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Genetic divergence studies for yield and yield attributing characters in maize (*Zea mays* L.)

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Abstract
A field experiment with 30 maize inbred lines was conducted to study the genetic divergence in maize genotypes at Horticulture Research Farm, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.) during Kharif-2018. Significant differences were observed among genotypes for all characters studied. These genotypes were grouped into 7 clusters which are indicating the existence of an ample amount of genetic diversity in the germplasm and therefore signifying the scope of selection for genetic improvement in maize. Cluster II had maximum ten genotypes followed by cluster I (seven genotypes), cluster V (four genotypes), cluster VI (three genotypes), cluster IV (three genotypes), VII (two genotypes) and cluster III (one genotype), respectively. The maximum inter-cluster distance (194.76) was recorded between cluster III and cluster V; while the minimum inter-cluster distance (38.49) was recorded between cluster IV and cluster V.

Keywords: Clustering, divergence, germplasm, maize

Introduction
Maize or corn (*Zea mays* L.) is one of the most important cereal crop in the world and a strategic food crop for the majority of the developing countries [1]. Being a C_4 plant, it has a very high yield potential, probably the highest among the cereal which designates it as ''Queen of Cereals''. It is grown almost in all states of India and occupies a prominent position with regard to area and production. Maize is one of the staple food crop globally. In world, it ranks third next to wheat and husked rice in production and ranks second next to wheat. Maize is predominantly a *Kharif* season crop.

Every part of the maize plant has economic value: the grain, leaves, stalk, tassel and shank can all be used to produce a large variety of food and non-food products. The grains apart from food as bread, pops and gruel are used for many industrial products like the manufacture of starch, alcohol, acetic and lactic acids, glucose, paper, rayon, plastic, textile, adhesives, dyes, synthetic rubber, resins, artificial leather and boot-polish. Maize is, therefore, an emerging industrial crop. Nutritionally, it ranks below wheat and sorghum but considerably above rice containing 10% protein, 4% oil, 70% carbohydrate, 2.3% crude fiber, 10.4% albuminoids and 1.4% ash in grains [2]

The success of the hybridization largely depends on the selection of parents showing high genetic diversity for traits of interest [3]. The genetic variability present among different genotypes of a species may arise either due to geographical separation or due to genetic barriers to crossability. One of the potent techniques of assessing genetic divergence is D^2 statistic proposed by [11]. This technique measures the forces of differentiation at two levels viz., intracluster and inter-cluster that help the selection of genetically divergent parents for exploitation in hybridization programmes. While selecting parents on the basis of D^2 statistic, three important points should be considered viz., (i) the relative contribution of each character to the total genetic divergence, (ii) the choice of clusters with the maximum statistical distance and (iii) the selection of one or a few genotypes from such clusters.

The present study was conducted to find out the degree of genetic divergence in maize genotypes so that suitable divergent parents may be identified for a breeding programme to develop high yielding varieties in maize.

Material and Methods
The present investigation was carried out during *Kharif*, 2018-19 at Horticulture Research Farm, Institute of Agricultural Sciences, Bundelkhand University; Jhansi (U.P.). The experimental material consisted of 30 maize inbred lines was evaluated in randomized block design with three replications accommodating 3 meters long two rows per replication at 45 cm spacing received from Chandra Shekhar Azad University of Agriculture and Technology Kanpur (U.P.). The name of the genotypes is presented in Table-1.

Table 1: List of genotypes of understudy

S. No.	Name of Genotypes	S. No.	Name of genotypes
1.	D-7	16.	CIMMYT-171
2.	D 1-2	17.	Hybrid 8
3.	K16/ 1384 A	18.	Hybrid 5
4.	K16/ 1384 B	19.	D-1
5.	Hybrid 6	20.	JNPW WFW 5
6.	IMR 413/ K 16	21.	TSK 11-1
7.	JN Pearl	22.	Hybrid 5
8.	CML-150	23.	REH 2009-12 Hybrid Cheack
9.	POP-65	24.	TSK11-1
10.	Hybrid 7	25.	DHOLI-M7
11.	D 2-2	26.	D3-3 OSDW 5
12.	D 3-1 YOFW 5	27.	CIMMYT-9
13.	JNY YOFW 5	28.	TSK 11-1
14.	REH 2003 Hybrid check 2	29.	Azad Kamal OFWS
15	60-828K- CML-115	30.	IMR 414/ K16

The observations were recorded for 18 quantitative characters *viz.,* Days to 50% germination, days to 50% flowering, days to 50% silking, days to 50% tasselling, plant height, leaf/plant, days to 50% maturity, biological yield/plant, cob ear weight, cob length, rows/cob, seeds per row, total seed/cob, 100 seed weight, seed yield per cob, shelling %, harvest index and seed yield per plant.

Observations were recorded on the basis of five random competitive plants selected from each genotype separately for yield and its attributing parameters were evaluated as per the standard procedure. The data were subjected to statistical analysis using Mahalanobis D^2- statistics to study the genetic divergence. The test of significance for correlated variables was done following [12] using 'V' statistic which in turn utilizes Wilk's criterion. Group constellation was performed according to the method suggested by Tocher [12]. The contribution of individual character towards total divergence in maize genotypes was calculated as per the method is given by [13].

Result and Discussion

Analysis of variance revealed significant differences among 30 maize inbred lines for all 18 characters studied is presented in table 2 and on the basis of D^2 statistic, 30 maize genotypes were grouped into 7 clusters which are presented in (Table 3).

Table 2: Analysis of variance for eighteen characters of maize genotypes

S. No.	Character	Mean Sum of Square		
		Replications [2]	Genotypes [29]	Error [58]
1	Days to 50% Germination	0.03	1.00	0.99
2	Days to 50% Tasseling	1.01	9.91**	4.54
3	Days to 50% Sillking	0.93	2.63	2.23
4	Plant height (cm)	368.81	721.91**	345.04
5	No. of leaves per plant	5.00**	2.09**	0.69
6	No. of Cobs Per Plant	0.04	0.02	0.02
7	Days to 50% Maturity	0.41	4.75**	1.72
8	Biological Yield Per Plant (g)	5536.85	6054.45*	3088.18
9	Cob Ear Weight (g)	193.82	396.59*	220.18
10	Cob length (cm)	3.52	10.54**	4.16
11	No. of Row Per Cob	0.04	1.23	0.83
12	No. of Seed Per Row	10.33	14.03	10.58
13	No. of Seed Per Cob	3094.25	2910.85	2295.94
14	100 Seed Weight (g)	17.45	61.62	51.46
15	Seed Yield Per Cob (g)	128.08	156.66	100.09
16	Seed Yield Per Plant (g)	327.83	187.24	155.72
17	Shelling % in Maize	6.24	58.19	60.33
18	Harvesting Index in Maize	115.88**	21.00	20.17

*, ** Significant at 5% and 1%, respectively

Table 3: Distribution of genotypes in different clusters

Cluster	No of Genotypes	Genotypes									
I	7	D 7	Hybrid7	CML-115	Hybrid8	JNPWWFW 5	Hybrid5	REH 2009-12 Hybrid Cheack			
II	10	D 1-2	K16/ 1384 B	IMR 413/ K 16	POP-65	D3-1 YOFW 5	Hybrid 5	DHOLI-M7	D3-3 OSDW 5	TSK 11-1	IMR 414/ K16
III	1	CIMMYT-171									
IV	3	CML-150	D 2-2	REH 2003 Hybrid check 2							
V	4	Hybrid 6	JNY YOFW 5	JNY YOFW 5	Azad Kamal OFWS						
VI	3	K16/ 1384 A	TSK 11-1	CIMMYT-9							
VII	2	JN Pearl	D-1								

Cluster II was found largest and consisted of 10 genotypes followed by cluster I with 7 genotypes, cluster V with 4 genotypes, cluster VI with 3 genotypes, cluster IV with 3 genotypes and cluster VII with 2 genotypes, respectively. The remaining cluster III was mono genotypic. The grouping pattern of genotypes indicated the presence of substantial diversity in maize genotypes.

Maximum intra-cluster distance (27.53) was recorded for cluster V followed by cluster II (23.88), cluster VII (23.53), cluster IV (22.81), cluster I (18.75) and cluster VI (18.55), respectively (Table 4).

Table 4: Average intra and inter cluster distances D^2 values in 30 genotypes of maize

Cluster	I	II	III	IV	V	VI	VII
I	18.75	49.522	71.116	103.110	127.625	68.663	64.376
II	49.522	23.889	118.776	55.808	86.256	54.576	98.281
III	71.116	118.776	0.00	172.653	194.761	128.723	74.255
IV	103.110	55.808	172.653	22.814	38.490	67.375	137.697
V	127.625	86.256	194.761	38.490	27.534	72.324	146.823
VI	68.663	54.576	128.723	67.375	72.324	18.556	75.715
VII	64.376	98.281	74.255	137.697	146.823	75.715	23.534

However, for remaining cluster III, the intra-cluster distance was zero because of solitary genotype. Highest inter-cluster distance was observed between cluster III and cluster V (194.76) followed by cluster III and cluster IV (172.65), cluster V and cluster VII (146.82), cluster IV and cluster VII (137.69), cluster III and cluster VI (128.72), cluster I and cluster V (127.62), cluster II and cluster III (118.77), respectively; while the lowest inter-cluster distance was observed between cluster IV and cluster V (38.49).

The mean values of eleven characters studied in maize genotypes for six clusters are presented in Table 5.

Table 5: Cluster means of 18 characters in maize

S. No.	Character	Cluster						
		I	II	III	IV	V	VI	VII
1	Days to 50% Germination	4.67	4.90	5.00	4.78	4.75	5.00	4.50
2	Days to 50% Tasseling	44.71	45.23	44.33	46.78	43.67	45.56	43.50
3	Days to 50% Sillking	50.95	51.13	53.67	51.67	50.92	51.89	51.00
4	Plant height (cm)	191.46	204.16	168.13	215.74	219.12	201.11	179.16
5	No. of leaves per plant	10.76	11.34	10.27	11.85	12.42	11.51	10.24
6	No. of Cobs Per Plant	1.05	1.09	1.00	1.20	1.13	1.11	1.10
7	Days to 50% Maturity	78.76	79.37	79.33	80.22	79.50	79.67	78.34
8	Biological Yield Per Plant	235.96	281.87	177.33	324.56	327.67	261.22	193.67
9	Cob Ear Weight (g)	72.14	74.77	51.23	87.06	94.60	89.64	72.40
10	Cob length (cm)	21.89	22.77	19.47	24.91	25.88	23.20	21.34
11	No. of Row Per Cob	12.29	12.54	13.27	12.00	12.68	12.33	12.90
12	No. of Seed Per Row	24.54	24.87	20.87	27.09	28.18	27.20	25.43
13	No. of Seed Per Cob	250.02	261.89	229.80	291.18	327.12	307.38	296.24
14	100 Seed Weight (g)	20.72	17.83	16.08	19.30	21.63	18.59	17.02
15	Seed Yield Per Cob (g)	44.42	47.59	37.22	54.40	61.32	56.89	45.90
16	Seed Yield Per Plant (g)	46.95	49.84	40.33	59.12	65.28	61.05	50.02
17	Shelling % in Maize	62.04	64.04	71.05	63.03	65.05	63.23	64.54
18	Harvesting Index in Maize	19.98	18.15	21.55	18.43	20.17	23.89	25.74

The cluster VII (4.50 and 43.50 days) had the early germination and tasselling genotypes whereas, cluster III (5.00) and cluster IV (46.78 days) had the late germination and tasselling genotypes. The short duration (50.92 days) genotypes accounted for cluster V, while the genotypes of cluster III (53.67days) were of late silking. The genotypes of cluster III (168.13cm) were shortest while genotypes of cluster V (219.12cm) were the tallest plant height. The number of leaves per plant was shortest in the cluster VII (10.24), while the number of leaves per plant was more in cluster V (12.42). The mean number of cobs per plant was low in cluster III (1.00) and high in the cluster IV (1.20). The mean days to 50% maturity was low in the cluster VII (78.34) and high in the cluster IV (80.22).

The mean biological yield per plant in the cluster III (177.33) had a less biological yield per plant, while genotypes in cluster V (327.67) had more Biological yield per plant. The genotypes of cluster I (74.14) produced more cob ear weight and cluster V (94.60) genotypes produced less cob ear weight. The mean value of cob length (25.88) was maximum for cluster V, whereas the lowest was recorded by the genotypes of cluster III (19.47). The Cluster III had the maximum number of row per cob of 13.27, while the genotypes in cluster IV recorded the least value of 12.00 per cob. The mean value of number of seed per row (28.18) was maximum for cluster V, whereas the lowest was recorded by the genotypes of cluster III (20.87). The Cluster V had the maximum number of seed per cob of 327.12, while the genotypes in cluster III recorded the least value of 229.80 per cob.

The genotypes of cluster V (21.63g) were highest while genotypes of cluster III (16.08) were the lowest 100 seed weight. The seed yield per cob was highest in cluster V (61.32); while the seed yield per cob was lowest in cluster III (37.22).The mean seed yield per plant was lowest in cluster III (40.33) and highest in cluster V (65.28). The mean shelling% was low in the cluster I (62.04) and high in the cluster III (71.05). The mean harvesting index was low in cluster II (18.15) and high in cluster VII (25.74).

Hence, it may be inferred that genotypes belonging to diversified clusters may be used in the hybridization

programme for developing high yielding maize varieties/hybrids. Similar results were also reported by [4-10] and [14-15].

Conclusion

It is to be stated that, on the basis of genetic divergence all genotypes of maize under investigation were grouped into 7 clusters which are indicating the existence of ample amount of genetic diversity in the germplasm and therefore signifying the scope of selection for genetic improvement in maize. The output of this particular research is very useful in the development of maize hybrids or composite varieties.

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