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Genetic Studies for Yield Components and Screening for Drought Tolerance at Seedling Stage of Maize (*Zea mays* L.) Genotypes

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment involving 30 genotypes of maize was carried out under the field condition during *Rabi* 2021-2022 to study the association of yield contributing characters among themselves along with direct and indirect effects on grain yield per plant and identify the genotypes which are highly efficient with respect to different PEG induced drought stress. The results of the study revealed that plant height, leaf length, ear height, number of grain rows per cob, number of grains per row, cob girth, cob weight, biological yield per plant, 100 grains weight and harvest index showed positive significant association with grain yield per plant both at genotypic and phenotypic levels. Plant height showed positive significant association with leaf length, ear height, number of grain rows per cob, cob girth, cob weight, 100 grains weight, biological yield per plant and grain yield per plant. Days to fifty per cent silking, anthesis to silking interval, days to maturity, number of grain rows per

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cob exhibited negative direct effect while number of cobs per plant, leaf width, cob length, cob weight, biological yield per plant and harvest index exhibited positive direct effect on grain yield per plant. For improvement of seed yield, attention should be given for traits such as cob weight, biological yield per plant and harvest index which showed high positive correlation coefficients with a considerable direct and indirect effect on grain yield. MGC-192 has shown high root length, shoot length, seedling length, seedling dry weight, seedling vigour index 1, seedling vigour index II, germination percentage and MGW-392 has shown high relative water content under PEG induced stress condition, hence this genotype is suggested for future selection.

Keywords: Maize; correlation; path analysis; grain yield; PEG.

1. INTRODUCTION

Maize is known as queen of cereals because of its high production potential and wider adaptability. It is extensively grown all over the globe. Nearly half of the world's crop (42.5%) is produced in the United States, China, Brazil, Mexico, Argentina, India, and France rounding out the top ten producers. With 23 million tonnes of maize produced over an area of 9.4 million hectares and a productivity of 2.5 tonnes per hectare, India comes in fourth place (Indian Economic Survey, 2014).

In India, along with rice, wheat, and sorghum, maize is a significant cereal crop. Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, and Karnataka are the main growing regions. Due to the increasing need for a variety of purposes, particularly industrial and feed uses, it is becoming more and more significant. About 25% of the maize produced in India is used for food directly, 61% for poultry, pig, and fish meal, 10% to 12% for wet milling (such as starch and oil), and about 3% for dry milling (such as for traditional uses like Dalia and Sattu and other food products like corn bread and corn chips, brewing 1%, and seed 1%). However, there is a shift towards the demand for industry based maize products. Every component of the maize plant, including the grain, leaves, stalk, tassel, and even the pith (shank), has economic worth and is utilised to make many food and non-food goods. Maize is mainly grown for its grain and the whole plant fed to animals. As a green forage crop and animal feed, corn is being utilised more often. It is also the best for making silage. About 40 per cent is fed to hogs, followed by cattle (29%) and poultry (19%). The major industrial utilisation of shelled grain is the production of mixed feed. Gluten feed, gluten meal, oil cake meal, germ meal, distiller's and brewer's grains are all by-products of processing. Manufacturing of poultry and dairy feeds consumes around three-fourths of the output of the mixed feed businesses.

Maize is a significant source of cooking oil as well (corn oil). In its kernel, it has an oil content of 4.5%. It has a high concentration of polyunsaturated fatty acids (PUFA), including linoleic acid (61.99%), which is liquid at low temperatures and is effective in preventing cardiac ailments. Nine per cent of the protein in maize. Zein is the name of the protein found in maize. A soft, golden powder called zein is made from maize meal. Zein is used in food and industry in a number of ways. It has been used in the production of polymers, paper coatings, and textile fibres. The floury and opaque varieties are of excellent nutritional value and contain a lot of tryptophan and lysine, respectively.

Drought creates water stress that affects the growth and development of maize plants. Effects of water stress on maize include the visible symptoms of reduced growth, delayed maturity and reduced crop yield. Maize is most susceptible to drought at flowering and early seed development stage. The use of genetics to improve drought tolerance and provide yield stability is an important part of the solution to stabilizing global maize production. But, drought tolerance is a very complex trait, influenced by a broad range of processes spanning both the time scale and at the plant organization level. For many crops, a low genetic correlation is often observed for yield in high- and low-productivity environments indicating that different sets of genes may be important in conditioning the yield in different environments.

The efficiency of selection in any breeding programme depends on the direction and magnitude of association between yield and its components traits. Thus, correlation study helps in identifying the character or combination of characters which might be useful as an indicator of high yield by way of evaluating relative influence of various characters on yield and among themselves as well. The original concept of correlation was given by Galton [1] and later elaborated by Fisher [2]. Path analysis is done to understand the direct and indirect effect of different characters on grain yield. The direct contribution of each component to the yield and the indirect effects and its association with other characters cannot be differentiated by simple correlations. Path coefficient analysis fulfils this lacuna. It was first developed and described by Wright [3] as a tool in genetic analysis for deriving the direct and indirect effects of independent variables on dependent variable. Later it was employed for crop improvement by Dewey and Lu, [4].

2. MATERIALS AND METHODS

The experimental materials comprised of thirty genotypes taken from Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad, Telangana (Table 1). The experiment was laid out with three replications in a randomized block design during *Rabi* 2021-2022. The recommended packages of practices were followed for raising a healthy crop and all necessary plant protection measures were taken to control the pest and diseases.

Data were recorded on days to fifty per cent tasseling, days to fifty per cent silking, anthesis to silking interval, plant height (cm), leaf width (cm), leaf length (cm), tassel length (cm), days to maturity, ear height (cm), number of cobs per plant, number of grain rows per cob, number of grains per row, cob length (cm), cob girth (cm), cob weight (g), 100 grains weight (g), biological yield per plant (g), harvest index (%) and grain yield per plant (g). All the data were subjected to statistical analysis to test the differences among maize genotypes for various traits. Analysis of variance was done for partitioning the total variation due to treatments and replications according to procedure given by Panse and Sukhatme [5]. Correlation coefficients between different traits were determined as described by Singh and Chaudhary [6]. Path coefficients were determined following the method suggested by Dewey and Lu [4].

2.1 Screening for Drought Stress Using PEG- 6000

In vitro screening for drought tolerance at seeding stage using osmotic solution polyethylene glycol 6000 (PEG6000) were taken to screened the selected maize genotypes at seedling stage.

Paper Towel Method: Sterilised petri dishes and the seeds bed (Whatman paper) were used. Twenty seeds of each variety have been transferred into a sterilised 9 cm diameter petri dish lined with autoclaved filter paper and separated by two layers of filter paper. Then 3 ml of Polyethylene glycol (PEG 6000) was added to each petri dish with different concentrations and a control was maintained using distilled water for drought screening at seedling stage. The petri plates were kept in a dark room for 7 days and allowed germination and growth of seeds. After 7th days, observations were taken. The experiment used at four different levels of treatment (Table 2) with four replications.

Table 1. List of Genotypes

S.NO	Genotypes	SNO	Genotypes	S.NO	Genotypes
1	MGW-392	11	MGW-406	21	MGC-222
2	MGW-325	12	MGC-89	22	MGW-316
3	MGW-353	13	MGW-421	23	MGW-400
4	GP-68	14	MGW-304	24	GP-54
5	MGW-373	15	MGC-240	25	GP-176
6	MGC-18-1	16	MGC-80	26	GP-170
7	BML-51	17	MGC-192	27	MGW-313
8	GP-87	18	BML-14	28	MGC-50
9	MGW-428	19	MGW-364	29	BML-41
10	MGC-124	20	MGW-357	30	MGW-318

Table 2. Preparation of PEG (polyethylene glycol 6000) solution in 100 ml distilled water [7]

S.No	PEG 6000 concentrations	PEG 6000 in grams dissolvedin 100 ml of distilled water	Number of seeds treated in PEG 6000
1	Control	0	20
2	10	10	20
3	15	15	20
4	20	20	20

The observations were recorded 7 days after inducing PEG treatment. Data was recorded on root length, shoot length, seedling length, seedling fresh weight, seedling dry weight, seedling vigour index- II, seedling vigour index- I, relative water content (%), germination percentage.

3. RESULTS AND DISCUSSION

3.1 Correlation Studies

The correlation studies were made for grain yield per plant and other yield attributing traits. The association between two variables which can be directly observed is termed as phenotypic correlation, whereas the inherent or heritable association is known as genotypic correlation and in the present study in general the genotypic correlation coefficients (Table 3) were higher than phenotypic (Table 4) value indicating that strong intrinsic association is reduced at phenotypic level due to environmental effects. Path analysis is used to determine the amount of direct and indirect effect of the causal components on the effect component. Keeping this in view, the present study was therefore, designed to understand genetic basis of grain yield components and to develop suitable selection criteria for future maize breeding program. Days to fifty per cent tasseling was significantly and positively correlated with harvest index (0.361, 0.286) at both genotypic and phenotypic levels, respectively. It also had negative significant correlation with anthesis to silking interval (-0.380, -0.232), ear height (-0.517, -0.304) and biological yield per plant (-0.341, -0.226) at both genotypic and phenotypic levels, respectively. Leaf width was significantly and positively correlated with ear height (0.384, 0.247) at both genotypic and phenotypic levels, respectively. Number of grain rows per cob was significantly and positively correlated with number of grains per row (0.510, 0.435), cob girth (0.490, 0.303), cob weight (0.634, 0.595), biological yield per plant (0.605, 0.548), harvest index (0.390, 0.287) and grain yield per plant (0.662, 0.603) at both genotypic and phenotypic levels, respectively. Cob weight was significantly and positively correlated with 100 grains weight (0.310, 0.259), biological yield per plant (0.953, 0.895), harvest index (0.386, 0.267) and grain yield per plant (0.991, 0.913) at both genotypic and phenotypic levels, respectively. 100 grains weight was significantly and positively correlated with biological yield per plant (0.369, 0.338) and grain yield per plant (0.331, 0.285) at both genotypic and phenotypic levels, respectively and biological yield per plant was significantly and positively correlated with grain yield per plant (0.931, 0.862) at both genotypic and phenotypic levels, respectively. Grain yield per plant was significantly and positively correlated with plant height (0.445, 0.395), leaf length (0.524, 0.367), ear height (0.432, 0.386), number of grain rows per cob (0.662, 0.603), number of grains per row (0.725, 0.636), cob girth (0.880, 0.582), cob weight (0.991, 0.913), biological yield per plant (0.931, 0.862), 100 grains weight (0.331, 0.285) and harvest index (0.512, 0.505) at both genotypic and phenotypic levels, respectively. There was positive and non-significant correlation with tassel length (0.150, 0.122) and number of cobs per plant (0.025, 0.038) at both genotypic and phenotypic levels, respectively. It also had negative non-significant correlation with days to fifty per cent tasseling (-0.146, -0.056), days to fifty per cent silking (-0.070, -0.045), anthesis to silking interval (-0.194, -0.185) and cob length (-0.014, -0.014) at both genotypic and phenotypic levels, respectively. These results are in consonance with Pavan et al*.,* [8]; Bhusal et al*.,* [9].

3.2 Path Analysis

Among all the characters, positive direct effect on grain yield per plant were recorded by number of cobs per plant (0.0118, 0.0038), leaf width (0.0508, 0.0102), cob length (0.1019, 0.0517), cob weight (0.6583, 0.0990), biological yield per plant (0.1535, 0.7747), harvest index (0.5052, 0.4855) at both genotypic and phenotypic levels, respectively (Tables 5 and 6). On the other hand, negative direct effect on grain yield per plant were recorded by days to fifty per cent silking (-0.0696, -0.0067), anthesis to silking interval (-0.1430, -0.0179), days to maturity (-0.0712, -0.0070), number of grain rows per cob (-0.1343, -0.0088) at both genotypic and phenotypic levels, respectively. These results are in consonance with Jakhar et al*.* [10], Kharel et al*.* [11] and Kandel et al*.* [12].

Number of cobs per plant had positive direct effect (0.0118, 0.0038) on grain yield per plant. Positive indirect effect *via* days to fifty per cent silking (0.0040, 0.0006), number of grains per row (0.0004, 0.0001), leaf width (0.0016, 0.0002), cob length (0.0004, 0.0001), cob girth (0.0002, 0.0000), cob weight (0.0004, 0.0001), harvest index (0.0006, 0.0002) at both genotypic and phenotypic levels, respectively. Cob length had positive direct effect (0.1019, 0.0517) on

Table 3. Genotypic correlation among the different traits evaluated in Maize during Rabi-2021-2022

	DFT	DFS	ASI	PH	LW	LL	TL	DM	EH	NCPP	NGPC	NGPR	CL	CG	CW	GW	BYPP	HI	GYPP
DFT	**1.000**	0.299*	-0.380**	-0.429**	-0.490**	-0.173	-0.246*	0.672**	-0.517**	-0.007	-0.192	0.031	-0.378**	-0.258*	-0.140	-0.269*	-0.341**	0.361**	-0.146
DFS		**1.000**	-0.405**	-0.133	-0.185	-0.264*	-0.888**	-0.296*	0.316*	0.342**	-0.599**	-0.258*	0.007	-0.092	-0.128	0.037	-0.140	0.106	-0.070
ASI			**1.000**	0.000	-0.165	0.219*	0.271*	-0.046	0.010	-0.314*	0.019	-0.264*	-0.027	-0.083	-0.168	0.376**	-0.164	-0.069	-0.194
PH				**1.000**	0.065	0.445**	0.084	0.057	0.769**	-0.108	0.493**	0.165	0.025	0.330*	0.473**	0.302*	0.567**	-0.098	0.445**
LW					**1.000**	-0.107	-0.045	0.281*	0.384**	0.138	0.121	0.193	-0.026	0.460**	0.198	0.112	0.273*	0.069	0.268*
LL						**1.000**	0.611**	0.237*	0.147	-0.231*	0.552**	0.519**	-0.139	0.372**	0.593**	0.100	0.502**	0.192	0.524**
TL							**1.000**	-0.078	-0.356**	-0.117	0.379**	0.302*	-0.054	0.282*	0.199	-0.121	0.118	0.043	0.150
DM								**1.000**	0.055	0.187	0.145	0.049	0.088	0.255*	0.323*	0.472**	0.288*	0.265*	0.370**
EH									**1.000**	-0.105	0.365**	0.035	0.154	0.246*	0.432**	0.320*	0.600**	-0.130	0.432**
NCPP										**1.000**	-0.065	0.033	0.037	0.019	0.031	-0.085	-0.009	0.055	0.025
NGPC											**1.000**	0.510**	-0.162	0.490**	0.634**	0.005	0.605**	0.390**	0.662**
NGPR												**1.000**	-0.274*	0.788**	0.708**	0.031	0.625**	0.464**	0.725**
CL													**1.000**	-0.214*	0.098	-0.130	0.149	-0.500**	-0.014
CG														**1.000**	0.781**	0.412**	0.717**	0.659**	0.880**
CW															**1.000**	0.310*	0.953**	0.386**	0.991**
GW																**1.000**	0.369**	0.099	0.331*
BYPP																	**1.000**	0.180	0.931**
HI																		**1.000**	0.512**
GYPP																			**1.000**

DFT=Days to fifty per cent tasseling, DFS=Days to fifty per cent silking, ASI=Anthesis to silking interval, PH=Plant height (cm), LW=Leaf width (cm), LL=Leaf length (cm), TL=Tassel length (cm), DM=Days to maturity, EH=Ear height (cm), NCPP=Number of Cobs per plant, NGPC=Number of grain rows per cob, NGPR=Number of grains per row, CL=Cob length (cm), CG=Cob girth (cm), CW=Cob weight (g), GW=100 grains weight (g), BYPP=Biological yield per plant (g), HI=Harvest Index (%), GYPP=Grain yield per plant (gm)

Table 4. Phenotypic correlation among the different traits evaluated in Maize during rabi-2021-2022

	DFT	DFS	ASI	PH	LW	LL	TL	DM	EH	NCPP	NGPC	NGPR	CL	CG	CW	GW	BYPP	HI	GYPP
DFT	**1.000**	-0.038	-0.232*	-0.174	-0.046	-0.010	-0.118	-0.080	-0.304*	0.022	-0.105	-0.020	-0.187	-0.112	-0.119	-0.091	-0.226*	0.286*	-0.056
DFS		**1.000**	-0.150	0.044	-0.024	-0.104	-0.405**	-0.031	0.138	0.162	-0.247*	-0.158	0.026	0.051	-0.014	0.006	-0.004	-0.092	-0.045
ASI			**1.000**	0.000	-0.093	0.160	0.256*	0.004	-0.004	-0.301*	0.021	-0.219*	-0.024	-0.062	-0.147	0.326*	-0.152	-0.062	-0.185
PH				**1.000**	0.065	0.359**	0.097	-0.011	0.652**	-0.080	0.451**	0.145	-0.012	0.222*	0.443**	0.243*	0.519**	-0.095	0.395**
LW					**1.000**	-0.013	-0.063	-0.060	0.247*	0.057	0.101	0.137	0.048	0.183	0.123	0.088	0.149	0.037	0.141
LL						**1.000**	0.481**	0.062	0.096	-0.130	0.361**	0.364**	-0.151	0.140	0.442**	0.167	0.376**	0.050	0.367**
TL							**1.000**	0.012	-0.310*	-0.097	0.329*	0.247*	-0.024	0.197	0.199	-0.082	0.125	-0.010	0.122
DM								**1.000**	-0.047	-0.054	-0.054	-0.061	-0.049	0.072	-0.159	-0.071	-0.097	-0.070	-0.124
EH									**1.000**	-0.105	0.328*	0.019	0.160	0.155	0.400**	0.265*	0.554**	-0.106	0.386**
NCPP										**1.000**	-0.078	0.026	0.023	-0.009	0.017	-0.084	-0.008	0.055	0.038
NGPC											**1.000**	0.435**	-0.148	0.303*	0.595**	-0.023	0.548**	0.287*	0.603**
NGPR												**1.000**	-0.209*	0.488**	0.636**	0.008	0.553**	0.315*	0.636**
CL													**1.000**	-0.178	0.076	-0.120	0.147	-0.373**	-0.014
CG														**1.000**	0.563**	0.286*	0.503**	0.324*	0.582**
CW															**1.000**	0.259*	0.895**	0.267*	0.913**
GW																**1.000**	0.338**	0.070	0.285*
BYPP																	**1.000**	0.024	0.862**
HI																		**1.000**	0.505**
GYPP																			**1.000**

DFT=Days to fifty per cent tasseling, DFS=Days to fifty per cent silking, ASI=Anthesis to silking interval, PH=Plant height (cm), LW=Leaf width (cm), LL=Leaf length (cm), TL=Tassel length (cm), DM=Days to maturity, EH=Ear height (cm), NCPP=Number of Cobs per plant, NGPC=Number of grain rows per cob, NGPR=Number of grains per row, CL=Cob length (cm), CG=Cob girth (cm), CW=Cob weight (g), GW=100 grains weight (g), BYPP=Biological yield per plant (g), HI=Harvest Index (%), GYPP=Grain yield per plant (gm)

Table 5. Direct and indirect effect at genotypic level for different quantitative traits on grain yield

	DFT	DFS	ASI	PH	LW	LL	TL	DM	EH	NCPP	NGPC	NGPR	CL	CG	CW	GW	BYPP	HI	GYPP
DFT	0.0387	0.0116	-0.0147	-0.0166	-0.0190	-0.0067	-0.0095	0.0260	-0.0200	-0.0003	-0.0074	0.0012	-0.0146	-0.0100	-0.0054	-0.0104	-0.0132	0.0140	-0.1462
DFS	-0.0208	-0.0696	0.0282	0.0092	0.0129	0.0184	0.0618	0.0206	-0.0220	-0.0238	0.0417	0.0180	-0.0005	0.0064	0.0089	-0.0025	0.0097	-0.0074	-0.0695
ASI	0.0543	0.0579	-0.1430	-0.0001	0.0236	-0.0312	-0.0387	0.0066	-0.0015	0.0448	-0.0027	0.0378	0.0038	0.0119	0.0240	-0.0537	0.0234	0.0098	-0.1941
PH	0.0331	0.0102	0.0000	-0.0772	-0.0050	-0.0343	-0.0065	-0.0044	-0.0594	0.0083	-0.0381	-0.0127	-0.0019	-0.0255	-0.0365	-0.0233	-0.0438	0.0076	0.445**
LW	-0.0249	-0.0094	-0.0084	0.0033	0.0508	-0.0055	-0.0023	0.0143	0.0195	0.0070	0.0061	0.0098	-0.0013	0.0234	0.0100	0.0057	0.0139	0.0035	0.268*
LL	0.0172	0.0262	-0.0217	-0.0442	0.0107	-0.0993	-0.0607	-0.0235	-0.0146	0.0229	-0.0548	-0.0515	0.0138	-0.0369	-0.0589	-0.0099	-0.0498	-0.0191	0.524**
TL	-0.0711	-0.2560	0.0780	0.0242	-0.0130	0.1763	0.2884	-0.0225	-0.1027	-0.0336	0.1092	0.0869	-0.0154	0.0812	0.0573	-0.0350	0.0340	0.0124	0.1497
DM	-0.0479	0.0211	0.0033	-0.0041	-0.0200	-0.0169	0.0055	-0.0712	-0.0039	-0.0133	-0.0103	-0.0035	-0.0063	-0.0182	-0.0230	-0.0336	-0.0205	-0.0189	0.370**
EH	-0.1926	0.1179	0.0038	0.2867	0.1430	0.0548	-0.1327	0.0205	0.3728	-0.0390	0.1362	0.0130	0.0573	0.0917	0.1611	0.1191	0.2238	-0.0485	0.432**
NCPP	-0.0001	0.0040	-0.0037	-0.0013	0.0016	-0.0027	-0.0014	0.0022	-0.0012	0.0118	-0.0008	0.0004	0.0004	0.0002	0.0004	-0.0010	-0.0001	0.0006	0.0245
NGPC	0.0258	0.0805	-0.0025	-0.0663	-0.0162	-0.0741	-0.0509	-0.0195	-0.0491	0.0088	-0.1343	-0.0685	0.0217	-0.0659	-0.0851	-0.0006	-0.0812	-0.0524	0.662**
NGPR	0.0067	-0.0554	-0.0567	0.0354	0.0414	0.1113	0.0647	0.0105	0.0075	0.0070	0.1094	0.2145	-0.0588	0.1689	0.1519	0.0067	0.1339	0.0994	0.725**
CL	-0.0385	0.0008	-0.0027	0.0025	-0.0027	-0.0141	-0.0055	0.0090	0.0157	0.0037	-0.0165	-0.0279	0.1019	-0.0218	0.0100	-0.0133	0.0152	-0.0509	-0.0141
CG	0.0968	0.0345	0.0312	-0.1239	-0.1727	-0.1397	-0.1058	-0.0957	-0.0924	-0.0070	-0.1841	-0.2957	0.0802	-0.3755	-0.2931	-0.1545	-0.2692	-0.2475	0.880**
CW	-0.0921	-0.0840	-0.1107	0.3114	0.1300	0.3906	0.1308	0.2125	0.2845	0.0203	0.4170	0.4662	0.0647	0.5139	0.6583	0.2038	0.6273	0.2538	0.991**
GW	-0.0610	0.0083	0.0852	0.0686	0.0254	0.0227	-0.0275	0.1070	0.0724	-0.0193	0.0010	0.0071	-0.0295	0.0933	0.0702	0.2267	0.0838	0.0223	0.331*
BYPP	-0.0523	-0.0214	-0.0251	0.0870	0.0419	0.0771	0.0181	0.0442	0.0921	-0.0014	0.0928	0.0959	0.0229	0.1100	0.1462	0.0567	0.1535	0.0276	0.931**
HI	0.1825	0.0535	-0.0346	-0.0497	0.0347	0.0970	0.0217	0.1338	-0.0657	0.0276	0.1970	0.2342	-0.2525	0.3330	0.1948	0.0498	0.0908	0.5052	0.512**
GYPP	-0.1462	-0.0695	-0.1941	0.445**	0.268*	0.524**	0.1497	0.370**	0.432**	0.0245	0.662**	0.725**	-0.0141	0.880**	0.991**	0.331*	0.931**	0.512**	1.0000

DFT=Days to fifty per cent tasseling, DFS=Days to fifty per cent silking, ASI=Anthesis to silking interval, PH=Plant height (cm), LW=Leaf width (cm), LL=Leaf length (cm), TL=Tassel length (cm), DM=Days to maturity, EH=Ear height (cm), NCPP=Number of Cobs per plant, NGPC=Number of grain rows per cob, NGPR=Number of grains per row, CL=Cob length (cm), CG=Cob girth (cm), CW=Cob weight (g), GW=100 grains weight (g), BYPP=Biological yield per plant (g), HI=Harvest Index (%), GYPP=Grain yield per plant (gm)

Table 6. Direct and indirect effect at phenotypic level for different quantitative traits on grain yield

	DFT	DFS	ASI	PH	LW	LL	TL	DM	EH	NCPP	NGPC	NGPR	CL	CG	CW	GW	BYPP	HI	GYPP
DFT	-0.0270	0.0010	0.0063	0.0047	0.0012	0.0003	0.0032	0.0021	0.0082	-0.0006	0.0028	0.0005	0.0051	0.0030	0.0032	0.0024	0.0061	-0.0077	-0.0558
DFS	0.0003	-0.0067	0.0010	-0.0003	0.0002	0.0007	0.0027	0.0002	-0.0009	-0.0011	0.0017	0.0011	-0.0002	-0.0003	0.0001	0.0000	0.0000	0.0006	-0.0453
ASI	0.0041	0.0027	-0.0179	0.0000	0.0017	-0.0028	-0.0046	-0.0001	0.0001	0.0054	-0.0004	0.0039	0.0004	0.0011	0.0026	-0.0058	0.0027	0.0011	-0.1849
PH	-0.0081	0.0020	0.0000	0.0466	0.0030	0.0167	0.0045	-0.0005	0.0304	-0.0037	0.0210	0.0068	-0.0006	0.0103	0.0206	0.0113	0.0242	-0.0044	0.395**
LW	-0.0005	-0.0002	-0.0009	0.0007	0.0102	-0.0001	-0.0006	-0.0006	0.0025	0.0006	0.0010	0.0014	0.0005	0.0019	0.0013	0.0009	0.0015	0.0004	0.1414
LL	-0.0004	-0.0040	0.0062	0.0139	-0.0005	0.0387	0.0186	0.0024	0.0037	-0.0050	0.0140	0.0141	-0.0058	0.0054	0.0171	0.0064	0.0145	0.0019	0.367**
TL	0.0040	0.0137	-0.0086	-0.0033	0.0021	-0.0162	-0.0338	-0.0004	0.0105	0.0033	-0.0111	-0.0083	0.0008	-0.0066	-0.0067	0.0028	-0.0042	0.0004	0.1224
DM	0.0006	0.0002	0.0000	0.0001	0.0004	-0.0004	-0.0001	-0.0070	0.0003	0.0004	0.0004	0.0004	0.0003	-0.0005	0.0011	0.0005	0.0007	0.0005	-0.1236
EH	0.0256	-0.0116	0.0003	-0.0548	-0.0208	-0.0081	0.0261	0.0039	-0.0840	0.0089	-0.0275	-0.0016	-0.0134	-0.0130	-0.0336	-0.0222	-0.0465	0.0089	0.386**
NCPP	0.0001	0.0006	-0.0011	-0.0003	0.0002	-0.0005	-0.0004	-0.0002	-0.0004	0.0038	-0.0003	0.0001	0.0001	0.0000	0.0001	-0.0003	0.0000	0.0002	0.0382
NGPC	0.0009	0.0022	-0.0002	-0.0040	-0.0009	-0.0032	-0.0029	0.0005	-0.0029	0.0007	-0.0088	-0.0038	0.0013	-0.0027	-0.0052	0.0002	-0.0048	-0.0025	0.603**
NGPR	0.0003	0.0021	0.0030	-0.0020	-0.0019	-0.0049	-0.0034	0.0008	-0.0003	-0.0003	-0.0059	-0.0136	0.0028	-0.0066	-0.0086	-0.0001	-0.0075	-0.0043	0.636**
CL	-0.0097	0.0014	-0.0012	-0.0006	0.0025	-0.0078	-0.0012	-0.0025	0.0083	0.0012	-0.0076	-0.0108	0.0517	-0.0092	0.0039	-0.0062	0.0076	-0.0193	-0.0138
CG	-0.0004	0.0002	-0.0002	0.0009	0.0007	0.0005	0.0008	0.0003	0.0006	0.0000	0.0012	0.0019	-0.0007	0.0039	0.0022	0.0011	0.0020	0.0013	0.582**
CW	-0.0118	-0.0013	-0.0145	0.0438	0.0122	0.0437	0.0197	-0.0157	0.0396	0.0017	0.0589	0.0629	0.0075	0.0557	0.0990	0.0256	0.0885	0.0265	0.913**
GW	0.0025	-0.0002	-0.0089	-0.0067	-0.0024	-0.0046	0.0022	0.0019	-0.0073	0.0023	0.0006	-0.0002	0.0033	-0.0078	-0.0071	-0.0274	-0.0093	-0.0019	0.285*
BYPP	-0.1751	-0.0030	-0.1180	0.4024	0.1153	0.2910	0.0965	-0.0748	0.4290	-0.0059	0.4242	0.4285	0.1139	0.3900	0.6931	0.2620	0.7747	0.0182	0.862**
HI	0.1389	-0.0444	-0.0299	-0.0461	0.0180	0.0243	-0.0050	-0.0339	-0.0515	0.0268	0.1391	0.1530	-0.1809	0.1574	0.1298	0.0338	0.0114	0.4855	0.505**
GYPP	-0.0558	-0.0453	-0.1849	0.395**	0.1414	0.367**	0.1224	-0.1236	0.386**	0.0382	0.603**	0.636**	-0.0138	0.582**	0.913**	0.285*	0.862**	0.505**	1.0000

DFT=Days to fifty per cent tasseling, DFS=Days to fifty per cent silking, ASI=Anthesis to silking interval, PH=Plant height (cm), LW=Leaf width (cm), LL=Leaf length (cm), TL=Tassel length (cm), DM=Days to maturity, EH=Ear height (cm), NCPP=Number of Cobs per plant, NGPC=Number of grain rows per cob, NGPR=Number of grains per row, CL=Cob length (cm), CG=Cob girth (cm), CW=Cob weight (g), GW=100 grains weight (g), BYPP=Biological yield per plant (g), HI=Harvest Index (%), GYPP=Grain yield per plant (gm)

Table 7. Mean performance of Maize genotypes at various levels of PEG-6000 treatment

S. no	Genotypes	Root length	Shoot length	Seedling Length	Seedling Fresh weight	Seedling dry weight	Seed Vigour Index-2	Seed Vigour Index-1	Relative Water Content	Germination (%)
1	**MGW-392**	14.18	12.73	26.90	10.35	1.48	82.78	1151.80	66.00	39.17
2	**MGW-325**	14.83	14.12	28.83	10.43	1.78	116.63	1578.60	46.25	51.67
3	**MGW-353**	13.90	14.10	28.00	10.53	1.68	87.70	1206.75	50.18	38.33
4	**GP-68**	16.03	16.45	32.48	11.20	2.05	121.40	1742.18	52.40	50.00
5	**MGW-373**	14.48	14.63	29.10	10.13	1.80	89.88	1285.20	51.60	37.50
6	**MGC-18-1**	14.33	15.20	29.43	11.00	1.63	82.88	1276.70	60.13	37.50
7	**BML-51**	13.57	15.00	28.58	10.65	2.25	121.15	1323.15	54.57	42.50
8	**GP-87**	15.00	16.43	31.43	10.95	2.08	102.95	1275.63	54.65	39.17
9	**MGW-428**	10.90	12.48	23.40	8.40	1.70	89.08	1094.90	52.75	37.50
10	**MGC-124**	13.48	13.08	26.55	9.85	1.75	88.60	1124.03	64.65	39.17
11	**MGW-406**	13.73	13.45	27.18	9.83	2.15	118.05	1260.43	56.55	43.33

S. no	Genotypes	Root length	Shoot length	Seedling Length	Seedling Fresh weight	Seedling dry weight	Seed Vigour Index-2	Seed Vigour Index-1	Relative Water Content	Germination (%)
12	**MGC-89**	13.98	15.33	29.25	10.40	2.18	98.78	1073.40	63.15	33.33
13	**MGW-421**	13.30	13.55	26.85	9.15	1.53	74.70	1181.43	60.05	39.17
14	**MGW-304**	11.10	13.10	24.20	7.08	1.40	71.47	938.50	56.03	34.17
15	**MGC-240**	12.83	16.88	29.55	10.15	1.75	82.73	1082.53	54.85	34.17
16	**MGC-80**	10.50	11.50	21.93	8.63	1.85	100.65	972.80	57.98	36.67
17	**MGC-192**	19.33	19.43	38.78	12.98	2.38	165.58	2374.75	56.75	60.00
18	**BML-14**	13.70	14.90	28.53	11.47	1.95	125.10	1422.76	58.08	44.17
19	**MGW-364**	12.55	14.30	26.88	10.78	1.95	109.60	1211.78	58.25	40.00
20	**MGW-357**	15.43	15.03	30.38	12.05	2.20	149.73	1471.33	54.48	43.33
21	**MGC-222**	13.38	14.40	28.70	11.88	2.00	120.23	1644.40	61.30	52.50
22	**MGW-316**	15.63	14.43	30.05	7.88	1.88	105.65	1213.63	61.10	36.67
23	**MGW-400**	13.83	17.37	31.20	10.87	1.50	87.32	1492.65	58.10	41.67
24	**GP-54**	15.53	17.10	32.63	10.63	1.57	99.90	1651.90	49.48	48.33
25	**GP-176**	11.85	15.03	26.88	10.85	2.25	129.25	1417.35	56.85	45.83
26	**GP-170**	13.38	14.93	28.30	11.98	1.95	118.74	1503.40	64.88	50.00
27	**MGW-313**	14.10	15.50	29.60	9.70	2.15	119.83	1442.85	61.57	46.67
28	**MGC-50**	14.70	14.38	29.08	10.55	1.80	85.33	1161.93	62.00	35.83
29	**BML-41**	15.68	15.30	30.98	11.28	2.03	96.00	1319.65	57.93	36.67
30	**MGW-318**	13.50	14.63	28.13	10.90	1.50	78.55	1325.03	49.95	44.17
	C.D. (5%) Ai-Aj	0.295	0.308	0.619	0.222	0.041	3.161	38.26	1.154	0.951
	F (Prob)	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000
	PEG: 1	18.204	18.904	37.131	12.977	3.294	261.740	2934.71	59.390	79.112
	PEG: 2	15.024	16.984	31.944	11.564	2.200	109.829	1590.25	56.684	49.778
	PEG: 3	13.397	13.794	27.171	10.070	1.318	34.094	547.37	57.470	25.779
	PEG: 4	9.197	9.613	18.917	7.054	0.674	10.364	290.52	54.787	13.222
	C.D. (5%) Bi-Bj	0.108	0.112	0.226	0.081	0.015	1.154	13.97	0.421	0.347
	C.V. %	2.632	2.584	2.675	2.645	2.724	3.779	3.55	2.514	2.817

grain yield per plant. Positive indirect effect *via* days to fifty per cent silking (0.0008, 0.0014), ear height (0.0157, 0.0083), number of cobs per plant (0.0037, 0.0012), cob weight (0.0100, 0.0039) and biological yield per plant (0.0152, 0.0076) at both genotypic and phenotypic levels, respectively. Biological yield per plant had positive direct effect (0.1535, 0.7747) on grain yield per plant. Positive indirect effect *via* plant height (0.0870, 0.4024), leaf width (0.0419, 0.1153), leaf length (0.0771, 0.2910), tassel length (0.0181, 0.0965), ear height (0.0921, 0.4290), number of grain rows per cob (0.0928, 0.4242), number of grains per row (0.0959, 0.4285), cob length (0.0229, 0.1139), cob girth (0.1100, 0.3900), cob weight (0.1462, 0.6931), 100 grains weight (0.0567, 0.2620) and harvest index (0.0276, 0.0182) at both genotypic and phenotypic levels, respectively. Harvest index had positive direct effect (0.5052, 0.4855) on grain yield per plant. Positive indirect effect *via* days to fifty per cent tasseling (0.1825, 0.1389), leaf width (0.0347, 0.0180), leaf length (0.0970, 0.0243), number of cobs per plant (0.0276, 0.0268), number of grain rows per cob (0.1970, 0.1391), number of grains per row (0.2342, 0.1530), cob girth (0.3330, 0.1574), cob weight (0.1948, 0.1298), 100 grains weight (0.0498, 0.0338) and biological yield per plant (0.0908, 0.0114) at both genotypic and phenotypic levels, respectively.

3.3 Study the Responses of Maize Genotypes to Varying Degrees of PEG-Induced Drought Stress

Mean performance of thirty genotypes including under study at various levels of PEG-6000 treatment for nine qualitative characters are presented in Table 7. Germination (%) was observed maximum in genotype MGC-192 (60.00%), MGC- 222 (52.50%) and MGW-325 (51.67%). Maximum relative water content was observed in genotype MGW-392 (66.00), GP-170 (64.88) and MGW-124 (64.65)**.** Maximum seed vigour index-1 was observed in genotype MGC-192 (2374.75), MGC-222 and GP-68 (1742.18)**.** Maximum seed vigour index-2 was observed in genotype MGC-192 (165.58), MGW-357 (149.73) and GP-176 (129.25)**.** The genotype MGC-80 (10.50 cm) has the shortest root length. Among the thirty genotypes, MGC-192 (19.33 cm), GP-68 (16.03 cm), and BML-41 (15.68 cm) had the longest root length. MGC-192 (19.43 cm), MGW-400 (17.37 cm), and GP-54 (17.10) had the longest root length. Genotype MGC-192 (38.78 cm) followed by GP-68 (32.48 cm) and GP-54 (32.63 cm) was having high seedling length among thirty genotypes and MGC-192 (12.98 g) followed by MGW-357 (12.05 g) and GP-170 (11.98 g) was having high seedling fresh weight Whereas, genotype MGC-192 (2.38 g) followed by GP-176 (2.25 g) and MGW-357 (2.20 g) was having high seedling dry weight among thirty genotypes. Similar findings were confirmed by Partheeban et al., [13], Bukhari et al., [14], Dar et al., [15].

4. CONCLUSION

Analysis of variance revealed that the difference among the genotypes for all the characters were highly significant indicating wide range of variability for most of the traits therefore there is great scope for selection of elite genotype for crop improvement. The association studies indicated that the plant height, leaf length, ear height, number of grain rows per cob, number of grains per row, cob girth, cob weight, biological yield per plant, 100 grains weight and harvest index seems to be important yield attributing characters, thus selection of genotypes based on these characters will be useful in further breeding programmes. Path analysis revealed that number of cobs per plant, leaf width, cob length, cob weight, biological yield per plant and harvest index had highest direct positive effects on seed yield. Hence these traits should be considered for genetic improvement. Among these genotypes, MGC-192 has shown high root length (19.3), shoot length (19.4), seedling length (38.7), seedling fresh weight (12.975), seedling dry weight (2.37), seedling vigour index 1 (2374.7), seedling vigour index II (165.5), germination percentage MGC-192 (60%) and MGW-392 has shown high relative water content (66).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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