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Assessment of the Genetic Diversity of Maize Genotypes under Heat Stress

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ABSTRACT: Ensuring adequate nutrition worldwide in the face of increasing populations cannot be tackled by individual persons or countries; strong collaboration between different agricultural organizations is needed to face this threat. To improve maize cultivars, knowledge of the genetic diversity of different germplasms is important. In this study the genetic diversity of genotypes provided by CIMMYT was estimated with local accession (checks) based on PCA, cluster analysis and path analysis. The Maize and Millets Research Institute in Yusafwala, Sahiwal (MMRI, Pakistan) and the International Maize and Wheat Improvement Center (CIMMYT) are working on a joint project to evaluate maize genotypes under heat stress. A total of 55 genotypes were planted in spring, 2016 at MMRI. The data were evaluated for statistical significance and correlations with principal components analysis (PCA) and cluster analysis. According to PCA and Pearson's correlation, the selection of short-duration plants may favor higher yields. The purely heritable traits (independent of environmental influences) were male days to flowering with plant height, grain moisture with ear height; female days to flowering with plant height, grain moisture with ear height, plant height with ear height, field weight and grain moisture with grain yield, ear height with field weight and grain yield, field weight with grain moisture, and grain moisture with grain yield. According to PCA and cluster analysis, genotype YH-5427 was found to be the most suitable for selecting short-duration plants, and genotype sib was confirmed as an inbred line.

Keywords: Cluster analysis, Correlation, Path analysis, Principal components analysis, International Maize and Wheat Improvement Center, CIMMYT

I. INTRODUCTION

The world papulation is rising rapidly, and according to one estimate is expected to increase by upto 50% by 2050[6]. The demand for food is increasing even more rapidly. This is not a problem that can be solved by individual persons or countries; collaboration among different organizations is needed. Because agriculturalists are the principal managers of the global food market, collaboration between international agricultural organizations is urgently needed. Accordingly, the Maize and Millets Research Institute (MMRI) in Yusafwala, Sahiwal, Pakistan is working with the International Maize and Wheat Improvement Center (CIMMYT) in Mexico on different projects designed to evaluate maize genotypes under heat stress.

Heat stress is one of the major threats to agricultural production. The reproductive stage is the most sensitive stage to high temperatures, which can affect pollination and seed setting. These problems were reported to reduce maize yield significantly by 80%-90% [9, 33, 34].

Maize (corn) is an important crop worldwide and in Pakistan, ranking third after wheat and rice [19]. It is important because of its versatile uses to produce a variety of food and non-food products (e.g. biofuel and environmentally friendly fuel). Its grain can used as livestock feed, and stalks can also used as fodder [20, 26]. The main advantage of maize is that two crops per year can be raised [29]. Maize contributes 2.9% of the added value in agriculture and 0.6% of the GDP in Pakistan. Currently maize is cultivated on a total area of 14.13 million hectares, with a production of 7.24 million tonnes [8].

To improve maize cultivars, knowledge of the genetic diversity of different germplasms is important. Genetic diversity can be estimated with different methods [14, 15]. Principle components analysis (PCA) can be used to reduce the variables and groupings of genotypes with the aim of determining correlations between traits and genotypes. Genotype similarities can be estimated with the help of cluster analysis[5]. Path analysis provides information on the direct dependence among a set of variables. In this study the genetic diversity of genotypes provided by CIMMYT was estimated with local accession (checks) based on PCA, cluster analysis and path analysis. We foresee that the results will helpful in evaluating the suitability of these genotypes for agricultural purposes in the Pakistani environment.

II. MATERIAL AND METHODS

The trial named 16S_ASHII-117 consisted of 55 accessions of maize (52 imported from CIMMYT, Mexico and 3 local accessions (checks) that were planted at the MMRI in 2015 (Spring) in a randomized complete block design with three replications. The normal sowing dates of maize were 15 to 20 February in Pakistan but this trial is the part of a large project of CIMMYT, in which heat resistance of different genotypes were evaluated in South Asia region, that's why this trial was sown on 20 March. In February sowing crop, the pollination completed in first half of April, in which the temperature was not so much high (between 30-40 °C) while in 20 March sowing, the pollination started in May, in which the temperature is much high (40-50 °C) (Fig. 1). Plots measured 5 × 3 m.

All agronomic practices, i.e. irrigation, fertilizer application, pesticide application, hoeing and thinning, etc. were carried out at appropriate times. Five plants were selected randomly from each entry for data collection of plant height, ear height, while data was collected for other traits from whole plot except the guarded plants.

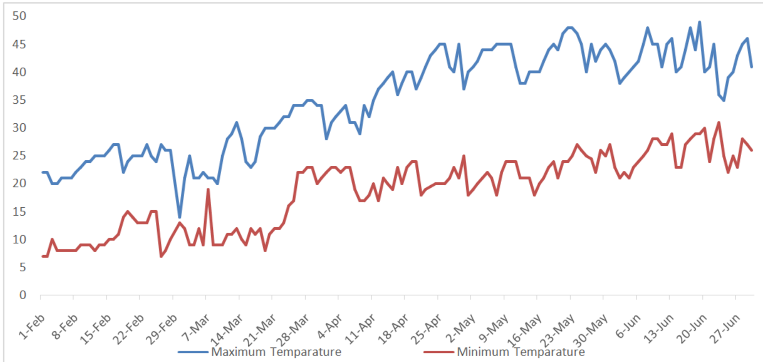

Fig. 1. Temparature Data, Yusafwala, Sahiwal, Pakistan, 2015.

Data were collected for the following traits: days to flowering for male plants, days to flowering for female plants, plant height, ear height, root lodging, stem lodging, number of ears, number of plants, field weight of cobs, grain moisture, grain weight, ear rot and ear aspect. For root lodging and stem lodging, the number of plants affected was calculated. For ear rot and ear aspect, a scale was established from 1 to 4: highly affected genotypes were scored 4 while genotypes showing no effect were scored 1. A scale of 1 to 5 was used to score plant aspect. Genotypes that appeared to be in very good condition were scored 1 and very poor genotypes were scored 5.

Statistical significance was calculated according to Steel *et al.* [26] with the help of Statistixv. 8.1software, and PCA and cluster analysis were done according to Sneath and Sokal, [25] with the help of XLSTAT software. Correlation coefficients were calculated from variance and covariance components, as suggested by Burton [3], Wright [31, 32], and Narasimharao and Rachie [17]. The correlation coefficient was partitioned into direct and indirect causes according to Dewey and Lu [4], Turner and Stevens [30], and Wright [28] with the help of R software [21].

III. RESULTS AND DISCUSSION

Significant differences among genotypes were found for ear height, field weight of cobs, grain moisture, female days to flowering, male days to flowering, plant height and grain yield. Non significant differences were obtained for number of plant, number of ears, stem lodging and root lodging. The percentage coefficient of variance (CV%) of all traits was less than 20% except for root lodging and stem lodging, so all traits except root and stem lodging were used for correlation and path analysis. The percentage CV for ear height was 20.63%, which is nearly equal to 20% and acceptable for further evaluation. Non-significant difference was found for number of plants and number of ears, indicating that data for the selected plants and ears were suitable for statistical analysis without bias (Table 1). Sharma *et al.* (2014) found significant differences among 20 maize genotypes for plant height, days to 50% flowering, cob length, 100 grain weight, biological yield per plant and grain yield per plant [24].

Akbari *et al.,* (2015) also found significant difference among plant height in maize [1]. Descriptive statistics are given in Table 2. Maximum range was found for ear height and minimum range was found for grain yield. The range for male days to flowering and female days to flowering was same. Because root lodging and stem lodging were calculated by counting the number of plants affected, the range in these data was small (Table 2). The average performance of varieties with their least significant difference value is given in Table 3.

A. Correlation

Correlation studies are presented in Table 4. Grain moisture was significantly and positively correlated with male days to flowering and female days to flowering. A significant positive correlation was observed between male days to flowering and female days to flowering. Plant height was significantly and positively correlated with ear height. Grain yield was significantly and positively correlated with field weight, and negatively correlated with grain moisture. From correlation studies it can be inferred that both male and female plants with less days to flowering have less moisture. So, selection of plants with a shorter time to flowering (male and female) is likely to favor low moisture content in grains. Moetamadipoor *et al.,* (2015) found that early maturity plants have opportunity of higher yield in wheat [13]. The days to female plant flowering can be reduced by crossing with male plants with a shorter time to flowering, and vice versa. If more grain yield is needed, then plants with low grain moisture should be selected. Lower grain moisture can be obtained with plants that have a shorter time to flowering, and the selection of short-duration plants will presumably be highly favorable (Table 4).

Table 1: Analysis of Variance.

Source	DF	Ear Height	Field Weight	Grain Moisture	Female Flowering	Male Flowering	No. of Ears	No. of Plants	Plant Height	Grain Yield	Root Lodging	Stem Lodging
Rep	1	1178.18	2.24	0.12	15.28	18.40	53.90	158.4	687.5	0.67	0.36	0.08
Gen	54	871.14*	3.35**	7.35**	6.51**	7.22**	21.44^{NS}	30.16^{NS}	524.06*	1.90**	0.29^{NS}	0.43^{NS}
Error	54	538.37	1.39	0.36	1.72	1.72	18.94	24.82	243.52	0.67	0.35	0.56
Total	109											
CV		20.22	17.57	2.6	2.0	2.1	13.22	15.59	7.41	17.61	27.1	23.5

**Highly significant, *Significant, ^{NS}= Nonsignificant

Table 2: Descriptive Statistics.

Statistic	Entry Name	Male Flowering Days	Female Flowering Days	Plant Height	Ear Height	Root Lodging	Stem Lodging	Number of Ears	Field Weight	Grain Moisture	Grain Weight
No. of observations	55	55	55	55	55	55	55	55	55	55	55
Minimum	1.000	59.000	62.000	180.000	62.500	0.000	0.000	21.500	2.556	19.050	1.803
Maximum	55.000	67.500	70.500	262.500	202.500	1.500	1.500	37.000	8.768	26.100	6.614
1st Quartile	14.500	61.500	64.500	202.500	105.000	0.000	0.000	31.750	6.019	21.525	4.420
Median	28.000	62.500	65.500	210.000	112.500	0.000	0.000	34.000	6.948	22.850	5.080
3rd Quartile	41.500	63.500	66.250	221.250	120.000	0.500	0.500	34.750	7.644	24.550	5.617
Mean	28.000	62.482	65.391	210.591	114.727	0.218	0.318	32.918	6.703	22.940	4.865
Variance (n-1)	256.667	3.620	3.266	256.473	424.693	0.146	0.216	10.822	1.743	3.662	0.948
Standard deviation (n-1)	16.021	1.903	1.807	16.015	20.608	0.382	0.465	3.290	1.320	1.914	0.974

Table 3: LSD All-Pairwise Comparisons (Means).

Sr. No	Entry	MFD	FFD	PH	EH	NE	NP	FW	GM	GY	SL	RL	EA	ER
1	Sib	67	70	202.5	62.5	22	21.5	2.56	25.05	2403	0.5	1.0	4.5	0.0
2	VH112537	63	66	222.5	120.0	35	34.0	7.05	22.70	6849	1.5	0.5	2.5	0.5
3	VH112859	64	67	202.5	102.5	33	32.5	7.66	23.55	7360	0.0	0.5	2.5	0.0
4	VH121035	66	69	187.5	92.5	35	34.0	6.66	22.45	6495	1.0	0.0	2.0	0.0
5	VH121301	65	68	205.0	117.5	36	35.0	7.38	21.55	7285	0.0	0.0	2.5	0.5
6	VH12263	62	64	227.5	130.0	31	29.5	6.84	25.40	6393	0.0	0.0	2.5	0.0
7	VH123012	63	66	197.5	105.0	33	32.0	6.17	19.95	6223	0.0	0.0	3.0	1.0
8	VH131167	62	65	235.0	127.5	30	28.5	5.41	22.85	5245	0.0	0.0	3.0	2.0
9	VH142085	63	65	262.5	202.5	37	35.0	7.35	22.70	7145	1.5	0.0	2.5	1.0
10	YH-1898	65	66	202.5	115.0	28	26.5	7.02	25.05	6620	0.0	0.5	2.0	2.0
11	YH-5427	61	64	225.0	102.5	36	34.0	8.77	19.85	8856	0.5	0.5	2.0	0.5
12	YH-949	63	66	210.0	120.0	29	28.0	7.89	24.15	7512	0.0	0.0	2.0	0.0
13	ZH111755	64	67	200.0	112.5	34	33.0	7.82	22.15	7657	1.5	0.0	2.0	0.0
14	ZH137087	62	65	210.0	105.0	37	37.0	6.86	21.25	6802	0.0	1.5	2.5	0.0
15	ZH137087S	63	66	237.5	135.0	34	34.0	6.33	22.90	6137	0.0	0.0	3.0	0.0
16	ZH137119	63	66	227.5	127.5	35	34.0	7.63	24.90	7187	0.5	0.5	2.0	2.5
17	ZH137177	68	71	212.5	122.5	35	34.5	7.87	21.90	7733	0.5	0.0	2.0	0.0
18	ZH137413	64	67	230.0	127.5	34	32.0	8.49	24.95	7991	0.5	0.5	2.0	1.5
19	ZH138098	66	69	220.0	110.0	35	33.5	5.43	25.95	5042	0.0	0.0	2.5	0.0
20	ZH138125	62	65	202.5	105.0	34	33.5	7.71	21.25	7637	0.0	0.0	2.0	0.0
21	ZH141199	62	65	210.0	112.5	35	34.0	8.01	24.75	7560	0.5	0.0	2.0	0.0
22	ZH141592	64	67	232.5	125.0	34	34.0	7.62	24.10	7252	0.0	0.0	2.0	0.0
23	ZH141592S	64	67	225.0	107.5	31	16.0	5.44	24.15	5183	0.5	0.0	2.0	1.0
24	ZH15281	61	64	190.0	80.0	35	33.5	6.48	19.95	6534	0.0	1.5	2.5	0.0
25	ZH15286	63	66	222.5	112.5	33	32.5	7.59	22.60	7382	0.0	0.0	2.0	0.0
26	ZH15291	62	65	205.0	117.5	33	32.0	5.30	21.55	5235	0.0	0.0	3.5	0.0
27	ZH15297	62	64	195.0	90.0	34	33.0	5.46	19.35	5549	0.0	0.0	4.0	1.0
28	ZH15299	62	65	210.0	105.0	27	25.5	4.38	25.35	4093	1.5	0.5	3.5	0.0
29	ZH15300	65	66	205.0	112.5	29	29.5	5.48	24.65	5186	0.0	0.5	3.0	0.0
30	ZH15302	62	65	217.5	112.5	34	33.0	5.61	24.35	5325	0.0	0.0	3.0	1.5

31	ZH15311	61	64	202.5	162.5	35	34.0	6.95	22.35	6786	0.0	0.0	2.5	0.0
32	ZH15324	63	64	210.0	120.0	34	33.5	7.65	19.05	7811	0.0	0.0	2.0	1.5
33	ZH15329	62	65	202.5	105.0	37	36.5	7.71	21.10	7655	0.5	0.5	2.5	0.0
34	ZH15331	62	65	200.0	117.5	34	33.5	6.59	23.85	6295	0.0	0.0	3.0	0.0
35	ZH15333	62	65	215.0	125.0	36	35.0	7.89	23.55	7574	0.5	0.5	2.5	0.0
36	ZH15338	63	66	230.0	117.5	34	33.0	6.91	21.40	6836	1.5	0.0	2.5	0.0
37	ZH15340	63	66	215.0	107.5	30	30.0	4.52	23.50	4339	0.0	0.0	3.0	0.0
38	ZH15345	59	62	200.0	157.5	34	31.5	5.82	19.75	5885	0.0	0.5	3.0	0.0
39	ZH15347	59	62	187.5	107.5	33	31.5	4.14	21.25	4099	0.0	0.0	2.5	0.0
40	ZH15350	59	63	192.5	155.0	30	29.5	6.31	25.10	5923	0.5	0.0	2.0	0.0
41	ZH15353	62	65	180.0	100.0	35	33.0	7.64	22.00	7493	0.0	0.0	2.5	0.0
42	ZH15379	59	62	207.5	110.0	35	34.5	6.44	22.75	6244	0.0	0.0	2.5	0.0
43	ZH15381	62	64	210.0	117.5	37	36.0	7.24	22.35	7070	0.0	0.0	2.0	3.0
44	ZH15383	60	66	207.5	115.0	32	31.5	6.90	20.65	6895	0.0	0.0	3.0	0.0
45	ZH15410	66	69	212.5	115.0	29	28.5	7.45	24.00	7106	0.0	1.0	2.0	0.0
46	ZH15416	64	67	242.5	135.0	37	36.0	7.62	21.05	7573	0.5	0.0	2.5	0.5
47	ZH15421	64	67	190.0	97.5	35	34.5	7.96	24.55	7535	0.5	0.0	2.5	1.0
48	ZH15422	63	66	217.5	105.0	33	31.5	8.57	24.05	8173	0.5	0.0	3.0	0.0
49	ZH15433	61	64	182.5	92.5	34	33.0	7.60	23.85	7268	0.5	0.0	2.5	0.0
50	ZH15434	62	65	222.5	120.0	36	35.5	5.87	24.55	5558	0.0	0.0	3.5	0.0
51	ZH1615	65	68	210.0	95.0	32	31.5	6.43	25.20	6028	0.5	0.0	3.5	0.0
52	ZH1679	62	65	205.0	107.5	22	21.0	3.24	26.05	3003	0.0	1.0	2.5	0.5
53	ZH1679S	64	67	217.5	107.5	35	34.0	7.31	26.10	6765	1.0	0.5	2.0	0.5
54	ZH1680	63	66	210.0	105.0	34	33.0	7.12	22.90	6896	0.0	0.0	2.0	0.0
55	ZH1681	59	62	180.0	95.0	32	31.5	6.64	19.45	6741	0.5	0.0	2.5	0.0
LSD		2.63	2.63	31.28	46.52	NS	NS	2.36	1.20	2294	NS	NS	1.2	1.8

MFD= Male Flowering Days, FFD= Female Flowering days, PH=Plant Height, EH=Ear Height, Number of Ears, NP =Number of Plants, FW= Field Weight, GM= Grain Moisture, GY= Grain Yield, Stem Lodging, RL = Root Lodging, EA =Ear Aspect, ER= Ear Rot, NS = Non-Significant

Table 4: Correlation According to Pearson's r statistic.

Variables	**Male Flowering Days**	**Female Flowering Days**	**Plant Height**	**Ear Height**	**Field Weight**	**Grain Moisture**	**Grain Weight**
Days to Male Flowering	**1**	**0.943**	0.224	-0.199	0.027	**0.347**	-0.011
Days to Female Flowering		**1**	0.201	-0.209	0.031	**0.350**	-0.007
Plant Height			**1**	**0.526**	0.158	0.199	0.130
Ear Height				**1**	0.201	0.003	0.190
Field Weight					**1**	-0.168	**0.993**
Grain Moisture						**1**	**-0.284**
Grain Weight							**1**

Bold values are statistically significant

Malik *et al.* (2005) found a positive genetic correlation between grain yield and plant height, and between ear height and ear weight [12]. They also found a positive correlation for days to silking with tasseling. They found a negative correlation between grain moisture and grain yield. In contrast, they found no genetic correlation between grain yield with ears per plant^{-1}, kernel rows per ear^{-1} and 100-kernel weight. Nemati *et al.* (2009) found the highest positive correlation for grain yield with kernels per ear [18]. They observed a significant negative correlation between grain yield and kernels per ear. Pavlov *et al.* (2015) found a significant positive correlation for grain yield with plant height and ear height [20]. They also found a significant positive correlation between plant height and ear height. Mumtaz *et al., (*2017) found a significant positive correlation between plant height and grain yield [16]. Taiwo *et al.,* (2020) found positive correlation between number of plants harvested, number of ears harvested and field weight [27]. Seyedzavar *et al.* (2015) also found positive correlation between grain yield and ear height in corn [23].

B. Path Analysis

Yield and yield components were partitioned into direct and indirect effects, and are presented in Table 5. Lenka and Mishra (1973) rated the direct and indirect effects in five ranges of yield, *i.e* negligible, low, moderate, high and very high [11]. In the present study, field weight had the greatest positive direct effect (0.9652) on high level yield, while plant height had the lowest positive direct effect (0.0267) on negligible yield. Grain moisture (-0.1503) had the largest negative direct effect on low yield level, while ear height (-0.0289) had the lowest negative direct effect on negligible yield. Male days to flowering made the largest positive contribution to grain yield via field weight (0.0682) and the smallest positive contribution via plant height (0.0105), both for negligible yield level. Male days to flowering made the greatest negative contribution via female days to flowering (-0.0748) and the lowest negative contribution via grain moisture (-0.0608), both for negligible yields. The direct effect of male days to flowering (0.0612) for negligible yield was cancelled out by cumulative indirect effects, all at the negligible yield level. As a result, the genotypic correlation was non-significant. Female days to flowering made the greatest positive contribution via field weight (0.0806) and the lowest positive contribution via plant height (0.0092), both at the negligible yield level. Female days to flowering contributed negatively via grain moisture (-0.0574), also at the negligible yield level. The direct effect of female days to flowering (-0.0748) at the negligible yield level was cancelled out by cumulative indirect effects, all at the negligible yield level. As a result the genotypic correlation was non-significant. Male and female days to flowering made direct and indirect contributions, reflecting an equivalent but reciprocal effect of these traits. Plant height made the largest positive contribution to grain yield via field weight (0.2622) at the moderate yield level, and the lowest positive contribution via male flowering days (0.0240) at the negligible yield level. Plant height made the largest negative contribution via grain moisture (-0.0430) and the smallest negative contribution via ear height (-0.0187), both at the negligible yield level. Because the direct effect of plant height (0.0267) appeared at the negligible yield level and was insufficient to offset the cumulative indirect effects, some effects were seen at the moderate yield level, and therefore the genotypic correlation with grain yield was significant.

Table 5: Direct (Diagonal) and indirect effect path coefficients.

	Days to Male Flowering	**Days to Female Flowering**	**Plant Height**	**Ear Height**	**Field Weight**	**Grain Moisture**	**Grain Yield**
Days to Male Flowering	**0.0612**	-0.0748	0.0105	0.0119	0.0682	-0.0608	0.01615
Days to Female Flowering	0.0612	**-0.0748**	0.0092	0.0108	0.0806	-0.0574	0.02965
Plant Height	0.0240	-0.0257	**0.0267**	-0.0187	0.2622	-0.0430	0.22549*
Ear Height	-0.0252	0.0281	0.0173	**-0.0289**	0.3685	-0.0012	0.35867*
Field Weight	0.0043	-0.0062	0.0072	-0.0110	**0.9652**	0.0297	0.9892*
Grain Moisture	0.0247	-0.0286	0.0076	-0.0002	-0.1907	**-0.1503**	-0.33739*

Bold values are statistically significant

Residual effect^2 = 0.00009

Ear height made the largest positive contribution via field weight (0.3685) at high yield levels, and the lowest positive contribution via female days to flowering (0.0281) at the negligible yield level. Ear height made the largest negative contribution via male days to flowering (-0.0252) and the smallest negative contribution via grain moisture (-0.0012), both at the negligible yield level. Its genotypic correlation for grain yield was also significant because one of its indirect effects was seen for high yield whereas its direct effect (-0.0289) observed for negligible yield was insufficient to offset the cumulative indirect effects. Field weight made the greatest positive contribution to grain yield via grain moisture (0.0297) and the smallest positive contribution via plant height (0.0072), both for negligible yield. Field weight made the largest negative contribution to grain yield via ear height (-0.011) and female days to flowering (-0.0062), both at the negligible yield level. The direct effect of field weight (0.9652) was seen for high yield, and its indirect effect was seen for negligible yield; its indirect effects were thus insufficient to cancel out its direct effect, and as a result, its genotypic correlation was significant. Grain moisture made the largest positive contribution via male days to flowering (0.0247) and the smallest positive contribution via plant height (0.0076), both at the negligible yield level. Grain moisture made the largest negative contribution via field weight (-0.1907) at the moderate yield level, and the smallest negative contribution via ear height (-0.0002) at the negligible yield. The direct effect of grain moisture (-0.1503) was seen for the moderate yield level, and its indirect effects appeared for negligible yield except for field weight (-0.1907), seen for moderate yield. As a result, its genotypic correlation was negative and significant, which indicated that grain moisture negatively affected grain yield (Table 5). The very low residual effect (0.00009) indicated that maximum variability was influenced by the traits of choice, which means the choice of traits for this study was very good. Rafiq *et al.* (2010) found the largest direct effect for 100 grain weight on grain yield in maize [11]. Kumar *et al.* 2015 found the greatest direct effect of days to 50% tasseling on grain yield per plant, followed by ear height, 100-kernel weight and ear diameter [10]. Pavlov *et al.* (2015) found a positive direct effect of plant height and ear height on grain yield [20]. In their study of sorghum, Mumtaz *et al.* (2017) found indirect effects for the negligible yield level [13].

Phenotypic, genotypic and environmental correlations are presented in Table 6. Genotypic correlations for the following traits were significant and greater than environmental correlations.

Table 6: Phenotypic, Genotypic and Environmental Correlations.

		Days to Male Flowering	Days to Female Flowering	Plant Height	Ear Height	Field Weight	Grain Moisture	Grain Yield
Days to Male Flowering	r_p	**1.000**	**0.910**	0.148	-0.131	0.003	**0.307**	-0.025
	r_g	**1.000**	**1.000**	**0.392**	**-0.411**	0.071	**0.404**	0.016
	r_e	**1.000**	**0.776**	-0.069	0.029	-0.075	0.041	-0.074
Days to Female Flowering	r_p		**1.000**	0.138	-0.158	0.003	**0.331**	-0.027
	r_g		**1.000**	**0.344**	**-0.376**	0.084	**0.382**	0.030
	r_e		**1.000**	-0.036	-0.046	-0.086	0.262	-0.091
Plant Height	r_p			**1.000**	**0.497**	0.111	0.157	0.094
	r_g			**1.000**	**0.648**	**0.272**	**0.286**	**0.225**
	r_e			**1.000**	**0.448**	0.001	-0.020	0.003
Ear Height	r_p				**1.000**	0.148	0.001	0.144
	r_g				**1.000**	**0.382**	0.008	**0.359**
	r_e				**1.000**	0.045	-0.008	0.047
Field Weight	r_p					**1.000**	-0.152	**0.994**
	r_g					**1.000**	**-0.198**	**0.989**
	r_e					**1.000**	-0.103	**0.999**
Grain Moisture	r_p						**1.000**	**-0.255**
	r_g						**1.000**	**-0.337**
	r_e						**1.000**	-0.150
Grain Yield	r_p							**1.000**
	r_g							**1.000**
	r_e							**1.000**

Bold values are statistically significant

1. Male days to flowering with female days to flowering (0.910), plant height (0.392), grain moisture (0.404) and ear height (-0.411)
2. Female days to flowering with plant height (0.344), grain moisture (0.382) and ear height (-0.376)
3. Plant height with ear height (0.648), field weight (0.272), grain moisture (0.286) and grain yield (0.225)
4. Ear height with field weight (0.382) and grain yield (0.359)
5. Field weight with grain moisture (-0.198) and grain yield (0.989)
6. Grain moisture with grain yield (-0.337)

It can be inferred from above results that joint selection is feasible for male days to flowering with plant height, grain moisture and ear height, female days to flowering with plant height, grain moisture and ear height, plant height with ear height, field weight, grain moisture and grain yield, ear height with field weight and grain yield, field weight with grain moisture, and grain moisture with grain yield, given that these are purely heritable and not affected by environmental factors. No environmental correlation for any trait was larger than the correlation found for genotypic traits, which implies that none of the traits was affected by the environment (Table 5). Rafiq *et al.,* (2010) found higher genotypic correlation for 100 grain weight and grains per row [22]. Kumar *et al.* (2015) reported significant positive phenotypic correlations for grain yield with plant height, and for ear length with ear height [10]. They observed a negative phenotypic correlation for grain yield with number of kernels row per ear and 100-kernel weight, except for maturity traits. In sorghum, Mumtaz *et al.,* (2017) found a significant genotypic correlation for plant height with grain yield, which was greater than the correlation for environmental factors [13]. Aman *et al.,* (2020) found that highest direct positive effect on yield/ha was by ear height [2]. They also found positive genotypic correlation of days to 50% tasseling, ear heigh and plant height. Taiwo *et al.,* (2020) found positive direct effects on grain yield by field weight and days to tasseling [27].

C. Principle Components Analysis

In this study total variation was divided into 12 principal components (PCs). Four PCs had eigenvalues greater than 1 and explained 69.13% the total variation in the results.

Table 7: Principle Component Analysis.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Eigenvalue	2.826	2.363	1.516	1.031	0.951	0.802	0.717	0.450	0.292	0.051	0.000
Variability (%)	25.695	21.481	13.779	9.371	8.645	7.289	6.521	4.093	2.658	0.465	0.002
Cumulative %	25.695	47.176	60.955	70.326	78.972	86.260	92.782	96.875	99.532	99.998	100.000

The variation explained by the remaining PCs was lower, and the twelfth PC was very small (0.002) (Table 7). Total variation is also illustrated in the scree plot (Fig. 2), which clearly shows that the first four PCs explained most of the variation, with less variation accounted for by the remaining PCs.

The largest PC correlated highly with grain yield (0.907) and showed considerable positive factor loading, and with male flowering days (-0.011), with negative factor loading. The second PC represented male flowering days (0.923), with considerable positive factor loading, and ear aspect (-0.037), with considerable negative factor loading. Principal component 3 correlated with ear height (0.713) with positive factor loading, and with root lodging (-0.080) with negative factor loading. Principal component 4 reflected positive factor loading by ear rot (0.707)and negative factor loading by grain yield (-0.003) (Table 8).

Sib (27.731), ZH1679S (8.445) and VH14208 (6.469) made the largest contributions to total variation in PC1. Sib (9.196), ZH1681 (8.803) and ZH15345 (8.358) made maximum contributions to PC2. VH14208 (24.494), VH13116 (7.705) and VH12103 (6.393) made maximum contributions to PC3.ZH15381 (15.528), YH-1898 (10.771) and ZH-15338 (8.761) made maximum contributions to PC4 (Table 9). From the above results it can be inferred that PC1 represents positive grain yield and negative male flowering days, so selection based on sib, ZH1679S and VH14208 can be helpful in creating short-duration, high-yielding varieties. The second PC was explained by positive male flowering days and negative ear aspect, so selection based on sib, ZH1681 and ZH15345 would not be expected to be favorable because it would result in long-duration, low-aspect varieties. Principal component 3 was explained by positive ear height and negative root lodging, so selection with VH14208, VH13116 and VH12103 would favor efforts to obtain varieties with greater ear height and less root lodging. Principal component4 represented positive ear rot and negative grain yield; selection with ZH-15381, YH-1898 and ZH-15338 would thus be undesirable because it would favor ear rot and low grain yield (Table 10). Ali *et al.* (2015) found 90.55% variability in the contribution of selected traits [2]. They found that the first three PCs contributed most to variability, with 49.6% of the variation explained by PC1, which comprised plant height, fresh leave weight, number of leaves per plant, leaf area, stem diameter, stomata conductance, photosynthetic rate, substomata CO_2 and absorption rate. Tanavar *et al.* (2014) found that the first two PCs contributed maximum variability in maize genotypes, and their second group contained the largest number of genotypes [28].

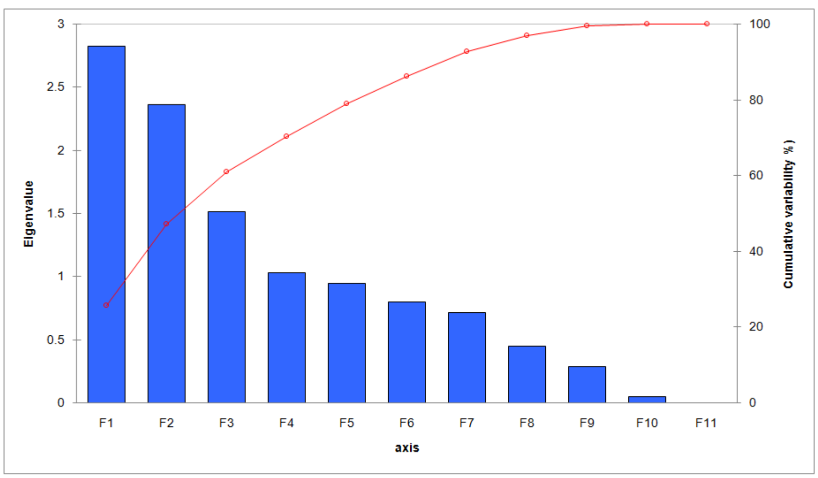

Fig. 2. Scree plot.

Table 8: Factor Loading.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Days to Male Flowering	-0.011	0.923	-0.209	0.108	-0.103	-0.159	-0.121	-0.113	-0.063	-0.159	0.000
Days to Female Flowering	-0.022	0.920	-0.243	0.014	-0.120	-0.139	-0.143	-0.095	-0.064	0.160	0.000
Plant Height	0.370	0.401	0.669	-0.031	0.146	-0.168	-0.254	0.182	0.327	0.001	0.000
Ear Height	0.479	-0.106	0.713	-0.159	-0.041	0.070	-0.274	-0.209	-0.318	0.000	0.000
Root Lodging	-0.280	0.164	-0.080	0.165	0.904	0.149	-0.118	-0.034	-0.077	0.004	0.000
Stem Lodging	0.269	0.339	0.104	-0.662	0.233	-0.143	0.529	-0.097	0.002	-0.005	0.000
Field Weight	0.912	-0.002	-0.311	0.000	0.061	0.020	-0.033	0.241	-0.088	-0.001	-0.011
Grain Moisture	-0.170	0.582	0.270	0.036	-0.139	0.642	0.201	0.285	-0.074	-0.002	0.001
Ear Rot	0.286	0.075	0.362	0.707	0.032	-0.268	0.450	-0.024	-0.073	0.015	0.000
Ear Aspect	-0.737	-0.037	0.153	-0.163	0.013	-0.440	-0.045	0.403	-0.216	-0.003	0.000
Grain Yield	0.907	-0.067	-0.339	-0.003	0.081	-0.058	-0.058	0.198	-0.071	-0.003	0.011

Table 9: Contributions of Different Genotypes to Each Vector.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
ZH141592	0.810	1.362	0.900	0.069	2.317	1.203	1.952	5.910	8.524	0.199	0.356
ZH141592S	3.109	0.787	0.178	0.291	0.091	0.037	0.302	1.648	3.042	0.243	1.334
ZH15422	0.770	0.084	0.492	1.102	0.127	0.047	0.000	14.115	0.070	0.123	0.256
ZH137087	0.159	0.012	0.172	0.187	21.066	0.111	8.734	0.937	0.053	0.105	0.288
ZH137087S	0.025	0.014	0.051	0.006	0.897	0.007	1.782	0.022	1.346	0.006	0.399
ZH1679	0.367	2.750	0.000	0.310	1.195	3.376	3.128	0.076	0.486	0.067	4.010
ZH1679S	8.445	0.169	2.027	1.772	2.506	7.927	0.278	4.280	0.698	0.436	12.322
ZH1680	0.174	0.023	0.748	0.069	0.875	0.813	0.593	0.058	3.136	0.005	0.044
VH142085	6.469	0.636	24.494	6.649	0.528	2.582	0.197	1.433	2.435	0.844	0.954
ZH15421	0.301	0.455	2.287	0.475	0.933	0.089	4.747	1.276	3.950	0.169	0.077
ZH15286	0.938	0.004	0.169	0.021	0.475	0.278	2.121	0.090	4.884	0.005	0.058
Sib	25.731	9.196	0.288	0.038	1.694	3.050	0.339	0.405	0.147	0.364	2.557
ZH15416	2.237	0.666	0.941	0.280	0.013	4.738	2.828	0.000	1.454	0.573	1.977
ZH137413	3.512	1.933	0.583	2.009	1.470	0.407	0.379	1.002	0.250	0.852	2.884
ZH15291	2.361	1.159	0.273	0.287	0.887	1.772	0.866	0.156	0.520	0.015	1.478
ZH15281	1.264	2.770	5.129	0.984	20.695	0.108	0.223	0.449	0.689	0.044	3.734
ZH137119	2.227	0.736	2.915	6.984	1.674	0.109	5.077	0.082	0.168	2.033	0.490
ZH141199	1.185	0.003	0.285	0.562	0.344	3.404	0.275	1.033	0.390	0.062	0.962
ZH15433	0.004	1.719	2.868	0.665	0.327	2.160	4.210	2.252	0.363	0.269	0.001
ZH15434	1.298	0.101	2.067	0.282	0.933	0.005	0.958	7.487	0.001	0.051	0.853
ZH15345	0.273	8.358	2.022	0.510	1.600	0.160	3.111	2.567	8.083	0.060	0.796
ZH15347	3.807	7.347	0.112	0.051	0.793	0.653	0.587	6.258	2.602	0.049	13.795
ZH15350	0.066	2.688	2.117	1.874	0.656	11.342	0.865	2.454	5.818	3.232	2.080
ZH15353	0.017	1.788	4.695	0.008	0.888	0.227	0.040	0.202	2.082	0.044	1.525
ZH15379	0.079	4.987	0.133	0.073	0.203	1.481	0.012	1.066	3.286	0.171	0.006
ZH15381	1.597	0.688	1.065	15.528	0.227	0.843	7.346	0.375	0.014	0.230	0.561
ZH15383	0.010	1.817	0.155	0.208	0.304	1.548	1.514	0.682	0.010	30.787	0.661
ZH15297	3.332	2.686	0.206	0.675	0.357	14.532	0.616	1.404	0.504	0.593	6.036
ZH15300	2.415	0.802	0.002	0.116	0.005	0.600	0.968	0.001	1.570	29.714	0.005
ZH15311	0.366	2.377	1.284	0.450	0.720	0.770	2.864	0.971	10.344	0.845	2.022
ZH15338	0.731	0.202	0.321	8.761	0.267	2.813	1.421	0.400	5.151	0.089	0.035
VH131167	0.172	0.000	7.705	4.653	0.463	3.293	0.243	0.103	0.869	1.374	0.145
ZH15340	3.521	0.003	0.754	0.018	1.708	0.001	0.456	0.111	2.677	0.012	0.474
ZH15324	2.307	1.227	0.155	3.951	0.069	4.350	0.003	3.012	0.210	13.283	5.782
ZH15331	0.351	0.577	0.000	0.077	1.175	0.460	0.159	1.900	1.924	0.050	0.232
ZH15302	0.706	0.000	2.413	3.030	1.067	0.176	1.170	1.117	0.051	0.628	0.429
ZH15333	0.651	0.000	0.003	0.680	1.614	0.663	0.293	1.295	0.814	0.022	0.010
ZH15329	0.262	0.325	2.066	0.424	2.001	0.233	0.021	0.023	0.032	0.007	1.803
ZH15299	4.988	0.596	1.852	7.904	1.645	0.021	8.621	0.142	0.003	0.126	2.591
ZH1681	0.059	8.803	2.584	1.147	0.000	0.302	2.847	0.838	0.471	0.263	0.035
VH112537	0.506	1.002	0.267	3.818	3.713	0.827	3.146	0.426	0.054	0.013	0.244
ZH1615	1.283	3.574	0.385	0.759	1.669	0.518	0.048	5.720	0.905	0.000	0.000
ZH15410	0.098	4.022	1.657	1.017	3.474	1.900	5.331	0.945	0.923	0.440	3.146
VH121301	0.290	0.419	1.144	0.556	1.301	1.564	1.607	0.541	1.697	0.302	1.028
VH12263	0.049	0.015	1.994	0.046	0.818	3.220	1.353	3.024	0.713	5.988	0.131
ZH137177	1.712	7.316	2.902	0.214	1.512	1.637	3.484	5.532	1.216	0.329	0.288
ZH111755	1.736	0.532	1.809	6.454	0.000	0.158	4.246	2.904	0.080	0.057	0.211
ZH138098	1.136	5.135	0.093	0.112	3.665	1.226	1.545	0.154	0.915	0.200	0.463
VH123012	0.338	0.270	0.576	1.412	0.816	6.853	0.001	0.911	0.692	0.477	0.734
VH112859	0.013	0.656	2.781	0.298	0.189	0.401	1.418	0.670	1.012	0.057	0.255
VH121035	0.000	3.682	6.393	1.305	1.211	0.233	1.950	9.518	0.062	0.079	1.347
ZH138125	0.721	0.736	2.374	0.039	0.450	0.037	0.682	0.170	1.313	0.000	1.778
YH-5427	3.848	1.699	0.805	0.000	5.273	0.848	0.006	0.904	8.225	0.006	15.828
YH-1898	0.184	1.090	0.006	10.771	0.092	1.092	2.060	0.627	3.066	4.007	0.015
YH-949	0.992	0.000	0.301	0.020	1.006	2.796	0.976	0.327	0.006	0.001	0.474

Table 10: Cluster Analysis (Class centroids).

Class	Days to Male Flowering	Days to Female Flowering	Plant Height	Ear Height	Root Lodging	Stem Lodging	Field Weight	Grain Moisture	Ear Rot	Ear Aspect	Grain Weight
1	62.650	65.467	216.083	118.667	0.183	0.267	6.875	23.012	0.550	2.450	4.981
2	62.542	65.542	206.667	105.000	0.250	0.333	6.369	23.267	0.167	2.583	4.614
3	62.500	65.000	262.500	202.500	0.000	1.500	7.351	22.700	1.000	2.500	5.312
4	62.875	65.875	185.000	95.625	0.000	0.500	7.463	23.213	0.250	2.375	5.390
5	66.500	69.500	202.500	62.500	1.000	0.500	2.556	25.050	0.000	4.500	1.803
6	62.333	65.167	198.333	88.333	0.500	0.167	6.119	21.500	0.333	3.333	4.516
7	59.500	63.000	198.333	158.333	0.167	0.167	6.357	22.400	0.000	2.500	4.638
8	60.500	63.500	225.000	102.500	0.500	0.500	8.768	19.850	0.500	2.000	6.614

Biplot

Biplot analysis clearly illustrated a strong correlation between days to male flowering and days to female flowering, and between grain moisture and root lodging. It also showed the close association among plant height, stem lodging and ear rot. A close association was also observed among field weight, grain yield and ear height. The arrows for field weight and grain weight were the same length, so the magnitude of their correlation was greatest. Ear aspect showed no positive correlation with any trait.

Negative correlations can also be estimated from the biplot: traits located opposite each other were negatively correlated. Male days to flowering, female days to flowering and grain moisture were negatively correlated with ear height. Root lodging was negatively correlated with ear height, field weight and grain weight. Similarly, ear aspect was negatively correlated with ear rot, stem lodging and plant height (Fig. 3).

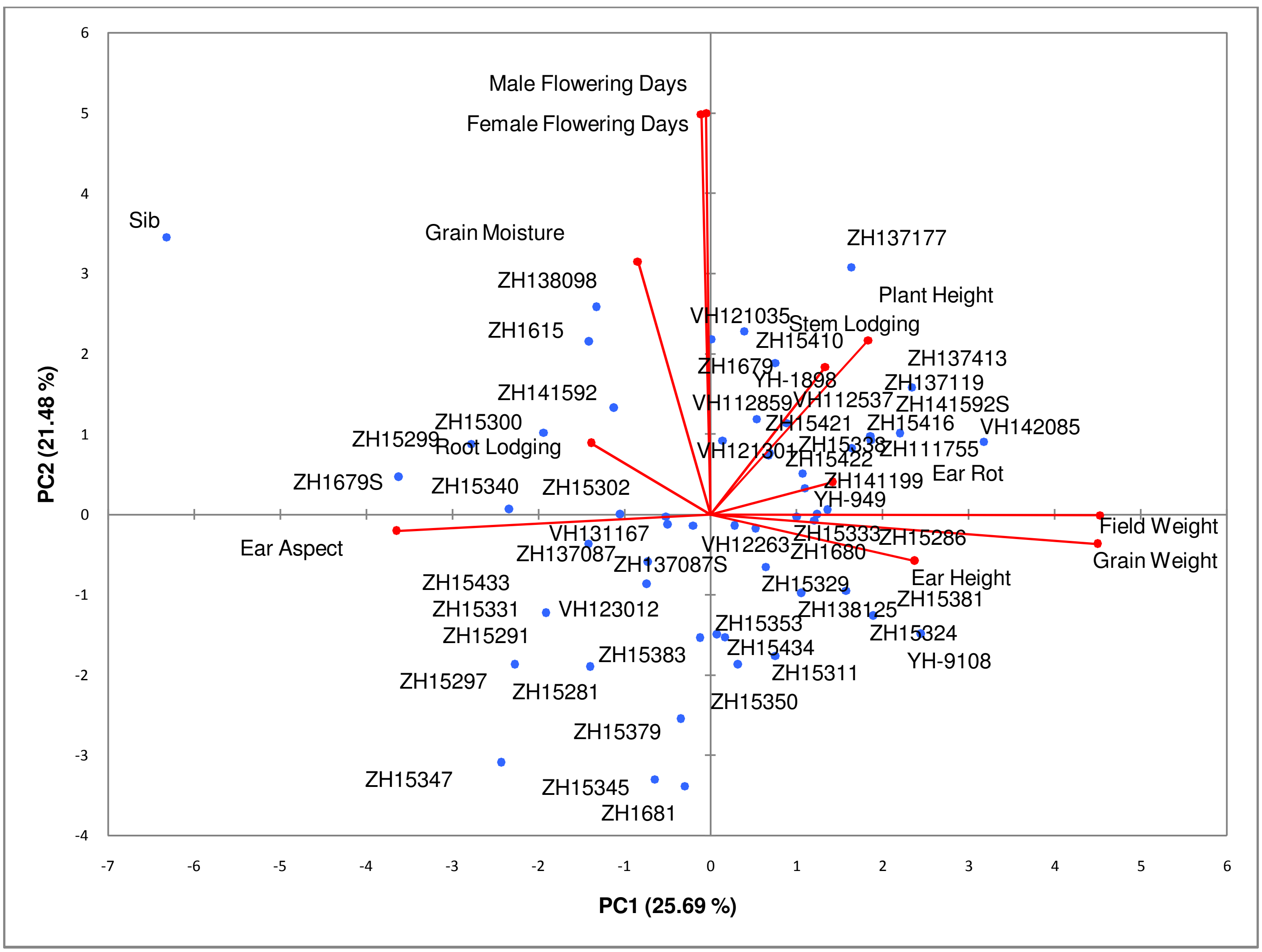

Fig. 3 Biplot (axes PC1 and PC2: 47.18 %).

These results partly confirm the results of Pearson correlation analysis (Table 4). Correlations between genotypes and traits can also be explained by the axis (Fig. 3), as detailed below.

1. ZH138098 and ZH1615 were correlated with grain moisture, male days to flowering and female days to flowering, while ZH15350, ZH15311, ZH15433, ZH15353 and VH-12263 were negatively correlated with male days to flowering and female days to flowering. Similarly, YH-5427, ZH15324, ZH138125 and ZH15329 were negatively correlated with grain moisture.

2. Sib, ZH15300, ZH15299 and ZH141592 were positively correlated with root lodging. ZH15329, ZH138125, ZH15324 and YH-5427 were negatively correlated with root lodging.

3. ZH137177, ZH137413, ZH137119, VH142085 and YH-1898 were positively correlated with plant height and stem lodging. ZH15433, ZH15331, ZH15291 and ZH15297 were negatively correlated with plant height and stem lodging.

4. VH142085, Zh111755, ZH141199, YH949 and ZH15416 were positively correlated with ear rot. Zh15345, ZH15331, ZH15297, ZH15347 and ZH15291 were negatively correlated with ear rot.

5. YH5427, ZH15381, ZH15324 and Zh138125 were positively correlated with field weight, grain weight and ear height. Sib, ZH15300, ZH15299 and ZH141592 were negatively correlated with field weight, grain weight and ear height.

6. VH131167, ZH137087 and ZH137087S were positively correlated with ear aspect. ZH141199, YH-949, ZH15422 and ZH111755 were negatively correlated with ear aspect.

Cluster Analysis

The 55 genotypes were grouped into eight clusters (Table 10). The first cluster comprised 30 genotypes, cluster 2 consisted of 12 genotypes, cluster 3 consisted of 1 genotype, cluster 4 consisted of 4 genotypes, cluster 5 consisted of 1 genotype, cluster 6 consisted of 3 genotypes, cluster 7 consisted of 3 genotypes and cluster 8 consisted of 1 genotype (Table 11). These results were further confirmed by the tree diagram, which showed three main groups. Sib was separate from all other genotypes. The second group was divided into 2 subgroups, and the third group was divided into 5subgroups (Fig. 4). VH142085 was found to be best for tall plants, greater ear height, more stem lodging, more ear rot and less root lodging. ZH15421, ZH15433, ZH15353 and VH121035 were best for short plants, less root lodging and less stem lodging.

Table 11: Genotypes in Cluster Analysis.

Cluster No.	No. of Genotypes	Genotypes Name	Significant Traits
1	30	ZH141592, ZH141592S, ZH137087, ZH137087S, ZH15286, ZH15416, ZH137413, ZH15291, ZH137119, ZH141199, ZH15434, ZH15347, ZH15379, ZH15381, ZH15383, ZH15300, ZH15338, VH131167, ZH15324, ZH15331, ZH15302, ZH15333, VH112537, ZH15410 VH121301, VH12263, ZH137177, ZH111755, YH-1898, YH-949	
2	12	ZH15422, ZH1679, ZH1679S, ZH1680, ZH15340, ZH15329, ZH15299, ZH1681, ZH138098, VH123012, VH112859, ZH138125	
3	1	VH142085	**Highest Traits (Means)** Plant height, Ear height, Stem lodging, Ear rot **Lowest Traits (Means)** Root lodging
4	4	ZH15421, ZH15433, ZH15353, VH121035	**Lowest Traits (Means)** Plant height, Root lodging, Stem lodging
5	1	Sib	**Highest Traits (Means)** Male days to flowering, Female days to flowering, Root lodging, Stem lodging, Grain moisture, Ear aspect **Lowest Traits (Means)** Ear height, Field weight, Ear rot, Grain weight
6	3	ZH15281, ZH15297, ZH1615	**Lowest Traits (Means)** Stem lodging
7	3	ZH15345, ZH15350, ZH15311	**Lowest Traits (Means)** Male days to flowering, Female days to flowering, Stemlodging, Ear rot
8	1	YH-5427	**Highest Traits (Means)** Field weight, Grain weight **Lowest Traits (Means)** Grain moisture, Ear aspect

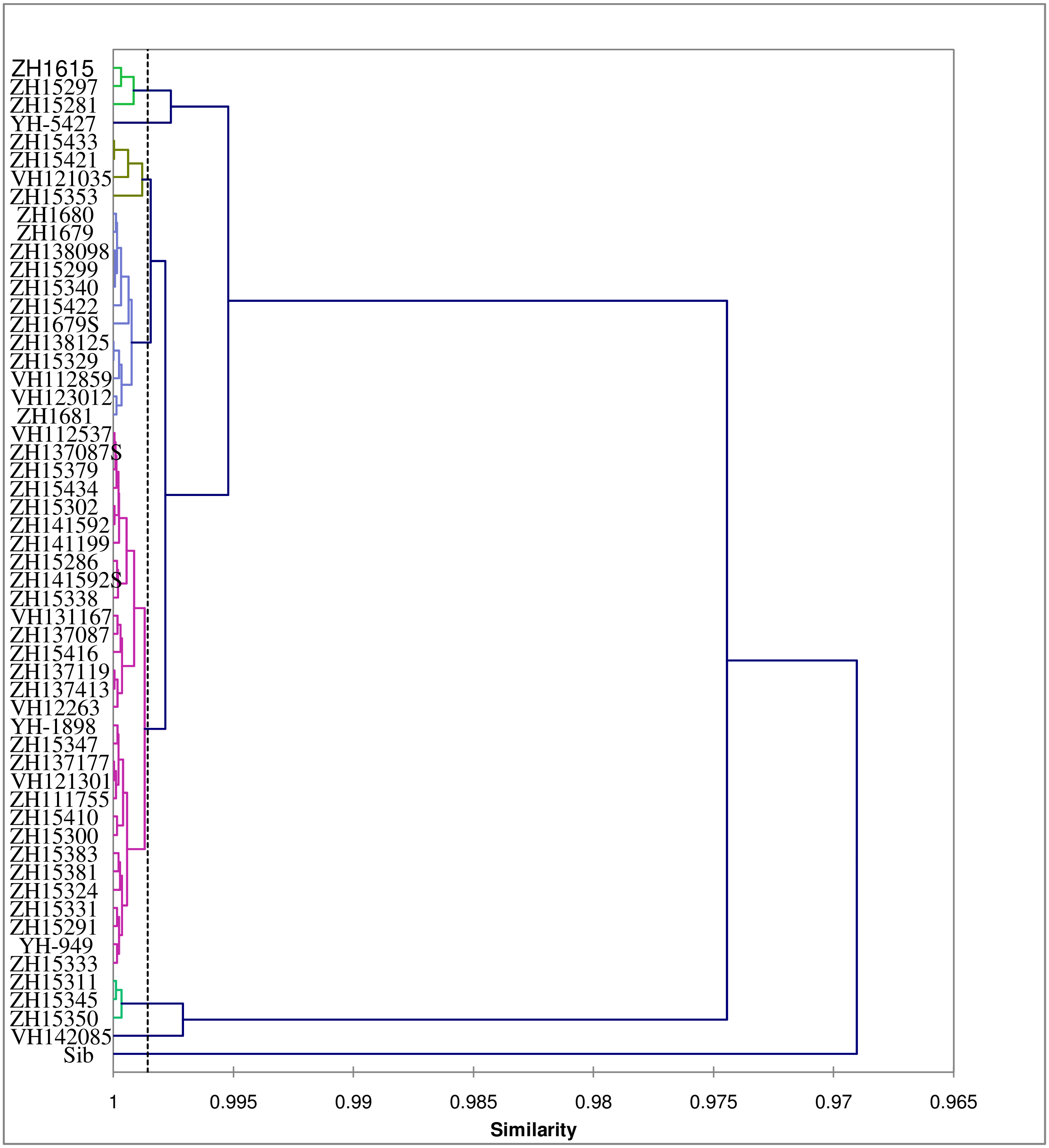

Fig. 4. Dendrogram.

Sib was best for long-duration plants, i.e. more days to male and female flowering, more root lodging, more stem lodging, greater grain moisture, good ear aspect, lower ear height, lower field weight, less ear rot and lower grain yield. ZH15281, ZH15297 and ZH1615 were best for less root lodging. ZH15345, ZH15350 and ZH15311 were best for short-duration plants i.e. fewer days to male and female flowering, less stem lodging and less ear rot. YH-5427 was best for high field weight, high grain yield, lower grain moisture and lower ear aspect. Genotypes in cluster 1 and 2 represent the genotypes with medium range values.

Ali *et al.* 2015 separated the genotypes they studied into three clusters, and observed the best-performing genotypes in cluster 3 [2]. Tanavar *et al.* 2014 categorized maize genotypes into four clusters, and found that cluster 2 contained the largest number of genotypes [28]. These earlier findings corroborate the results of our PCA and cluster analysis. According to both methods, ZH138098 produces long-duration plants and has the greatest grain moisture. ZH15350 and ZH15311 have short-duration plants. ZH15324 has the lowest root lodging. VH142085 has the greatest plant height, ear rot and stem lodging. ZH15433 has the lowest height and stem lodging. ZH15345 has the lowest ear rot. YH-5427 has the greatest field weight and grain yield, and the lowest grain moisture. Sib has the lowest field weight and grain yield, and the greatest root lodging and ear height. ZH138125 has the greatest ear height. Our results with PCA and cluster analysis were somewhat contradictory given that grain moisture was greatest in sib according to PCA whereas the highest value for this trait according to cluster analysis was found for ZH1615. The results for sib confirmed maximum in breeding depression in this genotype, which means that it could be used as an inbred line in future research.

IV. CONCLUSIONS

Statistically significant associations were found for all traits except number of plants, number of cobs, root lodging and stem lodging. The percentage coefficient of variation for all traits was less than 20%. Maximum range was found for ear height and minimum range was found in grain yield. If more grain yield is desired, it is necessary to select plants with low grain moisture, a trait that can be obtained by selecting for shorter periods to flowering. This makes it desirable to select for short-duration plants. The very low residual effect we obtained indicated that maximum variability was controlled by traits of selection. Joint selection strategies likely to be of interest should be based on male days to flowering with plant height, grain moisture and ear height; female days to flowering with plant height, grain moisture with ear height; plant height with ear height, field weight, grain moisture with grain yield; ear height with field weight and grain yield; field weight with grain moisture; grain moisture with grain yield, given that these are purely heritable traits that are not effected by the environment. According to our PCA and cluster analysis, genotype ZH138098 has long-duration plants and maximum grain moisture. Genotypes ZH15350 and ZH15311 produce short-duration plants. ZH15324 has minimum root lodging. VH142085 has maximum plant height, ear rot and stem lodging. ZH15433 has minimum height and minimum stem lodging. ZH15345 has minimum ear rot. YH-5427 has maximum field weight, maximum grain yield and minimum grain moisture. Sib has minimum field weight, minimum grain yield, maximum root lodging and maximum ear height. ZH138125 has maximum ear height. The results of PCA and cluster analysis were somewhat contradictory since according to PCA, sib has maximum grain moisture while according to cluster analysis, ZH1615 has maximum grain moisture. The results for the sib genotype confirmed maximum inbreeding depression, which means that it can be used as an inbred line for future research. YH-5427 was found to be the best genotype in terms of high yield and low moisture content.

V. FUTURE SCOPE

YH-5427 hybrid is currently approved hybrid by Punjab Seed Council, Punjab, Pakistan. And its best performance is an indication that farmers can use this climate resilient hybrid with confidence that they can get higher yield than before with it.

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REFERENCES

[1]. Akbari, M.M., Mobasser, H.R. and Ganjali, H.R. (2015). Influence of Salt Stress and Variety on some Characteristics of Corn. *Biological Forum-An International Journal, 7*(1):441-445.

[2]. Ali, M., Fida M.R., Arsalaan, A.S. and Adnan, A. (2015). Implementation and Analysis of Clustering Techniques Applied on Pocket Switched Network. *Intl. J. Distributed Sensor Networks,* Article No.: 2 https://doi.org/10.1155/2015/239591

[3]. Burton, G.W. (1951). Quantitative Inheritance in Pearl Millet (*Pennisetum glaucum*). *Agron. J.*, *43*: 409–417.

[4]. Dewey, D.R. and Lu, K.H. (1959). A Correlation and Path Coefficient Analysis of Components of Crested Wheat Grass and Seed Production. *Agron, J., 51*: 515–517.

[5]. Evgenidis, G., Mavrona, E.T. and Sotiriou, M.K. (2011). Principal Component and Cluster Analysis as a Tool in the Assessment of Tomato Hybrids and Cultivars. *Intl. J. Agron.,* Article No. 697879 (Accessed 2018 January 19) Available from https://www.hindawi.com/journals/ija/2011/697879/

[6]. FAOSTAT. (2018). Food and Agriculture Organization of the United Nations, Rome, Italy. Available from http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/ How_to_Feed_the_World_in_2050.pdf

[7]. Govindraj, M., Vetriventhan. M. and Srinivasan, M. (2015). Importance of Genetic Diversity Assessment in Crop Plants and Its Recent Advances: An Overview of Its Analytical Perspectives. *Genet. Res. Intl.*, Article ID 431487 (Accessed 2018 January 19) Available from https://www.hindawi.com/journals/gri/2015/431487/

[8]. Govt. of Pakistan. (2019-20). Economic Survey of Pakistan, Ministry of Finance, Economic Advisor Wing, Islamabad. Available From http://www.finance.gov.pk/survey/chapters_18/02-Agriculture.pdf

[9]. Hatfield, J.L., Stanley, C.D. and Carlson, R.E. (1976). Evaluation of an Electronic Foliometer to Measure Leaf Area in Corn and Soybeans. *Agron. J., 68*: 434–436

[10]. Kumar, V., Singh, S.K., Bhatti, P.K., Sharma, A., Sharma, S.K. and Mahajan, V. (2015). Correlation, Path and Genetic Diversity Analysis in Maize (*Zea mays* L.). *Environ. Eco*., *33*(2A): 971-975.

[11]. Lenka, D. and Mishra, B (1973). Path coefficient analysis of yield in rice varieties. *Indian J. Agric. Sci.*, *43*: 376-379.

[12]. Malik, H.N., Malik, S.I., Hussain, M., Chughtai, S.U.R. and Javed, H.I. (2005). Genetic Correlation among Various Quantitative Characters in Maize (*Zea mays* L.) Hybrids. *J. Agri. Social Sci., 1*(3): 262-265.

[13]. Moetamadipoor, S.A., Mohammadi, M., Khaniki, G.R.B. and Karimizadeh, R.A. (2015). Relationships between Traits of Wheat Using Multivariate Analysis. *Biological Forum-An International Journal, 7*(1): 994-997.
[14]. Mumtaz, A., Hussain, D., Saeed, M., Arshad, M. and Yousaf, M.I. (2018). Estimation of genetic diversity in sorghum genotypes of Pakistan. *J. Natn. Sci. Foundation Sri Lanka, 46*(3): 271–280.
[15]. Mumtaz, A., Hussain, D., Saeed, M., Arshad, M. and Yousaf, M.I. (2019). Stability and Adaptability of Sorghum Hybrids Elucidated With Genotype–Environment Interaction Biplots. *Turk J.* Field Crops, *24*(2), 155-163.
[16]. Mumtaz, A., Hussain, D., Saeed, M., Arshad, M. Yousaf, M.I. and Akbar, W. (2017). Association Studies of Morphological Traits in Grain Sorghum (*Sorghum bicolor* L.). *J. Agric. Basic Sci., 2*(1): 37-43.
[17]. Narasimharao, D.V. and Rachie, K.O. (1964). Correlations and Heritability of Morphological Characters in Grain Sorghum. *Madras Agric. J., 51*: 156–161.
[18]. Nemati, A., Sedghi, M., Sharifi, R.S. and Seiedi, M.N. (2009). Investigation of Correlation between Traits and Path Analysis of Corn (*Zea mays* L.) Grain yield at the Climate of Ardabil Region (Northwest Iran). *Not. Bot. Hort. Agrobot. Cluj.* 37(1): 194-198.
[19]. PARC. 2021. Maize. Available from http://www.parc.gov.pk/index.php/en/faq-s/60-faqs/86-maize accessed on 03.03.2021
[20]. Pavlov, J., Delic, N., Markovic, K., Crevar, M., Camdžija**,** Z. and Stevanovic, M. (2015). Path analysis for morphological traits in maize (*Zea mays* L.). *Genetika, 47*(1): 295-30.
[21]. Core Team, R. (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing. *Vienna, Austria: URL https://www. R-project. org/.[Google Scholar]*.
[22]. Rafiq, C.M., Rafique, M., Hussain, A. and Altaf, M. (2010). Studies on Heritability, Correlation and Path Analysis in Maize (*Zea mays* L.). *J. Agric. Res., 48*(1): 35-38.
[23]. Seyedzavar, J., Norouzi, M. and Aharizad, S. (2015). Relationships of Morphological Characters and Yield Components in Corn Hybrids under Water Deficit Stress. *Biological Forum-An International Journal, 7*(1): 1512-1519.
[24]. Sharma, B.K., Sharma, S., Kandel, B.P. and Shrestha, J. (2018). Varietal evaluation of promising maize genotypes. *Azarian J. Agri. 5*(4): 120-124.
[25]. Sneath, P.H.A. and Sokal, R.R. (1973). Numerical Taxonomy: The Principles and Pratice of Numerical Classification. San Francisco: Freeman, 573 pp.
[26]. Steel, R.G.D., Torrie, J.W.H. and Dickey, M. (1997). Principles and procedures of statistics. A biometrical approach. McGraw Hill Book Company, New York.
[27]. Taiwo, O.P., Nwonuala, A.I., Isaiah, B.F., Olawamide, D.O., Agbugba, I.K. (2020). Correlation and Path Coefficient Analysis Studies on Grain Yield and Its Contributing Characters in Maize (*Zea mays* L.). *Intl J. Plant Soil Sci., 32*(7): 7-13
[28]. Tanavar, M., Bahrami, E., Asadolahi, A.R., Kelestanie, A.R.A. (2014). Genetic Diversity of 13 Maize (*Zea mays* L.) Hybrids Based on Multivariate Analysis Methods. *Intl. J. Farm Alli. Sci., 3*(5): 467-470.
[29]. Tariq, M., Iqbal, H. (2010). Maize in Pakistan – An Overview. *Kasetsart J. (Nat. Sci.) 44*: 757–763.
[30]. Turner, M.E., Stevens, C.D. (1959). The regression analysis of causal paths. *Biomet. 15*; 236-258.
[31]. Wright, S. (1960). Path Coefficient and Path Regression: Alternative or Complementary Concepts?. *Biomet. 16*: 189–202.
[32]. Wright, S. (1968). Evolution and the genetics of populations 1. Genetics and Biometrics Foundations. The University of Chicago.
[33]. Yousaf, M.I., Hussain, K., Hussain, S., Ghani, A., Arshad, M., Mumtaz, A. and Hameed, R.A.. (2018). Characterization of Indigenous and Exotic Maize Hybrids for Grain Yield and Quality Traits under Heat Stress. *Intl. J. Agri. Bio., 20*(2): 333-337.
[34]. Yousaf, M.I., Hussain, K., Hussain, S., Shahzad, R., Ghani, A., Arshad, M., Mumtaz, A. and Akhter N. (2017). Morphometric and Phenological Characterization of Maize (*Zea mays* L.) Germplasm under Heat Stress. *Intl. J. Bio. Biotech., 14*(2): 271-278.

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