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Genetic diversity in tropical maize inbreds under well watered and water stress condition

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Abstract

Maize being a widely grown crop succumbs to changed climatic conditions especially drought. Breeding for drought tolerant maize hybrids necessitates selection of diverse drought tolerant inbreds which can help in development of heterotic hybrids suitable for both normal and moisture stress situations. Hence, the present study has been conducted to assess genetic diversity among 28 tropical maize inbreds based on physiological, phenological, yield and yield components under well watered (WW) and water stressed (WS) condition. Seven clusters were formed under WS and 14 clusters under WW condition. Cluster 1 was the largest with 15 inbreds in WS and nine inbreds under WW condition. Many mono-genotypic clusters under WS condition (5) and under WW condition (13) were shown by analyses. Based on inter-cluster distance, the maize inbred PDM 77-4 and PDM 4641 belonging to mono-genotypic clusters due to their performance both under well watered and water stress condition resulted in diverse nature of these inbreds. Shelling percentage (41.2 %, 33.1 %), grain yield (20.5 %, 25.9 %), cobs per plant (17.8 %, 19.1 %), contributed maximum towards genetic divergence both under WW and WS condition and hence these characters may be given weightage while selecting diverse inbreds to develop superior hybrids suitable for both WW and WS condition. The inbred PDM 4541 exhibited higher relative water content (RWC), lower days to 50 % tasseling, 50 % silking with reduced anthesis silking interval (ASI) under WS condition and hence can be a potential inbred in developing hybrids suitable specifically for WS condition. Maximum cob length (CL), cob girth (CG), kernel row number (KRN), number of kernels per row (NKR), 100 seed weight (HSW) and grain yield was distributed in different mono-genotypic clusters having maize inbreds CML 451, CAL 1426-2, CML 563 and PML 54 and hence these inbreds can be used in population improvement programme to derive inbred lines combining many productive traits.

Abbreviations

ASI: Anthesis Silking Interval
CL: Cob Length
CG: Cob Girth
DAS: Days After Sowing
DFS: Days to 50 % Silking
DFT: Days to 50 % Tasseling
EH: Ear Height
GDDU: Growing Degree Day Units
KRN: Kernel Row Number
NKR: Number of Kernels per Row
PH: Plant Height
RWC: Relative Water Content
SCMR : SPAD Chlorophyll Meter Reading
SLW: Specific Leaf Weight
SP: Shelling Percentage
SLW: Specific Leaf Weight
WW: Well Watered
WS: Water Stressed

Introduction

Maize (*Zea mays* L.), a versatile crop is grown across the globe due to its higher production potential. It is an important food crop in addition to rice and wheat all over the World more specifically in the developing countries (Hoisington *et al.*, 1996). The demand for maize would double as compared to the current demand in the developing countries (Rosegrant *et al.*, 2009). The yield loss due to moisture stress ranges from 30 to 90

Table 1 - List of maize inbreds with their pedigree and source

Sl. No.	Genotype	Pedigree	Source
1	PDM 77-4	(Comp 85164 × Comp 8527) × 10-2-8-7-1-1-4-f	IARI Regional center, Dharwad
2	PDM 260-1	PS-28-3-1-2-2-1-1-AE	IARI Regional center, Dharwad
3	PDM 4341	(Comp8551 X Comp 8527 x Ageti 76 X MDR) -9- 4-2-8-7-1-1-2-1-L-1	IARI Regional center, Dharwad
4	PDM 4251	PS-25-1-1-1-1-1-1-1-1-R-1	IARI Regional center, Dharwad
5	PDM 4641	KDMH-176-5-1-1-R-1	IARI Regional center, Dharwad
6	PML 17	KDMH-176-5-1-1-R-2	IARI Regional center, Dharwad
7	PML 46	SAFAL-X12-9-1-1	IARI Regional center, Dharwad
8	PML 93	KDMH-176-5-1-1-R-6-1	IARI Regional center, Dharwad
9	PML 54	KDMH-755-12-1-1	IARI Regional center, Dharwad
10	PML 102	KMH-218PLUS-1-1-3-R-1	IARI Regional center, Dharwad
11	DIM 204	Advanta 7074-1-2-1-1-1	IARI Regional center, Dharwad
12	DIM 302	PHB-12-1-3-3-1-K-1	IARI Regional center, Dharwad
13	CDM 112	CA 1 45 14-1 0-8-2-8*4-8	IARI Regional center, Dharwad
14	D 2287	PMH-3-2Bulk-Bulk-1-2-1-1	IARI Regional center, Dharwad
15	D 1013	Sel-LCY3-7-1-2-2-1-1-f	IARI Regional center, Dharwad
16	CM 111	Cuba-342-2-F-#-#	AICRP on Maize, UAS, Dharwad
17	GPM 114	EC 618990	AICRP on Maize, UAS, Dharwad
18	CML 451	Hy 09R-N9251-18	AICRP on Maize, UAS, Dharwad
19	CAL 1426-2	CA-1457/P145C4MH7-1-B-1-1-B-1-1B*17	CIMMYT
20	CML 563	HY18 R-Y75-2	CIMMYT
21	IMIC 2030	VL-19008-[DTPYsyn16HG(B)]-6-2-1-2-B_1	CIMMYT
22	CML 579-1	HY 18 R-Y75-6-1	CIMMYT
23	CML 579-2	HY18R-Y75-6-2	CIMMYT
24	CML 580	HY18R-Y75-7	CIMMYT
25	CML 582	(CA-34505 × CA-00302)-B-2-1-B-1-BB(T-B3-#15-2-B-1-B*6-B2)	CIMMYT
26	IMIC 2024	VL-162283-AMDROUT1c3-B-5-1-BB-B1	CIMMYT
27	PML 9	Polo-1-2-2-R-1-R-1-2	IARI Regional center, Dharwad
28	PML 21	DMH-119-1-1-4-K-1-K-1-21	IARI Regional center, Dharwad

% depending on the crop stage and duration of moisture stress (Pandit *et al.*, 2018) and this loss could increase further due to frequent occurrence of drought during various stages of the cropping period under the changed climatic scenario. In the climate change scenario, there is change in the rainfall pattern and distribution. Maize being an irrigated crop is unable to grow properly under limited and unevenly distributed rainfall conditions and result in reduced productivity. Therefore, there is need to reduce such losses using different management practices.

Different management practices include increasing the area under irrigation, using agronomical practices (mulching, wider row spacing, frequent inter cultivation), physiological practices (use of growth regulators) and genetic approaches. The genetic approach involves selecting the drought tolerant maize inbreds with minimum reduction in grain yield when compared to normal WW conditions. This necessitates selection of diverse drought tolerant lines which can be tested for their combining ability and subsequently using them in producing heterotic hybrids. High heterotic hybrids can be produced using genetically diverse parents which can be known by genetic diversity between the genotypes (Falconer, 1960; Arunachalam, 1981; Ghaderi *et al.*, 1984; Vasal, 1998, Saxena *et al.* 1998). In hybrid maize breeding, characterization of genetic diversity of maize germplasm occupies greater importance (Xia *et al.*, 2005).

The strategy of developing drought tolerant hybrids depends on the existence of substantial genetic diversity for various morpho-physiological, yield and yield attributes in the available inbreds. The genetic divergence among the lines or genotypes can be estimated by using biometrical tools such as Mahalanobis D2 statistics which assesses the degree of divergence at genotypic level between biological populations and also measures the relative contribution of various components to the total divergence both at intra- and inter-cluster level (Murty and Arunachalam, 1966; Sachan and Sharma, 1971). Assessment of genetic divergence also helps in downsizing the breeding lines to be maintained.

There are many studies in assessing the genetic diversity of the maize inbreds under normal grown crop (Xia et

Table 2 - Weather conditions during the crop period (December 2020 to May 2021)

Month	Rainfall (mm)		Rainy days	Temperature (°C)				Relative humidity (%)	
				Maximum		Minimum			
	1950-2020	2021		1950 - 2020	2021	1950 - 2020	2021	1950 - 2020	2021
December	0.4	0	0	28.5	28.9	14.2	14.6	60.9	75.4
January	0.80	27.20	3	29.50	29.40	14.65	15.90	54.90	63.40
Feb	10.70	10.00	1	32.02	30.30	16.40	15.20	45.92	52.80
March	9.65	0.40	0	34.62	34.80	19.05	18.50	45.62	44.50
April	40.62	103.00	9	36.32	35.40	20.90	20.50	56.75	58.50
May	43.67	129.20	14	36.25	31.70	21.97	21.40	62.75	70.40
Mean	17.6	45.2	4.5	32.9	31.8	17.9	17.7	54.6	61.0

al., 2005; Singh *et al.*, 2005; Liu *et al.*, 2006; Chen *et al.*, 2008; Azad *et al.*, 2012; Kage *et al.*, 2013; Meena *et al.*, 2014; Suman *et al.*, 2020; Antony *et al.*, 2021). But the studies on assessing the genetic diversity under stress environments are limited (Makumbi *et al.*, 2011). Therefore, present study was conducted to assess the genetic diversity in the tropical maize inbreds under WW and WS conditions by studying various morpho-physiological, phenological and productivity traits. This would help in identification of diverse maize inbreds suitable for WW and WS conditions. The information on diverse inbreds will be useful in studying their combining ability and developing heterotic hybrids suitable for cultivation under normal and WS environments.

Materials and methods

Materials

The material for the present study comprised twenty-eight inbreds collected from All India Coordinated Research Project on Maize, Main Agriculture Research Station, University of Agricultural Sciences, Dharwad and Indian Agricultural Research Institute Regional Research Centre, Dharwad. Pedigree and source details of the inbreds are provided in Table 1.

Table 3 - Soil moisture status of the experimental plot at AICRP on Maize, MARS, Dharwad during rabi-summer 2020-21

Days after sowing	Soil moisture at 0 – 30 cm depth	
	Well watered plot	Water stressed plot
15 DAS	25.16 %	26.12 %
30 DAS	23.8 %	23.8 %
45 DAS	26.9 %	21.1 %
60 DAS	26.1 %	15.4 %
75 DAS	27.2 %	12.3 %
90 DAS	25.3 %	25.1 %
105 DAS	26.7 %	26.5 %

Field trial

The study was carried out during rabi season of 2020 at All India Coordinated Research Project on Maize, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (15°26' N latitude, 70°26' E longitude and 678 m above the mean sea level). The rabi season was chosen for the study to ensure rain free period during mid-season to simulate drought. The details of the different weather parameters during the crop growth are provided in Table 2.

The inbreds were sown on December 14th, 2020 in two sets by following Split Plot Design with well watered and water stress as main factor and inbreds as sub factor with two replications in each set. In each replication of each set, individual maize inbreds were hand dibbled in two rows of 4 m row length with 60 cm spacing between rows and 20 cm between plants.

Methodology

In case of WW and WS plots, the normal irrigation was provided at an interval of 8-10 days until 40 days. Thereafter, the scheduled irrigation was continued in WW plots and irrigation was withheld in WS plots until 75 days. This corresponded to 568°C GDDU to 785°C GDDU (Zaman *et al.*, 2016). This period was coinciding with the pre-tasselling and pre-silking which are critical phases in the growth of maize. The irrigation was reinitiated on 76th day in case of WS also and subsequently, the same irrigation schedule was followed in both moisture regimes. A buffer area of 2 m (with a trench) was provided between the WW and WS plots to prevent the lateral movement of water into water stress exposed plots during irrigation. All other recommended agronomic and plant protection practices were followed to raise a good yield crop.

The soil moisture was measured randomly from five spots separately in both WW and WS plots at 15 days interval and the soil moisture details are provided in Table 3. GDD was calculated using the following formula using 10°C as the base temperature for maize (Monteith, 1984).

$$GDDU = \frac{\sum (T_{max} + T_{min})}{2} - T_b$$

Where,

T_{max} – Maximum temperature

T_{min}– Minimum temperature

T_b = Base temperature (10°C for maize)

Experimental observation: Traits

Five plants from each maize inbred were selected randomly and tagged from both the rows (2 or 3 plants in each row) to account for row effect at 30 days after sowing (DAS) for recording morpho-physiological observations. Three traits, *viz.*, relative water content (RWC), specific leaf weight (SLW) and SPAD chlorophyll meter reading (SCMR), were recorded twice at 60 and 75 DAS while, proline content and wax content were recorded at 75 DAS. Besides, pollen fertility at 50 % tasselling, days to 50 % tasselling (DFT) and days to 50 % silking (DFS) were also recorded in each maize inbreds. ASI was calculated as difference between the DFT and DFS. Plant height (PH) and ear height (EH) were recorded at the time of harvest in five randomly tagged plants in each maize inbreds. Post harvest observations *viz.*, cob length (CL), cob girth (CG), kernel row number (KRN) in cob, number of kernels per row (NKR) were measured form randomly selected five cobs in each maize inbreds. Shelling percentage (SP) and 100 seed weight (HSW) were recorded from a sample of cobs in each maize inbreds. The grain yield was recorded from the total plot of each maize inbreds. The harvest index was calculated as a ratio of grain yield to the total bio-mass in total plot of each inbred.

RWC was estimated by following the procedure outlined by Barrs and Weatherly (1962). SLW was calculated as the ratio between leaf dry weight (g) to the leaf area (dm^2). SCMR was taken at 60 and 75 DAS. The top, middle and bottom leaves were used for measuring SCMR, which was taken on one side of leaf blade, midway between the leaf base and tip. Pollen fertility was estimated as the ratio of number of fertile pollen to the total pollen used for the study. Proline content was estimated by following the procedure described by Bates *et al.* 1973 at 75 DAS. Wax content was determined by the spectro-photometric method of Ebercon *et al.* (1977).

Statistical analysis

The data of WW and WS was subjected to Mahalanobis D^2 (Mahalanobis, 1936) analysis using Windowstat statistical package.The generalized distance between any two populations is given in the formula,

$$D^2 = \Sigma\Sigma\lambda_{ij} s_i s_j$$

Where,

D^2 = square of generalized distance

λ_{ij} = reciprocal of the common dispersal matrix

$si = (\mu i_1 - \mu i_2)$

$sj = (\mu j_1 - \mu j_2)$

μ = general mean

Since, the formula for computation requires inversion of higher order determinant, transformation of the original correlated un-standardized character means (Xs) to standardized uncorrelated variable (Ys) was done to simplify the computational procedure. The D^2 values were obtained as the corresponding uncorrelated (Ys) values of any two uncorrelated genotypes (Rao, 1952).

Clustering by D^2 values

All the $[n\ (n-1)/2]\ D^2$ values were clustered using Tocher's method as described by Rao (1952).

i) Intra-cluster distance

The intra-cluster distance was calculated by the formula given by Singh and Chaudhary (1977).

Square of intra cluster distance=$\Sigma Di^2/n$

Where,

ΣDi^2= Sum of distance between all possible combinations of the entries included in a cluster.

n=Number of all possible combinations.

ii) Inter-cluster distance

The inter cluster distance were calculated by the formula described by Singh and Chaudhary (1977).

Square of inter cluster distance= $\Sigma Di^2/n_i n_j$

Where,

ΣDi^2= Sum of distance between all possible combinations (ninj) of the entries in the cluster study.

n_i= Number of entries in cluster i.

n_j= Number of entries in cluster j.

iii) Contribution of individual characters towards genetic divergence

The character contribution towards genetic divergence was computed following the method given by Singh and Chaudhary (1977). In all combinations, each character is ranked on the basis of $di = Y_{ij} - Y_{ik}$ values.

Where,

d_i = mean deviation

Y_{ij}= mean value of the j^{th} genotype for the i^{th} character.

Y_{ik}= mean value of the k^{th} genotype for the i^{th} character.

Results and Discussion

Clustering pattern

Twenty-eight maize inbreds were evaluated under WW and Ws condition during rabi season to avoid obstruction to the experiment due to rains (Table 2). Water stress was created by withholding irrigation from 40 to 75 DAS which was coincided with pre-tasselling and pre-silking period. The water stress was evident by reduction in the soil moisture in the WS plots (Table 3). Individual analysis of variance for WW and WS indicated significant differences (data not shown) among maize inbreds for all the traits under study indicating existence of genetic variability among genotypes which is a pre-requisite for genetic diversity analysis.

Fourteen clusters were formed under WW condition (Fig 1) and seven clusters under Ws condition (Fig 2). This indicates differential grouping of same set of maize inbreds into different clusters based on differential response of maize inbreds to WW and WS condition. In case of WW condition, cluster 1 was having nine inbreds (DIM 204, CDM 112, D 2287, PML 9, DIM 102, PDM 260-1, PML 93, PML 102, PDM 4341). These inbreds also grouped into cluster 1 even under WS condition in addition to other genotypes. Cluster 3 was having seven inbreds under well watered condition (IMIC 2030, CML 579-1, IMIC 2024, PML 21, GPM 114, CML 580 and CML 582) and the same genotypes grouped in Custer 2 under WS condition in addition to other genotypes. In case of WW condition, 12 clusters were solitary while, in case of WS condition, five clusters were solitary. The maize inbreds which were within the same cluster by and large exhibit a narrow range of genetic variability and are said to be less diverse. Earlier, Kumar *et al.* (2015) reported wider genetic variability among 24 inbred lines of maize and grouped them under five major clusters. Seshu *et al.* (2014) also

Table 4 - Cluster means for various traits in 28 maize inbreds under well watered condition

Cluster	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20
1	71.50	0.40	41.58	3.87	2.06	95.35	74.67	78.33	3.67	119.43	59.07	14.17	3.69	15.30	26.71	0.79	84.07	29.83	41.81	3.20
2	83.49	0.36	41.07	3.81	2.20	95.90	75.50	79.00	3.50	118.70	62.20	15.76	3.89	13.60	26.00	0.83	77.57	29.00	40.19	2.11
3	87.59	0.38	45.55	3.71	2.02	96.39	85.29	87.86	2.57	155.06	77.72	16.24	4.08	14.47	28.03	0.98	83.24	31.93	43.42	2.77
4	79.98	0.45	48.47	4.30	1.86	97.55	68.50	72.00	3.50	142.85	73.45	15.14	4.03	13.60	30.60	0.72	76.17	34.00	42.06	3.73
5	69.75	0.42	49.98	4.13	1.95	95.75	76.00	78.50	2.50	160.80	82.10	14.75	3.90	13.40	23.30	0.90	83.45	33.50	41.56	3.82
6	91.69	0.47	41.04	4.13	1.85	97.65	74.00	77.50	3.50	154.70	73.65	18.42	4.15	15.00	35.70	0.98	87.44	33.50	48.88	4.06
7	76.29	0.43	44.12	3.99	1.75	94.40	79.00	83.50	4.50	135.00	70.10	15.73	4.40	14.50	21.90	0.82	81.62	32.00	41.08	1.35
8	71.01	0.42	41.45	3.29	1.87	95.55	91.00	94.50	3.50	164.20	89.75	15.41	4.02	16.50	24.60	1.06	81.84	32.50	44.50	3.00
9	78.72	0.56	39.54	4.20	1.89	95.35	84.50	88.50	4.00	107.60	75.90	18.82	4.02	15.20	32.40	1.13	85.56	36.00	36.65	2.55
10	56.01	0.46	41.70	3.70	1.88	96.20	78.50	81.50	3.00	133.80	78.45	15.69	3.78	19.50	27.40	0.80	82.56	31.50	45.61	3.35
11	67.67	0.36	36.49	4.00	1.94	90.80	76.50	82.00	5.50	101.45	46.80	13.98	3.49	17.10	24.60	0.69	80.75	26.50	40.87	2.17
12	94.52	0.55	43.74	3.91	1.91	98.60	72.00	74.50	2.50	99.50	41.70	14.58	3.94	13.20	24.20	0.89	88.88	33.50	47.76	3.14
13	73.90	0.47	43.48	4.04	2.03	95.40	75.50	79.50	4.00	163.85	91.90	16.76	4.83	15.80	34.10	1.13	91.13	32.00	47.01	2.74
14	84.84	0.38	42.72	3.71	2.22	96.95	76.00	79.50	3.50	98.15	54.15	11.60	4.10	16.40	24.60	0.89	91.03	29.50	42.25	1.60

X1 - Relative water content (60 DAS)
X2 - Specific leaf weight (60 DAS)
X3 - SCMR (60 DAS)
X4 - Pollen fertility
X5 - Proline
X6 - Wax
X7 - Days to 50 % tasseling
X8 - Days to 50% silking
X9 - Anthesis-Silking interval (ASI)
X10 - Plant height
X11 - Ear height
X12 - Cob length
X13 - Cob girth
X14 - NKR (Number of kernel rows per cob)
X15 - KNR (Number of kernels per row)
X17 - Shelling per centage
X16- NCP (Number of cobs per plant)
X18 - 100 grain weight
X19 - Harvest index
X20 - Grain yield

Table 5 - Cluster means for various traits in 28 maize inbreds under water stress condition

Cluster	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20
1	73.51	0.41	42.59	3.90	2.00	95.51	76.43	80.07	3.63	126.94	65.67	14.87	3.83	14.97	26.61	0.84	82.85	31.03	41.49	3.02
2	88.10	0.39	44.98	3.76	2.00	96.54	83.88	86.56	2.69	155.01	77.21	16.51	4.10	14.54	28.99	0.98	83.77	32.13	44.11	2.93
3	56.01	0.46	41.70	3.70	1.88	96.20	78.50	81.50	3.00	133.80	78.45	15.69	3.78	19.50	27.40	0.80	82.56	31.50	45.61	3.35
4	67.67	0.36	36.49	4.00	1.94	90.80	76.50	82.00	5.50	101.45	46.80	13.98	3.49	17.10	24.60	0.69	80.75	26.50	40.87	2.17
5	94.52	0.55	43.74	3.91	1.91	98.60	72.00	74.50	2.50	99.50	41.70	14.58	3.94	13.20	24.20	0.89	88.88	33.50	47.76	3.14
6	73.90	0.47	43.48	4.04	2.03	95.40	75.50	79.50	4.00	163.85	91.90	16.76	4.83	15.80	34.10	1.13	91.13	32.00	47.01	2.74
7	84.84	0.38	42.72	3.71	2.22	96.95	76.00	79.50	3.50	98.15	54.15	11.60	4.10	16.40	24.60	0.89	91.03	29.50	42.25	1.60

X1 - Relative water content (60 DAS)
X2 - Specific leaf weight (60 DAS)
X3 - SCMR (60 DAS)
X4 - Pollen fertility
X5 - Proline
X6 - Wax
X7 - Days to 50 % tasseling
X8 - Days to 50% silking
X9 - Anthesis-Silking interval (ASI)
X10 - Plant height
X11 - Ear height
X12 - Cob length
X13 - Cob girth
X14 - NKR (Number of kernel rows per cob)
X15 - KNR (Number of kernels per row)
X17 - Shelling per centage
X16- NCP (Number of cobs per plant)
X18 - 100 grain weight
X19 - Harvest index
X20 - Grain yield

reported wide range of genetic diversity for 11 characters studied wherein they grouped 63 genotypes into eight clusters under normal condition. Both have suggested that based on the inter-cluster distances genotypes present in different clusters can be used as parents for hybridization programme to develop potential hybrids.

Cluster distance

In case of WW condition, the maximum intra-cluster distance among maize inbreds was observed in cluster 3 (1055) which has seven genotypes followed by cluster 1 (1032) which has nine genotypes (Fig. 3). The maximum inter-cluster distance was observed between 11 and 12 (13216) followed by clusters 10 and 12 (12673), cluster 6 and 11 (11303) and between cluster 6 and 10 (10206). This shows that, there is maximum diversity between inbred PDM 77-4 belonging to cluser 11 and PDM 4641 belonging to cluster 12 under WW condition (Fig 1) and hence can be used in development of heterotic hybrids suitable for growing under WW condition.

In case of WS condition, the maximum intra-cluster distance was recorded in cluster 1 (1374.5) which included 15 genotypes followed by cluster 2 (1286.3) which has eight genotypes. The maximum inter-cluster distance was between cluster 4 and 5 (13216) followed by clusters 3 and 5(12673.4) and cluster 2 and 4 (8098.1). The lowest inter-cluster distance was recorded between clusters 3 and 4 (1472.3). This shows that maize inbred PDM 77-4 belonging to cluster 4 and PDM 4641 belonging to cluster 5 are diverse under WS (Fig 4) and hence can be used in combining ability analysis and development of heterotic hybrids suitable for growing under WS condition. This could be due to different population improvement programmes in deriving these two inbreds (Table 1). Both under WW and WS condition, there is maximum diversity between PML 77-4 and PDM 4641 suggesting the heterotic hybrid between these inbreds can be suitable for both WW and WS condition. Earlier, Suman *et al.*, (2020) reported wide

Table 6 - Contribution of each character towards genetic divergence among 28 maize inbreds under well watered and water stress condition

Sl. No.	Source	Per cent contribution	
		Well watered	Water stress
1	Relative water content at 60 DAS	1.1	1.4
2	SPAD at 60 DAS	0.2	0.3
3	Pollen fertility	0.6	0.5
4	Days to 50 % tasseling	4.1	4.0
5	Ear height	4.2	4.3
6	Cob girth	2.3	1.9
7	Kernel row number per cob	0.9	0.3
8	Kernels number per row	2.6	2.2
9	Cobs per plant	17.8	19.1
10	Shelling percentage	41.2	33.1
11	Harvest index	9.2	7.4
12	Grain yield	20.5	25.9
	Total	**100.0**	**100.0**

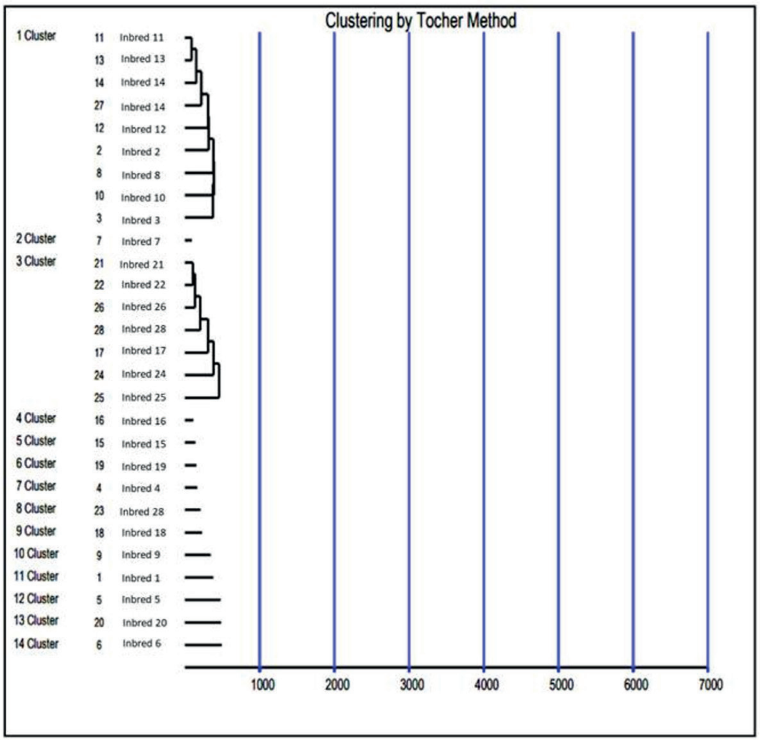

Fig. 1 - Clustering of 28 maize inbreds into fourteen clusters under well-watered condition

Inbred 11- DIM 204	Inbred 21- IMIC 203	Inbred 4- PDM 4251
Inbred 13- CDM 112	Inbred 22- CML 579-1	Inbred 23- CML 579-2
Inbred 14- D2287	Inbred 26- IMIC 2024	Inbred 18- CML 451
Inbred 27- PML 9	Inbred 28- PML 21	Inbred 9-PML 54
Inbred 12- DIM 302	Inbred 17- GPM 114	Inbred 1- PDM 77-4
Inbred 2- PDM 260-1	Inbred 24-CML 580	Inbred 5- PDM 4641
Inbred 8- PML 93	Inbred 25- CML 582	Inbred 20- CML 563
Inbred 10- PML 102	Inbred 16- CM 111	Inbred 6- PML 17
Inbred 3- PDM 4341	Inbred 15- D1013	
Inbred 7- PML 46	Inbred 19- CAL 1426-2	

range of genetic diversity among 11 maize genotypes and grouped them under three clusters wherein the highest inter cluster distance was observed between cluster 2 and 3 (4.88) under normal condition. Singh *et al.*, (2019) also studied genetic divergence in maize inbreds and inferred that, selection of maize inbreds based on diversity will lead to deriving of heterotic hybrids.

Trait contribution to diversity

Under WW condition, cluster 12 containing inbred PDM 4641 had highest RWC (94.5 %) and lower DFT (72). The inbreds under cluster 3 (7 inbreds), 5 (D 1013) and 12 (PDM 4641) have lesser ASI (2 days). The cluster 8 containing inbred CML 579-2 had highest PH (164.2 cm) and cluster 13 containing genotype CML 563 had highest EH (91.9 cm). Maximum CL was observed in cluster 9 (CML 451) and 6 (CAL 1426-2), CG in cluster 13 (CML 563), KRN in cluster 10 (PML 54) and NKR in cluster 4 (CAL 1426-2). The cluster 9 containing inbred CML 451 had highest HSW (36 g) and grain yield was higher in the clusters 6 (CAL 1426-2) and 10 (PML 54). The genotypes under these clusters superior for different traits can be used in population improvement programme to derive inbred lines combining many productive traits.

Perusal of cluster means under WS condition indicated that the cluster 5 containing genotype PDM 4641 had highest mean RWC (94.5), highest HSW (33.5 g), lower DFT (72 days) and DFS(74.5 days) and lower ASI (2.5 days). The inbreds under cluster 2 have highest PH (155 cm) and NKR (19.5). EH was highest in the cluster 6

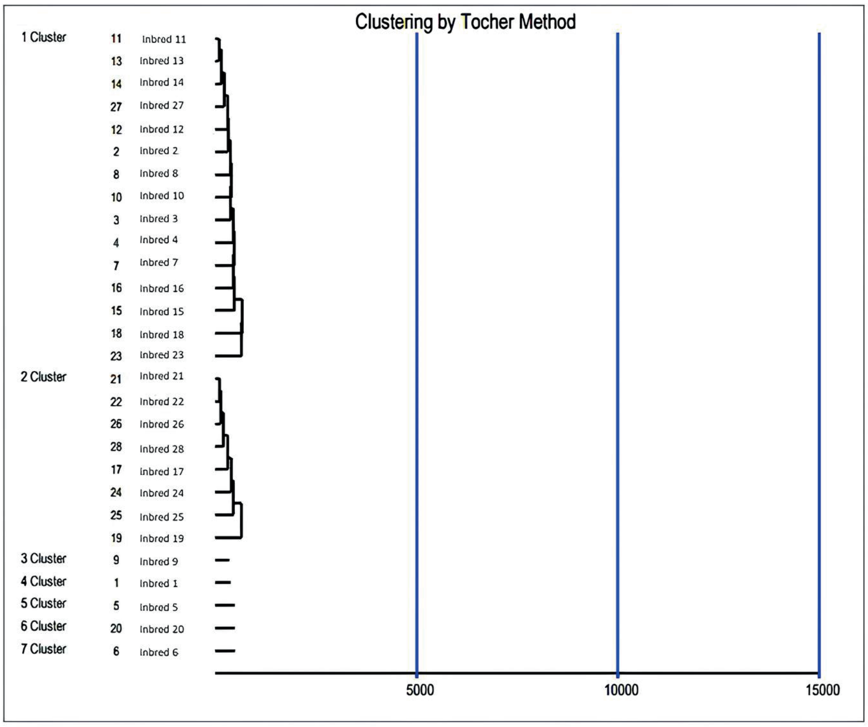

Fig. 2 - Clustering of 28 maize inbreds into seven clusters under limited water stress condition

Inbred 11 - DIM 204	Inbred 15 - D1013	Inbred 9 -PML 54
Inbred 13 - CDM 112	Inbred 18 - CML 451	Inbred 1 - PDM 77-4
Inbred 14 - D2287	Inbred 23 - CML 579-2	Inbred 5 - PDM 4641
Inbred 27 - PML 9	Inbred 21 - IMIC 2030	Inbred 20 - CML 563
Inbred 12 - DIM 302	Inbred 22 - CML 579-1	Inbred 6 - PML 17
Inbred 2 - PDM 260-1	Inbred 26 - IMIC 2024	
Inbred 8 - PML 93	Inbred 28 - PML 21	
Inbred 10 - PML 102	Inbred 17 - GPM 114	
Inbred 3 - PDM 4341	Inbred 24 - CML 580	
Inbred 4 - PDM 4251	Inbred 25 - CML 582	
Inbred 7 - PML 46	Inbred 19 - CAL 1426-2	
Inbred 16 - CM 111		

containing inbred CML 563 (91.9 cm). Maximum mean values for cob traits such as CL and KRN was in cluster 3, CG in cluster 6. The inbreds under cluster 1, 2 and 3 have higher grain yield indicating genotypes present in cluster 1, 2 and 3 can be used as parents for hybridization programme to develop potential hybrids for WS condition (Table 5).

It is interesting to note that both under WW and WS condition, SP (41.2 %, 33.1 %) followed by grain yield (20.5 %. 25.9 %), cobs per plant (17.8 %. 19.1 %), contributed maximum towards genetic divergence (Table 6). These characters should be given weightage while selecting diverse inbreds to develop superior hybrids suitable for both WW and WS condition. Earlier Ganeshan *et al.* (2010), Kage *et al.* (2013) and Wali (2019) also identified SP, EH and grain yield as the principal components contributing to variation in maize under moisture stress condition.

Conclusions

The study of 28 maize inbreds under well watered and water stressed condition resulted in formation of 14 and 7 clusters, respectively indicating differential clustering pattern. Higher mean values of cob length, cob girth, kernel row number, number of kernels per row, 100 seed weight and grain yield are distributed in different clusters having maize inbreds CML 451, CAL 1426-2, CML 563 and PML 54 and hence these inbreds can be used in population improvement programme to derive inbred lines combining many productive traits

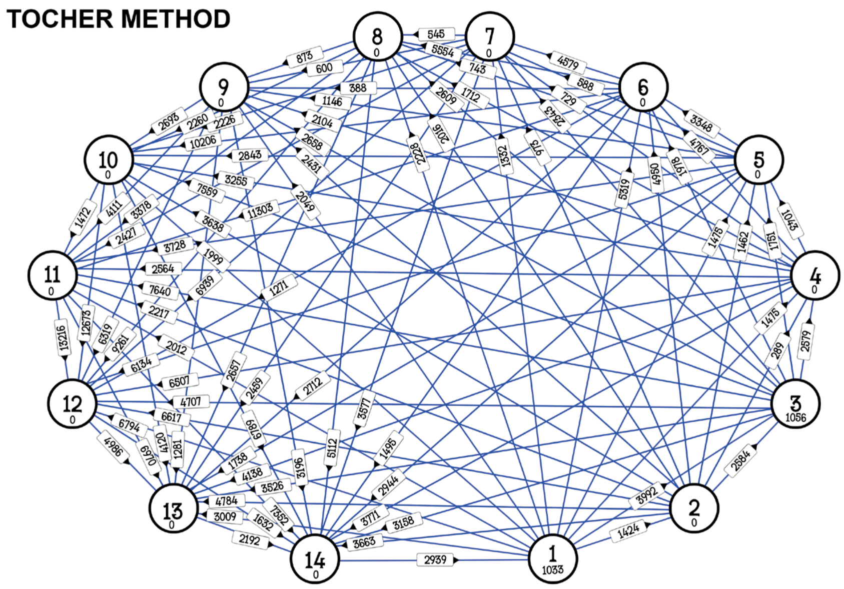

Fig. 3 - Intra and inter cluster distance formed by 28 maize inbreds under well watered condition

suitable for WS condition. Shelling percentage, grain yield, cobs per plant contributed maximum towards genetic divergence both under WW and WS condition

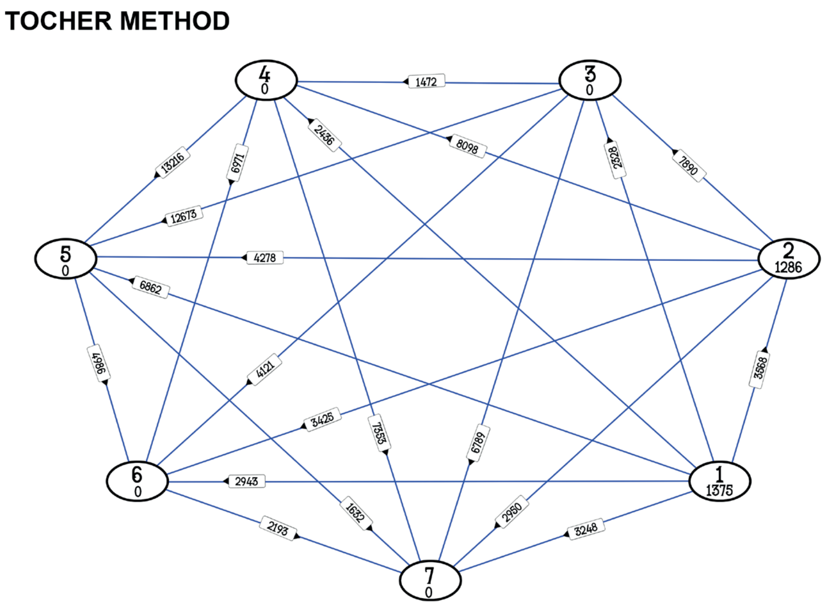

Fig. 4 - Intra and inter cluster distance formed by 28 maize inbreds under water stress condition

and hence these traits need to be given weightage while selecting diverse inbreds to develop superior hybrids suitable for both WW and WS condition

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