Combining ability analysis for various physiological, grain yield and quality traits of *Zea mays* L.

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Abstract: Maize gain yield and quality traits are very important traits to improve its demand. Combining ability analysis provides an opportunity to plant breeder for the development of synthetic (using General Combining Ability) and hybrids (using Specific Combining Ability). The present study was conducted in the research area of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan during crop growing season 2012-13. It was concluded that higher values of General Combining Ability (GCA) were found for inbred lines B-316, F-96, B-11, Sh-139, EV-340, Pop/209, E-322, E-336 and EV1097 for physiological, grain yield and quality traits. Higher GCA suggested that the genotypes may be used for the development of higher yielding and good quality maize synthetic varieties. Higher Specific Combining Ability (SCA) was found for B-11×Pop/209, E-336×Pop/209 and E-336×E-322 for chlorophyll content, EV-1097×B-316 and E-336×E-322 for leaf temperature, Sh-139×Pop/209 and Sh-139×EV-347 for photosynthetic rate, E-336×F-96, E-336×EV-340 and Sh-139×B-316 for stomata conductance, Sh-139×Pop/209, EV-1097×E-322 and Sh-139×B-316 for transpiration rate, B-327×EV-347 and Sh-139×Pop/209 for sub-stomata CO2 concentration and E-336×EV-340, EV-1097×Pop/209 and Sh-139×B-316 for water use efficiency. Higher SCA of grain yield was found for E-336×Pop/209 and Sh-139×B-316 for cobs per plant, B-11×B-316 and Sh-139×F-96 for grain rows per cob, E-336×EV-340 and Raka-poshi×F-96 for cob length, B-11×EV-347 and Sh-139×Pop/209 for cob diameter, E-336×EV-340 and Raka-poshi×F-96 for cob weight, Sh-139×EV-340 and Raka-poshi×F-96 for 100-seed weight, B-11×Pop/209 and B-327×B-316 for stover weight, E-336×EV-340 and Raka-poshi×B-316 for grain yield per plant. Higher SCA of grain quality was found for E-336×Pop/209 and Raka-poshi×E-322 for grain protein percentage, B-11×Pop/209 and EV-1097×EV-347 for grain oil percentage, E-336×EV-340 and B-327 × EV-347 for grain crude fibre percentage, B-11×B-316, EV-1097×EV-347 and Raka-poshi×Pop/209 for grain starch percentage, B-11×EV-347 and E-336×Pop/209 for embryo percentage. Higher SCA suggested that the hybrids may be used for the development of higher grain yield and good grain quality maize hybrids.

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1. Introduction

Zea mays L. is the most important cereal food crop of the world with supplementary importance for countries akin to Pakistan where swiftly increasing population has already outstripped the existing food provisions. Maize is the third vital cereal in Pakistan after wheat and rice. Maize contributes with the 5.67 % of the total value of agriculture outputs. It was estimated that maize have been grown in Pakistan over 1083 thousands hectares yielding an annual production of 4271 thousands tons (Anonymous, 2011-12). Maize is used as food for humans as well as for livestock and also it is used as industrial raw material to produce diverse types of by-products. It has its highest 9.9% crude protein at early and at full bloom stages that decreases to 7% at milk stage (grain formation starting stage) and to 6% at maturity. Maize contains 72% starch, 10% protein, 4.80% oil, 9.50% fiber, 3.0% sugar, 1.70% ash, 82% endosperm, 12% embryo, 5% bran testa and 1% tip cap (Chaudhary, 1983; Bureau of Chemistry, U.S., 2010).

Maize production in Pakistan is low as compared to other maize growing countries due to non-availability of resources and improved germplasm. Grain yield is related to others various morphological, physiological and agronomic traits in maize. By improving these traits, production of maize genotypes may be increased. Combining ability analysis provides an opportunity to a plant breeder to select genotypes on the basis of strong correlations among grain yield contributing traits as reported by Grzesiak *et al.* (2007); Ali *et al.* (2011a, b); Ali *et al.* (2012); Qamar *et al.* (2013a,b); Jahangir *et al.* (2013); Anwar *et al.* (2013) and Muhammad *et al.* (2013). The present study was conducted to evaluate several maize accessions for physiological, grain yield and quality traits.

2. Material and methods

The present study was conducted in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad to assess the maize genotypes for physiological traits for the period of the crop season in February 2012-13. The germplasm consisted of F1 hybrids developed through 6 × 6 North Carolina matting design II (Comstock and Robinson, 1952); and during growing season of August 2011-12 they were grown in the field following three replications in a completely randomized block design. The plant-to-plant and row-to-row distances were 25cm and 75cm respectively. The data from 10 randomly selected plants were recorded for the following traits, viz., chlorophyll content (mg g-1 fr. wt.) by using chlorophyll meter, photosynthetic rate (µg CO2 s−1), transpiration rate (mm day-1), stomata conductance (mmol m-2 s-1), sub-stomata CO2 concentration (µmol mol−1 CO2), water use efficiency (%) and leaf temperature (°C) at maturity stage by using IRGA (Infrared Gas Analyzer).

Quality Traits

The grain and plant samples containing leaves and stem will be collected and ground into a fine powder and the following quality traits were estimated.

GRAIN CRUDE PROTEIN PERCENTAGE (%)

Grain protein percentage was calculated by multiplying N-contents with a factor 6.25 (Proximate analysis, AOAC. Association of Official Analytical Chemists, 1996) assuming that all nitrogen content (100/16) of sample are from protein. It included pure protein and non-protein nitrogenous compounds of sample. The crude protein percentage was calculated by using following formula:

Crude Protein (%) = 100 × 6.25 [(ml N/10 H2SO4 neutralized by NH3 × 0.0014 × Total diluted volume)/(Sample weight × ml of dil. Digested material distilled)]

GRAIN OIL PERCENTAGE (%)

Soxhlet apparatus was used to find out oil percentage as ether extract by using a thimble filled with weighed amount of sample and condenser (filled with circulating cold water) were fitted in Soxhlet apparatus. The processing of apparatus was adjusted at 400C until no oil content was left in the sample (checked through change in the sample color). Ether obtained was transferred to an oven (Model: Fisher Scientific Isotop Oven 665°F) in a glass dish at 250C in order to evaporate ether from sample. The glass dish was then cooled out in a desiccator and (meaindicated?) weight immediately. The oil percentage was estimated by using the following formula (i.e. proximal analysis, AOAC. Association of Official Analytical Chemists, 1996).

Ether extract (%) = 100× [Residue weight/ Sample weight]

GRAIN CRUDE FIBRE (%)

The crude fiber percentage was determined by using Proximate analysis, (AOAC, 1996) procedure. Water and fatty material were removed from the sample feed; sample was boiled in 200 ml of weak acid (1.25% H2SO4) and after then in 200 ml of weak base (1.25% NaOH) for same time duration. After performing the described procedure proteins, starches and sugars leave out the sample as residues and remaining material was considered as crude fibre (cellulose, complex polysaccharides and mineral materials). The crude fiber percentage was calculated by using following formula:

Crude Fibre % = 100× [(Dried residue weight – Ash weight)/ Dried sample weight]

GRAIN STARCH PERCENTAGE (%)

The grain starch percentage was calculated by using titration method. A 0.5 g maize grain sample was taken in a conical flask and 100 ml distilled water was added to it. Five ml of HCl (Hydrochloric acid) was also added to the solution. The solution was boiled for 30 minutes and pH of solution was maintained by the addition of 40% solution of NaOH (Sodium hydroxide). After boiling the solution was filtered and volume was made to 100 ml. The titration was performed by using 5 ml of CuSO4 (Copper Sulphate) and 5 ml NaK (Sodium Potash) titrate solution, that was prepared by mixing them in 100 ml of distilled water in a conical flask (Fehling solution). The solution was heated until the boiling started 10 ml of maize solution were taken by burette for titration of 100 ml (Fehling solution) and when colour was changed to brown, 2 drops of methylen blue were added. The process of titration was continued till the colour was changed to brick red. The volume of titrated maize solution was recorded and starch percentage was calculated by using the following formula.

A ml of maize solution (maize ml to titrate 100 ml Fehling solution) = 0.05g (B = reducing sugars)

100 ml of maize solution (maize ml to titrate 100 ml Fehling solution) = 0.05/A × 100 = B

0.5 g sample of maize contain reducing sugars = B

100 g sample of maize contain reducing sugars = B/10 × 100 = C %

Starch % = C% - Glucose %

The C percentage is the sum of starch and glucose. The starch percentage was calculated by subtracting glucose percentage that was calculated by using UV-Visible Spectrophotometer (Model Hitachi U-2001) from values of C and multiplying the answer by a factor 0.9 to determine the amount of starch percentage in maize grain.

EMBRYO PERCENTAGE (%)

The seed weight was recorded and embryo of seed was removed carefully, recording also the weight of separated embryo. The percentage of the embryo was recorded by using following formula: Embryo % = [Embryo weight/Seed weight] × 100

The parents and F1 crosses are shown below (Table 1) and they were evaluated in the field experiment for all above given traits during growing season of February 2012-13.

Table 1. Parents and F_1 crosses used in evaluation experiment

Sr. No.	Genotypes	Sr. No.	Genotypes	Sr. No.	Genotypes
1	Pop/209	17	B-11×F-96	33	B-327×EV-340
2	B-316	18	B-11×EV-347	34	B-327×E-322
3	EV-340	19	B-336×Pop/209	35	B-327×F-96
4	E-322	20	B-336×B-316	36	B-327×EV-347
5	F-96	21	B-336×EV-340	37	Raka-poshi×Pop/209
6	EV-347	22	B-336×E-322	38	Raka-poshi×B-316
7	B-11	23	B-336×F-96	39	Raka-poshi×EV-340
8	B-336	24	B-336×EV-347	40	Raka-poshi×E-322
9	EV-1097	25	EV-1097×Pop/209	41	Raka-poshi×F-96
10	B-327	26	EV-1097×B-316	42	Raka-poshi×EV-347
11	Raka-poshi	27	EV-1097×EV-340	43	Sh-139×Pop/209
12	Sh-139	28	EV-1097×E-322	44	Sh-139×B-316
13	B-11×Pop/209	29	EV-1097×F-96	45	Sh-139×EV-340
14	B-11×B-316	30	EV-1097×EV-347	46	Sh-139×E-322
15	B-11×EV-340	31	B-327×Pop/209	47	Sh-139×F-96
16	B-11×E-322	32	B-327×B-316	48	Sh-139×EV-347

Statistical Analysis

Combining ability effects

They were calculated as expressed by Kempthorn (1957), following the formulas:

GCA effects of lines (gi) = $\frac{x_{i..}}{rt} - \frac{x_{...}}{rlt}$

GCA effects of testers (gj) = $\frac{x_{.j.}}{rl} - \frac{x_{...}}{rlt}$

SCA effects of hybrids (sij) = $\frac{x_{ij.}}{r} - \frac{x_{..}}{rt} - \frac{x_{i..}}{rl} + \frac{x_{...}}{rlt}$

Where, x… = Total of all hybrids over replications, xi.. = Total of i^{th} lines over t testers and r replications, x.j. = Total of j^{th} tester over l lines and r replications, xij. = Total of the hybrid between i^{th} lines and j^{th} tester over r replications

3. Results and discussions

3.1.Physiological Traits

Chlorophyll content (mg g^{-1} fr. wt.)

Higher and positive GCA effects were recorded for E-336 (3.653) and EV-340 (4.282) followed by E-322 (1.352) and Raka-poshi (1.108) while negative GCA effects were recorded for EV-347 (-5.027) and B-11 (-2.801). Higher GCA effects indicated additive type of gene action and the performance of the parents for chlorophyll content. Higher GCA effects suggested that the increase in the chlorophyll content may be fixed for next generations. Higher chlorophyll content reflect higher photosynthetic rate due to which accumulation of organic compounds in the plant body that improved crop yield and production.

Higher SCA was recorded for crosses B-11×Pop/209 (7.957), B-11×EV-347 (7.180), E-336×Pop/209 (8.407) and E-336×E-322 (5.744) while negative SCA was recorded for B-11×F-96 (-6.086), E-336×EV-347 (-7.270) and EV-1079×Pop/209 (-10.162). The higher SCA showed that the crosses have higher dominance effects. The selection of hybrids on the basis of chlorophyll content will be helpful for the development of hybrids through heterosis breeding. Additive variance was recorded as 0.572 but higher dominance variance was 121.646 for chlorophyll content. The lower contribution of female (26.815) and male (7.033) was recorded as compared to male × female interaction (66.152) (Table 2). Findings were found similar as reported by Ahsan *et al*. (2011); Ali *et al*. (2011); Ahsan *et al*. (2013); Ali *et al*. (2012); Amir *et al*. (2012); Bibi *et al*. (2012) and Ali *et al*. (2013).

Leaf temperature (°C)

As presented in Table 2 higher and positive GCA effects were recorded for F-96 (0.343) and EV-340 (0.221) followed by EV-347 (0.299) and B-327 (0.393) while negative GCA effects were recorded for Pop/209 (-0.339) and B-316 (-0.473). Higher GCA effects indicated additive type of gene action and the performance of the parents. The selection on the basis of leaf temperature may be effective to improve crop yield and production. Higher SCA was recorded for crosses B-11×EV-340 (0.756), Sh-139×EV-340 (0.950), EV-1097×B-316 (1.212) and E-336×E-322 (1.128) while negative SCA was recorded for Sh-139×B-316 (-0.899), E-336×EV-340 (-0.743) and EV-1079×F-96 (-0.832) (Table 2).

The higher SCA showed that the crosses have higher dominance effects. The selection of hybrids on the basis of leaf temperature will be supportive for the development of hybrids through heterosis breeding. Higher leaf temperature also indicated that photosynthetic rate may also be increased to improve crop yield and production. Additive variance was recorded as 0.002 but higher dominance variance was 1.581 for leaf temperature. The lower contribution of female (23.368) and male (6.610) was recorded as compared to male × female interaction (70.021). Findings were found similar to Grzesiak *et al*. (2007); Ali *et al*. (2011); Ali *et al*. (2012) and Ahsan *et al*. (2013).

Table 2: Combining ability analysis for various physiological traits in maize

Source of variation/ Traits	Photosynthetic rate (µg CO_2 s^{-1})	Stomata conductance (mmol m^{-2} s^{-1})	Transpiration rate (mm day^{-1})	Sub-stomata CO_2 concentration (µmol mol^{-1} CO_2)	Water use efficiency (%)	Leaf temperature (°C)	Chlorophyll contents (mg g^{-1} fr. wt.)
GCA							
Pop/209	1.432	0.013	0.752	-15.018	-20.550	-0.339	1.730
B-316	0.000	0.055	1.271	-29.129	26.013	-0.473	-1.786
EV-340	-0.500	-0.007	-0.756	19.759	8.969	0.221	4.282
E-322	-1.188	-0.005	0.136	4.148	9.400	-0.050	1.352
F-96	-1.621	-0.036	-0.872	-14.018	-1.516	0.343	-0.551
EV-347	1.877	-0.019	-0.532	34.259	-22.316	0.299	-5.027
B-11	-3.110	-0.046	-1.351	7.370	-3.001	0.287	-2.801
E-336	6.991	0.029	0.670	7.703	-30.433	-0.284	3.653
EV-1097	-5.728	0.025	0.439	-53.296	39.598	-0.034	-2.363
B-327	5.106	-0.037	-1.292	46.759	-38.479	0.393	-0.438
Raka-poshi	1.013	0.027	1.012	-46.685	10.051	-0.134	1.108
Sh-139	-4.273	0.001	0.521	38.148	22.265	-0.228	0.842
SCA							
B-11×Pop/209	-2.966	-0.001	0.288	4.185	17.045	0.001	7.957
B-11×B-316	-1.005	0.001	0.359	-67.481	18.802	0.239	-1.631
B-11×EV-340	2.921	-0.113	-3.611	-13.481	-54.115	0.756	-3.180
B-11×E-322	-9.653	0.087	2.843	28.796	62.923	-0.571	-4.238
B-11×F-96	9.236	0.005	0.231	-35.759	-30.280	-0.210	-6.086
B-11×EV-347	1.466	0.021	-0.111	83.741	-14.375	-0.215	7.180
E-336×Pop/209	-2.187	-0.057	-1.803	-50.037	-38.473	0.367	8.407
E-336×B-316	3.016	-0.022	0.297	13.296	-32.986	-0.160	-2.881
E-336×EV-340	-6.919	0.147	3.142	-11.037	165.009	-0.743	1.836
E-336×E-322	5.649	-0.135	-4.189	34.907	-49.042	1.128	5.744
E-336×F-96	5.298	0.085	2.635	61.352	-55.241	-0.510	-5.836
E-336×EV-347	-4.858	-0.018	-0.083	-48.481	10.732	-0.082	-7.270
EV-1097×Pop/209	-9.510	-0.001	0.501	1.407	107.845	-0.126	-10.162
EV-1097×B-316	9.277	-0.155	-6.104	-10.593	-49.071	1.212	1.715
EV-1097×EV-340	12.024	0.057	2.247	46.074	-79.258	-0.371	2.646
EV-1097×E-322	-1.960	0.104	3.472	-85.981	4.337	-0.832	-0.438
EV-1097×F-96	-11.574	-0.001	0.284	1.463	64.605	-0.137	2.534
EV-1097×EV-347	1.742	-0.004	-0.401	47.630	-48.459	0.256	3.703
B-327×Pop/209	3.900	-0.015	-1.161	-45.981	-43.875	0.012	-0.195
B-327×B-316	2.201	0.035	0.779	14.685	-15.446	-0.349	0.945
B-327×EV-340	-1.187	-0.034	-0.158	-28.315	-19.517	-0.099	2.330
B-327×E-322	9.167	-0.014	-0.543	11.630	-25.731	0.139	-1.828
B-327×F-96	-11.129	0.050	1.401	-26.926	103.805	0.001	-0.375
B-327×EV-347	-2.953	-0.020	-0.317	74.907	0.764	0.295	-0.876
Raka-poshi×Pop/209	0.964	-0.020	-1.296	-20.148	-30.416	0.517	-4.895
Raka-poshi×B-316	0.122	0.001	0.381	30.185	-5.730	-0.043	3.782
Raka-poshi×EV-340	-0.006	0.046	1.983	45.852	-5.616	-0.493	1.600
Raka-poshi×E-322	5.064	-0.002	-0.041	-16.204	-12.080	-0.154	-2.524
Raka-poshi×F-96	0.400	-0.031	-1.060	18.574	-37.976	0.173	5.141
Raka-poshi×EV-347	-6.545	0.007	0.033	-58.259	91.818	0.000	-3.105
Sh-139×Pop/209	9.798	0.095	3.470	110.574	-12.127	-0.771	-1.111
Sh-139×B-316	-13.613	0.142	4.285	19.907	84.430	-0.899	-1.930
Sh-139×EV-340	-6.833	-0.103	-3.602	-39.093	-6.504	0.950	-5.232
Sh-139×E-322	-8.268	-0.039	-1.541	26.852	19.592	0.289	3.285
Sh-139×F-96	7.768	-0.108	-3.492	-18.704	-44.913	0.684	4.621
Sh-139×EV-347	11.148	0.014	0.880	-99.537	-40.479	-0.254	0.367
Additive variance	-2.660	-0.0002	-0.288	-15.5	-171.5	0.002	0.572
Dominance Variance	338.529	0.0309	32.262	17138.6	19522.7	1.5817	121.646
Contribution of males	2.300	12.792	9.568	11.6	7.3	23.368	26.815
Contribution of Females	15.201	6.665	6.098	15.9	8.6	6.610	7.033
Contribution of M×F	82.499	80.541	84.333	72.6	84.1	70.021	66.152

3 Photosynthetic rate (µg CO_2 s^{-1})

Higher and positive GCA effects were recorded for E-336 (6.991) and B-327 (5.106) followed by EV-347 (1.877) and Pop/209 (1.432) while negative GCA effects were recorded for EV-1097 (-5.728) and Sh-139 (-4.273) (Table 2). Higher GCA effects indicated additive type of gene action and the performance of the parents. Higher photosynthetic rate caused the increase in total dry matter and fodder yield of maize. Improved photosynthetic rate may be used for the development of synthetic varieties for higher fodder yield. It was indicated from Table 2 that higher SCA was recorded for crosses Sh-139×Pop/209 (9.798), EV-1097×EV-340 (12.024), EV-1097×B-316 (9.277) and Sh-139×EV-347 (11.148) while negative SCA was recorded for Sh-139×B-316 (-13.613), B-327×F-96 (-11.129) and EV-1079×F-96 (-11.574). The higher SCA showed that the crosses have higher dominance effects. The selection of hybrids on the basis of photosynthetic rate will be useful for the development of hybrids with higher grain and fodder yield through heterosis breeding. Additive variance was recorded as -2.660 but higher dominance variance was 338.529 for photosynthetic rate. The lower contribution of female (2.300) and male (15.201) was recorded as compared to male × female interaction (82.499). Findings were found similar to Grzesiak *et al*. (2007); Ali *et al*. (2011); Ali *et al*. (2012); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Stomata conductance (mmol m^{-2} s^{-1})

Higher and positive GCA effects were recorded for B-316 (0.055) and E-336 (0.029) followed by EV-1097 (0.025) and Raka-poshi (0.027) while negative GCA effects were recorded for B-11 (-0.046) and B-327 (-0.037) (Table 2). Higher GCA effects indicated additive type of gene action and the performance of the parents for the improvement of crop yield on the basis of stomata conductance. Higher stomata conductance indicated that the absorption of CO_2 will be increased that lead to wards the increase in the photosynthetic rate. It was indicated from Table 2 that higher SCA was recorded for crosses E-336×F-96 (0.085), E-336×EV-340 (0.147), EV-1097×E-322 (0.104) and Sh-139×B-316 (0.142) while negative SCA was recorded for B-11×EV-340 (-0.113), E-336×F-96 (-0.135) and EV-1079×B-316 (-0.155). The higher SCA showed that the crosses have higher dominance effects. The selection of hybrids will be useful for the development of hybrids for batter stomata conductance through heterosis breeding to improve crop yield and production. Additive variance was recorded as -0.0002 but higher dominance variance was 0.031 for stomata conductance. The lower contribution of female (12.792) and male (6.665) was recorded as compared to male × female interaction (80.541). Findings were found similar to Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Transpiration rate (mm day^{-1})

Higher and positive GCA effects were recorded for B-316 (1.271) and E-336 (0.670) followed by Pop/209 (0.752) and Raka-poshi (1.012) while negative GCA effects were recorded for B-11 (-1.351) and B-327 (-1.292) (Table 2). Higher GCA effects indicated additive type of gene action and the performance of the parents. Transpiration rate helps the plant to balance plant body temperature and to improve photosynthetic rate due to higher stomata conductance and chlorophyll content. It was indicated that higher SCA was recorded for crosses Sh-139×Pop/209 (3.470), E-336×EV-340 (3.142), EV-1097×E-322 (3.472) and Sh-139×B-316 (4.285) while negative SCA was recorded for B-11×EV-340 (-3.611), E-336×E-322 (-4.189) and EV-1079×B-316 (-6.104) (Table 2). The higher SCA showed that the crosses have higher dominance effects. The selection of hybrids on the basis of transpiration rate will be helpful for the development of hybrids through heterosis breeding. Additive variance was recorded as -0.288 but higher dominance variance was 32.262 for transpiration rate. The lower contribution of female (9.568) and male (6.098) was recorded as compared to male × female interaction (84.333). Findings were found similar to Grzesiak *et al*. (2007); Ali *et al*. (2011); Ali *et al*. (2012); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Sub-stomata CO_2 concentration (µmol mol^{-1} CO_2)

Higher and positive GCA effects were recorded for EV-340 (19.759) and EV-347 (34.259) followed by B-327 (46.759) and Sh-139 (38.148) while negative GCA effects were recorded for EV-1097 (-53.296) and Raka-poshi (-46.685) (Table 2). Higher GCA effects indicated additive type of gene action and the performance of the parents. Increased CO_2 concentration indicated that photosynthetic rate may be increased due to higher stomata conductance and chlorophyll content. The accumulation of organic compounds may also be increased that caused to improve fodder and grain yield in maize. It was indicated from Table 2 that higher SCA was recorded for crosses B-11×EV-347 (83.741), E-336×F-96 (61.352), B-327×EV-347 (74.907) and Sh-139×Pop/209 (110.574) while negative SCA was recorded for B-11×B-316 (-67.481), Sh-139×EV-347 (-99.537) and EV-1079×E-322 (-85.981). The higher SCA showed that the crosses have higher dominance effects. Heterosis breeding may be effective for the improvement of grain and fodder yield of maize. Additive variance was recorded as -15.5 but higher dominance variance was 17138.6 for transpiration rate. The lower contribution of female (11.6) and male (15.9) was recorded as compared to male × female interaction (72.6). Findings were found similar to Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Water use efficiency (%)

Higher and positive GCA effects were recorded for B-316 (26.013) and EV-1097 (39.598) followed by Raka-poshi (10.051) and Sh-139 (22.265) while negative GCA effects were recorded for E-336 (-30.433) and B-327 (-38.479) (Table 2). Higher GCA effects indicated additive type of gene action and the performance of the parents. The genotypes that used water efficiently may be selected for the improvement of grain and fodder yield in maize. Higher water use efficiency also suggested that photosynthetic rate may be increased due to higher stomata conductance, transpiration rate and chlorophyll content. Higher SCA was recorded for crosses E-336×EV-340 (165.009), EV-1097×Pop/209 (107.845), B-327×F-96 (103.805), Raka-poshi×EV-347 (91.818) and Sh-139×B-316 (84.430) while negative SCA was recorded for B-11×EV-340 (-54.115), E-336×F-96 (-55.241) and EV-1079×EV-340 (-79.258) (Table 2). The higher SCA showed that the crosses have higher dominance effects. Heterosis breeding may be used for the improvement of water use efficiency in order to increase grain and fodder yield of maize. Additive variance was recorded as -171.5 but higher dominance variance was 19522.7 for water use efficiency. The lower contribution of female (7.3) and male (8.6) was recorded as compared to male × female interaction (84.1). Findings were found similar to Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013

3.2. Grain Yield Traits

Cobs per plant

Higher and positive GCA effects were recorded for EV-340 (0.329) and E-336 (0.312) while negative GCA effects were recorded for EV-347 (-0.398) and Sh-139 (-0.342) (Table 3). Higher GCA effects indicated additive type of gene action and also suggested that increase in the cobs per plant may be fixed in next generation. Greater number of cobs per plant indicated that the crop productivity may be increased that caused to improve grain yield per plant. Higher SCA was recorded for crosses E-336×Pop/209 (0.548), E-336×EV-340 (0.514) and Sh-139×B-316 (84.430) while negative SCA was recorded for B-11×Pop/209 (-0.546), B-327×Pop/209 (-0.496) and Raka-poshi×Pop/209 (-0.457) (Table 3).

The higher SCA showed that the crosses have higher dominance effects. Higher yield hybrids may be developed on the basis of cobs per plant. Additive variance was recorded as -0.006 but higher dominance variance was 0.741 for cobs per plant. The lower contribution of female (28.057) and male (9.669) was recorded as compared to male × female interaction (62.272). Findings were found similar to Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Grain rows per cob

Higher and positive GCA effects were recorded for EV-340 (1.122) and E-336 (1.250) while negative GCA effects were recorded for F-96 (-1.238) and B-11 (-0.692) (Table 3). Higher GCA effects indicated additive type of gene action and the performance of the parents. Higher grain rows per cob suggested that number of grains per cob will be higher that may help to improve grain yield per plant. GCA effects may be helpful to produce synthetic varieties for higher grain yield on the basis of higher grain rows per cob. Higher SCA was recorded for crosses E-336×Pop/209 (3.175), B-11×B-316 (4.164) and Sh-139×F-96 (2.393) while negative SCA was recorded for B-11×Pop/209 (-5.049), E-336×F-96 (-2.461) and Sh-139×B-316 (-4.045) (Table 3).

The higher SCA showed that the crosses have higher dominance effects. Hybrids with higher grain yield may be produced on the basis of grain rows per cob through heterosis breeding. Additive variance was recorded as -0.115 but higher dominance variance was 19.474 for grain rows per cob. The lower contribution of female (14.978) and male (5.505) was recorded as compared to male × female interaction (79.516). Findings were found similar to Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Cob length (cm)

Higher and positive GCA effects were recorded for F-96 (0.961) and B-11 (1.511) while negative GCA effects were recorded for Sh-139 (-0.912) and B-316 (-1.479). Higher GCA effects indicated additive type of gene action and the performance of the parents (Table 3). Longer the cob higher will be the number of grains per cob and hence the grain yield per plant may also be improved. Higher SCA was recorded for crosses E-336×EV-340 (2.290), B-11×F-96 (2.438) and Raka-poshi×F-96 (2.482) while negative SCA was recorded for B-327×F-96 (-6.927), E-336×EV-347 (-4.570) and Raka-poshi×B-316 (-5.340) (Table 3). The higher SCA showed that the crosses have higher dominance effects. Heterosis breeding may be helpful to improve grain yield through the improvement of cob length. Additive variance was recorded as -0.288 but higher dominance variance was 30.093 for cob length. The lower contribution of female (10.110) and male (4.480) was recorded as compared to male × female interaction (85.409). Findings were found similar to Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Cob diameter (cm)

Higher and positive GCA effects were recorded for Pop/209 (0.089) and E-322 (0.074) while negative GCA effects were recorded for F-96 (-0.067) and EV-347 (-0.093). Higher GCA effects indicated additive type of gene action and the performance of the parents. Higher cob diameter suggested that the number of grain rows and grain per cob may be increased due to which the grain yield per plant may also be increased. Higher SCA was recorded for crosses B-11×EV-347 (0.194), E-336×B-316 (0.200) and Sh-139×Pop/209 (0.174) while negative SCA was recorded for E-336×F-96 (-0.230), E-336×EV-347 (-0.264) and Raka-poshi×B-316 (-0.237). The higher SCA showed that the crosses have higher dominance effects. The hybrids with higher cob diameter may be developed to improve grain yield per plant in maize. Heterosis breeding may be used to develop hybrids with greater vigour. Additive variance was recorded as -0.001 but higher dominance variance was 0.091 for cob diameter. The lower contribution of female (21.364) and male (2.436) was recorded as compared to male × female interaction (76.198) (Table 3). Findings were found similar to Akhtar (2002); Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Cob weight (g)

Higher and positive GCA effects were recorded for E-336 (21.511) and E-322 (19.709) while negative GCA effects were recorded for F-96 (-22.256) and Sh-139 (-28.745). Higher GCA effects indicated additive type of gene action and the performance of the parents. Greater cob weight suggested that the grain weight, number of grain row and grain may be higher due to which the grain yield may be improved. Higher SCA was recorded for crosses E-336×EV-340 (68.438), B-327×B-316 (40.049) and Raka-poshi×F-96 (37.967) while negative SCA was recorded for Raka-poshi×EV-340 (-47.121), E-336×EV-347 (-60.433) and Raka-poshi×B-316 (-58.083). The higher SCA showed that the crosses have higher dominance effects. Greater cob weight will be useful for the development of hybrids with higher grain yield through heterosis breeding. Additive variance was recorded as 5.50 but higher dominance variance was 5372.98 for cob weight. The lower contribution of female (21.53) and male (8.27) was recorded as compared to male × female interaction (70.20). Findings were found similar to Akhtar (2002); Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

100-seed weight (g)

Higher and positive GCA effects were recorded for B-11 (1.451) and B-327 (1.907) while negative GCA effects were recorded for EV-1097 (-2.753) and EV-340 (-1.224). Higher GCA effects indicated additive type of gene action and the performance of the parents. Higher 100-seed weight indicated that the seed size may be higher that caused to increase crop yield. Greater seed weight also indicated that the genetic effects may be fixed in next generation on the basis of higher GCA effects. It was indicated from table 3 that higher SCA was recorded for crosses B-327×E-322 (3.242), Sh-139×EV-340 (3.403) and Raka-poshi×F-96 (4.175) while negative SCA was recorded for Raka-poshi×EV-340 (-7.974), B-11×E-322 (-2.929) and B-327×F-96 (-3.012). The higher SCA showed that the crosses have higher dominance effects. Hybrids on the basis of 100-seed weight may be developed through heterosis breeding to improve grain yield per plant. Additive variance was recorded as -0.197 but higher dominance variance was 36.446 for 100-seed weight. The lower contribution of female (9.381) and male (11.939) was recorded as compared to male × female interaction (78.678). Findings were found similar to Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Stover weight (g)

It was persuaded from Table 3 that higher and positive GCA effects were recorded for E-322 (6.879) and EV-1097 (4.434) while negative GCA effects were recorded for B-316 (-3.265) and Raka-poshi (-1.224). Higher GCA effects indicated additive type of gene action and the performance of the parents. Additive effects suggested that the increase in the traits may be fixed in the next generation to improve grain yield per plant. Higher stover weight indicated that fodder yield per plant may be increased. It was indicated from Table 3 that higher SCA was recorded for crosses B-11×Pop/209 (11.576), E-336×EV-340 (19.126) and B-327×B-316 (21.865) while negative SCA was recorded for EV-1097×EV-340 (-9.340), B-11×B-316 (-9.184) and B-11×E-322 (-8.079). The higher SCA showed that the crosses have higher dominance effects. Hybrids on the basis of stover weight may be developed through heterosis breeding to increase grain and fodder yield in maize. Additive variance was recorded as -1.963 but higher dominance variance was 317.690 for stover weight. The lower contribution of female (16.165) and male (3.953) was recorded as compared to male × female interaction (79.882). Findings were found similar to Akhtar (2002); Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

Grain yield per plant (g)

It was indicated from Table 3 that higher and positive GCA effects were recorded for E-336 (14.618) and Pop/209 (11.899) while negative GCA effects were recorded for F-96 (-21.142) and Sh-139 (-20.042). Higher GCA effects indicated additive type of gene action and the performance of the parents. Higher grain yield per plant indicated that cobs per plant, grain rows per plant, grains per row, cob diameter and 100-seed weight was higher that caused to improve grain yield per plant. Hence on the basis of higher GCA effects synthetic varieties of improved grain yield per plant may be developed. It was indicated from table 3 that higher SCA was recorded for crosses Raka-poshi×Pop/209 (31.209), E-336×EV-340 (56.680) and Raka-poshi×B-316 (41.784) while negative SCA was recorded for EV-1097×Pop/209 (-36.957), Raka-poshi×B-316 (-47.451) and Raka-poshi×EV-340 (-40.763). The higher SCA showed that the crosses have higher dominance effects. Hybrids through heterosis breeding may be developed to improve grain yield per plant. Additive variance was recorded as -6.08 but higher dominance variance was 3552.11 for grain yield per plant. The lower contribution of female (20.35) and male (6.07) was recorded as compared to male × female interaction (73.58). Findings were found similar to Akhtar (2002); Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ahsan *et al*. (2013).

3.4. Quality Traits

Grain protein (%)

Higher and positive GCA effects were recorded for EV-340 (0.553) and E-322 (0.148) followed by Raka-poshi (0.120) and Sh-139 (0.070) while negative GCA effects were recorded for F-96 (-0.290) and EV-347 (-0.418). Higher GCA effects indicated additive type of gene action and the performance of the parents. Higher grain protein is very important trait to improve grain quality. On the basis of higher GCA effects synthetic varieties may be developed with higher grain protein quality (Table 4). Higher SCA was recorded for crosses E-336×Pop/209 (0.368), EV-1097×EV-340 (0.396), B-327×Pop/209 (0.446) and Raka-poshi×E-322 (0.368) while negative SCA was recorded for B-11×E-322 (-0.303), EV-1097×Pop/209 (-0.559) and B-327×EV-347 (-0.431). The higher SCA showed that the crosses have higher dominance effects. Hybrids may be developed on the basis of grain protein percentage through heterosis breeding. Additive variance was recorded as 0.019 but higher dominance variance was 0.290 for grain protein percentage. The lower contribution of male × female interaction (34.564) and male (2.588) was recorded as compared to female was (62.846). Findings were found similar to Li and Liu (1994); Mazur *et al*. (2001); Vafias and Ipilandis (2005); Xiang *et al*. (2010); Amir *et al*. (2012); Bibi *et al*. (2012) and Ali *et al*. (2013).

Grain oil (%)

It was suggested from Table 4 that higher and positive GCA effects were recorded for F-96 (0.282) and B-11 (0.093) followed by B-316 (0.054) and E-336 (0.087) while negative GCA effects were recorded for EV-1097 (-0.134) and EV-347 (-0.212). Higher GCA effects indicated additive type of gene action and the performance of the parents. Maize grain oil is used as golden maize; higher grain oil may be used to improve maize demand worldwide. Higher GCA effects may be used to fix higher oil content in maize in next generations. It was indicated from table 4 that higher SCA was recorded for crosses B-11×F-96 (0.317), B-11×EV-347 (0.350), B-11×Pop/209 (0.356) and EV-1097×EV-347 (0.328) while negative SCA was recorded for B-11×EV-340 (-0.487), Raka-poshi×EV-347 (-0.304) and B-327×EV-347 (-0.321). The higher SCA showed that the crosses have higher dominance effects. Hybrids with higher grain oil percentage may be developed through heterosis breeding in order to improve grain quality and demand. Additive variance was recorded as 0.0013 but higher dominance variance was 0.275 for grain oil percentage. The lower contribution of female (29.804) and male (3.742) was recorded as compared to male × female interaction was (62.453). Findings were found similar to Li and Liu (1994); Khalil *et al*. (2000); Awan *et al*. (2001); Yousaf and Saleem (2001); Mazur *et al*. (2001); Vafias and Ipilandis (2005); Xiang *et al*. (2010); Amir *et al*. (2012); Bibi *et al*. (2012); Ali *et al*. (2012); Ali *et al*. (2014).

Grain crude fibre (%)

It was indicated from Table 4 that higher and positive GCA effects were recorded for EV-340 (0.026) and B-316 (0.132) followed by E-336 (0.126) and B-327 (0.071) while negative GCA effects were recorded for F-96 (-0.117) and Raka-poshi (-0.101). Higher GCA effects indicated additive type of gene action and the performance of the parents. Crude fibe help in the digestion of food materials and maize grain with higher crude fibre may be used as trait to improve grain quality of maize. It also is shown in Table 4 that higher SCA was recorded for crosses EV-1097×F-96 (0.245), E-336×EV-340 (0.162), Raka-poshi×Pop/209 (0.173) and B-327×EV-347 (0.262) while negative SCA was recorded for EV-1097×B-316 (-0.237), E-336×EV-347 (-0.437) and Raka-poshi×E-322 (-0.215). The higher SCA showed that the crosses have higher dominance effects. Hybrids with enhanced grain crude fibre percentage may be developed through heterosis breeding. Additive variance was recorded as -0.0007 but higher dominance variance was 0.1417 for grain crude fibre percentage. The lower contribution of female (15.814) and male (6.552) was recorded as compared to male × female interaction was (77.633). Findings were found similar to Li and Liu (1994); Seo *et al*. (1998); Khalil *et al*. (2000); Awan *et al*. (2001); Yousaf and Saleem (2001); Mazur *et al*. (2001); Vafias and Ipilandis (2005) and Xiang *et al*. (2010).

Table 3: Combining ability analysis for various grain yielding traits of maize

Source of variation/ Traits	Cobs per plant	Grain rows per cob	Cob length (cm)	Cob diameter (cm)	Cob weight(g)	100-seed weight (g)	Stover weight (g)	Grain yield per plant (g)
GCA								
Pop/209	0.190	0.880	0.638	0.089	11.759	0.596	-2.070	11.899
B-316	0.096	-0.421	-1.479	0.008	-6.682	-0.487	-3.265	0.779
EV-340	0.329	1.122	0.020	-0.010	16.759	-1.559	0.167	10.390
E-322	-0.192	-0.066	0.238	0.074	19.709	1.224	6.879	11.791
F-96	-0.025	-1.238	0.961	-0.067	-19.290	0.035	0.421	-21.142
EV-347	-0.398	-0.277	-0.379	-0.093	-22.256	0.190	-2.132	-13.717
B-11	0.151	-0.692	1.511	0.006	10.132	1.451	-1.243	-0.876
E-336	0.312	1.250	-0.583	0.048	21.511	-0.042	1.451	14.618
EV-1097	-0.048	-0.693	0.092	-0.048	-5.384	-2.753	4.434	4.163
B-327	-0.153	-0.443	0.299	-0.019	-3.140	1.907	0.345	-4.378
Raka-poshi	0.079	0.745	-0.407	0.033	5.626	0.029	-3.228	6.515
Sh-139	-0.342	-0.166	-0.912	-0.020	-28.745	-0.592	-1.759	-20.042
SCA								
B-11×Pop/209	-0.546	-5.049	-1.079	-0.195	-29.621	-1.674	11.576	-36.699
B-11×B-316	0.225	4.164	-1.484	0.135	-12.000	-0.046	-9.184	-3.827
B-11×EV-340	0.387	0.175	-0.161	-0.030	-0.071	1.731	-5.301	26.894
B-11×E-322	-0.140	-1.241	-1.158	-0.079	-3.448	-2.929	-8.079	0.856
B-11×F-96	0.125	-0.296	2.438	-0.022	23.351	2.681	5.595	8.875
B-11×EV-347	-0.051	2.247	1.444	0.194	21.790	0.237	5.393	3.900
E-336×Pop/209	0.548	3.175	-0.294	0.142	17.855	-0.257	-3.662	-2.979
E-336×B-316	0.120	1.032	1.733	0.200	11.519	-0.829	-7.456	19.426
E-336×EV-340	0.514	0.143	2.290	0.150	68.438	-0.085	19.126	56.680
E-336×E-322	-0.412	-0.272	-1.116	0.001	3.627	0.787	2.282	-19.277
E-336×F-96	-0.446	-2.461	1.957	-0.230	-41.006	0.664	-3.243	-26.004
E-336×EV-347	-0.324	-1.617	-4.570	-0.264	-60.433	-0.279	-7.045	-27.846
EV-1097×Pop/209	0.248	-1.402	-0.294	-0.092	-43.121	1.348	3.004	-36.957
EV-1097×B-316	0.120	0.721	0.833	-0.124	12.032	-1.690	-3.790	14.548
EV-1097×EV-340	-0.451	0.699	-1.842	-0.090	-23.071	0.553	-9.340	-26.963
EV-1097×E-322	0.287	1.182	0.050	0.130	24.684	-0.774	4.815	21.178
EV-1097×F-96	-0.012	0.527	-0.509	0.147	4.517	-2.029	4.389	3.251
EV-1097×EV-347	-0.190	-1.728	1.762	0.027	24.956	2.592	0.920	24.942
B-327×Pop/209	-0.496	0.619	1.353	-0.077	4.229	-0.701	-7.240	19.675
B-327×B-316	0.342	-0.789	2.089	0.090	40.049	-0.774	21.865	12.980
B-327×EV-340	0.070	-0.845	-1.427	0.077	-4.954	2.370	2.015	-0.424
B-327×E-322	0.142	-0.261	3.432	-0.127	-11.832	3.242	-1.629	-13.622
B-327×F-96	-0.024	0.182	-6.927	-0.001	-20.398	-3.012	-8.388	-12.149
B-327×EV-347	-0.035	1.093	1.478	0.036	-7.093	-1.124	-6.623	-6.458
Raka-poshi×Pop/209	0.437	1.792	1.277	0.048	25.662	1.520	0.517	31.209
Raka-poshi×B-316	-0.457	-1.083	-5.340	-0.237	-58.083	0.914	-2.076	-47.451
Raka-poshi×EV-340	-0.396	-1.039	-0.050	-0.066	-47.121	-7.974	-6.460	-40.763
Raka-poshi×E-322	-0.257	0.010	-0.124	0.147	17.367	0.531	7.028	5.478
Raka-poshi×F-96	0.475	-0.345	2.482	0.038	37.967	4.175	-2.676	41.784
Raka-poshi×EV-347	0.198	0.666	1.755	0.068	24.206	0.831	3.667	9.742
Sh-139×Pop/209	-0.190	0.864	-0.961	0.174	24.995	-0.235	-4.195	25.751
Sh-139×B-316	-0.351	-4.045	2.167	-0.064	6.482	2.425	0.643	4.323
Sh-139×EV-340	-0.124	0.866	1.190	-0.040	6.779	3.403	-0.040	-15.422
Sh-139×E-322	0.381	0.582	-1.083	-0.073	-30.398	-0.857	-4.418	5.386
Sh-139×F-96	-0.118	2.393	0.557	0.067	-4.432	-2.479	4.323	-15.757
Sh-139×EV-347	0.403	-0.661	-1.870	-0.062	-3.426	-2.257	3.687	-4.282
Additive variance	0.0064	-0.1157	-0.288	-0.0003	5.50	-0.197	-1.963	-6.08
Dominance Variance	0.7406	19.474	30.0939	0.0910	5372.98	36.446	317.690	3552.11
Contribution of males	28.057	14.978	10.110	21.364	21.53	9.381	16.165	20.35
Contribution of Females	9.669	5.505	4.480	2.436	8.27	11.939	3.953	6.07
Contribution of M×F	62.272	79.516	85.409	76.198	70.20	78.678	79.882	73.58

Table 4. Combining ability analysis for various grain quality traits of maize

Source of variation/ Traits	Grain protein (%)	Grain oil (%)	Grain crude fibre (%)	Grain starch (%)	Embryo (%)
GCA					
Pop/209	0.014	-0.006	-0.023	0.614	0.051
B-316	-0.007	0.054	0.132	-0.446	0.056
EV-340	0.553	-0.084	0.026	-0.057	-0.032
E-322	0.148	-0.034	-0.001	0.370	0.189
F-96	-0.290	0.282	-0.117	-0.301	-0.049
EV-347	-0.418	-0.212	-0.017	-0.179	-0.215
B-11	-0.007	0.093	-0.050	0.225	0.084
E-336	-0.051	0.087	0.126	0.259	0.051
EV-1097	0.025	-0.134	0.010	0.164	-0.021
B-327	-0.157	0.032	0.071	-0.062	-0.076
Raka-poshi	0.120	-0.073	-0.101	-0.241	-0.121
Sh-139	0.070	-0.006	-0.056	-0.346	0.084

SCA					
B-11×Pop/209	-0.120	-0.149	-0.154	0.412	-0.334
B-11×B-316	-0.075	-0.243	-0.165	1.412	-0.200
B-11×EV-340	0.012	-0.487	0.050	0.474	-0.028
B-11×E-322	-0.303	0.212	0.156	-0.231	-0.106
B-11×F-96	0.185	0.317	0.128	-1.120	-0.028
B-11×EV-347	0.301	0.350	-0.015	-0.948	0.699
E-336×Pop/209	0.368	0.356	0.123	-0.325	0.293
E-336×B-316	0.212	0.062	0.145	-0.292	0.160
E-336×EV-340	-0.064	0.017	0.162	0.035	-0.134
E-336×E-322	-0.114	-0.082	0.134	0.029	-0.145
E-336×F-96	-0.292	-0.110	-0.126	0.074	-0.001
E-336×EV-347	-0.109	-0.243	-0.437	0.479	-0.173
EV-1097×Pop/209	-0.559	-0.271	-0.237	-0.781	-0.117
EV-1097×B-316	-0.081	-0.232	0.050	-0.581	-0.050
EV-1097×EV-340	0.007	0.089	-0.032	-0.287	-0.112
EV-1097×E-322	-0.009	-0.010	-0.093	0.374	0.076
EV-1097×F-96	0.246	0.095	0.245	0.651	0.187
EV-1097×EV-347	0.396	0.328	0.067	0.624	0.015
B-327×Pop/209	0.446	0.278	-0.010	-0.109	-0.039
B-327×B-316	-0.042	0.317	-0.054	-0.309	0.126
B-327×EV-340	0.179	-0.026	-0.037	-0.081	-0.001
B-327×E-322	0.029	-0.126	0.034	0.146	-0.012
B-327×F-96	-0.181	-0.121	-0.193	0.390	-0.001
B-327×EV-347	-0.431	-0.321	0.262	-0.037	-0.073
Raka-poshi×Pop/209	-0.281	-0.071	0.173	0.496	0.165
Raka-poshi×B-316	-0.003	0.100	-0.037	-0.037	-0.034
Raka-poshi×EV-340	0.018	0.289	-0.187	-0.009	0.071
Raka-poshi×E-322	0.368	-0.043	-0.215	-0.348	-0.073
Raka-poshi×F-96	-0.009	0.028	0.123	-0.003	-0.095
Raka-poshi×EV-347	-0.092	-0.304	0.145	-0.098	-0.034
Sh-139×Pop/209	0.146	-0.143	0.106	0.307	0.032
Sh-139×B-316	-0.009	-0.004	0.062	-0.192	-0.001
Sh-139×EV-340	-0.153	0.117	0.045	-0.131	0.204
Sh-139×E-322	0.029	0.050	-0.015	0.029	0.260
Sh-139×F-96	0.051	-0.210	-0.176	0.007	-0.062
Sh-139×EV-347	-0.064	0.189	-0.021	-0.020	-0.434
Additive variance	0.0193	0.0013	-0.0007	0.0156	0.0009
Dominance Variance	0.2905	0.2758	0.1417	1.3599	0.1704
Contribution of males	62.846	29.804	15.814	33.997	26.757
Contribution of Females	2.588	3.742	6.552	5.835	6.291
Contribution of M×F	34.564	66.453	77.633	60.167	66.951

Grain starch (%)

It can be noticed in Table 4 that higher and positive GCA effects were recorded for Pop/209 (0.614) and E-336 (0.259) followed by B-11 (0.225) and E-322(0.370) while negative GCA effects were recorded for B-316 (-0.446) and Sh-139 (-0.346). Higher GCA effects indicated additive type of gene action and the performance of the parents. Maize starch is used in various by products. The genotypes with higher grain starch may be used to improve maize grain quality and demand. The higher GCA effects may be helpful to fix the starch percentage in the grain in next generation and selection of higher starch content genotypes may be used to develop synthetic varieties with good grain quality. Also, it can be seen in Table 4 that higher SCA was recorded for crosses B-11×B-316 (1.412), EV-1097×F-96 (0.651), EV-1097×EV-347 (0.624) and Raka-poshi×Pop/209 (0.496) while negative SCA was recorded for B-11×B-316 (-0.948), EV-1097×Pop/209 (-0.781) and EV-1097×B-316 (-0.581). The higher SCA showed that the crosses have higher dominance effects. The hybrids with higher starch percentage may be developed by using higher SCA effects. Additive variance was recorded as 0.015 but higher dominance variance was 1.359 for grain starch percentage. The lower contribution of female (33.997) and male (5.835) was recorded as compared to male × female interaction was (60.167). Findings were found similar to Alvi *et al*. (2003); Rai *et al*. (2004); Vafias *et al*. (2005); Vafias and Ipilandis (2005); Welcker *et al*. (2005); Grzesiak *et al*. (2007); Amir *et al*. (2012); Bibi *et al*. (2012) and Ali *et al*. (2014a,b,c,d).

Embryo (%)

It is presented in Table 4 that higher and positive GCA effects were recorded for B-316 (0.056) and Sh-139 (0.084) followed by B-11 (0.084) and E-322(0.189) while negative GCA effects were recorded for EV-347 (-0.215) and Raka-poshi (-0.121). Higher GCA effects indicated additive type of gene action and the performance of the parents. Greater embryo percentage suggested that the seed may be healthy that may be helpful to develop healthy maize plant. The grain and fodder yield may be improved by selecting genotypes on the basis of embryo percentage. It was indicated in Table 4 that higher SCA was recorded for crosses B-11×EV-347 (0.699), Sh-139×E-322 (0.260), Sh-139×EV-340 (0.204) and E-336×Pop/209 (0.293) while negative SCA was recorded for B-11×B-316 (-0.201), B-11×Pop/209 (-0.334) and Sh-139×EV-347 (-0.434). The higher SCA showed that the crosses have higher dominance effects. Hybrids with good yield and quality may be developed by selecting on the basis of higher SCA effects. Additive variance was recorded as 0.0009 but higher dominance variance was 0.170 for embryo percentage. The lower contribution of female (26.757) and male (6.291) was recorded as compared to male × female interaction was (66.951). Findings were found similar to Alvi *et al.* (2003); Rai *et al.* (2004); Vafias *et al.* (2005); Vafias and Ipilandis (2005); Grzesiak *et al.* (2007); Amir *et al.* (2012) and Bibi *et al.* (2012).

Conclusions

The inbred lines B-316, F-96, B-11, Sh-139, EV-340, Pop/209, E-322, E-336 and EV1097 showed higher General Combining Ability (GCA) for most grain, fodder and quality traits which indicated that these lines may be used for the development of synthetic varieties for physiological, grain yield and quality traits. On the other hand, higher Specific Combining Abilities (SCA) for some crosses indicated that particular genotypes may be used to develop higher grain yield and improved quality maize hybrids. The F1 hybrids B-11×E-322, EV-1097×Pop/209, B-327×F-96, E-336×B-316, EV-1097×E-322, B-327×E-340, Sh-139×Pop/209, EV-1097×EV-340, EV-1097×B-316, Raka-poshi×Pop/209, E-336×EV-347, E-336×Pop/209, EV-1097×Pop/209, B-316×E-340, Raka-poshi×F-96, B-327×Pop/209 showed higher SCA for most of the measured physiological, grain and quality traits, which indicated that these lines may be used to develop hybrids through heterosis in order to get higher grain yield and good quality genotypes for a further breeding programme.

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