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Genetic diversity studies for yield and kernel micronutrient concentration in inbred lines of maize (*Zea mays* L.)

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Abstract
Forty-six maize inbred lines were evaluated for fourteen traits to study the genetic diversity. The experiment was conducted in randomized complete block design (RCBD) with two replications. All the 46 genotypes were grouped into 5 clusters. Cluster III was the largest cluster comprising of sixteen maize genotypes followed by cluster I (10), cluster V (9), cluster III (7) and cluster III (4). Cluster distance indicated by the average inter and intra cluster distance are the approximate measure of the cluster divergence. The maximum inter cluster distance was observed between cluster I and III (6.75) and minimum between cluster II and IV (4.89). The maximum value of inter-cluster distances indicated that the genotypes belonging to the cluster I is far diverged from those cluster III. Genotypes of cluster III show high intra cluster distance indicating high degree of divergence among the genotypes studied. It was observed that plant height contributed highest (30.53%) for divergence, followed zinc concentration (17.20%), hundred seed weight (11.98%), iron concentration (10.72%) while cob diameter contributed lowest (0.19%) for divergence. It can be inferred that crossing between these genotypes may result in good recombinants for successful breeding programme.

Keywords: Cluster analysis, yield, iron, zinc, maize

Introduction
Bioavailability of micronutrients, mainly iron and zinc are low from plant foods. The bioavailability of iron is known to be influenced by various dietary components, which include both inhibitors and enhancers of absorption. Among inhibitors, phytic acid, tannins, dietary fibre and calcium are the most potent, while organic acids are known to promote iron absorption (Gibson, 1994 and Sandberg, 2002) [3, 7].

India contributes nearly 4% of world maize growing area and 2% of total production. India's rank among the maize growing countries in area and production is 4th and 7th respectively. During 2018-19, India's maize growing area has reached 9.20 million ha (DACNET, 2020). Over 1950-51 India used to produce 1.73 million MT maize, which has increased to 27.8 million MT by 2018-19, recording close to 16 times increase in production. During this time, the average productivity increased by 5.42 times, from 547 to 2965 kg/ha, while the area nearly tripled. Despite the fact that India's productivity is about half that of the rest of the world, the average daily productivity of Indian maize is at par to that of several of the world's leading maize producing countries.

In India, maize is principally grown in two seasons, rainy (*Kharif*) and winter (*Rabi*). *Kharif* maize represents around 83% of maize area, while *Rabi* maize corresponds to 17% of maize area. Over 70% of *Kharif* maize is cultivated in rainfed conditions, with a number of biotic and abiotic stressors prevalent. The stress-prone ecology contributes towards lower productivity of *Kharif* maize (2706 kg/ha) as compared to *Rabi* maize (4436 kg/ha), which is predominantly grown under an assured ecosystem. In the recent past, spring maize growing area has increased rapidly in the north western regions of the nation, particularly in the states of Punjab, Haryana and Western Uttar Pradesh. Unfortunately, the area and production data of spring maize is not well documented. However, an informal estimate suggests the area be around 150 thousand ha. Among cereals, maize has the highest growth rate in terms of area and productivity. Among Indian states, Karnataka and Madhya Pradesh have the highest area under maize (15% each) followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%), Bihar (7%), Telangana State (6%), Gujrat (5%), Tamil Nadu (4%), J&K (3%) and others (18%).

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Bihar produces highest maize after Karnataka and Madhya Pradesh. Andhra Pradesh is having the highest state productivity (Anonymous, 2021) [1].

Materials and Methods
Genetic materials and field evaluation
The experiment was involving a set of forty-six maize inbreds obtained from CIMMYT, Hyderabad and Maize Improvement Programme, Institute of Agricultural Sciences, BHU, Varanasi. The details of maize genotypes used in the study is given in (Table 1). Experiment was conducted during *Kharif* 2018 in RCBD with two replications. Each genotype was sown into two rows of 3 m each with 70 cm row to row and 20 cm plant to plant distance. The soil of the experimental plot was fertile, alluvial loam and was characterized as the type of soil of Indo-Gangetic plains. Standard agronomic practices were performed for raising and maintenance of the healthy plants.

Observations recorded
Observations were taken from competitive five randomly selected plants from each plot and each replication and their mean were calculated. Data was recorded for fourteen traits namely, days to 50% tasseling, days to 50% silking, anthesis-silking interval (days), plant height (cm), tassel length (cm), number of cobs per plant, cob length without husk, cob diameter without husk (cm), number of kernel rows per cob, number of kernels per row, hundred seed weight (g), grain yield per plant (g), iron concentration (mg/kg) and zinc concentration (mg/kg). The estimation of kernel iron and zinc concentration in maize kernels was done di-acid mixture of nitric acid (HNO_3: $HClO_4$) in a ratio of 10:4 by using Atomic Absorption Spectroscopy (AAS Agilent 240FS AA) at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, BHU, Varanasi as per the protocol described by (Zarcinas *et al.*, 1987) [11] with some modifications suggested by (Singh *et al.*, 2005) [10].

Results and Discussion
D^2 analysis
Genetic divergence among forty-six maize inbreds were studied based on Mahalanobis D^2 statistics revealed presence of considerably diversity among the 46 inbreds. Detail insight into the diversity is therefore, important in order to select desirable genotype / parents for utilizing in breeding programmes.

Grouping of maize inbreeds into different cluster
Forty-six maize inbreds were grouped into five distinct clusters by Wards's method as shown in (Table 2 and Figure

1). Cluster III emerged as largest cluster with 16 inbreds. The cluster I had 10 inbreds, cluster V had 9 inbreds and cluster II had 7 inbred lines, while cluster IV had only 4 inbreds reflected as smallest cluster. In the present study, Wards's method was used to cluster the maize inbreds. Forty-six inbred lines were grouped into 5 distinct clusters. Among the different clusters, the cluster III with 16 inbred lines emerged as the largest cluster. The cluster I had 10 inbred lines, cluster V had 9 inbred lines and cluster II had 7 inbred lines, while cluster IV had only 4 inbred lines. Reddy *et al.* (2013) [6] evaluated 50 genotypes and grouped into 8 clusters. Mallikarjuna *et al.* (2020) [5] grouped the 49 maize genotypes into 9 distinct clusters.

Mean intra and inter cluster distances
Intra and inter cluster distances are presented in (Table 3). The intra cluster distance was highest in cluster III (4.39) followed by cluster IV (4.29) and cluster V, while cluster I (4.13) had minimum value. The maximum inter cluster distance was observed between cluster I and III (6.75) followed by cluster II and V (6.07), cluster I and V (6.04), cluster II and V (5.58), cluster III and IV (5.57), cluster IV and V (5.52) and cluster II and III (5.35). The minimum inter cluster distance was observed between cluster II and IV (4.89).

In the present study, the intra cluster distance was highest in cluster III followed by cluster IV and cluster V, while cluster I had minimum value. The maximum inter cluster distance was observed between cluster I and III followed by cluster II and V, cluster I and V, cluster II and V, cluster III and IV, cluster IV and V and cluster II and III. The minimum inter cluster distance was observed between cluster II and IV. These results are in general agreements with the findings of similar results were reported by Seshu *et al.* (2015) [8], Shankar *et al.* (2021) [9]. The high intra cluster distance revealed the presence of genetic diversity among the genotypes which were grouped together in those clusters. Hence, there is a lot of scope for exchange of genes among genotypes within these clusters. With regard to inter cluster distance the cluster I and cluster III were most diverse with each other. It can be inferred that crossing between these genotypes may result in good recombinants for successful breeding programme.

Percent contribution of various characters for divergence
The percent contribution of fourteen maize traits studied towards total divergence is given in (Table 4). It was observed that plant height contributed highest (30.53%) for divergence, followed zinc concentration (17.20%), hundred seed weight (11.98%), iron concentration (10.72%), grain yield per plant (8.50%), number of kernel rows per cob (6.76%), number of kernels per row (5.02%), days to 50% tasselling (3.38%), number of cobs per plant (2.51%) and cob length without husk (1.84), while cob diameter contributed lowest (0.19%) for divergence.

Table 1: List of forty-six maize inbred lines used in the study.

S. No.	Inbred lines	Source	S. No.	Inbred lines	Source
1.	CML-162	CIMMYT, Hyderabad	24.	VL-1248	CIMMYT, Hyderabad
2.	CML-163	- do -	25.	VL-1010923	- do -
3.	CML-164	- do -	26.	VL-055199	- do -
4.	CML-187	- do -	27.	VL-1018148	- do -
5.	CML-229	- do -	28.	VL-108720	- do -
6.	VL-108866	- do -	29.	VL-1010848	- do -
7.	VL-1010856	- do -	30.	VL-1033	- do -
8.	VL-1018162	- do -	31.	VL-1037	- do -
9.	VL-1028	- do -	32.	VL-1056	- do -
10.	VL-108725	- do -	33.	VL-109452	- do -
11.	SNL-153277	- do -	34.	VL-109582	- do -
12.	VL-1030	- do -	35.	VL-109800	- do -
13.	VL-102	- do -	36.	VL-121096	- do -
14.	VL-1018604	- do -	37.	HUZM-58	BHU, Varanasi
15.	VL-05552	- do -	38.	HUZM-65-1	- do -
16.	VL-1016173	- do -	39.	HUZM-77	- do -
17.	VL-1012837	- do -	40.	HUZM-185	- do -
18.	SNL-153292	- do -	41.	HUZM-320	- do -
19.	VL-0512595	- do -	42.	HUZM-265	- do -
20.	VL-109309	- do -	43.	HUZM-97-1-2	- do -
21.	VL-109524	- do -	44.	HUZM-90	- do -
22.	VL-1016210	- do -	45.	HUZM-242	- do -
23.	VL-1016211	- do -	46.	HUZM-55	- do -

**Table 2:** Grouping of forty-six maize inbreds into five clusters by Ward's method.

Cluster	No. of inbreds	Name of maize inbreds
I	10	HUZM-242, SNL-153292, HUZM-90, VL-1248, CML-187, VL-109452, VL-1018604, HUZM-77, CML-162 and HUZM-320
II	7	VL-1010856, VL-108866, VL-108725, VL-102, HUZM-97-1-2, VL-1018162 and HUZM-58
III	16	VL-1028, VL-109309, VL-1016211, CML-229, VL-109524, VL-1010848, VL-1012837, VL-1033, CML-163, VL-1037, VL-108720, HUZM-185, CML-164, HUZM-265, VL-1016210 and VL-055199
IV	4	HUZM-55, HUZM-65-1, VL-1056 and VL-121096
V	9	VL-109582, VL-109800, VL-1030, SNL-153277, VL-0512595, VL-05552, VL-1016173, VL-1010923 and VL-1018148

Table 3: Intra and inter cluster distances of 5 clusters of 46 maize genotypes.

Cluster	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
I	4.13	5.15	6.75	5.23	6.04
II		4.22	5.35	4.89	5.58
III			4.39	5.57	6.07
IV				4.29	5.52
V					4.26

Table 4: Percentage contribution of traits towards diversity of maize genotypes

Sr. No.	Traits	Times ranked 1st	Percentage contribution
1.	Days to 50% tasseling	35	3.38
2.	Days to 50% silking	8	0.77
3.	Anthesis-silking interval (days)	0	0.00
4.	Plant height (cm)	316	30.53
5.	Tassel length (cm)	6	0.58
6.	Number of cobs per plant	26	2.51
7.	Cob length without husk	19	1.84
8.	Cob diameter without husk (cm)	2	0.19
9.	Number of kernel rows per cob	70	6.76
10.	Number of kernels per row	52	5.02
11.	Hundred seed weight (g)	124	11.98
12.	Iron Concentration (mg/kg)	111	10.72
13.	Zinc concentration (mg/kg)	178	17.20
14.	Grain yield per plant (g)	88	8.50
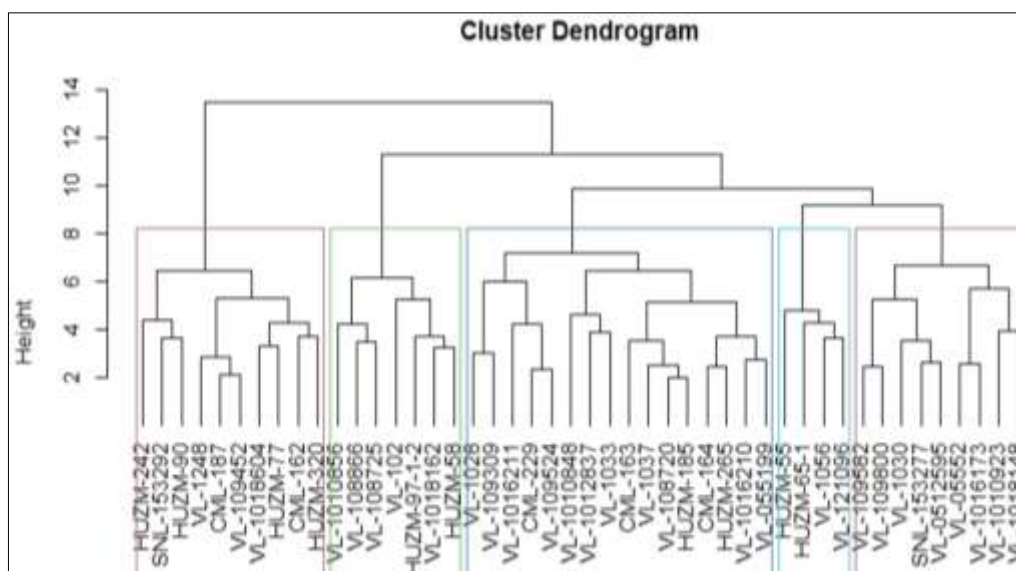
Fig 1: Dendrogram showing genetic diversity among forty-six maize genotypes

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