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Impact on morpho-physiological and yield traits in maize in environments differing in water availability

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Abstract
A group of hundred maize lines were evaluated for irrigation impact. Individual effects of irrigation regimes over years revealed highly significant mean sum of squares due to lines for all traits indicating importance of water for these traits at critical stages of plant development. High GCV values for all the traits were recorded under stress conditions for most of the traits except canopy temperature and canopy temperature that revealed increment in GCV with increment in water. Highest GCV was recorded for ears plant^{-1}, followed by ASI and grain yield plot^{-1}. Desirable influence of water on all maturity, morphological, yield, quality, physiological traits was noticed. On an average irrigation regimes resulted in early maturity and low ASI. For yield and related traits water application recorded highest average increase in grain yield plot^{-1} (47.80%) followed by kernel row^{-1} (32.47%), ear plant^{-1} (18.09%), 100 grain weight (14.30%). Elite lines identified exhibited earliness in maturity and superiority in morpho-physiological, yield, quality traits indicating the inbuilt potential of lines. These elite lines exhibited maximum % decrease over population mean for maturity, canopy temperature and stomatal count with maximum percent increase for morpho-physiological and yield traits in stress regime as compared to well watered regime.

Keywords: irrigation, drought, anthesis-silking interval (ASI), heritability, variability, genetic gain

Introduction
Zea mays L. is one of the main cereal and fodder crop grown worldwide and among the abiotic stresses drought stress also affects the maize crop causing yield losses. Drought is a complex quantitative trait governed by many genotype × environment (G × E) interactions, therefore, improvement and stability in maize grain yield is topmost priority among the research programmes to meet the requirements of population and industries. Drought sensitivity varies from stage to stage in different crops. In maize extreme sensitivity is confined to the period of 2 to 22 days after silking, with a peak at 7 days, and almost complete barrenness can occur if maize plants are stressed in the interval from just before tassel emergence to the beginning of grain fill (Grant *et al*., 1989) [15]. Drought when coincides with flowering and grain filling periods of maize growth, causes yield losses of 40-90 percent (Nesmith and Ritchie, 1992) [19]. Maize is thought to be more drought susceptible than other crops during three weeks bracketing flowering stage because: (i) its florets develop virtually simultaneously and are usually borne on a single ear on a single stem, (ii) drought affects rate of photosynthesis, therefore reduced supply of current assimilate, and (iii) drought at flowering also reduces the capacity of developing kernels to use available assimilates (Westgate, 1997) [25].
Grain yield, the trait of interest is always used as a selection criterion in almost every breeding programme for crop improvement. Heritability and genetic variability of grain yield is less under stress conditions as compared to normal conditions. Selection for yield in optimal environments is less effective and not accurate in identifying the cultivars that perform good in low-yielding stressful conditions (Banziger and Lafitte, 1997) [6, 7]. Hence, breeding programmes in stress environments use secondary traits, where heritability remains high, while genetic and phenotypic correlations between grain yield and those secondary traits increase sharply, which give good estimate of yield potential before final harvest. are stable and easy to measure, not associated with yield penalty under optimal conditions, observed easily at or before flowering time to reduce the risk of crossing undesirable (Banziger *et al*., 1997; Edmeades *et al*., 1998) [6, 14] for example anthesis silking interval (ASI) and ears per plant (reduced barrenness) in maize, stay green (reduced lower leaf senescence) and root growth. Therefore, this study was aimed to study the impact of irrigation on a set of hundred homozygous maize inbred lines assembled from diverse sources and at different stages of selfing to understand the effect of factors like irrigation and years in identifying the underlying mechanisms for inbuilt tolerance of lines towards moisture stress.

Magnitude of variability and percent increase for traits viz., morphologic maturity, physiological, yield and quality traits over different irrigation regimes and years was studied especially in stress moisture management regime for the lines.

Materials and Methods

Location: The study was conducted in the experimental fields of Dryland Agriculture Research Station, Budgam, Kashmir, India, AIRCP Srinagar centre during Kharief 2014, 2015 to analyze the interaction and responses of both indigenous and exogenous maize germplasm inbred lines at different stage of selfing towards water-deficit stress. Soil moisture content of the experimental field (0–15 cm) was measured gravimetrically for all the plots.

Experimental design and layout: Study material comprised of a group of hundred maize lines comprising inbred lines from AICRP (All India Co-ordinated Research Programme) Maize Srinagar Centre, CIMMYT (International Maize and Wheat Improvement Centre) Mexico, AAU, Anand and MPUAT, Udaipur. Inbred lines were planted in a factorial randomized complete block design with two replications. Each inbred line was planted in two row experimental plot of 1 metre length with inter and intra row spacing of 60 x 20 cm. The materials were evaluated against four moisture management regimes viz;

1. Well Watered (WW): water provided by flooding at 5 intervals viz; 3 weeks (21 days), 6 weeks (42 days), 9 weeks (63 days), 12 weeks (84 days) and 15 weeks (102 days) after sowing.
2. Intermediate Stress (IS): water provided by flooding at 2 intervals viz; 3 weeks (21 days) and 6 weeks (42 days) after sowing.
3. Mild Stress (MS): water provided by flooding at 1 interval; 3 weeks (21 days) after sowing.
4. Stress (S): No water provided.

Phenotyping: The recommended fertilizer dose was provided during cropping season. The fields were monitored for pest and disease with protection measures. The meteorological data, including weekly average minimum and maximum temperature, relative humidity and total rainfall received during the crop growth period was recorded during the dry season for both the years as suggested by Banziger *et al.* (2000) [8]. Data was recorded on four representative plants of each inbred line in each replication for various maturity, morphological, physiological, yield and quality traits for all the traits viz., days to 50% tasseling, days to 50% silking, anthesis-silking interval (ASI), days to maturity, plant height (cm), ear height (cm), leaf relative water content (LRWC %). LRWC was estimated as per the method of Barrs and Weatherly (1962) [9]. Five discs from the third leaf from top were collected randomly in each line per replication per treatment a week before tasseling and weighed which was considered as fresh weight. The weighed leaf discs were allowed to float on distilled water in a petridish and allowed to absorb water for four hours. After four hours, the leaf discs were blotted gently and weighed. This was referred to as the turgid weight. After taking turgid weight the leaf discs were dried in an oven at 80 °C for 48 hours and the dry weight was recorded The RWC was calculated by using the following formula.

$$\text{Relative water content (RWC\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

Canopy temperature was recorded on five leaves of each selected inbred line per replication per treatment at 13.00-15.00 from fully exposed leaves to sun light using infrared thermometer (Fluke 62 MAX - FLUKE Corporation, USA). Stomatal count (mm^{-2}) was determined by nail polish impression method (Roberts and King, 1987) [22]. Five leaf strips from each inbred line per replication per treatment were selected for counting the number of stomata. Stomatal count was calculated by using the formula given below and expressed as number of stomata mm^{-2} (Aneja, 2001) [3].

$$\text{Stomatal count} = \frac{\text{Number of stomata}}{\text{Area of microscopic field}} \times 100$$

SPAD meter measures the relative greenness of leaves by measuring the absorbance of leaf in two wavelength regions. The SPAD meter measures the absorbance of the leaf in the red and near far red regimes. Using these two transmittances, the meter calculates a numerical SPAD value, which is proportional to the amount of chlorophyll present in the leaf. Chlorophyll content of youngest and the most fully expanded leaves from the top of five inbred line per replication per treatment was recorded using SPAD meter (Hanstech, Model CL-01) before flowering and before maturity and was expressed in SPAD value (Nepolean *et al*., 2012) [18]. Yield traits included ears plant^{-1}, kernels row^{-1}, 100 grain weight (g), grain yield plot^{-1} (g) and protein content (%). Mean/medium values for all the traits were estimated for analysis of variance (ANOVA), components of variability and heritability for individual and pooled analysis using Windostat version 9.1 software.

Results: Individual effects of different moisture management regimes over years revealed highly significant mean sum of squares due to lines over different moisture management regimes viz; stress, intermediate stress, mild stress and well watered for all the traits under study indicating importance of water for these traits at critical stages of plant development (Table-1). Year effects also exhibited highly significant mean sum of squares revealing differential response of individual effects of moisture management regimes over years. Line × year interaction exhibited significant mean sum of squares for all the traits except for leaf relative water content and stomatal count. Irrigation within year within replication exhibited significant mean sum of squares for all the traits except for maturity traits viz. days to 50% tasseling, days to 50% silking, anthesis-silking interval and days to maturity. Application of water did not affect the genetic components of variance (Table-1-2). High GCV values for all the traits were recorded under stress conditions for most of the traits except canopy temperature before flowering and canopy temperature before maturity that revealed increment in GCV with increment in water. Highest GCV was recorded for ears plant^{-1} (28), followed by anthesis-silking interval (24.86), grain yield plot^{-1} (19.58), chlorophyll content before flowering (15.13), leaf relative water content (13.19), protein content (12.69), kernels row^{-1} (12.06), stomatal count (10.94), 100 grain weight (9.77), ear height (7.50), plant height (6.49), days to 50% silking (6.63), days to 50% tasseling (5.75), days to maturity (3.89) and canopy temperature before flowering (3.58). Similar trend was observed for genetic gain as percent of mean. High genetic gain under stress conditions was observed for ears plant^{-1} (50.74), followed by anthesis-silking interval (50.14), chlorophyll content before maturity (42.78), grain yield plot^{-1} (40.33), chlorophyll content before flowering (30.11), protein content (26.09), leaf relative water content (25.89), stomatal count (20.53), 100 grain weight (18.36), kernels row^{-1} (18.32), ear height (13.49), days to 50% silking (12.94), plant height (12.81), days to 50% tasseling (10.96), days to maturity (7.37) and canopy temperature before flowering (6.59), whereas canopy temperature before flowering and canopy temperature before maturity recorded high genetic gain at well watered conditions to the tune of 7.01 and 11.27 respectively.

Identified elite lines exhibited earliness in maturity and superiority in morphological, physiological, yield, quality and seedling traits indicating inbuilt potential of these identified elite lines towards moisture stress (Table-2). Elite lines, on an average, recorded earliness for days to 50% tasseling by 11.98% in pooled analysis over population mean with a range of 11.07 to 13.53% in pooled analysis. Data pooled over years recorded superiority of KDM-1156 exhibiting earliness by 13.53% followed by KDM-912A (13.45%), KDM-961 (12.97%), KDM-932A, KDM-402 and KDM-1236 (12.42%), KDM-918A (12.34%), KDM-1051 (11.54%), CM-129 (11.46%), KDM-361A and KDM-717 (11.30%), KDM-343A and KDM-372 (11.22%), KDM-331 (11.15%), KDM-463 (11.07%). Similarly, elite lines exhibited earliness for days to 50 percent silking by 13.14% in pooled analysis with a range of 12.27 to 14.60% over population mean. For ASI which is an important drought tolerant trait all the elite lines exhibited superiority over population mean by 33.63%. For days to maturity elite lines exhibited early maturity by 7.81% with a range of 7.20 to 8.54%. Elite lines were observed to be taller in the population as revealed by the percent increase in plant height over population mean. Elite lines on an average recorded superiority of 10.39% with a range of 9.22 to 11.62% in pooled analysis. For ear height elite lines showed superiority over population mean by 10.46% and it ranged from 11.55 to 9.58%. Among physiological traits elite lines showed percent increase over population mean for leaf relative water content, chlorophyll content, whereas for canopy temperature and stomatal count percent decrease over population mean was observed. Elite lines recorded maximum percent increase of 16.80% in pooled analysis associated with a range of 13.67 to 21.52% in pooled analysis.

Elite lines revealed low canopy temperature viz., 8.23% in pooled analysis as percent decrease over population mean associated with a range of 9.70 to 7.33% in pooled analysis respectively. For stomatal count elite lines exhibited 14.15% decrease with a range of 20.71 to 1.92% decrease over population mean. Elite lines for chlorophyll content revealed superiority by 28.46% with range of 21.26 to 34.10%. For yield and yield related traits viz; ears plant^{-1}, kernels row^{-1}, 100 grain weight and grain yield plot^{-1} superiority in terms of percent increase over population mean was recorded. Elite lines, on an average, exhibited 48.67% increase in ears plant^{-1} over population mean associated with a range of 39.60 to 57.19% in pooled analysis. Elite lines exhibited heavier grains as compared to the population. For grain yield plot^{-1} elite lines possessed superiority over population mean by exhibiting 34.99% with a range of 15.57 to 53.48%. Data pooled over years revealed superiority of elite line KDM-361A for grain yield plot^{-1} by 53.48% followed by elite line CM-129 (52.86%), KDM-372 (51.99%), KDM-331 (50.34%), KDM-1051 (38.65%), KDM-402 (38.64%), KDM-717 (36.85%), KDM-463 (35.79%), KDM-912A (33.88%), KDM-343A (27.69%), KDM-932A (26.42%), KDM-961 (25.46%), KDM-918A (18.85%), KDM-1156 (18.35%) and KDM-1236 (15.57%). Protein content also revealed superiority of elite lines over population mean.

Perusal of fig. 1 revealed response and superiority of elite lines in stress regimes over well watered regime pooled over years for all the traits. Elite lines exhibited maximum percent decrease over population mean for days to 50% tasseling in stress regime (13.29%) as compared to well watered moisture management regimes (10.87%). Similarly, for days to 50% silking maximum percent decrease over population mean ranged from 15.07% in stress regime to 11.38% in well watered regime. For anthesis-silking interval percent decrease over population mean ranged from 42.64% in stress regime to 21.67% in well watered regime. For days to maturity it ranged from 8.76% in stress regime to 7.49% in well watered regime. However, plant height recorded significant increase under moisture management regimes. Under stress conditions elite lines recorded 128.08 cm plant height and that was increased to 136.84 cm in mild stress followed by 199.24 cm under intermediate stress and 239.72 cm under well watered situations indicating response of elite lines to water. In elite lines plant height showed 8.96% increase over population mean in well watered conditions followed by 12.82% in stress conditions. Elite lines exhibited increase in ear height under the influence of water as revealed by height of 63.15 cm under stress regime which increased to 121.40 cm under well watered regime. Ear height showed percent increase over population mean from 8.84% in well watered regime to 14.01% in stress regime.

In elite lines, leaf relative water content was observed to be 61.52% under stress conditions, whereas under well watered regime it was observed to be 163.49%. Percent increase over population mean was observed to be maximum under stress regime (17.63%) followed by well watered regime (16.41%). Among physiological traits viz; canopy temperature before flowering, canopy temperature before maturity and stomatal count exhibited decline in performance of elite lines with application of water. Canopy temperature before flowering was observed to be 31.60˚C under stress conditions whereas under well watered regime it was observed to be 25.37˚C. Percent decrease over population mean was observed to be more under well watered regime (8.61%) followed by stress regime (8.06%). Canopy temperature before maturity was observed to be 19.33˚C under stress conditions whereas under well watered regime it was observed to be 13.84˚C. Percent decrease over population mean was observed to be more under well watered regime (15.25%) followed by stress regime (12.45%). Stomatal count was observed to be 67.28 mm^{-2} under stress conditions whereas under well watered regime it was observed to be 74.02 mm^{-2}. Percent decrease over population mean was observed to be more under stress regime (14.27%) followed by well watered regime (14.05%). However, chlorophyll content before flowering and chlorophyll content before maturity recorded high value 57.87 (SPAD Units) and 18.68 (SPAD Units) under well watered regime with low value of 49.60 (SPAD Units) and 15.41 (SPAD Units) under stress regime. For chlorophyll content before flowering and chlorophyll content before maturity elite lines on an average exhibited highest percent increase of 29.34 and 49.03% in stress regime followed by 27.61 and 45.03% in well watered regime. Elite lines exhibited superiority in terms of yield and yield related traits over population mean with application of water.

Among yield traits maximum influence of water was exhibited on grain yield plot^{-1} followed by kernels row^{-1}, 100 grain weight and ears plant^{-1}. In elite lines, grain yield plot^{-1} was observed to be 431.32 g under stress conditions whereas under mild stress it was 475.98 g, under intermediate stress it was 548.02 g and under well watered regime it was observed to be 772.69 g. Percent increase over population mean was observed to be maximum under stress regime (42.00%) followed by mild stress (37.66%), intermediate stress (35.20%) and well watered regime (29.72%). Elite lines recorded highest kernels row^{-1} (39.48) in well watered regime whereas lowest kernels row^{-1} (25.11) was recorded in stress regime. Percent increase over population mean was observed to be maximum under stress regime (21.30%) followed by well watered regime (15.51%). Maximum 100 grain weight (30.11 g) in well watered regime was observed for elite lines whereas lowest 100 grain weight (23.12 g) was observed in stress regime. Percent increase over population mean was observed to be maximum under stress regime (19.18%) followed by well watered regime (18.87%). Highest number of ears plant^{-1} (1.81) was recorded in well watered regime whereas lowest ears plant^{-1} (1.60) was recorded in stress regime. Percent increase over population mean was observed to be maximum under stress regime (60.00%) followed by well watered regime (38.17%). Protein content was highest in well watered regime (9.85) and lowest in stress regime (8.80). Percent increase over population mean was observed to be maximum under stress regime (22.22%) followed by well watered regime (20.71%). Figure-2 shows the impact of stress regime on elite and inferior lines.

Table 1: Analysis of variance for maturity, morphological, physiological, yield and quality trriats over irrigations (pooled over years) in inbred lines of maize (*Zea mays* L.) -Mean Sum of Squares

SV	d.f	DT				DS				ASI			
		S	IS	MS	WW	S	IS	MS	WW	S	IS	MS	WW
Rep	1	3.06	2.89	2.25	3.8	4.2	2.56	1.96	2.1	0.09	0.01	0.01	0.25*
Years	1	18.92**	26.01**	21.16**	21.62**	19.80**	24.01**	20.25**	22.56**	0.01**	0.04**	0.01**	0.01**
Lines	99	88.01**	75.10 **	65.33**	59.17**	130.99**	100.44**	86.33**	70.67**	6.81 **	2.47**	2.18**	0.75**
Line x Year	99	10.16**	10.24**	10.32**	10.31**	10.25**	10.27**	10.25**	10.35**	0.10*	0.21**	0.17**	0.12*
Rep x year	1	1.82	1.44	2.25	2.1	1.82	1.44	2.25	2.1	0.01	0.01	0.01	0.01
Irrigation within years within rep	3	7.93	10.11	8.55	9.17	8.6	9.33	8.15	8.92	0.03	0.01	0.01	0.08
Error	297	3.53	3.56	3.59	3.59	3.6	3.6	3.58	3.68	0.07	0.04	0.03	0.05
GCV		5.75	5.35	5.02	4.79	6.63	5.88	5.5	5.01	24.86	17.03	16.54	10.86
GG		10.96	10.06	9.32	8.8	12.94	11.31	10.47	9.35	50.14	33.89	33.06	19.29

*,** Significant at 5 and 1% level, respectively, Stress=S, Intermediate stress=IS; Mild stress= MS; Well watered=WW; Days to 50% tasseling=DT; Days to 50% silking=DS; anthesis-silking interval=ASI.

Table 1: (contd.):

SV	d.f	DM				PH				EH			
		S	IS	MS	WW	S	IS	MS	WW	S	IS	MS	WW
Rep	1	0.01	3.61	0.16	0.12	3485.19**	3562.71**	5815.20**	6764.81**	809.68**	890.69**	1453.36**	1691.22**
Years	1	19.27**	12.04**	15.09**	25.57**	121.58**	103.60**	181.50**	222.08**	111.64**	25.90**	46.00**	56.87**
Lines	99	144.95**	101.50**	106.81**	113.88**	205.00**	19817.49**	350.63**	405.50**	74.53**	50.04**	87.66**	101.37**
Line × Year	99	18.08**	15.04**	16.56**	8.74**	10.07**	9.08**	8.06**	4.14**	12.32**	5.44**	4.01**	6.46**
Rep× year	1	0.31	0.25	0.25	0.02	0.14	0.92	0.01	0.45	0.76	0.23	0.01	0.11
Irri within years within rep	3	7.76**	6.29	5.16	2.90**	1202.30**	3667.24**	1998.90**	2329.11**	307.36**	305.60**	499.79**	582.73**
Error	297	6.34	5.27	5.75	3.14	4.42	3.26	7.62	8.5	5.39	1.14	1.9	2.12
GCV		3.89	3.27	3.38	3.57	6.49	5.68	5.12	4.52	7.5	5.58	5.04	4.46
GG		7.37	6.1	6.29	6.97	12.81	11.19	10.1	8.95	13.49	10.99	9.94	8.82

*,** Significant at 5 and 1% level, respectively Days to maturity=DM; Plant height (cm)= PH; Ear height (cm)=EH

Table 1: (contd.):

SV	d.f	LRWC				CC				CT			
		S	IS	MS	WW	S	IS	MS	WW	S	IS	MS	WW
Rep	1	158.03**	158.58**	764.91**	988.33**	95.39**	95.46**	107.17**	115.07**	0.04	0.08	0.18	0.05
Years	1	506.25**	506.25**	2450.55**	3164.25**	200.19**	201.48**	226.75**	248.55**	446.98**	441.27**	353.19**	298.40**
Lines	99	195.51**	195.51**	946.32**	1221.99**	137.24**	136.98**	153.94**	169.45**	6.44**	6.20**	5.40**	4.85**
Line × Year	99	0.01	0.01	0.01	0.01	5.01**	4.03**	3.81**	3.55**	0.90**	1.04**	0.92**	0.77**
Rep × year	1	0.01	0.01	0.01	0.01	0.01	0.03	0.04	0.04	0.01	0.01	0.02	0.01
rri within years within rep	3	221.42**	221.61**	1071.82**	1384.19**	98.52**	98.98**	111.31**	121.21**	149.01**	147.11**	117.80**	99.48**
Error	297	4.9	4.91	23.74	30.67	2.44	2.32	2.74	2.99	0.38	0.41	0.35	0.3
GCV		13.19	12.79	12.54	12.28	3.58	3.59	3.7	3.84	15.13	15.07	14.41	14.22
GG		25.89	25.09	24.61	24.1	6.59	6.52	6.74	7.01	30.11	29.97	28.66	28.3

*,** Significant at 5 and 1% level, respectively; Leaf relative water content (%)=LRWC; Chlorophyll content (SPAD units)=CC; Canopy temperature (˚C)=CT

Table 1: (contd.):

SV	d.f	SC				EPP				KPR			
		S	IS	MS	WW	S	IS	MS	WW	S	IS	MS	WW
Rep	1	131.44**	131.44**	131.44**	153.33**	0.22**	0.21**	0.18**	0.19**	163.07**	163.09**	163.09**	234.84**
Years	1	189.06**	189.06**	189.06**	220.49**	1.19**	0.49**	0.50**	0.49**	242.08**	280.89**	2039.42**	861.39**
Lines	99	310.12**	309.48**	309.39**	360.85**	0.33**	0.31**	0.27**	0.25**	30.22**	30.22**	30.22**	43.53**
Line × Year	99	0.01	0.01	0.01	0.01	0.90**	0.85**	0.72**	0.67**	1.07**	1.01**	0.94**	0.71**
Rep × year	1	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.01	0.01	0.1
Irri within years within rep	3	106.83**	106.83**	106.83**	124.61**	0.47**	0.23**	0.23**	0.23**	135.05**	147.99**	734.17**	365.41**
Error	297	15.12	15.1	15.1	17.61	0.02	0.02	0.02	0.02	5.24	5.24	5.24	7.55
GCV		10.94	10.88	10.77	10.75	28	25.67	21.54	18.26	12.06	10.7	10.09	8.77
GG		20.53	20.41	20.21	20.18	50.74	46.31	37.73	31.93	18.32	16.25	15.32	13.32

*,** Significant at 5 and 1% level, respectively; Stomatal count (mm^{-2})=SC; ears $plant^{-1}$ =EPP and kernels row^{-1} =KPR

Table 1: (contd.):

SV	d.f	100 GW				GYP				PC			
		S	IS	MS	WW	S	IS	MS	WW	S	IS	MS	WW
Rep	1	23.49**	23.57**	23.51**	33.97**	20.67**	8.73**	14.92**	31.15**	0.10**	0.10**	0.10**	0.11**
Years	1	619.53**	298.14**	117.18**	76.04**	471.25**	652.11**	944.64**	2168.11**	1.41**	3.22**	3.20**	1.57**
Lines	99	14.71**	14.67**	14.59**	21.13**	14153.67**	14434.92**	17464.85**	27065.76**	3.34**	3.34**	3.34**	3.69**
Line × Year	99	9.07**	9.48**	7.06**	5.14**	10.32**	7.44**	7.01**	6.46**	0.11* *	0.09* *	0.09**	0.07**
Rep × year	1	0.14	0.92	0.01	0.45	0.76	0.23	0.01	0.11	0.01	0.01	0.01	0.01
Irri within years within rep	3	214.34**	107.24**	46.89**	36.67**	163.97**	220.28**	319.85**	733.09**	0.50**	1.10**	1.10**	0.56**
Error	297	0.7	0.7	0.71	1.02	1.67	0.56	0.76	1.58	0.01	0.01	0.01	0.01
GCV		9.77	9.44	9.09	8.85	19.58	17.37	16.3	13.8	12.69	12.33	11.99	11.75
GG		18.36	17.73	17.06	16.62	40.33	35.78	33.57	28.44	26.09	25.36	24.65	24.15

*,** Significant at 5 and 1% level, respectively, 100 grain weight (g)=100GW, grain yield $plot^{-1}$ (g)=GYP and protein content=PC.

Table 2: Percent increase/decrease of elite lines over population mean for maturity, morphological, physiological, yield and quality traits in maize inbred lines (pooled over year)

Elite lines	DT	% decrease	DS	% decrease	ASI	% decrease	DM	% decrease	PH	% increase	EH	% increase
CM-129	69.69	-11.46	72.69	-12.65	3.00	-33.63	137.88	-7.62	176.41	11.46	89.50	11.36
KDM-331	69.94	-11.15	72.94	-12.35	3.00	-33.63	138.13	-7.45	175.76	11.05	89.65	11.55
KDM-343A	69.88	-11.22	72.88	-12.42	3.00	-33.63	138.50	-7.20	174.11	10.01	88.35	9.93
KDM-361A	69.81	-11.30	72.81	-12.50	3.00	-33.63	137.94	-7.58	175.63	10.97	89.11	10.87
KDM-372	69.88	-11.22	72.88	-12.42	3.00	-33.63	137.56	-7.83	176.66	11.62	89.62	11.51
KDM-402	68.94	-12.42	71.94	-13.55	3.00	-33.63	137.00	-8.21	175.15	10.67	88.87	10.57
KDM-463	70.00	-11.07	73.00	-12.27	3.00	-33.63	138.38	-7.29	175.44	10.85	89.01	10.75
KDM-717	69.81	-11.30	72.81	-12.50	3.00	-33.63	138.19	-7.41	174.19	10.06	88.39	9.98
KDM-912A	68.13	-13.45	71.13	-14.52	3.00	-33.63	136.50	-8.54	174.14	10.03	88.36	9.94
KDM-918A	69.00	-12.34	72.00	-13.47	3.00	-33.63	137.61	-7.80	174.09	10.00	88.34	9.92
KDM-932A	68.94	-12.42	71.94	-13.55	3.00	-33.63	137.55	-7.84	173.65	9.72	88.12	9.64
KDM-961	68.50	-12.97	71.50	-14.07	3.00	-33.63	137.06	-8.17	173.55	9.66	88.07	9.58
KDM-1051	69.63	-11.54	72.63	-12.72	3.00	-33.63	137.69	-7.75	175.37	10.80	88.98	10.71
KDM-1156	68.06	-13.53	71.06	-14.60	3.00	-33.63	136.50	-8.54	173.77	9.79	88.18	9.71
KDM-1236	68.94	-12.42	71.94	-13.55	3.00	-33.63	137.31	-8.00	172.87	9.22	89.18	10.96
Elite mean	69.28	-11.98	72.28	-13.14	3.00	-33.63	137.59	-7.81	174.72	10.39	88.78	10.46
Population mean	78.71		83.21		4.52		149.25		158.27		80.37	

Table 2: (contd.):

Elite lines	LRWC	% increase	CT	% decrease	SC	% decrease	CC	% increase
CM-129	111.09	20.84	28.61	-9.11	64.39	-20.28	54.33	31.84
KDM-331	108.48	18.00	28.71	-8.80	64.63	-19.99	54.08	31.24
KDM-343A	107.39	16.82	29.00	-7.89	65.15	-19.34	52.79	28.10
KDM-361A	111.71	21.52	28.43	-9.70	64.04	-20.71	55.26	34.10
KDM-372	108.98	18.55	28.63	-9.06	65.99	-18.30	54.63	32.56
KDM-402	108.23	17.73	28.77	-8.60	66.60	-17.54	53.84	30.65
KDM-463	107.64	17.09	28.93	-8.10	67.04	-17.00	53.38	29.52
KDM-717	107.79	17.26	28.84	-8.39	66.61	-17.53	52.91	28.40
KDM-912A	107.44	16.87	29.12	-7.50	69.24	-14.28	53.08	28.80
KDM-918A	104.65	13.84	29.07	-7.65	75.24	-6.84	51.56	25.12
KDM-932A	105.60	14.87	28.97	-7.98	74.36	-7.94	52.26	26.81
KDM-961	104.74	13.94	29.03	-7.77	72.81	-9.85	51.99	26.16
KDM-1051	106.85	16.23	28.90	-8.19	79.22	-1.92	53.71	30.34
KDM-1156	105.43	14.69	29.12	-7.49	73.40	-9.13	50.34	22.15
KDM-1236	104.49	13.67	29.17	-7.33	71.37	-11.64	49.97	21.26
Elite mean	107.37	16.80	28.89	-8.23	69.34	-14.15	52.94	28.46
Population mean	91.93		31.48		80.77		41.21	

Table 2: (contd.)

Elite lines	EPP	% increase	KPR	% increase	100 GW	% increase	GYP	% increase	PC	% increase
CM-129	1.76	55.64	30.89	20.01	26.28	24.03	630.74	52.86	9.62	26.57
KDM-331	1.78	57.19	30.69	19.24	26.01	22.74	620.36	50.34	9.73	28.04
KDM-343A	1.63	43.92	30.15	17.11	25.16	18.73	526.90	27.69	9.09	19.58
KDM-361A	1.74	53.87	30.93	20.17	26.36	24.38	633.30	53.48	10.03	31.97
KDM-372	1.70	50.00	30.81	19.70	26.20	23.63	627.16	51.99	9.45	24.38
KDM-402	1.68	48.34	30.52	18.56	25.69	21.26	572.06	38.64	9.28	22.11
KDM-463	1.73	52.65	30.33	17.83	25.30	19.38	560.32	35.79	9.08	19.45
KDM-717	1.66	46.57	30.47	18.36	25.43	20.03	564.67	36.85	9.12	20.02
KDM-912A	1.76	55.97	30.18	17.26	25.12	18.53	552.44	33.88	9.05	19.05
KDM-918A	1.67	47.79	30.16	17.16	24.52	15.71	490.43	18.85	8.89	16.95
KDM-932A	1.68	48.45	30.26	17.54	25.07	18.33	521.64	26.42	9.03	18.78
KDM-961	1.68	48.45	30.18	17.24	24.94	17.69	517.68	25.46	9.01	18.51
KDM-1051	1.59	40.71	30.81	19.70	25.51	20.36	572.12	38.65	9.11	19.85
KDM-1156	1.58	39.60	30.01	16.58	24.62	16.20	488.35	18.35	8.95	17.72
KDM-1236	1.58	39.60	29.23	13.57	24.28	14.57	476.88	15.57	8.89	16.95
Elite mean	1.68	48.67	30.37	17.99	25.37	19.73	557.00	34.99	9.22	21.32
Population mean	1.13		25.74		21.19		412.63		7.6	

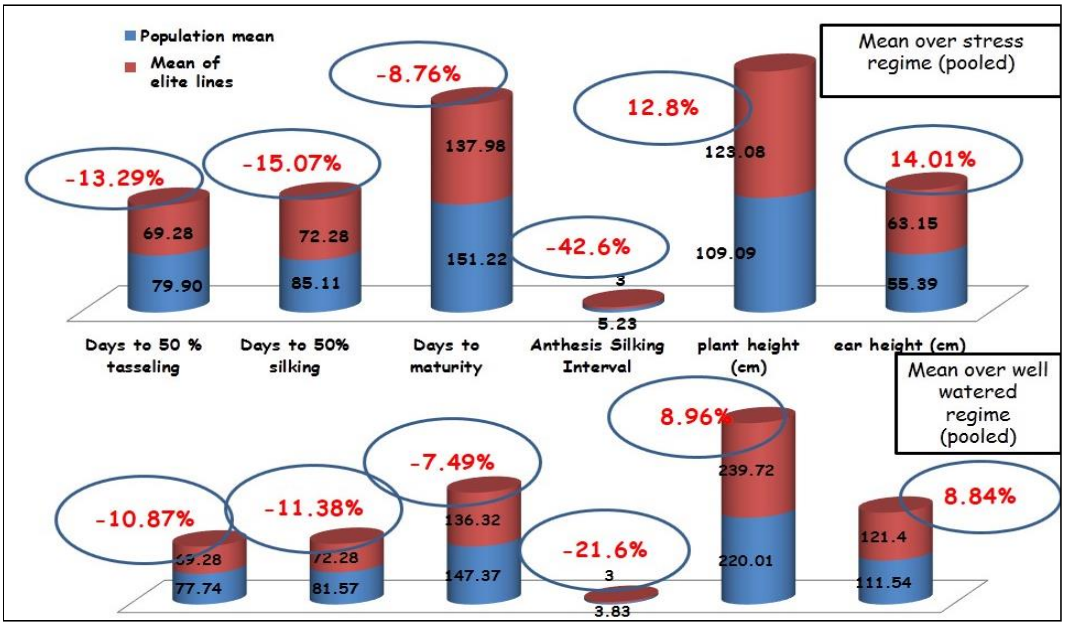
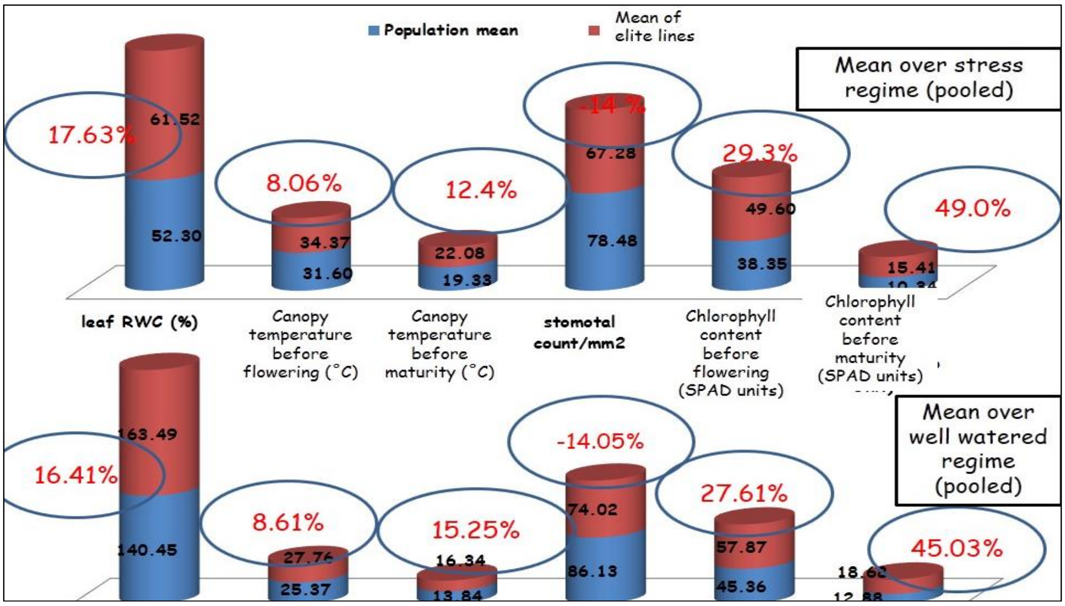


Fig 1: Identification of elite lines viz; KDM-361A, CM-129, KDM-372, KDM-331, KDM-1051, KDM-402, KDM-463, KDM-717, KDM-912A, KDM-932A, KDM-343A, KDM-961, KDM-918A, KDM-1156 and KDM-1236 by comparing the respective means



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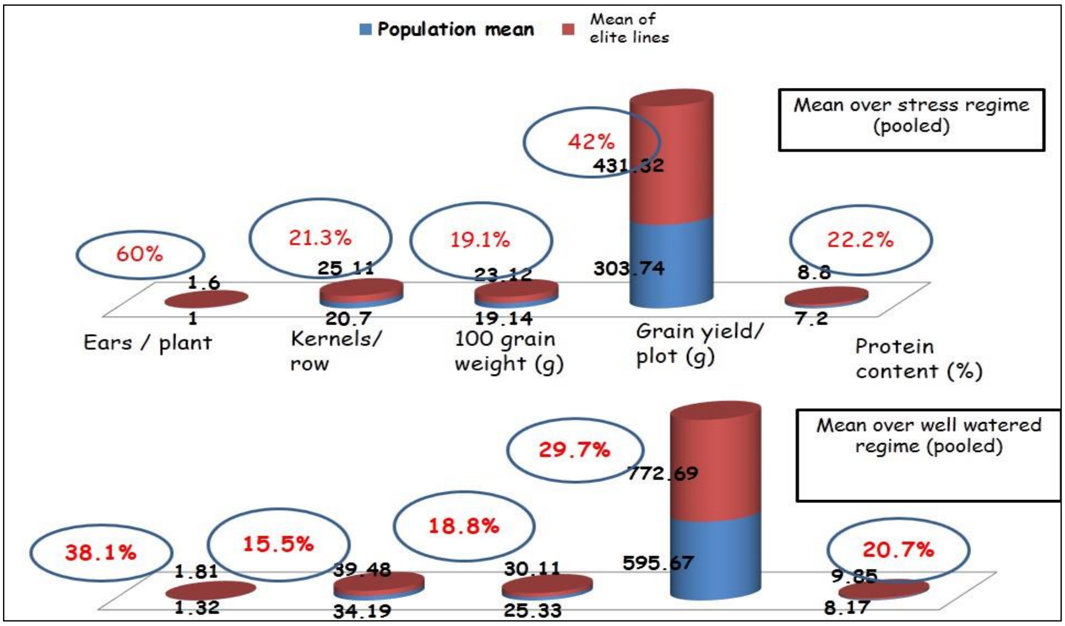

Fig 1: Identification of elite lines viz; KDM-361A, CM-129, KDM-372, KDM-331, KDM-1051, KDM-402, KDM-463, KDM-717, KDM-912A, KDM-932A, KDM-343A, KDM-961, KDM-918A, KDM-1156 and KDM-1236 by comparing the respective means

Elite lines viz; KDM-361A, CM-129, KDM-372, KDM-331, KDM-1051, KDM-402, KDM-463, KDM-717, KDM-912A, KDM-932A, KDM-343A, KDM-961, KDM-918A, KDM-1156 and KDM-1236 under stress

Inferior lines under Stress

Fig 2: Effect of stress regime on plant population of elite lines and inferior lines of maize

Well watered Intermediate stress Mild stress Stress

Fig 3: Effect of irrigation regimes on cob of elite maize line (KDM-372, KDM-343A and KDM-331)

Discussion: Dubey *et al*. (2010) [13] reported presence of significant genetic variation for all the studied traits under different moisture management regimes revealing importance of locations/seasons, environments, location/season × treatment and environment x treatment interaction for almost all the characters. Significant differences among the inbred lines for majority of the traits over different moisture management regimes and over years indicated the presence of wide genetic variation amenable for breeding for drought tolerance. Results were in conformity with Saindass *et al*. (2001) [23]; Zaidi *et al*. (2004) [26], Meseka *et al*. (2008) [17] Nepolean *et al*. (2012) [18]; Rajesh *et al*. (2013) [20] and Umar *et al*. (2015) [24]. Study materials were more responsive to application of water for enhanced plant height, ear height, leaf relative water content, stomatal count, chlorophyll content at flowering, kernels row^{-1}, 100 grain weight, grain yield plot^{-1}. Well watered situations enhanced plant height by 110.92 cm, ear height by 56.15 cm, leaf relative water content by 88.15%, stomatal count by 7.64 mm^{-2}, chlorophyll content at flowering by 7.01 SPAD Units, kernels row^{-1} by 13.48, 100 grain weight by 6.2 gm, grain yield plot^{-1} by 290.93 g, number of seminal roots by 1.56, number of crown roots by 0.98, fresh root weight by 2.21g and dry root weight by 0.88g. Whereas negative effects of water under well watered situations were observed for canopy temperature at flowering by 6.6˚C, canopy temperature at maturity by 5.7˚C, anthesis-silking interval by 1.3 days and maturity traits by 2 to 3 days. For protein content and primary root length little or no effect of water was observed on the performance of study materials as the population mean for these traits was observed to be similar under stress and well watered situations. Similar results on influence of water on positive and negative effect on traits under study have also been reported by Bolanoes and Edmeades (1993) [10]; Bolanoes and Edmeades (1996) [11]; Edmeades *et al*. (1997); Banziger (2000) [8]; Saindass *et al*. (2001) [23]; Campos *et al*. (2004) [12]; Zaidi *et al*. (2004) [26]; Zaidi *et al*. (2008) [28]; Dubey *et al*. (2010) [13] and Nepolean *et al*. (2012) [18].

Genetic advance being the function of heritability, selection intensity and phenotypic standard deviation indicates the magnitude of improvement in the desired direction that can be expressed in a particular character by selecting a certain proportion of population. Heritability (b.s.) was observed to be higher (> 60%) for all the maturity, morphological, physiological, yield, quality, seedling and root traits in individual year, pooled over years analysis and over different moisture management regimes suggesting that selection for improvement of these characters would be effective through phenotypic selection. Similar results were reported by Aminu and Izge (2012) [2] and Azam *et al*. (2014) [5]. High heritability estimates is indicative to preponderance of additive gene action. High values of heritability in broad sense indicate character is less influenced by environmental effects. High estimates of broad-sense heritability for most of the traits revealed that variations were transmitted to the progeny and indicated potential for developing high yielding varieties through selection of desirable plants in succeeding generations

(Aminu and Izge, 2012) [2]. However, the selection for improvement of such characters may not be useful because broad sense heritability is based on total genetic variance which includes additive, dominant and epistatic variances. Thus, heritability values coupled with high genetic advance would be more reliable and useful on correlating selection criteria (Ram Reddy *et al*., 2012) [21]. High heritability estimates with high genetic gain were observed in present set of lines for traits like anthesis-silking interval, leaf relative water content, stomatal count, chlorophyll content, ears plant^{-1}, grain yield plot^{-1} protein content and root related traits over years and over different moisture management regimes. Similar results were reported by Ali *et al.* (2010) [1] and Ram Reddy *et al.* (2012) [21]. High heritability estimates coupled with moderate genetic gain were observed in present set of lines for traits like days to 50% tasseling, days to 50% silking, plant height, ear height, canopy temperature before maturity, kernels row^{-1} and 100 grain weight. High heritability with moderate genetic advance arises from dominance or epitasis. Similar results were reported by Anshuman *et al*. (2013) [4] and Kumar *et al*. (2014) [16]. Therefore, for these traits hybridization followed by selection is expected to result in some promising recombinants. Low estimates of genetic gain were revealed for days to maturity and canopy temperature before flowering. Under different moisture management regimes, classification of genetic gain exhibited disparity for days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height and ear height. Results confirmed that phenotypic selection has a paramount significance for identification of elite lines as most of the characters exhibited variability due to genetic causes and thus, offers ample scope for improvement despite the fact that the two years could not be representative of random environment required to remove genotype x environment interaction, respectively. Maximum genetic gain was observed for fresh root weight (80.70%), chlorophyll content before maturity (45.10%), anthesis-silking interval (27.37%) and ear plant^{-1} (22.33%) indicating heritable nature of the characters for the materials under study.

Conclusion

Application of phenotypic selection in maize means that lines with excellent parameters should be selected for positive traits. Comparison of 100 diverse maize lines confirmed identification of 15 elite lines over years (viz., KDM-463, KDM-912A, KDM-717, KDM-343A, KDM-961, KDM-932A, KDM-1051, KDM-402, KDM-918A, KDM-1156, KDM-1236, KDM-372, CM-129, KDM-331 and KDM-361A) showing early maturity, least ASI, taller plants with more leaf relative water content, least canopy temperature, more chlorophyll content with good yield attributes viz., they had more number of ears per plant, more number of kernels row^{-1}, heavier grains, more grain yield plot^{-1} associated with better quality. Study confirmed that the identified lines were superior due to their inbuilt mechanism against moisture stress. Highest desirable *per se* performance under stress conditions revealed that variability among the lines was genetic in nature and application of water had little or no effect on improving the traits under study. With application of water the percent increase/decrease over population mean of elite lines, confirmed that crossing programme for development of single cross hybrid could be initiated between the lines.

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