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Genetic Variability Studies Involving Drought Tolerance Related Traits in Maize Genotypes

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Authors' contributions

This work was carried out in collaboration between all authors. Author IAD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZAD, AAL, K, PAS and SH managed the analyses of the study. Authors MSD and WA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was carried out at Dryland Agriculture Research Station (DARS) Budgam, under natural rainfed conditions during *Kharif* 2017 season. Thirteen varieties of maize were evaluated and the experiment was laid out in a randomized block design with three replications. Highest genotypic and phenotypic coefficient of variation was found in anthesis, silking interval and lowest in no of cobs/plant. High heritability coupled with a high genetic advance was observed for shoot weight, grains/cob and plant height. The genotypes KG-1 (122.00 days), KG-2 (124.00 days) and GM-6 (130.00 days) mature earlier indicating some escape mechanism in these genotypes under water stress. The ASI was lowest in KDM-72 (2.00 days) and KG-2 (2.00 days) and was highest in C-8 (5.00 days). Among the yield parameters plant height was significantly higher in C-15 (269.00) similarly, shoot weight was significantly higher in C-15 (917.50), cob height was significantly higher in C-8 (141.60), cob length was significantly higher in C-15 (22.33), no of cobs plant^{-1} was significantly higher in PM-5 (1.94), kernel rows cob^{-1} was significantly higher in C-4 (16.00), kernel rows^{-1} was significantly higher in C-6 (40.66), grains cob^{-1}

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was significantly higher in C-6 (596.46), 100-seed weight was significantly higher in C-15 (34.40) and grain yield plant^{-1} was significantly higher in C-6 (116.75). Among resource remobilization traits that are indicative of source sink efficiency cob partitioning index was significantly higher in PM-3 (87.70), cob harvesting index was significantly higher in PM-4 (62.64) and harvest index was significantly higher in PM-3 (33.57).

Keywords: Rainfed; Kharif; variability; anthesis silking interval; resource remobilisation.

1. INTRODUCTION

The drought has been highlighted as one of the major causes of reduced maize production and food insecurity across the globe and particularly, where agricultural production is mainly rainfed [1]. [2] estimated that the occurrence of midseason droughts, particularly at the vegetative and productive phases for maize, reduces yields by 39.3%. Hence, the only way to meet this demand is through intensification of cropping systems and increased productivity. But this goal of increasing maize production and productivity has been hindered by the global climate change which is imposing severe adverse effects on agriculture, resulting in rising temperatures, frequent heat waves, drought, floods, desertification and weather extremes [3]. It has been predicted that during growing season temperature in the tropics and subtropics will exceed the most extreme seasonal temperatures recorded from 1900 to 2006, while in temperate regions, the hottest seasons on record will become the standard temperature [4].

Maize requires a substantial quantity of water supply especially at critical stages such as knee height, tasseling and silking to ensure optimum production. However, it invariably suffers from varying degrees of water stress. Water being a mobile resource can be a major limiting factor for yield reduction. Plant breeding efforts to develop climate-resilient varieties of maize that could yield optimally under stress conditions will be determined by our ability to enhance acquisition of water by maize genotypes to meet the evaporative demands under drought. In this case, roots are of paramount importance and define the plants ability to procure water from different soil regions. Moreover, the amount of photosynthates which are translocated from stem to cob and then to seeds under drought also holds promise to understand plant response to drought. Fortunately for plant breeder's substantial natural variation has been observed for root architecture as well as biomass partitioning in maize under both stress and non-stress conditions and the variation is genetically determined [5,6,7,8]. The released varieties and pipeline composites of SKUAST-K and varieties explicitly bred for drought elsewhere have not been studied for different yield and resource remobilisation traits under rainfed conditions. Understanding the natural variation for such parameters for development of an integrated selection index is highly imperative. Breeding maize for drought tolerance is important to close the gap between rainfed and well-watered yields. Keeping the above views in mind, the present study was undertaken in maize to study the effect of water on different yield and resource remobilisation traits.

2. MATERIALS AND METHODS

The present study was conducted to evaluate maize genotypes for variability in yield and yield component traits at Dry land Agriculture Research Station (DARS) Budgam, Kashmir under natural rainfed conditions. The meteorological data of location was recorded for the period of an experiment for drawing inferences. Thirteen varieties of maize were evaluated in the present study viz., Shalimar maize composite-4 (C-4), C-6, C-8, C-15, Shalimar maize composite -7 (KDM-72), Kishan Ganga-1 (KG-1), Kishan Ganga-2 (KG-2), Pratap Makka -3 (PM-3), Pratap Makka-4 (PM-4), Pratap Makka-5 (PM-5), Pratap Makka-Chari-6 (PM Chari-6), Aravali Makka-1 (AM-1), Gujrat Makka-6 (GM-6). The field experiment was laid out in a randomized completely block design with 13 genotypes as treatments with three replications.

Data was recorded for the following traits: Days to tasseling (days), Days to silking (days), Anthesis silking interval, Days to maturity (days), Plant height (cm), Shoot weight (g), Cob height (cm), Cob length (cm), Number of Cobs/ plant, Kernel rows per cob, Kernels per row, Grains cob, 100-seed weight (g), Cobs per plant, Grain yield per plant (g), Shoot biomass (g), Cob partitioning index, Cob harvesting index, Harvest

Index, Variance (Genotypic variance, Phenotypic variance), Coefficient of variation (Genotypic coefficient of variation, Phenotypic coefficient of variation), Heritability (broad sense), Genetic advance, Genetic advance as percent of mean.

2.1 Meteorological Data

The weather parameters viz. temperature, relative humidity and rainfall recorded for the period of field experiment from May to October is presented below in the (Table-A). The mean temperature, relative humidity and rainfall recorded were 26.29°C, 82.07% and 2.18 mm respectively.

Table A. Weather parameters recorded during crop growing season (Monthly)

Month	Max temp. (°C)	Rainfall (mm)	RH (%)
MAY	18.71	3.89	87.67
JUNE	26.29	2.06	79.26
JULY	30.43	0.14	73.26
AUG	30.29	3.46	80.61
SEPT	27.32	3.17	86.38
OCT	28.93	0.40	85.23
Mean	26.99	2.18	82.07

Source: Division of Agronomy, SKUAST-K Shalimar, Kashmir, India.

3. RESULTS AND DISCUSSION

3.1 Mean Performance of 13 Maize Varieties for Maturity Traits under Rainfed Conditions

Among the genotypes days to tasseling, days to silking were significantly higher in PM-3 whereas anthesis silking interval and days to maturity were higher in C-8 and PM-3 respectively. However, lowest days to tasseling, days to silking, anthesis silking interval and days to maturity were found in KG-1, K G - 2 , KDM-72 and KG-2 and KG-1 respectively (Table 1). Severe drought stress at tasseling stage reduce the yield by affecting the number of kernels per row, number of kernel rows, harvest index, number of kernels per cob and grain yield per plant [9]. It is reported that silking is delayed by 6–9 days by prevalence of drought stress [10]. Delay in appearance of silk under drought stress conditions is responsible for increased anthesis-silking interval (ASI) which is very critical index for efficient completion of reproductive growth stage. Lower the value of ASI higher will be the productivity and vice the versa. Pollen grain productivity reduces from 3 to 8% on daily basis under drought stress [11]. Pollen shedding is accelerated and silking is delayed by drought prevalence for four consecutive days and this increases the anthesis-silking interval followed by 40–50% yield losses [12].

3.2 Mean Performance of 13 Maize Varieties for Yield Traits under Rainfed Conditions

Among the genotypes plant height, shoot weight and cob length were significantly higher in C-15. The plant height and shoot weight were found lowest in KG-1 whereas KG-2 recorded lowest cob length. Similarly, cob height was significantly higher in C-8 and lowest in PM-4. Kernel rows cob^{-1}, Grains cob^{-1}, No of cobs plant^{-1}, Kernels row^{-1}, 100-Seed weight, Grain yield plant^{-1} were significantly higher in C-4, C-6, PM-5, C-6, C-15 and C-6 respectively and were lowest in GM-6, KG-2, AM-1 and PM-4 respectively (Table 2).

Water plays a vital role in the vegetative growth of plant and causing improvement plant height. The finding of present study are similar to the findings of [13] those who observed highest maize plant height with irrigation. Similarly, [14] suggested that, maize crop are highly sensitive to drought stress conditions. The application of less water negatively responded on the plant height (crop sensitivity to drought stress) subsequently reducing the grain yield [15]. It was reported by various researchers that various plant growth attributes were reduced under different water stress conditions [16,17,18]. [19,20] reported that water use efficiency influenced the potential cob length. [21] found a positive association between kernel rows/cob and the amount of irrigation seasonally. The adding of excessive water was not significant to improve the production of grain yield. [22] also reported that deficit irrigation decreased the number of kernels per row, which was in agreement with findings of this study.

[23] reported that irrigation frequencies increased grain weight cob^{-1}. Maximum mean maize grain weight cob-1 produced by complete irrigation [13]. [24] those who reported reduction in grain and dry matter yield, and leaf area index by deficit irrigation conditions. The water stress

(deficit water) remarkably influenced productivity and quality in maize [25,26]. However, water availability is usually the most important crop production factor limiting yield and yield traits of maize.

3.3 Mean Performance of 13 Maize Varieties for Biomass Partitioning Traits under Rainfed Conditions

Among the genotypes cob partitioning index, cob harvesting index and harvest index were found significantly higher in PM-3, PM-4 and PM-3 respectively whereas lowest in PM-4, PM-3 and PM Chari-6 respectively (Table 3). Water stress during the grain-filling period reduces photosynthesis, induces early senescence and shortens the grain-filling period, but increases the remobilization of assimilates from the straw to the grains. Similar findings were also reported by [27,28,29]. The reduction in grain weight in response to drought or heat stress during the early periods of grain filling can mainly be attributed to the lower number of endosperm cells [30], while during the later stages stress results in the impairment of starch synthesis either because of the limited supply of assimilates for the grain [31] or the direct effects on the synthetic processes in the grain [32]. A considerable number of reports have been published on the effects of the environment on grain development in wheat [33,34].

3.4 Analysis of Variance

The analysis of variance for maturity, yield and biomass partitioning parameters are presented in Table-4 (i ii & iii). The mean sum of squares due to genotypes showed significant difference for all the characters. This indicates the presence of substantial genetic variability among the genotypes. In other words the performances of the genotypes with respect to these characters were statistically different, suggesting scope for improvement.

3.5 Estimates of Genetic Parameters

3.5.1 Variability

Variability plays an important role in crop breeding. An insight into the magnitude of variability present in crop species is of utmost importance as it provides the basis for selection. The total variation present in a population arises due to genotypic and environmental effects. Presence of substantial genetic variability in the breeding materials is essential for a successful plant breeding programme (Table 5).

3.5.2 Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV)

Variability is classified as low if co-efficient of variation is <10%, medium (10-20%) and high (>20%) as proposed by [35]. In the present study higher estimates of coefficients of variation were registered for anthesis silking interval (GCV 35.03%; PCV: 37.12%) followed by cob partitioning index (GCV: 32.52%; PCV: 35.74%), shoot weight (GCV: 26.99%; PCV: 29.70%), harvest index (GCV: 25.52%; PCV: 28.61%) are in the decreasing order of their magnitude, indicating the presence of large variation among the genotypes for these characters. These findings are in agreement with the findings of [36,37,38,39]. [40,41] reported high GCV and PCV values for grain yield per plant and anthesis silking interval; for harvest index by [42] and for shoot weight by [42].

Moderate estimates of coefficients of variation were recorded for grains cob^{-1} (GCV: 16.46%; PCV: 18.39%) followed by plant height (GCV: 14.82%; PCV 19.27%), kernels row^{-1} (GCV: 11.80%; PCV: 13.38%), cob length (GCV: 10.57%; PCV: 15.16%), cob height (GCV: 10.51%; PCV: 17.56%), no of cobs plant^{-1} (GCV: 10.19%; PCV:17.65%), grain yield plant^{-1} (GCV: 10.09%; PCV: 11.16%) are in the decreasing order of their magnitude. These findings are in agreement with the findings of [40] reported moderate PCV values for cob length and number of grain rows per ear; for cob height [43] reported moderate GCV.

Lower estimates of coefficients of variation were recorded for 100-seed weight (GCV: 9.90%; PCV: 10.02%) followed by cob harvesting index (GCV: 7.13%; PCV: 11.72%), kernel rows cob^{-1} (GCV: 6.23%; PCV: 9.15%), days to tasseling (GCV: 4.41%; PCV: 4.79%), days to silking (GCV: 4.39%; PCV: 4.59%), days to maturity (GCV: 3.75%; PCV: 4.00%) are in the decreasing order of their magnitude indicating the low range of variation found in these characters in the present experimental material, thus offers little scope for further improvement of these characters. These findings are in agreement with the findings of [44] reported low estimates for days to silking; [43] reported for days to tasseling and days to silking.

Table 1. Mean performance for maturity traits in maize (*Zea mays* L.) varieties under rainfed conditions

Genotypes	Days to tasseling (days)	Days to silking (days)	ASI (days)	Days to maturity (days)
C-15	72.00	75.33	3.33	135.00
C-6	76.00	79.00	3.00	140.00
C-4	74.00	77.66	3.66	140.00
KG-2	69.00	71.00	2.00	124.00
C-8	76.33	81.33	4.67	142.00
AM-1	76.00	80.00	4.00	136.00
GM-6	71.00	73.00	2.53	130.00
PM-3	83.00	85.66	2.66	147.00
PM CHARI-6	71.33	75.66	4.33	135.00
PM-4	80.66	83.33	2.66	139.00
PM-5	81.66	85.33	3.66	144.00
KDM-72	76.78	78.33	2.00	138.00
KG-1	68.00	71.33	3.33	122.00
CD ($P \leq 0.05$)	**2.37**	**1.78**	**1.70**	**3.26**
SEM$\pm$	**0.80**	**0.60**	**0.58**	**1.11**

A close perusal of genotypic and phenotypic coefficient of variation reveals that the difference between genotypic and phenotypic variability was very less for all the characters studied, which indicates the low effect of environment on the expression of these characters. On an average high to moderate phenotypic coefficient of variation and genotypic coefficient of variation were recorded anthesis silking interval, cob partitioning index, shoot weight, harvest index grains cob^{-1}, plant height, kernels row^{-1}, cob length, cob height, no of cobs plant^{-1} and grain yield plant^{-1} suggesting sufficient variability and thus offers scope for genetic improvement through selection of these traits.

3.5.3 Heritability

The heritability estimates were found to be high for 100-seed weight (97.76%) followed by days to silking (91.47%), anthesis silking interval (89.00%), days to maturity (87.60%), days to tasseling (84.87%), cob partitioning index (82.79%), shoot weight (82.55%), grain yield plant^{-1} (81.92%), grains cob^{-1} (80.08%), harvest index (79.57%), kernels row^{-1} (77.77%).

Moderate heritability was exhibited for plant height (59.16%) followed by cob length (48.62 %), kernel rows cob^{-1} (46.48 %), cob harvesting index (37.01%), cob height (35.80 %), no of cobs plant^{-1} (33.33 %). Similar results have been reported by [45,46,47,48,40] for grain yield per plant; for plant height by [42]; for cob height by [49]; for days to silking by [50]; for cob length by [36,51]; for number of grains per row by [49] and for 100 grain weight by [52]. In the present study, the estimates of heritability in broad sense were computed, which includes both additive and non-additive gene effects. High value of heritability in broad sense indicates that the character is least influenced by environmental effects.

The estimates of genotypic coefficient of variation (GCV) reflect the total amount of genotypic variability present in material. However, the proportion of this genotypic variability which is transmitted from parents to the progeny is reflected by heritability. [53] gave the concept of broad sense heritability. It determines the efficiency with which we can utilize the genotypic variability in a breeding programme. The genotypic variance and its components are influenced by the gene frequencies. Because the frequencies of genes differ from one population to another, estimates of heritability also vary from one population to another for a given character. The range of heritability was considered as low (<30%), medium (30-60%) and high (>60%) as proposed by [54]

3.5.4 Genetic advance

Heritability alone provides no indication of the amount of genetic improvement that would result

Table 2. Mean performance of maize varieties for morphological parameters and yield traits under rainfed conditions

Genotypes	Plant height (cm)	Shoot weight (g)	Cob height (cm)	Cob length (cm)	No of cobs plant^{-1}	Kernel rows cob^{-1}	Kernelsrow^{-1}	Grains cob^{-1}	100-Seed weight (g)	Grain yield plant^{-1} (g)
C-15	269.00	917.50	138.60	22.33	1.25	14.66	36.66	535.00	34.40	104.30
C-6	251.60	720.00	125.00	20.50	1.92	14.66	40.66	596.46	32.68	116.75
C-4	186.60	625.00	117.60	22.06	1.44	16.00	35.66	570.66	31.14	111.76
KG-2	155.00	295.00	98.60	14.00	1.66	12.00	25.33	304.00	28.59	96.43
C-8	264.60	520.00	141.60	18.66	1.29	12.66	34.66	438.66	28.98	97.91
AM-1	208.30	657.50	112.60	20.00	1.19	12.66	25.00	316.66	28.72	98.13
GM-6	181.60	480.00	96.60	17.33	1.86	12.00	32.33	388.00	26.89	91.06
PM-3	172.00	285.00	98.30	15.00	1.78	14.66	30.66	448.66	34.04	106.24
PM CHARI-6	228.60	795.00	119.60	18.23	1.84	12.66	29.66	374.66	26.99	93.23
PM-4	141.80	490.00	85.70	20.66	1.78	14.66	35.66	333.33	26.40	83.25
PM-5	217.30	770.00	120.00	18.00	1.94	12.66	26.33	524.00	34.18	109.67
KDM-72	207.30	362.50	117.60	21.83	1.77	14.66	39.00	570.66	32.65	110.74
KG-1	134.30	262.50	89.70	16.66	1.92	14.66	27.66	406.00	29.67	107.90
CD(P≤0.05)	**42.04**	**116.16**	**27.01**	**3.54**	**0.43**	**1.55**	**3.46**	**62.46**	**0.78**	**12.46**
SEM±	**14.32**	**39.56**	**9.20**	**1.20**	**0.15**	**0.53**	**1.18**	**21.27**	**0.26**	**4.24**

Table 3. Mean performance of maize varieties for biomass partitioning traits under rainfed conditions

Genotypes	Cob partitioning index	Cob harvesting index	Harvest index
C-15	37.10	58.41	21.68
C-6	26.90	54.93	14.20
C-4	47.80	52.77	25.24
KG-2	50.30	61.34	30.88
C-8	36.40	53.47	19.41
AM-1	27.00	49.96	13.46
GM-6	30.10	54.22	16.33
PM-3	87.70	40.73	33.57
PM CHARI-6	22.70	56.06	12.73
PM-4	22.70	62.64	14.22
PM-5	30.90	55.13	17.11
KDM-72	63.70	48.50	30.80
KG-1	73.60	45.47	33.41
CD ($P\leq0.05$)	**10.68**	**8.41**	**4.77**
SEM±	**3.64**	**2.86**	**1.62**

from selection of individual genotypes. Hence knowledge about genetic advance coupled with heritability is most useful. Genetic advance is the improvement in the mean of selected families over the base population [53,54]. A character exhibiting high heritability may not necessarily give high genetic advance. [54] showed that high heritability should be accompanied by high genetic advance to arrive at more reliable conclusion.

3.5.5 Genetic advance as percent mean

Expected genetic advance as percent of mean indicates the mode of gene action in the expression of a trait, which helps in choosing an appropriate breeding method. The range of genetic advance as per cent of mean was considered as low (<10%), medium (10-20%) and high (>20%) as proposed by [54].

The high genetic advance as percent of mean was recorded for anthesis silking interval (68.08%) followed by cob partitioning index (60.94%), shoot weight (50.50%), harvest index (46.89%), grains cob^{-1} (30.37%), plant height (23.48%), kernels row^{-1} (21.38%), no of cobs plant^{-1} (20.58%), 100-seed weight (20.10%).

Moderate estimates of genetic advance as percent mean were observed for grain yield plant^{-1} (18.81%) followed by cob length (15.13%), cob height (12.95%).

Low genetic advance as percent of mean was recorded for cob harvesting index (8.92%) followed by kernel rows cob^{-1} (8.66%), days to silking (8.64%), days to tasseling (8.37%), and days to maturity (7.22%).

The high heritability coupled with high genetic advance as percentage of mean was recorded for majority of characters viz., anthesis silking interval, cob partitioning index, shoot weight, harvest index, grains cob^{-1}, plant height, kernels row^{-1}, no of cobs plant^{-1}, 100-seed weight. Thus these traits are most probably controlled by additive gene action and hence these traits can be fixed by selection. Similar findings were reported for grain yield per plant by [55,56]; for plant height by [57]; for cob height by [50]; and for number of grains per row and 100-seed weight by [58]. High heritability coupled with moderate genetic advance as percentage of mean was recorded for days to 50 percent silking and ear girth. These two traits are most probably controlled by both additive and non-additive gene action. This decrease in genetic advance is due to influence of environment, hence these traits are less amendable for selection indicates that these characters showed intermediate expression for both the additive and dominance gene effect. So, the improvement of these characters is possible only through careful directional and restricted selection.

Table 4. Analysis of variance

i) Maturity Traits

Source of variation	d.f	Traits			
		Days to tasseling	Days to silking	ASI	Days to maturity
Replications	2	3.73	8.15	3.97	104.94
Genotypes	12	815.68**	862.92**	35.47**	1,928.30**
Error	24	47.15	26.51	24.30	88.80

ii) Morphological and Yield Traits

Source of variation	d.f	Plant height(cm)	Traits							
			Shoot weight(g)	Cob height (cm)	Cob length (cm)	No of cobs plant^{-1}	Kernel rows cob^{-1}	Kernels row^{-1}	Grains cob^{-1}	100- seed weight (g)	Grain yield plant^{-1}(g)
Replications	2	1,192.19	42,403.84	380.92	24.06	0.02	6.35	54.82	3,104.20	6.06	68.41
Genotypes	12	71,549.10**	1,655,867.30**	13,239.59**	343.09**	2.70*	62.76**	1,104.10**	409,280.41**	695.93**	4,572.43**
Error	24	14,764.97	112,696.15	6092.41	104.79	1.56	20.30	100.51	32,581.12	5.18	1,297.10

iii) Biomass Partitioning Traits

Source of variation	DF	Traits		
		Cob partitioning index	Cob harvesting index	Harvest index
Replications	2	99.81	34.53	80.85
Genotypes	12	14232.66**	1,338.41**	2,319.77**
Error	24	952.58	591.47	190.53

** Significant at 5% level, ** Significant at 1% level*

Table 5. Estimation of different variability parameters in maize (*Zea mays* L.)

Traits	Genotypic variance	Phenotypic variance	GCV	PCV	Heritability (h^2)	Genetic advance
Days to Tasseling	11.00	12.96	4.41	4.79	84.87	6.29
Days to Silking	11.80	12.90	4.39	4.59	91.47	6.76
ASI	0.77	0.87	35.03	37.12	89.00	1.71
Days to Maturity	26.16	29.86	3.75	4.00	87.60	9.85
Plant Height	891.20	1506.41	14.82	19.27	59.16	47.29
Shoot Weight	22215.54	26912.22	26.99	29.70	82.55	278.93
Cob Height	141.57	395.42	10.51	17.56	35.80	14.66
Cob Length	4.08	8.39	10.57	15.16	48.62	2.89
No of cobs plant^{-1}	0.03	0.09	10.19	17.65	33.33	0.35
Kernel rows cob^{-1}	0.73	1.58	6.23	9.15	46.48	1.19
Kernels row^{-1}	14.63	18.81	11.80	13.38	77.77	6.93
Grains Cob^{-1}	5458.19	6815.73	16.46	18.39	80.08	136.17
Cob Partitioning Index	191.06	230.75	32.52	35.74	82.79	25.90
Cob Harvesting Index	14.48	39.12	7.13	11.72	37.01	4.76
Harvest Index	30.89	38.82	25.52	28.61	79.57	10.21
100-Seed Weight	9.62	9.84	9.90	10.02	97.76	6.32
Grain Yield Plant^{-1}	108.99	133.03	10.09	11.16	81.92	19.45

4. CONCLUSION

- Under rainfed conditions the analysis of variance for yield and yield contributing parameters showed significant difference for all the characters. Hence, the data on all the seventeen traits which showed significant differences among the entries were subjected to further statistical analysis. In the field evaluation the genotypes were grown under natural rainfed conditions to differentiate lines on the basis of maturity, morphological, yield as well as resource remobilization. The genotypes GM-6 (130.0 days), KG-2 (124.0 days) and KG-1 (122.0 days) mature earlier indicating some kind of escape mechanism in these genotypes under water stress. The ASI was lowest in KDM-72 (2.00 days), KG-2 (2.00 days) and GM-6 (2.53 days) and was highest in C-8 (5.0 days) followed by PM Chari-6(4.33 days) and AM-1 (4.0 days). Among the yield parameters plant height was significantly higher in C-15 (269.0) followed by C-8 (264.4) and C-6 (251.6) similarly, shoot weight was significantly higher in C-15 (917.5) followed by PM Chari-6 (795.0) and PM-5 (770.0), cob height was significantly higher in C-8 (141.6) followed by C-15 (138.6) and C-6 (125.0), cob length was significantly higher in C-15 (22.33) followed by C-4 (22.06) and KDM-72 (21.83), no of cobs plant^{-1} was significantly higher in PM-5 (1.94) followed by C-6 (1.92) and KG-1 (1.92), kernel rows cob^{-1} was significantly higher in C-4 (16.0) followed by C-15 (14.66) and C-6 (14.66) PM-3 (14.66), PM-4 (14.66), KDM-72 (14.66) and KG-1 (14.66), kernel rows^{-1} was significantly higher in C-6 (40.66) followed by KDM-72 (39.00) and C-15 (36.66), grains cob^{-1} was significantly higher in C-6 (596.462) followed by C-4 (570.66) and KDM-72 (570.66), 100-seed weight was significantly higher in C-15 (34.40) followed by PM-5 (34.18) and grain yield plant^{-1} was significantly higher in C-6 (116.75) followed by C-4 (111.76) and KDM-72 (110.74).
- Among resource remobilization traits that are indicative of source sink efficiency genotypes cob partitioning index was significantly higher in PM-3 (87.70) followed by KG-1 (73.60) and KDM-72 (63.70), cob harvesting index was significantly higher in PM-4 (62.64) followed by KG-2 (61.34) and C-15 (58.41) and harvest index was significantly higher in PM-3 (33.57) followed by KG-1 (33.41) and KG-2 (30.88). The trait correlations were worked out to identify potential traits for indirect selection especially in case of genotypes where yield based evaluations are practically difficult all account of difficulty associated of managed stress conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Shiferaw B, Prasanna BM, Hellin J, Banziger M. Crops that feed the world 6: Past successes and future challenges to the role played by maize in global food security. Food Security. 2011;3:307–327.
2. Daryanto S, Wang L, Jacinthe PA. Global synthesis of drought effects on maize and wheat production. PLoS ONE. 2016;11(5): e0156362.
3. IPCC. The intergovernmental panel on climate change; 2009.
Available:http://www.ipcc.ch.
4. Battisti DS, Naylor RL. Historical warnings of future food insecurity with unprecedented seasonal heat. Science. 2009;323:240-244.
5. Hammer GLZ, Dong G, McLean A, Doherty C, Messina J, Schussler C, Zinselmeier Paszkiewicz S, Cooper M. Can changes in canopy and/or root system architecture explain historical maize yield trends in the U.S. Corn Belt? Crop Science. 2009;49:299-312.
6. Zhu J, Brown KM, Lynch JP. Root cortical aerenchyma improves the drought tolerance of maize (*Zea mays* L.). Plant, Cell & Environment. 2010;33(5):740-749.
7. Ge T, Sui F, Bai L, Tong C, Sun N. Effects of water stress on growth, biomass partitioning, and water-use efficiency in summer maize throughout the growth cycle. Acta Physio-logy Plant. 2012;34:1043.
8. Zaidi PH, Seetharam K, Krishna G, Krishnamurthy L, Gajanan S, Babu R, Zerka M, Vinayan MT, Vivek BS. Genomic regions associated with root traits under

drought stress in tropical maize. PloS One. 2016;11(10):0164340.
9. Anjum SA, Xie XY, Wang LC, Saleem MF, Man C, Lei W. Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research. 2011;6(9):2026-2032.
10. Dass S, Arora P, Kumari M, Dharma P. Morphological traits determining drought tolerance in maize (*Zea mays* L.). Indian Journal of Agriculture Research. 2001;35(3).
11. Rhoads FM, Bennett JM. Corn. In: Stewart BA, Nielsen DR (eds) Irrigation of agricultural crops. ASA-CSSA-SSSA. Madison; 1990.
12. Nielsen RL. Tassel emergence and pollen shed. Corny News Network, Purdue University; 2005.
13. Yazar A, Howell TA, Dusek DA, Copeland KS. Evaluation of crop water stress index for LEPA irrigated corn. Irrigation Science. 2012;18(4):171-180.
14. Otegui ME, Andrade FH, Suero EE. Growth, water use and kernel abortion of maize subjected to drought at silking. Field Crops Research. 1995;40(2):87-94.
15. English M. Deficit irrigation. I: Analytical framework. Journal of Irrigation and Drainage Engineering. 1990;116(3):399-412.
16. Al-Ashkar IM, Zaazaa EI, El Sabagh A, Barutçular C. Physio-biochemical and molecular characterization for drought tolerance in rice genotypes at early seedling stage. Journal of Experimental Biology and Agricultural Sciences. 2016;4(6):675-687.
17. Hassan MH, Arafat EFA, Sabagh AE. Genetic studies on agro-morphological traits in rice (*Oryza sativa* L.) under water stress conditions. Journal of Agriculture Biotechnology. 2016;1(02).
18. Rashwan E, Mousa A, Ayman ES, Barutçular C. Yield and quality traits of some flax cultivars as influenced by different irrigation intervals. Journal of Agricultural Science. 2016;8(10):226.
19. Igbadun HE, Salim BA, Tarimo AK, Mahoo HF. Effects of deficit irrigation scheduling on yields and soil water balance of irrigated maize. Irrigation Science. 2008;27(1):11-23.
20. Pandey RK, Marienville JW, Adum A. Deficit irrigation and nitrogen effect on maize in a sahelian environment. I. Grain yield components. Agriculture Water Management. 2000;46:1-13.
21. Payero JO, Tarkalson DD, Irmak S, Davison D, Petersen JL. Effect of irrigation amounts applied with subsurface drip irrigation on corn evapotranspiration, yield, water use efficiency, and dry matter production in a semiarid climate. Agricultural Water Management. 2008; 95(8):895-908.
22. Ertek A, Kara B. Yield and quality of sweet corn under deficit irrigation. Agricultural Water Management. 2013;129:138-144.
23. Hansona BR, Schwankl LJ, Schulbach KF, Pettygrove GS. A comparison of furrow, surface drip, and subsurface drip irrigation on lettuce yield and applied water. Agricultural Water Management. 1997;33(2-3): 139-157.
24. Abd el-wahed MH, Sanussi A, Saneoka H, Barutcular C. Improving yield and water productivity of maize grown under deficit-irrigated in dry area conditions. Azarian Journal of Agriculture. 2015;5:123-132.
25. El Sabagh A, Barutcular C, Saneoka H.. Assessment of drought tolerance maize hybrids at grain growth stage in Mediterranean area. Assessment. 2015;1: 37438.
26. Barutcular C, Sabagh AE, Konuskan O, Saneoka H, Yoldash KM. Evaluation of maize hybrids to terminal drought stress tolerance by defining drought indices. Journal of Experimental Biology and Agricultural Sciences. 2016;4(6):610-616.
27. Gebbing T, Schnyder H. Pre-anthesis reserve utilization for protein and carbohydrate synthesis in grains of wheat. Plant Physiology. 1999;121(3):871-878.
28. Plaut Z, Butow BJ, Blumenthal CS, Wrigley CW. Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and elevated temperature. Field Crops Research. 2004;86(2):185-198.
29. Altenbach SB, DuPont FM, Kothari KM, Chan R, Johnson EL, Lieu D. Temperature, water and fertilizer influence the timing of key events during grain development in a us spring wheat. Journal of Cereal Science. 2003;37(1):9-20.
30. Nicolas ME, Gleadow RM, Dalling MJ. Effect of post-anthesis drought on cell division and starch accumulation in

developing wheat grains. Annals of Botany. 1985;55(3):433-444.
31. Blum A. Improving wheat grain filling under stress by stem reserve mobilisation. Euphytica. 1998;100:77–83.
32. Yang J, Zhang J, Wang Z, Zhu Q, Liu L. Activities of fructan-and sucrose-metabolizing enzymes in wheat stems subjected to water stress during grain filling. Planta. 2004;220(2):331-343.
33. DuPont FM, Altenbach SB. Molecular and biochemical impacts of environmental factors on wheat grain development and protein synthesis. Journal of Cereal Science. 2003;38(2):133-146.
34. Yang J, Zhang J. Grain filling of cereals under soil drying. New Phytologist. 2006;169(2):223-236.
35. Sivasubramanian S, Madhavamenon P. Combining ability in rice. Madras Agricultural Journal. 1973;60:419-421.
36. Debnath SC. Genetic variability in maize. Bangladesh Journal of Agriculture. 1987; 12(4):217-221.
37. Saikia RB, Gargi S. Variability studies in some exotic maize genotypes. Indian Journal of Hill Farming. 2000;13(1-2):106-107.
38. Kumar PP, Satyanarayana E. Variability and correlation studies of full season inbred lines of maize (*Zea mays* L.). Journal of Research Acharya N. G. Ranga Agricultural University. 2001;29:71-75.
39. Satyanarayana E, Sai Kumar R. Genetic variability of yield and maturity components in maize hybrids. Current Research University Agricultural Sciences. 1996;25(1):10-16.
40. Singh P, Dass S, Kumar Y, Yagya Dutt J. Variability studies for grain yield and component traits in maize (*Zea mays* L.). Annals of Agriculture Biology and Research. 2003;8(1):29-31.
41. Abirami S, Vanniarajan C, Armugachamy S. Genetic variability Studies in maize (*Zea mays* L.) germplasm. Plant Archieves. 2005;5(1):105-108.
42. Robin S, Subramanian M. Genetic variability studies in biparental progenies in maize. Crop Research. 1994;7(1):77-83.
43. Manal Hefny. Genetic parameters and path analysis of yield and its components in corn inbred lines (*Zea mays* L.) at different sowing dates. Asian Journal of Crop Science. 2011;3(3):106-117.
44. Jha PB, Ghosh J. Variability and component analysis for fodder or dual purpose maize *(Zea mays* L.*).* Journal of Research Birsa Agriculture University. 2001;13:65-67.
45. Ayala OT, Churata BG. Estimates of genetic parameters in the maize composites (*Zea mays L.*) Arquitetura. In memorias de la III Reunion Latinomericana Y XVI Reunion de la Zona Andiana de Investigadores in maize. Cochabamba, Santa Cruz, Bolvia, Tomo II (edited by Avila LG, Cespedes PLM.) Cochabamba, Bolvia. 1995;769-779.
46. Choudhary AK, Chaudary LE. Genetic studies in some crosses of maize (Zea mays L.). Journal of Research Bisra Agricultural University. 2002;14:87-90.
47. Muhammad Akbar, Shakoor MS, Amer H, Muhmmad S. Evaluation of maize 3 way crosses through genetic variability, broad sense heritability, character association and path analysis. Journal of Agricultural Research Lahore. 2008;46(1):39-45.
48. Tusuz MA, Balabanli C. Heritability of main characters affecting yield and some maize varieties and determination of relationship among the characters. Anadoulu. 1997;7: 123-134.
49. Bhalla SK, Bali S, Sharma S, Sharma BK. Assessment of genetic variability and correlations in indigenous maize germ plasm of Himachal Pradesh. Himachal Journal of Agricultural Research. 1986;12(2):75-81.
50. Singh N, Prodhan HS. Character association in grain maize. Environment and Ecology. 2000;18:962-965.
51. Singh AK, Shahi JP, Singh JK, Singh RN. Genetic control of some traits in maize (*Zea mays* L.). Crop Improvement. 1998;28:56-61.
52. Liao SJ, Xu ZB, Wen SP. Analysis of combining ability for major quantitative characters in some maize inbred lines. Plant Breeding Abstracts. 1987;57:3724.
53. Lush JL. Inter-se, correlation and regression of characters. Proceeding of American Society of Animal Production. 1949;33:293-301.
54. Johnson HW, Robinson HF, Comstock RE. Estimates of genetic and environmental variability in soybean. Agronomy Journal. 1955;47:314-318.
55. Kumar S, Mishra SN. Genetic performance of S1 lines derived after modified ear to

row selection in maize. Annals of Agricultural Research. 1995;16(1):44-48.

56. Alake CO, Ojo DK, Oduwaye OA, Adekoya MA. Genetic variability and correlation studies in yield and yield related characters of tropical maize (*Zea mays* L.). An Agriculture Journal of Agricultural Sciences, Environment and Technology. 2008;8(1):241.

57. Ali AW, Hasan KA, Samir A, Ali AA. Genetic variances, heritability, correlation and path coefficient analysis in yellow maize crosses (*Zea mays* L.). Agriculture and Biology Journal of North America. 2010;1(4):630-637.

58. Suresh. Genetic analysis of protein and grain yield parameters in selected maize (*Zea mays*. L.) genotypes. Ph.D Thesis. Acharya NG Ranga Agricutural University, Hyderabad, India; 2004.

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