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Line × Tester analysis for morpho-physiological traits of *Zea mays* L. seedlings

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Key words: Heritability, Genetic advance, GCA, SCA, Line × Tester analysis, *Zea mays*

Abstract

Background: *Zea mays* L. is one of the most imperative cereal crop in world after wheat and rice. It is a used as food for human and feed for livestock. To meet the ever increasing demand, maize production can be increased by application of improved agronomic techniques to get varieties with higher qualitative and quantitative traits and resilience to abiotic stresses.

Methods: The genetic material was comprised of 8 parents and 12 F1 hybrids. The genotypes were sown in the iron treys filled with sand in three replications following completely randomized design. The data was recorded for fresh root length (FRL), fresh shoot length (FSL), fresh root-to-shoot length ratio (FRSLR), fresh root weight (FRW), fresh shoot weight (FSW), total fresh weight (TFW), fresh root-to-shoot weight ratio (FRSWR), dry root weight (DRW), dry shoot weight (DSW) and total dry weight (TDW), dry root-to-shoot weight ratio (DRSWR), chlorophyll contents (Ch.C), leaf temperature (LT), transpiration rate (E), photosynthetic rate (A), stomata conductance (gs), water use efficiency (WUS) and sub-stomata CO2 concentration (Ci). GCA (general combining ability) and SCA (specific combining ability) were calculated by using Kepmthorn, (1957) technique.

Results: Higher GCA of B-336 variety was recorded for FRL, FRW, FSW, TFW, A and Ci. Higher SCA of EV-1097Q × Pop/209, Sh-139 × Pop/209, EV-1097Q × B-316 and Sh-139 × B-316 varieties was recorded for FRL, FSL, FRW, FSW, TFW, A, Ci, WUE, LT, E and gs.

Conclusion: Higher heritability, genetic advance, GCA and SCA had decisive role in selection of drought tolerant maize varieties. F1 hybrids EV-1097Q × Pop/209, Sh-139 × Pop/209, EV-1097Q × B-316 and Sh-139 × B-316 showed higher SCA for all traits that persuaded that these hybrids may be used for higher grain and fodder yield under drought conditions.

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Introduction

Maize (*Zea mays* L.) is one of the most important cereal crop in world after wheat and rice. It is grown in Pakistan as a major cash crop under the area of 1.083 million hectares with production of 3990 thousand tones [1]. Maize is dual propose crop, used as a food for human and feed for livestock. It is also used as a raw material in medicine, food and textile industries. Maize was exported about 300 million tons during the year of 2013-2014. It contains 72 % starch, 10 % protein, 4.80 % oil, 9.50 % fiber, 3.0 % sugar, and 1.70 % ash [2]. There are many traits involved in the improvement of grain and fodder yield of maize and by improving those traits yield may be increased. Various morphological traits like fresh root weight (FRW), dry root weight (DRW), fresh shoot weight (FSW), dry shoot weight (DSW), fresh root length (FRL), fresh shoot length (FSL), and physiological traits like photosynthetic rate (A), chlorophyll contents (Ch.C), transpiration rate (E), leaf temperature (LT), stomata conductance (gs), water use efficiency (WUE) and sub-stomata CO2 concentration (Ci) play an important role in yield [3-7]. The present study was conducted to evaluate various maize parents and F1 hybrids for morpho-physiological traits at seedling stage for their general combining ability (GCA) and specific combining ability (SCA).

Methods

The present study was conducted in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan during cropping season of spring 2012-13. The genetic material was comprises of B-316 and POP/209 (male), B-11, B-327, Raka-poshi, B-336, Sh-139 and EV-1097Q (females) and their F1 developed by using 6 × 2 Line × Tester analysis design viz., B-11 x Pop/209, B-336 x Pop/209, EV-1097Q x Pop/209, B-327 x Pop/209, Raka-poshi x Pop/209, Sh-139 x Pop/209, B-11 x B-316, B-336 x B-316, EV-1097Q x B-316, B-327 x B-316, Raka-poshi x B-316 and Sh-139 x B-316. The genotypes were sown in the iron treys filled with sand in three replications following completely randomized design. The data was recorded for fresh root length, fresh shoot length (by using Vernier Caliper (Model RS232)), fresh root-to-shoot length ratio, fresh root weight, fresh shoot weight, total fresh weight, fresh root-to-shoot weight ratio, dry root weight, dry shoot weight and total dry weight, dry root-to-shoot weight ratio (by using electronic balance (OHAUS-GT4000, USA), chlorophyll contents (by using Chlorophyll meter), leaf temperature (by using Infrared leaf meter), transpiration rate, photosynthetic rate, stomata conductance, water use efficiency and sub-stomata CO2 concentration (by using IRGA, Infrared Gas Analyzer). The data was subjected for analysis of variance. GCA and SCA were calculated by using Kepmthorn technique [8]. The genetic advance was calculated by using Falconer formula [9].

Results

It is swayed from table 1 that significant differences were found for parents and F1 hybrids, and it is cleared that higher genotypic and phenotypic variance was recorded for sub-stomata CO2 concentration

(104207.33, 104305.33) and water use efficiency (256.213, 343.333) respectively, genotypic (1778.151, 1778.987) and phenotypic (360.909, 417.787) coefficients of variances, respectively were also higher followed by photosynthetic rate (61.450, 63.772) and (288.324, 293.721) respectively. The range of heritability was found to be 50.0% to 99.90%. The genetic advance was found to be 7.29% to 478.12%.

Combining ability analysis

It is persuaded from tables 2 and 2a that the significant differences were found for parents and F1 hybrids. The Fig.1 indicated that higher fresh root length was recorded for B-336 and B-316 from parents while from F1 hybrids EV-1097Q x Pop/209 and Sh-139 x Pop/209 followed by B-327 x B-316 and Raka-poshi x B-316. The higher GCA for fresh root length was recorded for B-336 (2.0022) and Raka-poshi (0.9822) followed by B-316 (0.4106) and Sh-139 (0.3689). The higher SCA effects were recorded for EV-1097Q x Pop/209 (8.5078) and Sh-139 x B-316 (8.1344) followed by EV-1097Q x B-316 (7.6078) and Sh-139 x Pop/209 (7.0433). The additive effects were found to be negative as -1.0088 while very higher dominance effects (600.8853) were found for fresh root length. The contribution of lines (females) was 510.5848 greater as compared to testers (males) and line x tester interactions (Table 3). The Fig.1 indicated that higher fresh shoot length was recorded for B-336 and B-316 from parents while from F1 hybrids EV-1097Q x Pop/209 and Sh-139 x B-316 followed by B-327 x Pop/209 and EV-1097Q x B-316.

The higher GCA for fresh shoot length was recorded for B-336 (0.8606) and Sh-139 (1.3922) followed by B-316 (0.0772). The higher SCA effects were recorded for EV-1097Q x Pop/209 (4.2161) and Sh-139 x B-316 (4.3950) followed by EV-1097Q x B-316 (4.2339) and Sh-139 x Pop/209 (3.7472). The additive effects were found to be negative as -1.1641 while very higher dominance effects (152.3269) were found for fresh shoot length. The contribution of lines (females) was 946.3039 greater as compared to testers (males) and line x tester interactions (Table 3). The Fig.1 indicated that higher fresh root-to-shoot length ratio was recorded for B-336 from parents while from F1 hybrids Sh-139 x Pop/209. The higher GCA for fresh root-to-shoot length ratio was recorded for EV-1097Q (0.2251) and Raka-poshi (0.1963) followed by B-316 (0.0902). The higher SCA effects were recorded for EV-1097Q x Pop/209 (1.3912) and Sh-139 x B-316 (1.2596) followed by EV-1097Q x B-316 (1.2235) and Sh-139 x Pop/209 (1.2947).

The additive effects were found to be as 2.7477 while very higher dominance effects (54.1903) were found for fresh root-to-shoot length ratio. The contribution of lines (females) was 500.8744 greater as compared to testers (males) and line x tester interactions (Table 3). The Fig.2 and Fig. 3 indicated that higher fresh and dry root weight was recorded for B-336 from parents while from F1 hybrids Raka-poshi x Pop/209, EV-1097Q x B-316 and Sh-139 x Pop/209 respectively. The higher GCA for fresh and dry root weight was recorded for EV-1097Q (0.1958), B-336 (0.0048), Sh-139 (0.0181) and Raka-poshi (0.1963) respectively.

Traits	MSS	GV	GCV %	PV	PCV %	EV	ECV %	h^2bs%	GA%
FRL	25.7190*	8.560	84.599	8.597	84.783	0.037	5.584	99.56	112.07
FSL	3.4210*	1.064	42.184	1.291	46.463	0.227	19.478	82.42	55.88
FRSLR	0.3760**	0.118	24.193	0.140	26.352	0.022	10.446	84.28	32.05
FRW	0.0760**	0.025	19.309	0.025	19.499	0.000	2.721	98.05	25.57
FSW	0.1840*	0.060	27.676	0.062	28.129	0.002	5.025	96.80	36.66
TFW	0.4560*	0.151	31.425	0.154	31.736	0.003	4.429	98.05	41.63
FRSWR	0.3520*	0.117	35.817	0.118	35.970	0.001	3.311	99.15	47.44
DRW	0.0050**	0.002	11.378	0.002	12.420	0.000	4.979	83.92	15.07
DSW	0.0020**	0.001	9.871	0.001	10.621	0.0001	3.922	86.36	13.07
TDW	0.0110*	0.004	13.782	0.003	14.542	0.0004	4.637	89.83	18.25
DRSWR	2.7680*	0.844	41.527	1.078	46.928	0.234	21.857	78.30	55.01
Ch.C	0.5710**	0.176	74.071	0.217	82.218	0.041	35.683	81.16	98.12
A	186.67*	61.450	288.32	63.772	293.72	2.322	56.046	96.35	381.96
Gs	0.0004**	0.0001	5.504	0.0002	7.785	0.0001	5.504	50.00	7.29
E	0.6940*	0.226	51.900	0.242	53.706	0.016	13.809	93.38	68.75
Ci	312720**	104207	1778.1	104305	1778.98	98.00	54.529	99.90	235.63
WUE	855.759*	256.21	360.90	343.3	417.787	87.120	210.453	74.62	478.12
LT	5.4920*	1.7607	0.2274	1.9707	0.0412	0.210	7.853	89.34	30.12

* = Highly significant, ** = significant, MSS = Mean sum of square, GV = Genotypic variance, PV = Phenotypic variance, EV = Environmental variance, GCV = Genotypic coefficient of variance, PCV = Phenotypic coefficient of variance, ECV = Environmental coefficient of variance, h^2bs = Broad sense heritability, GA = Genetic advance, FRL = Fresh root length, FSL = Fresh shoot length, FRSLR = Fresh root-to-shoot length ratio, FRW = Fresh root weight, FSW = Fresh shoot weight, TFW = Total fresh weight, FRSWR = Fresh root-to-shoot weight ratio, DRW = Dry root weight, DSW = Dry shoot weight, TDW = Total dry weight, DRSWR = Dry root-to-shoot weight ratio, A= Photosynthetic rate, E = Transpiration rate, Ci = Sub-stomatal CO_2 concentration, WUE = Water use efficiency, LT = Leaf temperature, gs = Stomatal conductance, Ch.C = Chlorophyll contents

Table 1: Estimation of genetic components for various morpho-physiological traits of maize seedlings

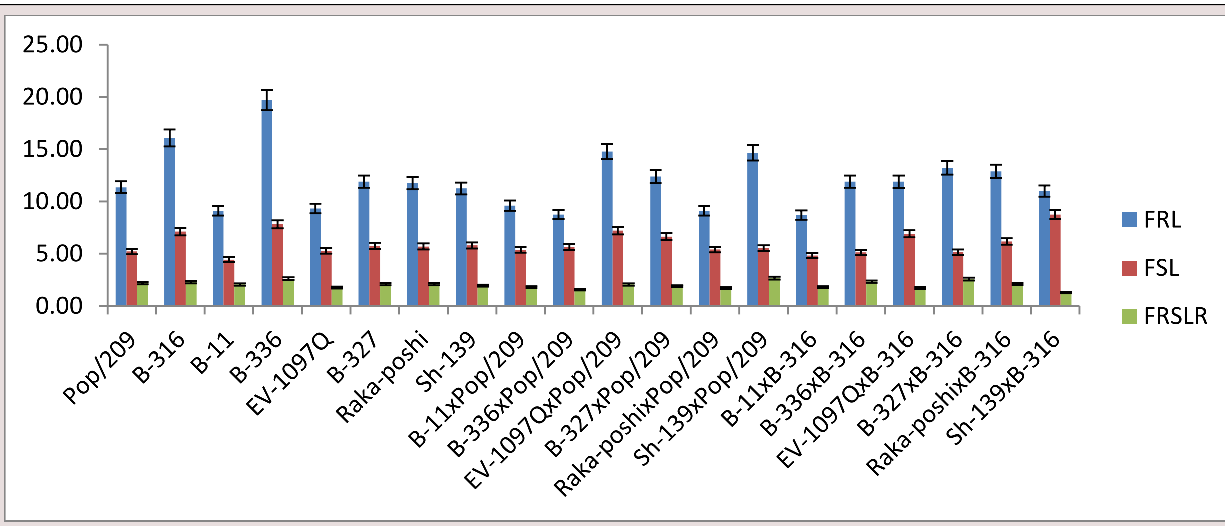

Figure 1: Fresh root length (FRL), Fresh shoot length (FSL) and Fresh root-to-shoot length ratio (FRSLR) of maize seedlings

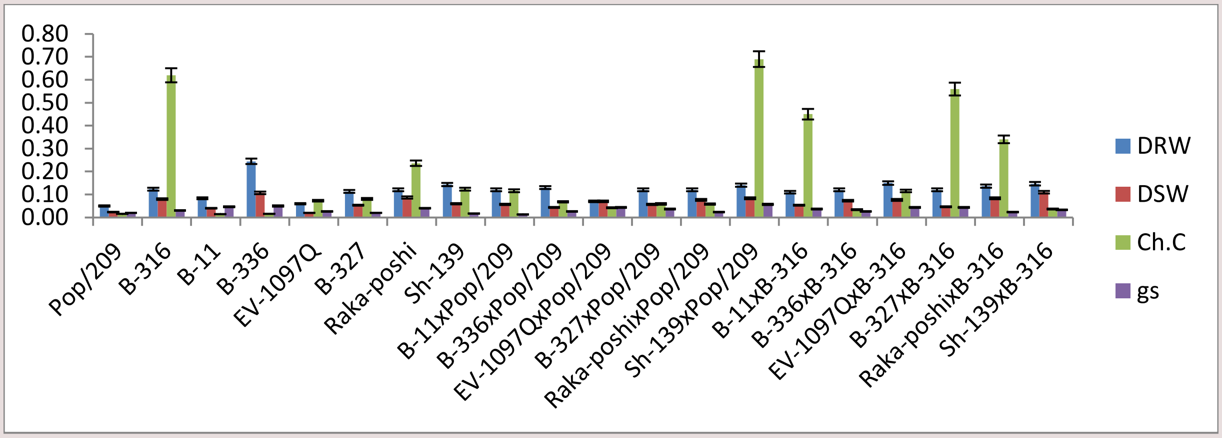

Figure 2: Fresh root weight (FRW), Fresh shoot weight (FSW), Fresh root-to-shoot weight ratio (FRSWR) and Total fresh weight (TFW) of maize seedlings

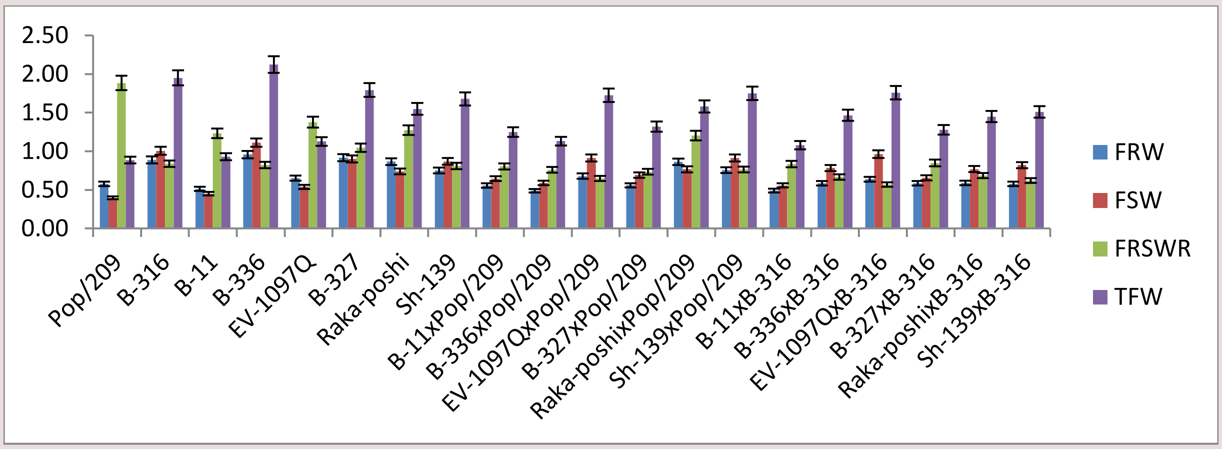

Figure 3: Dry root weight (FRW), Dry shoot weight (FSW) Chlorophyll contents (Ch.C) and Stomata conductance (gs) of maize seedlings

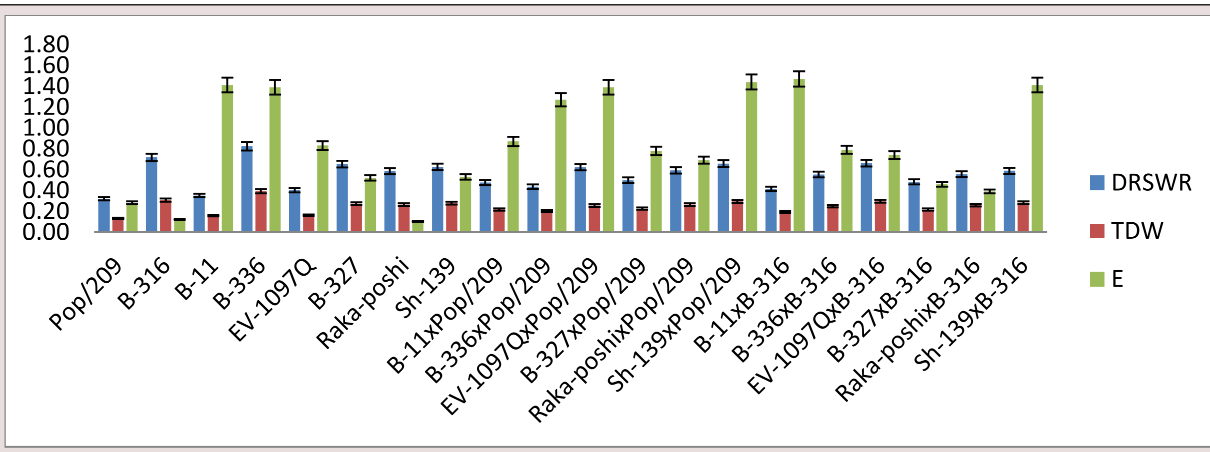

Figure 4: Dry root-to-shoot weight ratio (DRSWR), Total dry weight (TDW) and transpiration rate (E) of maize seedlings

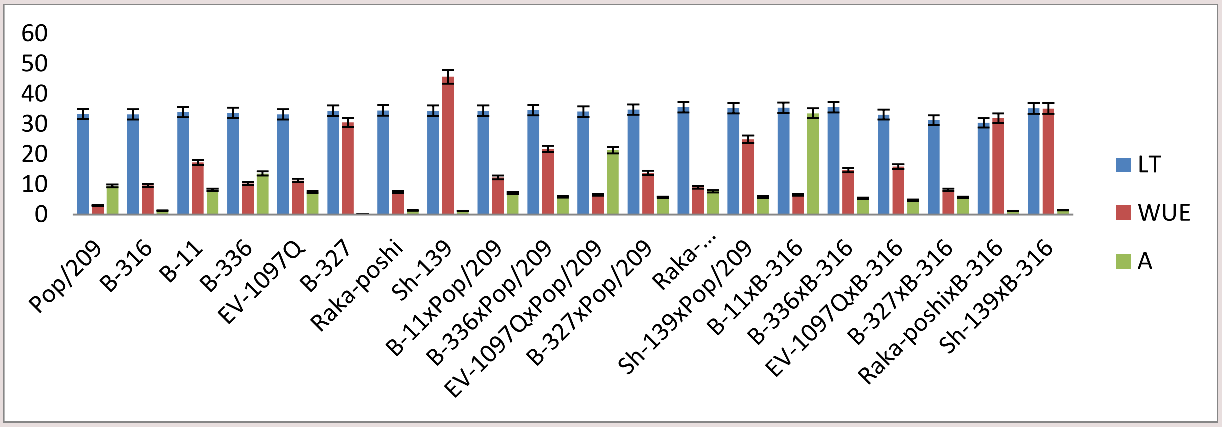

Figure 5: Leaf temperature (LT), Water use efficiency (WUE) and Photosynthetic rate (A) of maize seedlings

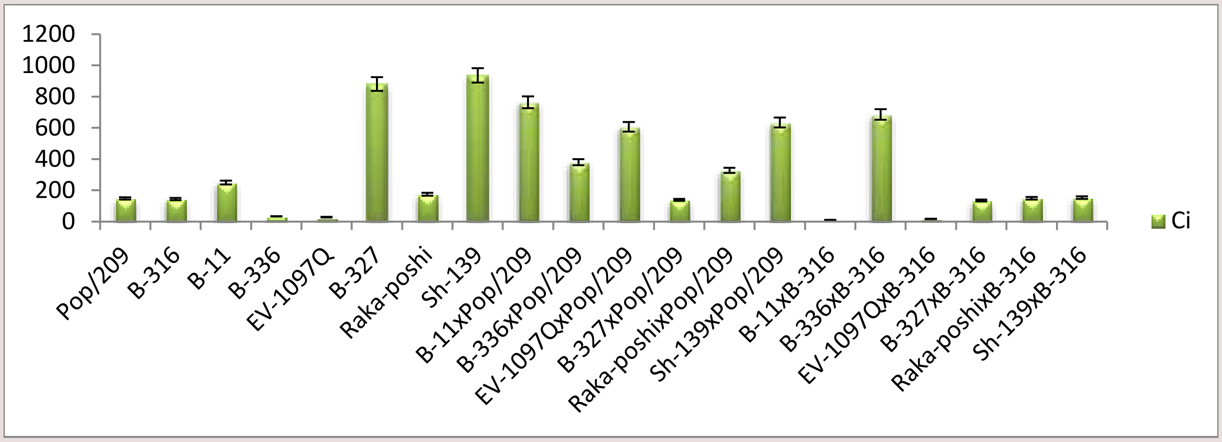

Figure 6: Sub-stomata CO2 concentration (Ci) of maize seedlings

The higher SCA effects were recorded for EV-1097Q x Pop/209 (0.4401, 0.0819) and Sh-139 x B-316 (0.4349, 0.0853) followed by EV-1097Q x B-316 (0.3444, 0.0803) and Sh-139 x Pop/209 (0.4080, 0.0919) respectively. The additive effects were found to be 0.0732 while very higher dominance effects (2.7050) were found higher for fresh root weight as compared to dry root weight 0.0027 and 0.1065 respectively. The contribution of lines (females) was for dry root weight was 1087.4512 greater as compared to testers (males) and line x tester interactions (Table 3) then the 2.77.9648 for fresh root weight. the development of hybrid seed. The Fig.2 and Fig. 3 indicated that higher fresh and dry shoot weight was recorded for B-336 and B-316 from parents while from F1 hybrids EV-197Q x Pop/209, EV-1097Q x B-316, Raka-poshi x Pop/209 and Sh-139 x Pop/209 respectively. The higher GCA for fresh and dry shoot weight was recorded for EV-1097Q (0.0279, 0.0108) and Sh-139 (0.0684, 0.0275) respectively. The higher SCA effects were recorded for EV-1097Q x Pop/209 (0.6043, 0.0525) and Sh-139 x B-316 (0.5821, 0.0481) followed by EV-1097Q x B-316 (0.5419, 0.0425) and Sh-139 x Pop/209 (0.5257, 0.0481) respectively. The additive effects were found to be as 0.1407 while very

SOV/Traits		FRL	FSL	FRSLR	FRW	FSW	FRSWR	TFW	DRW	DSW
	DF	MSS	MSS	MSS	MSS	MSS	MSS	MSS	MSS	MSS
Genotypes	19	264.74*	64.004*	7.24**	0.83*	1.22**	1.74*	3.97**	0.029**	0.009**
Parents	7	246.38*	49.10*	6.09**	0.85*	1.02**	2.17*	3.64*	0.029**	0.005**
Crosses	11	276.73*	75.75*	7.95*	0.77**	1.42*	1.21**	4.24*	0.031*	0.010**
Parents vs Crosses	1	261.34*	39.05**	7.47*	1.38*	0.41**	4.55**	3.31*	0.014**	0.017**
Lines	5	266.87*	73.91**	7.48**	0.76*	1.35**	1.16*	4.11*	0.030**	0.010**
Testers	1	966.82*	263.76*	27.49**	2.72*	4.92**	4.19**	14.97**	0.110**	0.034*
L x T	5	148.57*	40.003*	4.52*	0.39*	0.80**	0.67**	2.22*	0.016**	0.005**
Error	38	0.007	0.006	0.002	0.0001	0.0003	0.0008	0.0005	0.0001	0.0001

Table 2: ANOVA of Line × Tester (6 × 2) analysis for various morphological traits of maize seedlings

SOV/Traits		DRSWR	TDW	A	LT	Gs	Ch.C	E	Ci	WUE
	DF	MSS	MSS	MSS	MSS	MSS	MSS	MSS	MSS	MSS
Genotypes	19	8.14*	0.06**	279.25*	1964*	0.002**	0.77*	1.84**	464808*	1967.9*
Parents	7	8.06*	0.06*	111.84*	1513*	0.002**	0.44**	1.36**	545249*	958.14*
Crosses	11	8.00**	0.07**	411.03*	2302.*	0.003**	1.05*	2.32*	445114*	2782*
Parents vs Crosses	1	10.27*	0.02**	1.59**	1401*	0.001**	0.03**	0.003**	118351*	82.6*
Lines	5	7.71*	0.07*	319.48*	2249*	0.003**	0.57**	1.95*	358437*	2635.9*
Testers	1	26.66*	0.26*	869.04*	8411*	0.009*	1.16**	6.81*	809994*	4871.6*
L x T	5	4.55**	0.04**	410.98*	1132*	0.002**	1.52*	1.79*	458815*	2510.1
Error	38	0.31	0.0002	18.66	0.021	0.0001	0.00002	0.0003	2.28	1.05

* = Significant at 5% probability level, ** = Significant at 1% probability level, MSS = Mean sum of square, FRL = Fresh root length, FSL = Fresh shoot length, FRSLR = Fresh root-to-shoot length ratio, FRW = Fresh root weight, FSW = Fresh shoot weight, TFW = Total fresh weight, FRSWR = Fresh root-to-shoot weight ratio, DRW = Dry root weight, DSW = Dry shoot weight, TDW = Total dry weight, DRSWR = Dry root-to-shoot weight ratio, A= Photosynthetic rate, E = Transpiration rate, Ci = Sub-stomatal CO2 concentration, WUE = Water use efficiency, LT = Leaf temperature, gs = Stomata conductance, Ch.C = Chlorophyll contents

Table 2a: ANOVA of Line × Tester (6 × 2) analysis for various morpho-physiological traits of maize seedlings

higher dominance effects (5.0253) were found for fresh shoot weight as compared to dry shoot weight 0.0009 and 0.0343 respectively.

The contribution of lines (females) was for fresh shoot weight was 1625.0848 greater as compared to testers (males) and line x tester interactions (Table 3) then the 299.9012 for dry shoot weight. The Fig.2 and Fig. 4 indicated that higher total fresh weight was recorded for B-336 and B-316 and total dry weight B-336 and B-11 from parents while from F1 hybrids Sh-139 x Pop/209 and EV-1097Q x B-316 for total fresh weightwhile B-11 x B-316 and Sh-139 x B-316 for total dry weight respectively. The higher GCA for fresh and dry shoot weight was recorded for EV-1097Q (0.2237, 0.0172) and Sh-139 (0.0374, 0.0456) respectively. The higher SCA effects were recorded for EV-1097Q x Pop/209 (1.0444, 0.1344) and

SOV/Traits		FRL	FSL	FRSLR	FRW	FSW	FRSWR	TFW	DRW	DSW
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Table 2a: ANOVA of Line × Tester (6 × 2) analysis for various morpho-physiological traits of maize seedlings

Sh-139 x B-316 (1.0170, 0.1333) followed by EV-1097Q x B-316 (0.8863, 0.1228) and Sh-139 x Pop/209 (0.9338, 0.1400) respectively. The additive effects were found to be as 0.5890 while very higher dominance effects (17.3292) were found for total fresh weight as compared to total dry weight 0.0067 and 0.2594 respectively. The contribution of lines (females) was for total fresh weight was 1411.4902 greater as compared to testers (males) and line x tester interactions (Table 3) then the 620.4837 for dry shoot weight. It is indicated in Fig.3 that higher chlorophyll contents and stomata conductance was recorded for B-316 and B-11 from parents while from F1 hybrids Sh-139 x Pop/209 respectively. The higher GCA was recorded for EV-1097Q (0.1871, 0.0061) and Raka-poshi (0.2124, 0.0094) for chlorophyll contents and stomata conductance respectively. The higher SCA effects were recorded for EV-1097Q x Pop/209 (0.3711,

Genotypes/Traits	DRSWR	TDW	A	LT	Ch.C	gs	E	Ci	WUE
			GCA						
Pop/209	-0.17	-0.005	3.81	-0.31	-0.01	-0.003	-0.05	-21.22	-8.40
B-316	0.17	0.005	-3.87	0.31	0.003	0.003	0.05	21.22	8.40
B-11	0.67	-0.01	-2.31	0.42	-0.30	-0.01	0.08	239.27	-4.78
B-336	-0.34	-0.03	4.72	0.34	-0.35	0.006	0.11	39.61	-11.49
EV-1097Q	-0.27	0.01	-2.04	1.15	0.18	0.006	0.10	147.61	-4.50
B-327	-0.04	-0.01	10.68	1.37	0.13	-0.002	0.14	15.27	-11.77
Raka-poshi	0.39	0.003	-3.60	-1.94	0.21	0.009	-0.36	-258.72	-9.56
Sh-139	-0.40	0.04	-7.44	-1.35	0.12	-0.005	-0.07	-183.05	42.11
			SCA						
B-11xPop/209	-2.01	-0.25	-24.08	-44.42	-0.70	-0.05	-1.27	-29.66	-11.29
B-336xPop/209	-2.15	-0.28	-2.408	-46.14	-0.77	-0.05	-1.19	-540.33	-52.57
EV-1097QxPop/209	1.04	0.13	6.62	22.64	0.37	0.02	0.616	142.50	15.96
B-327xPop/209	-2.81	-0.28	-12.15	-44.66	-0.76	-0.02	-0.74	-119.44	-14.73
Raka-poshixPop/209	-2.71	-0.27	-4.95	-46.01	-0.77	-0.05	-1.68	-716.77	-58.07
Sh-139xPop/209	1.38	0.14	4.27	22.66	0.38	0.02	0.60	209.05	18.20
B-11xB-316	-2.26	-0.24	-23.56	-43.83	-0.93	-0.04	-1.45	-435.11	-14.69
B-336xB-316	-3.17	-0.24	-2.57	-45.75	0.11	-0.03	-0.99	-257.11	-48.80
EV-1097QxB-316	1.35	0.12	6.53	22.39	0.20	0.02	0.61	173.05	15.87
B-327xB-316	-1.84	-0.26	-1.92	-43.77	0.06	-0.03	-0.70	-711.00	-16.01
Raka-poshixB-316	-3.28	-0.26	-7.23	-45.52	-0.95	-0.06	-1.69	-157.66	-57.17
Sh-139xB-316	1.28	0.13	2.28	22.32	0.22	0.02	0.59	217.16	18.29
Contribution of lines	375.69	1411.4	100440	802.7	8757	1437.2	379082	1514.28	15943
Contribution of tester	259.59	1014.6	54641.5	600.2	3530	970.9	264222	684.39	5893.
Contribution of LxT	221.63	748.10	129204	404.0	23079	953.6	347371	1938.35	15183
Additive variance	2.82	0.006	-0.38	-1.09	0.05	0.0002	0.24	-0.35	-0.45
Dominance variance	54.49	0.25	680.93	5226.9	2.20	0.008	7.97	723213	4444

GCA = General combining ability, SCA = Specific combing ability, TDW = Total dry weight, DRSWR = Dry root-to-shoot weight ratio, A= Photosynthetic rate, E = Transpiration rate, Ci = Sub-stomata CO2 concentration, WUE = Water use efficiency, LT = Leaf temperature, gs = Stomata conductance, Ch.C = Chlorophyll contents

Table 3a: GCA and SCA of parents and cross for various morpho-physiological traits of maize seedlings

0.0272) and Sh-139 x B-316 (0.2231, 0.0233) followed by EV-1097Q x B-316 (0.2055, 0.0206) and Sh-139 x Pop/209 (0.3849, 0.0206) respectively. The additive effects were found to be as 0.0565 while very higher dominance effects (2.2012) were found for chlorophyll contents as compared to stomata conductance 0.0002 and 0.0085 respectively. The contribution of lines (females) was for chlorophyll contents was 8757.9728 greater as compared to testers (males) and line x Sh-139 from parents while from F1 hybrids B-11 x B-316 and B-316 respectively. The higher GCA was recorded for EV-1097Q (0.1014, 147.6111), B-327 (0.1431, 15.2778), B-336 (0.1131, 39.6111) and B-11 (0.0881, 239.2778) for transpiration rate and sub-stomata CO2 concentration respectively. The higher SCA effects were recorded for EV-1097Q x Pop/209 (0.6164, 142.500) and Sh-139 x B-316 (0.5981, 217.1667) followed by EV-1097Q x B-316 (0.6119, 173.0556) and Sh-139 x Pop/209 (0.6081, 209.0556) respectively. The additive effects were found to be as 0.2464 while lower dominance effects (7.9776) were found for transpiration rate as compared to sub-stomata CO2 concentration -0.3545 and 723213.5974 respectively. The contribution of lines (females) was for transpiration rate was 379082.3442 greater as compared to testers (males) and line x tester interactions (Table 3) then the 1514.2892 for sub-stomata CO2 concentration. The Fig. 5 indicated that higher leaf temperature, water use efficiency and photosynthetic rate was recorded for Raka-poshi, Sh-139 and B-336 from parents while from F1 hybrids B-11 x B-316 for leaf temperature and Sh-139 x B-316 for water use efficiency and photosynthetic. The higher GCA was recorded for B-327 (10.6858, 1.3750) for leaf temperature and photosynthetic rate respectively and Sh-139 (42.1195) for water use efficiency. The higher SCA effects were recorded for EV-1097Q x Pop/209 (6.6231, 22.6417, 15.9668) and Sh-139 x B-316 (2.2897, 22.3250, 18.2983) followed by EV-1097Q x B-316 (6.5347, 22.3972, 15.8755) and Sh-139 x Pop/209 (4.2764, 22.6694, 18.2040) respectively.

The negative additive effects were found leaf temperature, water use efficiency and photosynthetic rate while higher dominance effects (5226.9638) were found for leaf temperature. The contribution of lines (females) was for photosynthetic rate was 100440.0943 greater as compared to testers (males) and line x tester interactions (Table 3).

Discussion

The highest value of heritability was fond for fresh root length, fresh root and shoot weight, total fresh weight, photosynthetic rate and sub-stomata CO2 concentration. It was suggested that selection for drought tolerance maize genotypes may be helpful to improve grain yield [10-13]. The highest value of genetic advance was found for fresh root length, photosynthetic rate, transpiration rate, water use efficiency, and chlorophyll contents and sub-stomata CO_2 concentration. The higher values of heritability and genetic advance indicated that selection of higher yielding maize genotypes on the basis of fresh root length, photosynthetic rate, transpiration rate, water use efficiency, chlorophyll contents and sub-stomata CO2 concentration may be helpful to improve maize yield [4,5,14-16]. GCA reflects the ability of genotypes to transmit traits in a general of series of crosses which indicated the additive gene effects while specific combining ability showed ability of genotypes to transmit traits in specific crosses.

Higher GCA of B-336 was recorded for fresh root length, fresh root and shoot weight, total fresh weight, photosynthetic rate and sub-stomata CO2 concentration. Higher SCA of EV-1097Q × Pop/209, Sh-139 × Pop/209, EV-1097Q × B-316 and Sh-139 × B-316 was recorded for fresh root and shoot length, fresh root and shoot weight, total fresh weight, photosynthetic rate and sub-stomata CO_2 concentration, water use efficiency, leaf temperature, transpiration rate, stomata conductance, fresh and dry root-to-shoot weight ratio and chlorophyll contents. The higher GCA indicated the genotypes are good general combiner and may be used for the development of hybrid seed. The higher value of SCA and dominance effects indicated that the hybrids may be used for better yield [1,10,14,17].

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