz.*, days to 50 per cent pollen shed, days to 50 per cent silking and days to 75 per cent. These superior inbreds can be further evaluated and can be used as donor parents for various traits of interest in future breeding programs.

Keywords: Maize, inbred lines, yield, breeding programs

Introduction

Maize (*Zea mays* L.) also known as 'queen of cereals' is the most important food grain in the world having highest potential for carbohydrate production per unit area per day. Maize is grown in diverse environments with a range of 58°N to 40°S latitude, from sea level to higher than 3000 m altitude and in areas receiving annual rainfall of 250 to 5000 mm (Downsell *et al.*, 1996) [1]. It has originated from Mexico from where it spread to different parts of the world due to its wide adaptability and higher productivity potential. It occupies an important position in the world economy and trade as a food, feed and industrial crop. The maize kernel comprised of approximately 60-70 percent carbohydrates, 9-12% crude protein, 2-3.5% crude fibre, 3-5% lipids and 20 mg of Ca/100g of kernels. Maize endosperm consisting of approximately 9-12 per cent protein is, however, deficient in two essential amino acids *viz*., lysine and tryptophan which lead to poor net protein utilization and low biological value of traditional maize varieties. Development and adoption of Quality Protein Maize (QPM) would increase the nutritional value of food, feed and other maize products.

Assessment of genetic diversity is an essential prerequisite for identifying potential parents for hybridization for any crop improvement programme. With the development of hybrids, area and production under maize showed an increasing trend due to the high yield potential of hybrids. In maize, inbred lines are used as parents for hybrid production due to the cross-pollinated nature of the maize crop. Saxena *et al.*, (1998) [6] studied that manifestation of heterosis usually depends on the genetic divergence of the two parental lines. So, for hybrid development in maize selection of superior parents (inbred lines) is a pre-requisite. Vasal (1998) [10] reported that inbred lines from diverse genetic stocks tend to be more productive than crosses of inbred lines from same variety. The measurement of genetic variability among maize inbred lines help us to choose the genetically diverse parents for hybrid production. Such diverse parents are likely to yield higher frequency of heterotic hybrids which also generates a broad spectrum of variability in segregating generations. Himachal Pradesh is endowed with diverse maize gene pool which can be exploited to improve the existing genotypes. Many primitive land races cultivated in hilly areas possess useful characters like resistance to stalk rot, stem borer and can withstand water lodging and are sweet in taste.

Knowledge of genetic variation among QPM and normal maize varieties is important for efficient selection and development of new varieties. However, no such information is available on these aspects of genetic diversity in maize landraces cultivated in Himachal Pradesh. Therefore, the present study was undertaken to identify potential donor parents among the set of maize inbred lines for genetic variability for various yield and its related traits which could be utilized for hybrid production.

Material and Methods

The present investigation was carried out at the Experimental Farm of the Department of Crop Improvement, College of Agriculture, CSKHPKV, Palampur, Himachal Pradesh situated at 1290.80 m above mean sea level having latitude 32º6' N and longitude 76º3' E. Palampur represents the mid-hill zone of Himachal Pradesh which is characterized by humid sub-temperate climate with rainfall of 2500 mm per annum having acidic soil with pH ranging between 5.0 to 5.6. The experimental material for the present study comprised of forty maize inbred lines (fourteen QPM lines and twenty-six non-QPM lines) including four checks namely, CML193, CML180 (QPM lines) and CML429, BAJIM-08-27 (non-QPM lines) which were evaluated in α-RBD design with three replications having five blocks per replication and eight entries per block. Each inbred line was sown in two rows in a plot with plot size of 3.0 x 1.2 m^2 at spacing of 60 cm between rows and 20 cm between plants within the row. Data was recorded on all the important characters pertaining to the present study *viz;* days to 50% pollen shed, 50% silking, 75% maturity and grain yield which were recorded on plot basis whereas; plant height, cob placement height, cob length, cob girth, kernel rows per ear, grains per row and 100-grain weight, husk cover, grain color, grain texture and endosperm hardiness were recorded on ten random competitive plants for each inbred line across replication.

Briefly days to 50% pollen shed was recorded as number of days from planting until 50% of the tassels (male inflorescence) of plants within the plot shed pollen. Days to 50% silking was recorded as number of days from planting until 50% of the silk emergence (female inflorescence) of plants occurs within the plot. Days to maturity was recorded as number of days taken from sowing to the time when cobs attain 75% maturity in each plot. Plant height was measured from the base of the plant to the tassel bearing node at maturity in centimeters (cm). The cob placement height (cm) was measured at dry silk stage from the base of the plant to the base of the uppermost cob. The length of the individual cob (cm) of selected plants was measured with a measuring tape in centimeters from the base to the filled grain point. The cob girth (cm) of all the selected plants was recorded by wrapping a measuring tape just below the center of each cob in centimeters. The numbers of kernel rows per cob were counted for all the ears of the selected plants. The number of grains per row were counted per cob for all the ears of the selected plants. 100-grain weight was measured using digital weighing balance in grams (g) by taking random sample of normal hundred seeds from ten competitive plants and averaged to obtain mean for each sample. For the measurement of grain yield per plot (g) at harvest, the dehusked cob weight of all the plants was recorded. The moisture percentage was determined in the grains obtained from randomly selected cobs from each plot with the help of "Universal Moisture Meter". The grain weight was adjusted for 15 per cent moisture level, and was converted into grain yield assuming shelling percentage at 80 per cent.

Each entry was rated in each plot for husk cover on the 1 to 5 scale as described below. Entries were scored on the trait when ears were fully developed and husk was drying down. The best time was one to three weeks before harvest.

Sr. No.	Rating scale	Husk cover
1.	Excellent	Husk tightly covers ear tip and extends beyond it.
2.	Fair	Covers ear tip tightly.
3.	Exposed tip	Loosely covers ear up to its tip.
4.	Grain exposed	Husk leaves do not cover the ear adequately, leaving its tip somewhat exposed.
5.	Completely unacceptable	Poor husk cover tips clearly exposed.

Among grain quality traits, the grains of each genotype in each replication were visualized for their color i.e. white, yellow and orange. For grain texture the grains of each genotype in each replication were visualized for their texture i.e. dent, flint, semident and semi flint. The endosperm hardiness was measured as per method given by Vivek *et al.*, (2008) [11]. The data from the experiment was analyzed statistically, wherever treatment differences were found significant, the critical differences were worked out at 5% level of probability (*P*=0.05).

Results and Discussion

The mean performance of thirty-six maize inbred lines including twelve QPM and twenty-four non-QPM lines comprised the experimental material. QPM lines were tested against QPM checks *viz.*, CML180 and CML193 and non-QPM lines with non-QPM checks *viz*., CML429 and BAJIM-08-27. The results were interpreted with best check for individual trait. The mean values of each trait for all the lines are given in Table 1. In the present study it is evident that there was significant variation in the mean performance of the inbred lines for all the traits studied. This variability in yield and its contributing parameters may be due to their differential genetic constitution.

The days to 50 per cent pollen shed and 50 per cent silking ranged from 53.67-77.00 and 55.67–78.67 days, respectively with mean value of 64.55 days for 50% pollen shed and 66.48 days for 50% silking. Among QPM lines, VQL2 (56.67 days) was earliest to pollen shed while VQL1 (58.00 days) was earliest to silking. Whereas, among non-QPM lines, CM126 and KI-18 were earliest to pollen shed (53.67) and silking (55.67). The character days to 75% maturity exhibited a wide range of variation from 91.67-114.67 with a grand mean of 102.42 days. The non-QPM lines CM126 and KI-18 (91.67) was early maturing (114.67), while among QPM lines VQL1 (94.00 days) shows significant earliness in maturity over their respective mean values (Table 1). This indicates that in the present material there is opportunity to choose genotypes for desired earliness and several early maturing high- yielding cultivars must be developed in maize which consequently help in capturing high price in early market. Shah *et al.*, (2000) [8] also reported similar results related to different maturity traits among maize genotypes.

The plant height in the inbred lines ranged from 94.27cm to 197.43cm with a general mean of 142.23cm and two inbred lines *viz.*, CML189 (197.43cm) and CML192 (191.80cm) attained significantly greater plant height compared to respective mean Values.

Table 1: Mean values of maize inbreds for different characters

Sr. No.`	Inbreds	Days to 50% pollen shed (1)	Days to 50% silking (2)	Days to 75% maturity (3)	Plant height (cm) (4)	Cob placement height (cm) (5)	Grain yield/plot (g) (6)	100-seed weight (g) (7)	Cob length (cm) (8)	Cob girth (cm) (9)	Kernel rows/ear (10)	Grains/row (11)
1	VQL1	57.00	58.00	94.00	144.40	53.73	711.12	16.03	10.52	11.67	15.33	21.00
2	VQL2	56.67	58.33	94.67	119.47	55.60	771.36	22.49	10.87	11.51	14.67	22.33
3	CML162	67.67	69.00	105.00	163.07	97.80	715.17	20.01	14.21	11.71	13.33	25.00
4	CML163	74.00	75.00	110.00	149.37	65.03	754.40	20.48	12.50	10.81	12.67	19.67
5	CML169	69.67	72.00	109.00	167.53	88.40	654.34	22.68	11.83	11.50	14.00	16.00
6	CML170	70.00	72.33	108.00	109.07	57.53	802.88	18.11	12.13	10.78	11.33	23.67
7	CML171	69.33	71.67	107.33	161.37	51.87	619.77	19.97	11.76	10.99	11.33	18.00
8	CML189	61.00	64.00	99.67	197.93	89.20	1358.33	31.92	16.34	16.38	14.67	36.67
9	CML192	64.33	66.67	102.67	191.80	91.33	1585.91	33.22	16.62	16.85	15.33	36.00
10	HKI-1348	72.33	74.33	110.00	94.27	43.13	608.30	14.47	8.87	9.92	10.67	16.33
11	CML451Q	74.67	76.67	112.67	116.80	57.67	838.26	18.19	11.55	10.65	12.67	17.00
12	CL02450Q	71.67	74.00	109.67	167.93	86.80	1738.45	25.63	11.27	12.84	12.67	18.67
13	CM126	53.67	55.67	91.67	110.03	53.37	577.41	15.63	10.19	10.07	10.67	24.67
14	CM127	57.00	58.67	94.67	154.47	66.00	871.30	20.47	13.16	11.16	12.67	21.00
15	CM128	56.33	58.00	94.00	109.33	50.53	596.48	20.13	9.35	9.36	10.67	19.67
16	CM129	56.67	58.67	94.67	98.73	37.07	555.64	17.72	8.66	10.25	12.00	16.00
17	CM145	56.67	58.00	93.00	126.00	57.33	828.09	20.64	10.45	12.59	14.00	21.33
18	CM152	55.33	57.33	93.00	133.27	62.60	1248.01	25.08	14.07	13.73	13.33	27.67
19	CM212	57.00	59.00	95.67	142.10	58.90	700.09	16.29	9.88	12.53	13.33	23.00
20	CL02450	76.33	78.67	114.33	169.63	92.93	1060.12	24.22	10.86	11.21	11.33	23.00
21	CML451	74.33	76.33	111.33	144.60	58.00	815.32	26.85	13.13	12.37	13.33	22.33
22	CML470	60.33	62.33	98.00	127.60	61.93	725.06	27.06	11.16	11.75	12.00	19.00
23	CML472	69.67	72.33	110.00	152.20	73.13	1079.46	24.36	10.27	10.95	10.67	15.67
24	CML473	66.33	68.00	104.00	164.00	77.93	977.25	21.21	10.67	11.77	11.33	26.67
Sr. No.`	**Inbreds**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
25	CML474	66.67	68.33	104.33	135.27	75.93	1331.57	26.94	11.53	12.56	12.00	22.67
26	CML481	74.33	76.33	112.33	147.33	57.33	866.20	23.91	10.54	10.53	11.33	19.00
27	CML496	77.00	78.67	114.67	123.47	54.53	805.86	20.96	11.40	11.10	11.33	25.67
28	BAJIM-08-26	66.67	69.00	105.00	150.00	65.90	1667.63	29.04	11.54	14.55	14.67	29.33
29	BAJIM-11-1	67.00	68.33	104.33	134.60	59.20	572.41	18.25	9.95	11.49	14.67	23.33
30	BAJIM-11-2	69.33	71.33	108.00	105.87	47.20	351.45	19.01	9.23	10.50	12.67	14.00
31	BAJIM-11-3	60.67	62.67	98.67	166.53	59.27	647.98	22.38	9.50	11.08	11.33	24.33
32	BAJIM-11-4	61.33	62.67	98.33	105.80	50.13	339.23	20.82	10.22	10.21	11.33	17.67
33	KI-16	57.00	58.67	94.67	162.33	56.40	766.87	18.90	12.36	10.13	10.00	26.33
34	KI-18	53.67	55.67	91.67	130.07	51.13	680.73	19.94	10.45	10.74	11.33	21.33
35	KI-29	58.67	60.67	96.00	152.20	62.60	765.73	21.94	12..59	11.96	12.67	26.67
36	KI-30	57.00	59.00	95.00	177.40	80.80	1549.88	25.99	11.89	13.50	13.33	26.67
37	CML180 *	64.00	66.00	102.00	166.67	81.87	979.29	27.09	12.69	13.19	13.33	28.67
38	CML193 *	67.00	70.00	106.00	155.67	50.73	1207.86	21.87	11.76	12.53	13.33	24.33
39	CML429 **	64.00	65.33	101.00	147.00	73.00	1208.92	26.95	10.71	13.67	12.67	19.33
40	BAJIM-08-27**	69.67	72.00	108.00	114.13	58.20	1300.51	24.71	10.56	13.17	14.00	23.00
	Mean	64.55	66.48	102.42	142.23	64.30	905.86	22.29	11.43	11.86	12.60	22.57
	C.V. (%)	1.25	1.23	0.86	5.15	7.28	7.17	6.10	9.19	8.02	8.11	13.19
	C.D. @ 5%	1.34	1.31	1.43	11.92	7.61	105.54	2.53	1.71	1.55	1.66	4.84
	S.E.	0.46	0.46	0.51	4.23	2.70	37.49	0.90	0.61	0.55	0.59	1.72

* and ** indicates QPM and non-QPM checks, respectively

The variation in plant length might have been due to specific genetic makeup of different genotypes, inherent properties, environmental factor, hormonal factor and vigor of the crop. The general mean of cob placement height among the inbreds was 64.30cm where the least value was recorded in CM129 (37.07cm) and the highest value was recorded in CML162 (97.80cm). It was observed that three inbred lines *viz;* CML162, CML192 and CL02450 showed significantly superior values of more than 90.00cm for cob placement from ground level. The two lines *viz.*, CML189 and CML192 were found to be significantly superior with more than 16.00cm of cob length and cob girth with mean value of 11.43cm and 11.86cm, respectively. This variation in cob length and cob girth may be due to its own genetic makeup and also due to variation in cob placement height, internodal length, hormonal factor and environmental factors. The results of Shah *et al.*, (2000) [8] and Ullah (2004) [9] was in congruence with our findings revealing significant amount of variability for ear height among different maize populations.

The polygenic trait such as yield is a result of characters namely kernel rows per ear, grains per row and 100-grain weight. In the present study, higher kernel rows per ear (15.33) was recorded in VQL1 and CML192 among QPM lines and in non-QPM lines KI-30 (13.33) is at par with check BAJIM-08-27 (14.00), however CML189 and CML192 having more than 36.00 grains per row were found to be significantly superior among other inbreds. The QPM lines CML189 and CML192 had more than 30.00g of 100-grain weight as compared to check CML180 (27.09g) and among non-QPM lines BAJIM-08-26 showed the highest grain weight of 29.04g and KI-30 was found to be at par when compared with check CML429. For grain yield per plot three QPM inbred lines *viz;* CL02450Q, CML192 and CML189 were significantly higher yielding than check CML193, whereas among non-QPM lines BAJIM-08-26 and KI-30 were found to be significantly superior to the best non-QPM check BAJIM-08-27. These results indicate that kernel rows per ear, grains per row and 100-grain weight were important for getting higher yield, hence improvement in these traits is important for increasing the yield of maize genotypes. On the basis of phenotypic traits studied, Gausenard *et al.*, (1997) [2]; Wietholter *et al.*, (2008) [12]; Pabendon *et al.*, (2010) [4] and Nayak *et al.*, (2013) [3] also revealed significant variability for the studied traits among maize genotypes which is similar to the results of the present study. Any deviations in the results observed between the present study and other authors is attributed to the differences in the genotype used in the study, differences in number of genotypes, breeding methods employed, methods of statistical analysis adapted, soil characters and environmental conditions.

Among significantly superior high yielding lines CML189, CML192 (QPM) and BAJIM-08-26 and KI-30 (non-QPM); line CML192 was significantly superior for seven traits *viz.*, days to 50 per cent pollen shed, plant height, cob placement height, 100-seed weight, cob length, cob girth and grains per row. Whereas, line KI-30 was found to be significantly superior to best check(s) for three traits *viz.*, days to 50 per cent pollen shed, days to 50 per cent silking and days to 75 per cent maturity. The statistically superior lines on the basis of overall mean performance for different traits can be exploited directly in future breeding programme(s) after further evaluation.

Some of the ear and grain characteristics *viz.*, husk cover, grain color, grain texture and endosperm hardiness (Table 2) were also studied in the present investigation on the basis of visual observations. It was found that husk cover was excellent for all the inbreds except CML171, CML180 and CML189 (QPM) and CML472, CML473 and CML474 (non-QPM), being fair for them. Majority of the inbreds showed yellow grain color with some exceptions of orange and white grain color. Grain texture for majority of inbreds was flint type, however some inbreds also exhibited dent, semi flint and semident texture. Yang-Yin *et al*., (2005) [13] studied that harder the endosperm, better the physical characters and poorer the protein quality of kernels. Nutritional quality was influenced by the distribution, density and morphology of matrix protein, and the compact degree between starch granules and matrix protein. Endosperm hardiness revealed that most of the inbred lines were 25 per cent opaque with modification score of type 2 followed by type 1 and type 3. Pixley and Bjarnason (2002) [5] evaluated hybrids and open-pollinated cultivars of maize and revealed that protein quality and endosperm modification score were always within expected values for QPM and tryptophan concentration in protein was the most stable trait followed by protein concentration in grain, then endosperm modification score and finally grain yield. However, Scott *et al.*, (2004) [7] found that tryptophan levels were negatively correlated with endosperm translucence, a measure of kernel hardness suggesting the process of selection for hard kernels reduces tryptophan contents.

Table 2: Ear and grain characteristics of maize inbred lines

Sr. No	Inbreds	Husk cover (1-5)	Grain color	Grain texture	Endosperm hardiness (1-5)
1	VQL 1	1	Yellow	Semi flint	2
2	VQL 2	1	Yellow	Flint	2
3	CML 162	1	Yellow	Flint	3
4	CML 163	1	Yellow	Dent	2
5	CML 169	1	Yellow	Dent	1
6	CML 170	1	Yellow	Dent	3
7	CML 171	2	Yellow	Flint	2
8	CML 189	2	Yellow	Dent	2
9	CML 192	1	Yellow	Dent	1
10	HKI-1348	1	Orange	Flint	3
11	CML 451Q	1	Orange	Flint	2
12	CL02450Q	1	Orange	Semident	3
13	CM 126	1	Yellow	Flint	3
14	CM 127	1	Yellow	Flint	3
15	CM 128	1	Yellow	Flint	2
16	CM 129	1	Yellow	Flint	1
17	CM 145	1	Yellow	Flint	2
18	CM 152	1	Yellow	Flint	1
19	CM 212	1	Yellow	Semident	2
20	CL02450	1	Yellow	Flint	1
21	CML 451	1	Yellow	Dent	2
22	CML 470	1	Orange	Flint	2
23	CML 472	2	Orange	Dent	1
24	CML 473	2	Orange	Semident	2
25	CML 474	2	Orange	Semident	3
26	CML 481	1	Orange	Flint	1
27	CML 496	1	Orange	Flint	1
28	BAJIM-08-26	1	Orange	Flint	2
29	BAJIM-11-1	1	Orange	Flint	1
30	BAJIM-11-2	1	Orange	Flint	2
31	BAJIM-11-3	1	Orange	Flint	3
32	BAJIM-11-4	1	Orange	Flint	2
33	KI-16	1	Yellow	Flint	2

34	KI-18	1	Orange	Flint	2
35	KI-29	1	Yellow	Flint	2
36	KI-30	1	Yellow	Flint	2
37	CML180*	2	White	Dent	1
38	CML 193*	1	Yellow	Dent	1
39	CML 429**	1	Orange	Flint	1
40	BAJIM-08-27**	1	Orange	Flint	1

* and ** indicates QPM and non-QPM checks, respectively

Conclusion
On the basis of *per se* performance of inbred lines of maize, it can be concluded that there is existence of variations for the studied traits and four inbred lines *viz;* CML189, CML192, BAJIM-08-26 and KI-30 were observed as best inbreds for yield and its economic important traits which could be further evaluated and can be used as donor parents in future breeding programs for improvement through selection.

Disclosure statement
No conflict of interest was reported by the authors.

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